TÜV RHEINLAND ENERGY GMBH

Report on the performance test of the EDM 280 ambient air measuring system manufactured by Grimm Aerosol Technik GmbH for the components suspended particulate matter $PM_{2.5}$ and PM_{10}.

TÜV-Report: 936/21252222/A
Cologne, 03 February 2023

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

according to EN ISO/IEC 17025.

The accreditation has the DAkkS registration number: D-PL-11120-02-00
and covers the scope defined in the appendix to the certificate.

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Summary Overview

On behalf of the company Grimm Aerosol Technik GmbH in Muldestausee, TÜV Rheinland Energy GmbH carried out the performance testing of the EDM 280 measuring system for the components suspended particulate matter $PM_{2.5}$ and PM_{10} according to the following standards.

- Standard EN 16450 Ambient air – Automated measuring systems for the measurement of the concentration of particulate matter (PM_{10}; $PM_{2.5}$, German version dated July 2017)
- VDI Standard 4202, Part 3, Automated measuring systems for air quality monitoring - Performance test, declaration of suitability and certification of measuring systems for point-related measurement of mass concentration for particulate air pollutants, February 2019
- European standard EN 12341, Ambient air - Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2.5}$ mass concentration of suspended particulate matter; German version EN 12341:2014
- Guideline "Demonstration of Equivalence of Ambient Air Monitoring Methods", English version of January 2010

The EDM 280 dust monitor determines dust concentrations by means of the measuring principle of scattered light measurement on single particles in the total sample air (aerosol spectrometry) with a combination of a laser diode and a 90° scattered light detection. With the aid of a pump, ambient air is drawn in via a Sigma-2 sampling head and passes through the sampling tube to the actual measuring system. Adaptive heating in the sampling tube is actively adjusted to ensure that condensation cannot be formed as the aerosol passes through to the measuring cell, while at the same time ensuring that there is as little warming of the aerosol as possible. After the sampling tube, the sample air goes directly to the optical measuring cell in the measuring module. There, the particle-size distribution is determined using the scattered light measurement technique and the mass concentration is calculated by means of an algorithm.

The tests were performed in the laboratory and in an approx. 11-month long field test.

The field test, which lasted several months, was carried out at the sites listed in Table 1.

Table 1: Description of the test sites

	Cologne	Bornheim	Niederzier	JRC Ispra
Period	08/2021 – 11/2021	12/2021 – 03/2022	06/2022 – 09/2022	10/2022 – 01/2023
Number of measurement pairs: Candidate systems	PM_{10}: 84 $PM_{2.5}$: 84	PM_{10}: 79 $PM_{2.5}$: 79	PM_{10}: 81 $PM_{2.5}$: 81	PM_{10}: 82 $PM_{2.5}$: 82
Description	Urban background	Traffic	Industrial background	Rural background
Classification of ambient air pollution	Low to medium	Low to medium	Low to medium	Medium to high

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

Table 2: Results of equivalent testing (raw data)

Comparison campaigns		Slope	Axis intercept	All Data sets W_{CM}<25 % Raw data	Calibration yes/no	All Data sets W_{CM}<25% Cal. Data
4	$PM_{2.5}$	1.022	1.032	no	yes	yes
4	PM_{10}	0.982	0.951	yes	yes *	yes

* Calibration based on significance of slope and axis intercept.

Report on the performance test of the EDM 280 ambient air measuring system manufactured by Grimm Aerosol Technik GmbH for the components suspended particulate matter $PM_{2.5}$ and PM_{10}.

AMS designation: EDM 280

Manufacturer: Grimm Aerosol Technik GmbH
OT Friedersdorf
Vordere Aue 4
06774 Muldestausee

Test period: 04/2021 to 01/2023

Date of report: 03 February 2023

Report Number: 936/21252222/A

Editor: Karsten Pletscher

Technical supervisor: Guido Baum

Scope of report:

Report:		172	Pages
Appendix	pages	174	
Manual	pages	207	
Manual	with	70	Pages
Total		277	Pages

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1. General

1.1 Certification proposal

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

AMS designation:
EDM 280 for suspended particulate matter $PM_{2.5}$ und PM_{10}

Manufacturer:
Grimm Aerosol Technik GmbH, Muldestausee

Field of application:
For continuous and simultaneous measurement of the PM_{10} and $PM_{2.5}$ fraction in ambient air (stationary operation)

Measuring ranges during performance testing:

Component	Certification range	Unit
$PM_{2.5}$	0 – 5,100	µg/m³
PM_{10}	0 – 12,000	µg/m³

Software version:
1.01 (Firmware)
0.08 (FPGA)
1.01 (GUI)

Restrictions:
None

Notes:

1. The measuring module in the measuring system must be sent to Grimm Service or an authorized Grimm service partner at least every 12 months (or when the "Calibration" wear indicator is completely red) for maintenance, including a check of the calibration.
2. The measuring system can be operated with either the WS300, WS500 or WS600 weather sensors.
3. The measuring system can also be used in the fully air-conditioned, weatherproof housing Model 199 from Grimm Aerosol Technik.
4. This report on the performance test is available online at www.qal1.de.

Test Report:
TÜV Rheinland Energy GmbH, Cologne
Report no. 936/21252222/A dated 03 February 2023

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1.2 Summary report on test results

Summary of test results according to standard VDI 4202, part 3

Performance criterion	Requirement	Test result	Satisfied	Page
6. Performance criteria				
6.1 General remarks	The manufacturer's data in the operating instructions of the AMS are not permitted, under any circumstances, to be better than the results of the performance testing.	The operating instructions for the measuring system (status: 1.04 (German) or 1.01 (English)) are complete and correct. The manufacturer's specifications are no better than the results of the performance test.	yes	52
6.2 Multicomponent measuring instruments	Multicomponent measuring instruments have to comply with the performance criteria for each separate measured component independently of the other measured components.	Evaluation with regard to performance criteria was carried out for each individual measured component independently of the other measured components.	yes	53
6.3 General requirements				
6.3.1 Measured value display	The measuring system shall have an operative measured value display as part of the instrument.	The measuring system has an operative measured value display at the front of the instrument.	yes	54
6.3.2 Easy maintenance	It should be possible to perform the necessary maintenance works on the AMS without major overheads, preferably from outside.	Maintenance work can be carried out externally with standard tools and reasonable effort. The measuring module in the measuring system must be sent to Grimm Service or an authorized Grimm service partner at least every 12 months (or when the "Calibration" wear indicator is completely red) for maintenance, including a check of the calibration.	yes	55
6.3.3 Functional check	Special instruments for this purpose are to be considered as belonging to the equipment, to be used in the corresponding subtests and to be evaluated.	The tested device always performs a self-test at the start of measurement operation and, configurable by the user, at regular intervals (in the performance test every 24 h). Any warnings or errors are provided in a diagnostic code.	yes	56
6.3.4 Set-up times and warm-up times	The instruction manual shall include specifications in this regard.	The set-up time is approx. 1 h. The necessary work is described in the user manual. The warm-up time until valid measured values are available after switching on is approx. 15 min.	yes	57
6.3.5 Instrument design	The instruction manual shall include specifications in this regard.	Specifications made in the instruction manual concerning instrument design are complete and correct.	yes	58

Performance criterion	Requirement	Test result	Satis-fied	Page
6.3.6 Unintended adjustment	It has to be possible to secure the adjustment of the AMS against unintentional and unauthorised alteration.	Unintentional adjustment of the calibration is prevented by a hierarchical concept for calibrations of the measuring equipment as well as maintenance and service work. In order to safely protect the measuring system from unauthorised access during measuring operation, the system must be operated in a locked measuring container.	yes	60
6.3.7 Data output	The output signals shall be provided digitally and/or as analogue signals.	The measured signals are provided digitally.	yes	62
6.3.8 Digital interface	The digital interface shall allow the transmission of output signals, status signals, and others. Access to the measuring system shall be secured against unauthorised use.	Digital transmission of measured values operates correctly. In order to safely protect the measuring system from unauthorised access during measuring operation, the system must be operated in a locked measuring container.	yes	63
6.3.9 Data transmission protocol	For digital transmission of the measured signals, the AMS has to have at least one data transmission protocol.	The AMS has the digital transmission protocols GRIMM protocol (GP280 V1.1), Modbus TCP and GESYTEC / Bayern-Hessen protocol as standard. Measured and status signals are transmitted correctly.	yes	64
6.3.10 Measuring range	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 execution, evaluation and assessment for the test point "Measuring range" is identical to the test point "Measuring ranges" according to Table 1 No. 1 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 1 Measurement ranges.	yes	66
6.3.11 Negative measured signals	Negative measured signals or readings shall not be suppressed.	The execution, evaluation and assessment for the test point "Negative measured signals" is identical to the test point "Negative signals" according to Table 1 No. 2 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 2 Negative signals.	yes	67
6.3.12 Power failure	Instrument parameters shall be secured against loss. On return of the mains voltage the instrument shall automatically resume functioning.	The execution, evaluation and assessment for the test point "Power failure" is identical to the test point "Effect of failure of mains voltage" according to Table 1 No. 10 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 10 Effect of failure of mains voltage.	yes	68

Performance criterion	**Requirement**	**Test result**	**Satis-fied**	**Page**
6.3.13 Instrument functions	The measuring system shall allow the control of important operating states by telemetrically transmitted status signals.	The AMS can be comprehensively monitored and controlled from an external computer via a modem or router.	yes	69
6.3.14 Switching	The switching between measurement and function control and/or calibration has to be capable of being triggered telemetrically through computerised control and manually at the AMS.	In principle, it is possible to monitor all tasks necessary for a functional check on the instrument itself or telemetrically.	yes	70
6.3.15 Instrument software	The version of the instrument's software has to be capable of being displayed by the AMS.	The current software version can be viewed at any time in the menu under "Service Information" (for GUI in the Display and Language menu). Software changes are communicated to the test laboratory.	yes	71
6.4 Requirements relating to performance characteristics for the laboratory test				
6.4.1 General requirements	The performance characteristics in the laboratory shall be determined in accordance with section 7.4 of VDI 4202 Part 3 (2019).	The test was carried out using the performance criteria and requirements of VDI 4202 Part 3 (2019) and EN 16450 (2017).	yes	73
6.4.2 Test requirements	Must comply with the criteria of VDI 4202 Part 3 (2019).	The test was carried out using the performance criteria and requirements of VDI 4202 Part 3 (2019) and EN 16450 (2017).	yes	74
6.4.3 Zero level and detection limit	Zero level: ≤ 2.0 µg/m³ Detection limit: ≤ 2.0 µg/m³	The execution, evaluation and assessment for the test point "Zero level and detection limit" is identical to the test point "Zero level and detection limit" according to point 7.4.3 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 3 Zero level and detection limit (7.4.3).	yes	76
6.4.4 Volumetric flow rate accuracy	≤ 2.0%	The execution, evaluation and assessment for the test point "Volumetric flow rate accuracy" is identical to the test point "Flow rate accuracy" according to point 7.4.4 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 4 Flow rate accuracy (7.4.4).	yes	77
6.4.5 Sample flow rate constancy	≤ 2.0% sampling flow (averaged flow) ≤ 5% rated flow (instantaneous flow)	The execution, evaluation and assessment for the test point "Sample flow rate constancy" is identical to the test point "Constancy of sample flow rate" according to point 7.4.5 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 5 Constancy of sample flow rate (7.4.5).	yes	78

Performance criterion	Requirement	Test result	Satis-fied	Page
6.4.6 Leak tightness of the sampling system	≤ 2.0 % of the averaged sample volume flow rate	The execution, evaluation and assessment for the test point "Leak tightness of the sampling system" is identical to the test point "Leak tightness of the sampling system" according to point 7.4.6 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 6 Leak tightness of the sampling system (7.4.6).	yes	79
6.4.7 Dependence of the zero point and of the reference point on the ambient temperature	≤ 2.0 µg/m³ (Zero point) ≤ 5 % from the value at the nominal test temperature (reference point)	The execution, evaluation and assessment for the test point "Dependence of the zero point and the reference point on the ambient temperature" is identical to the test points "Dependence of the zero point on surrounding temperature" and "Dependence of the measured value on surrounding temperature" according to point 7.4.7 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 7 Dependence of zero on surrounding temperature (7.4.7) and Chapter 7.1 8 Dependence of measured value (span) on surrounding temperature (7.4.7).	yes	80
6.4.8 Dependence of the reference point on mains voltage	≤ 5 % from the value at the nominal test voltage	The execution, evaluation and assessment for the test point "Dependence of the reference point on mains voltage" is identical to the test point "Dependence of span on supply voltage" according to point 7.4.8 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 9 Dependence of span on voltage supply (7.4.8).	yes	81
6.4.9 Dependence of the readings on the water vapour concentration	≤ 2.0 µg/m³ in zero air	The execution, evaluation and assessment for the test point "Dependence of the readings on the water vapour concentration" is identical to the test point "Dependence of readings on water vapour concentration" according to point 7.4.9 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 11 Dependence of reading on water vapour concentration (7.4.9).	yes	82

Performance criterion	**Requirement**	**Test result**	**Satis-fied**	**Page**
6.5 Requirements relating to performance characteristics for the field test				
6.5.1 General requirements	The performance characteristics in the field test shall be determined in accordance with section 7.5 of VDI 4202 Part 3 (2019).	The test was carried out using the performance criteria and requirements of VDI 4202 Part 3 (2019) and EN 16450 (2017).	yes	83
6.5.2 Experimental conditions	Must comply with the criteria of VDI 4202 Part 3 (2019).	The test was carried out using the performance criteria and requirements of VDI 4202 Part 3 (2019) and EN 16450 (2017).	yes	84
6.5.3 Zero point tests	Absolute value ≤ 3.0 µg/m³	The execution, evaluation and assessment for the test point "Zero point tests" is identical to the test point "Zero checks" according to point 7.5.3 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 12 Zero checks (7.5.3).	yes	86
6.5.4 Recording of operating parameters	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 Ambient air pressure Air temperature in measuring section Temperature of sampling inlet if heated inlet is used	The execution, evaluation and assessment for the test point "Recording of operating parameters" is identical to the test point "Recording of operating parameters" according to point 7.5.4 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 13 Recording of operational parameters (7.5.4).	yes	87
6.5.5 Daily means	The AMS shall allow for the formation of daily averages or values.	The execution, evaluation and assessment for the test point "Daily means" is identical to the test point "Daily averages" according to point 7.5.5 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 14 Daily averages (7.5.5).	yes	88

Performance criterion	Requirement	Test result	Satis-fied	Page
6.5.6 Availability	At least 90%.	The execution, evaluation and assessment for the test point "Availability" is identical to the test point "Availability" according to point 7.5.6 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 15 Availability (7.5.6).	yes	89
6.5.7 Inspection interval	At least 14 days.	The execution, evaluation and assessment for the test point "Inspection interval" is identical to the test point "Maintenance interval" according to point 7.5.7 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 18 Maintenance interval (7.5.7).	yes	90
6.5.8 Data analysis	Between-AMS uncertainty ≤ 2.5 µg/m³ ≤ 25% at the level of the relevant limit value related to the 24-hour average results (If necessary after applying correction factors/terms).	The execution, evaluation and assessment for the test point "Data analysis" is identical to the test point "Data evaluation" according to point 7.5.8 of the EN 16450 (2017) standard. Therefore, reference is made here to chapters 7.1 Method used for equivalence testing (7.5.8.4 & 7.5.8.8); 7.1 16 Between-AMS uncertainty (7.5.8.4), 7.1 17 Expanded uncertainty (7.5.8.5 – 7.5.8.8) and 7.1 17 Use of correction factors/terms (7.5.8.5–7.5.8.8).	yes	91

Summary of test results in accordance with standard EN 16450

Performance criterion	Requirement	Test result	Satis-fied	Page
1 Measurement 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 linear measuring range is 0 - 5,100 µg/m³ for PM2.5 and 0 - 12,000 µg/m³ for PM10 for the standardised aerosol Arizona Dust A1 (ultrafine) with max. 10% linearity error. Higher measured values are subject to higher linearity errors and require shorter maintenance intervals.	yes	92
2 Negative signals	Negative measured signals or readings shall not be suppressed.	Negative measured signals can be directly displayed by the measuring system and output via the corresponding measured signal outputs, but are not to be expected due to the measuring principle and design.	yes	93
3 Zero level and detection limit (7.4.3)	Zero level: ≤ 2.0 µg/m³ Detection limit: ≤ 2.0 µg/m³	The zero level and the detection limit for both PM2.5 and PM10 were determined to be 0.00 µg/m³ from the tests for both systems.	yes	94
4 Flow rate accuracy (7.4.4)	≤ 2.0%	The maximum relative difference between the average value of the measurement results for the volumetric flow at +5 °C and +40 °C and the nominal value of 1.2 l/min was 0.75 % .	yes	96
5 Constancy of sample flow rate (7.4.5)	≤ 2.0% sampling flow (averaged flow) ≤ 5% rated flow (instantaneous flow)	All determined instantaneous values deviate less than 5 %; all averaged values deviate less than 1.00 % from the nominal value.	yes	98
6 Leak tightness of the sampling system (7.4.6)	≤ 2.0 % of the averaged sample volume flow rate	The leak test procedure specified by the manufacturer proved to be suitable for monitoring the unit's tightness during testing. Leakages of a maximum of 0.55 % were determined during the test.	yes	101
7 Dependence of zero on surrounding temperature (7.4.7)	≤ 2.0 µg/m³	The tested ambient temperature range is +5 °C to +40 °C. The maximum deviation from the mean measured value at $T_{S,n}$ was 0.0 µg/m³ for both $PM_{2.5}$ and PM_{10}.	yes	103
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 was +5 °C to +40 °C. The maximum deviation from the average reading at 20 °C was at -4.5 µg/m³.	yes	105

Performance criterion	Requirement	Test result	Satis-fied	Page
9 Dependence of span on voltage supply (7.4.8)	≤ 5 % from the value at the nominal test voltage	No fluctuations of more than -3.9 %, related to the average value at 230 V, could be detected due to mains voltage changes.	yes	107
10 Effect of failure of mains voltage	Instrument parameters shall be secured against loss. On return of the mains voltage the instrument shall automatically resume functioning.	All instrument parameters are secured against loss. On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring.	yes	109
11 Dependence of reading on water vapour concentration (7.4.9)	≤ 2.0 µg/m³ in zero air	No difference was found between the measured values at 40 % and at 90 % relative humidity.	yes	110
12 Zero checks (7.5.3)	Absolute value ≤ 3.0 µg/m³	The maximum absolute measured value determined at the zero point was 0.0 µg/m³.	yes	112
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 Ambient air pressure Air temperature in measuring section Temperature of sampling inlet if heated inlet is used	The AMS allows for comprehensive telemetric monitoring and control of the measuring system via various paths. The instrument provides operating statuses and all relevant parameters.	yes	114
14 Daily averages (7.5.5)	The AMS shall allow for the formation of daily averages or values.	The measuring system enables the measurement of the suspended dust mass concentrations in high temporal resolution with high reproducibility. The formation of valid daily average values is easily possible.	yes	116
15 Availability (7.5.6)	At least 90%.	Availability was 100% for system FE111 and 98.3% for system FE114.	yes	121

Performance criterion	**Requirement**	**Test result**	**Satis-fied**	**Page**
16 Between-AMS uncertainty (7.5.8.4)	≤ 2.5 µg/m³	At no more than 1.19 µg/m³ the uncertainty between the candidate systems ubs remains well below the permissible maximum of 2.5 µg/m³.	yes	124
17 Expanded uncertainty (7.5.8.5 – 7.5.8.8)	≤ 25% at the level of the relevant limit value related to the 24-hour average results (If necessary after applying correction factors/terms).	The determined uncertainties WAMS are already below the permissible expanded relative uncertainty Wdqo of 25 % for particulate matter for all considered data sets for the component PM10 without applying correction factors. For the PM2.5 component, without applying correction factors, some of the data sets are still above the allowable expanded relative uncertainty Wdqo of 25% for fine dust. Since for both PM2.5 and PM10 the intercept is significantly different from 0 and the slope is significantly different from 1, the application of correction factors shall be made appropriately in accordance with Section 7.1 17 Use of correction factors/terms . After applying correction factors and terms, all considered data sets are below the specified expanded relative uncertainty Wdqo of 25%.	yes	140
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	After the use of correction factors, the candidate systems met the requirements for data quality of ambient air monitors for all data sets.		161
18 Maintenance interval (7.5.7)	At least 14 days.	The maintenance interval is three months.	yes	168

Performance criterion	Requirement	Test result	Satis-fied	Page
19 Automatic diagnostic check (7.5.4)	Shall be possible for the AMS	The tested device always performs a self-test at the start of measurement operation and, configurable by the user, at regular intervals (in the performance test every 24 h). Any warnings or errors are provided in a diagnostic code.	yes	169
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	The sensors for recording the ambient temperature, air pressure and relative humidity can be easily checked on site. The deviations of the sensors were within the requirements at all times.	yes	170

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2. Task definition

2.1 Nature of the test

On behalf of Grimm Aerosol Technik GmbH, performance testing was carried out by TÜV Rheinland Energy GmbH for the EDM 280 measuring system for the components suspended particulate matter $PM_{2.5}$ and PM_{10}.

2.2 Objective

The measuring system is designed to determine the content of suspended particulate matter $PM_{2.5}$ and PM_{10} in ambient air.
The measuring system determines the suspended fine dust concentration by means of scattered light measurement.

The test was performed on the basis of the following standards:

- Standard EN 16450 “Ambient air – Automated measuring systems for the measurement of the concentration of particulate matter (PM_{10}; $PM_{2.5}$), German version dated July 2017
- VDI Standard 4202, Part 3, Automated measuring systems for air quality monitoring - Performance test, declaration of suitability and certification of measuring systems for point-related measurement of mass concentration for particulate air pollutants, February 2019
- European standard EN 12341, Ambient air - Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2.5}$ mass concentration of suspended particulate matter; German version EN 12341:2014
- Guideline “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English version dated January 2010 version

3. Description of the AMS tested

3.1 Measuring principle

The EDM 280 measuring system is a measuring device for suspended dust in ambient air. The determination of the suspended dust concentration is carried out with an optical aerosol spectrometer, which determines the particle number size distribution via scattered light analysis on the individual particle and calculates the corresponding mass concentrations by means of an algorithm.

The Figure 1 shows the schematic structure of the optical measuring cell of the EDM 280 measuring system.

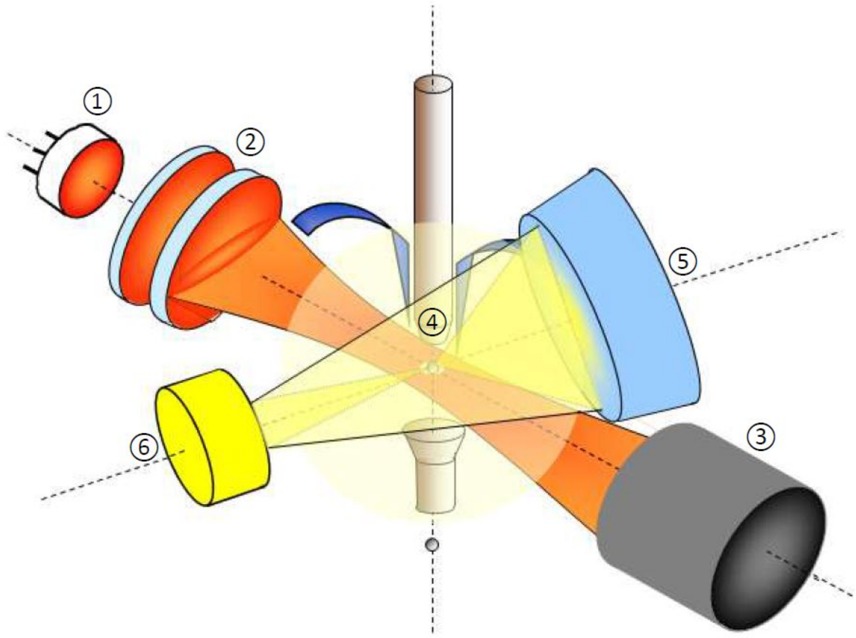

Figure 1: Schematic structure of the optical measuring cell

The instrument works using the principle of scattered light measurement on single particles. A laser diode serves as a light source ①. An illumination optics unit ② is used to focus the light as a narrow laser band into the measuring cell and then channel it to the measuring field in a light trap ③. All sample air is aerodynamically focussed into the focal point of the laser band ④, as set out in Annex A.3 “Definition of the sensing zone”, ISO 21501-1 (2009).

When a particle crosses through the laser beam, it is illuminated by the laser beam. This produces scattered light. The scattered light is collected by a wide-range lens ⑤ on a photodetector ⑥. The position of the detector is perpendicular to the laser beam.

Each electrical signal from the detector is counted and classified after appropriate amplification. The count events are output in 72 size increments. The size scale of the classification channels was determined on the basis of a unique, logarithmically equidistant allocation in diameter for polystyrene latex (PSL) spheres. The diameter thus corresponds to a "light scattering equivalent particle diameter" for polystyrene latex spheres as defined in ISO 21501-1 (2009).

The dust mass fractions are calculated on the basis of the measured particle number size distribution. Assuming spherical particles, a volume distribution is calculated and, in a further step, a mass distribution is calculated by multiplication with size-dependent density factors. The calculation of PM fractions incorporates results from comparative measurements in outdoor air with gravimetric dust collectors during the equipment development phase.

The time resolution of the measurement is 6 s, whereby the measured values are output as non-moving average values over the selectable measurement interval (6 s, 1, 5, 10, 15, 30, 60 minutes, daily average).

3.2 Functioning of the measuring system

The EDM 280 measuring system is made up of the following components:

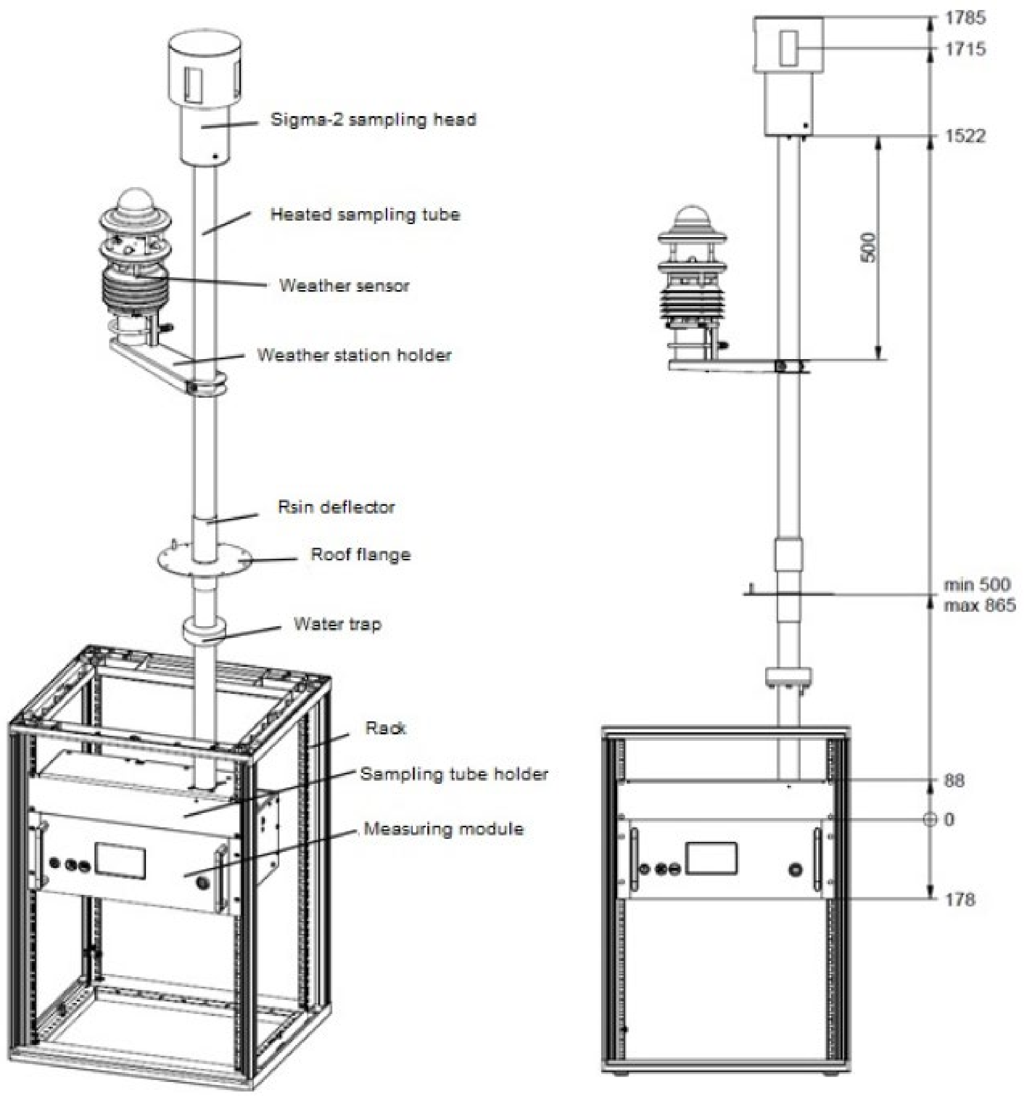

Figure 2: Schematic structure of the EDM 280

The EDM 280 measuring system is designed for installation in a measuring container with a roof bushing (or alternatively in the fully air-conditioned, weatherproof Model 199 housing). It essentially consists of the sampling assembly and measuring module. The sampling assembly is designed for permanent installation in a 19″ rack and is made up of a sampling tube with the sampling head (Sigma-2) and weather sensor from the company Ott Hydromet / Lufft (WS300, WS500 oder WS600), a roof flange with a rain deflector, and on the inside the water trap and sampling tube holder.

The measuring module is mounted in the rack under the sampling tube holder and connected to the sampling assembly in just a few steps. It contains the aerosol spectrometer and all components prone to wear, so it can be easily removed for maintenance and calibration. The touch display can be used to control the measuring operation on site, to view the measured values and the status, and to adjust settings.

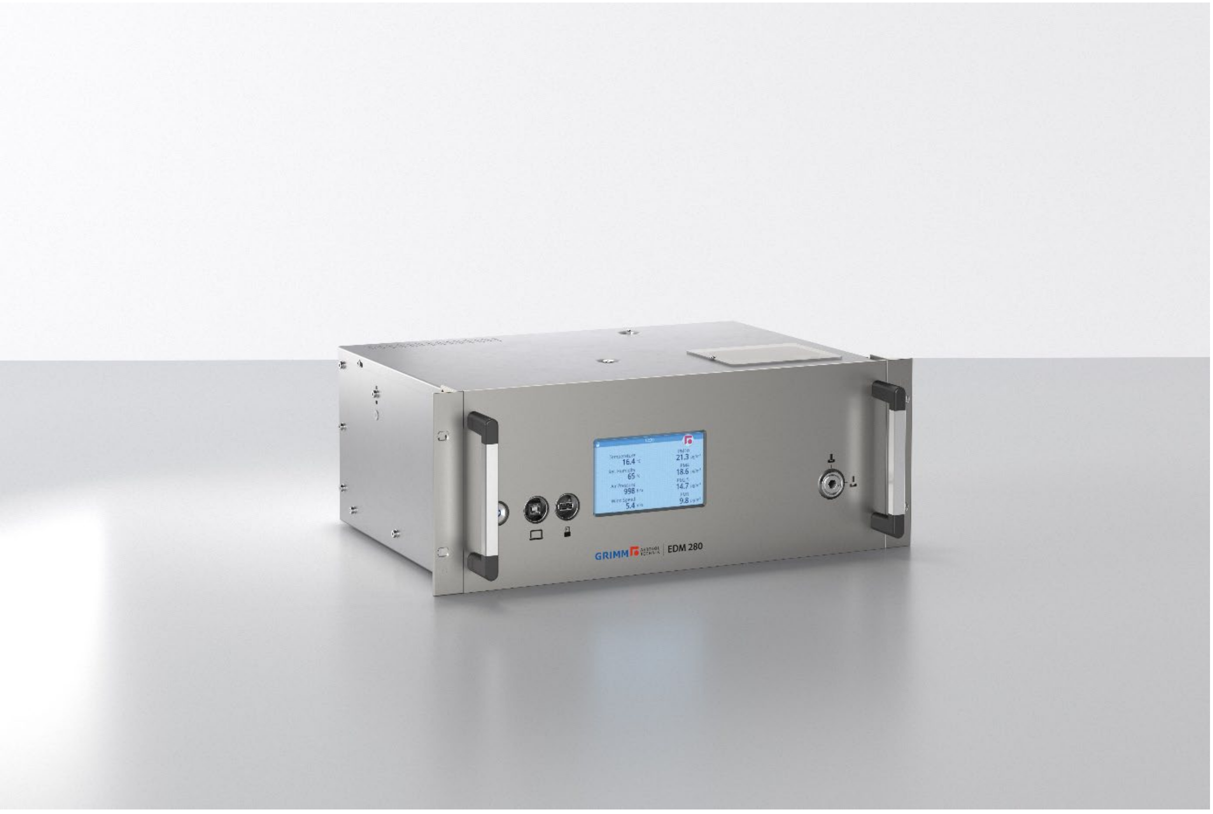

Figure 3: Measuring module of the EDM 280

Figure 4: Sampling tube holder + measuring module in housing Modell 199

The sample air is drawn in at a constant flow rate of 1.2 l/min (based on operating conditions at the measuring orifice) via the Sigma-2 sampling head (non-fractionating, equipped with a head heater to prevent ice formation) and fed vertically via the sampling tube for sample air conditioning into the optical measuring cell in the measuring module. The adaptive heating in the sampling tube is actively adjusted to ensure that condensation cannot be formed as the aerosol passes through to the measuring cell, while at the same time ensuring that there is as little warming of the aerosol as possible.

The determination of the mass concentrations for the suspended particulate fractions for PM_{10} and $PM_{2.5}$ is carried out in the optical measuring cell (for a description of the measuring principle, see point 3.1 Measuring principle).

In addition to the particulate matter fractions for PM_{10} and $PM_{2.5}$, further extensive measurement data (particulate matter fractions TSP, PM_4, PM_1 as well as PM_{Coarse},) total particle number concentration, particle-size distribution in 72 size channels (0.178 µm to 29,4 µm optical latex equivalent diameter) as well as data from the weather station Ott Hydromet / Lufft WS300 (ambient temperature, humidity, ambient pressure), WS500 (like WS300, additionally wind direction and wind speed) or WS600 (like WS300, additionally wind direction, wind speed and precipitation) are available.

A condensate trap, which is automatically emptied during the self-test, and a two-stage dust filter with a pre-filter and a residual dust filter are located downstream of the optical measuring cell. The sample volume flow is adjusted automatically. The sample air pump also conveys the purge air, which is taken from the pump outlet air in the device through an ultrafine filter and kept constant by a purge air controller. The purge air prevents contamination of the illumination and detection optics and is used as particle-free reference air during the instrument self-test.

The system is controlled using either the touch display on the front of the unit or via one of the interfaces (RS-232, USB-B, Ethernet) and one of the data protocols (GRIMM protocol, Modbus TCP, GESYTEC / Bayern-Hessen protocol).

In addition to transmitting the measurement data to a connected PC via interfaces and the selected data protocol, the measurement data can also be stored on a USB stick (plugged into the front of the device), e.g. as a backup. The data is written to text files in the GRIMM protocol.

The user can retrieve measurement data and system information from the AMS, change parameters (Service Mode 0 and 1, 2 only with service dongle for trained users) and carry out tests to check the functionality of the measuring system.

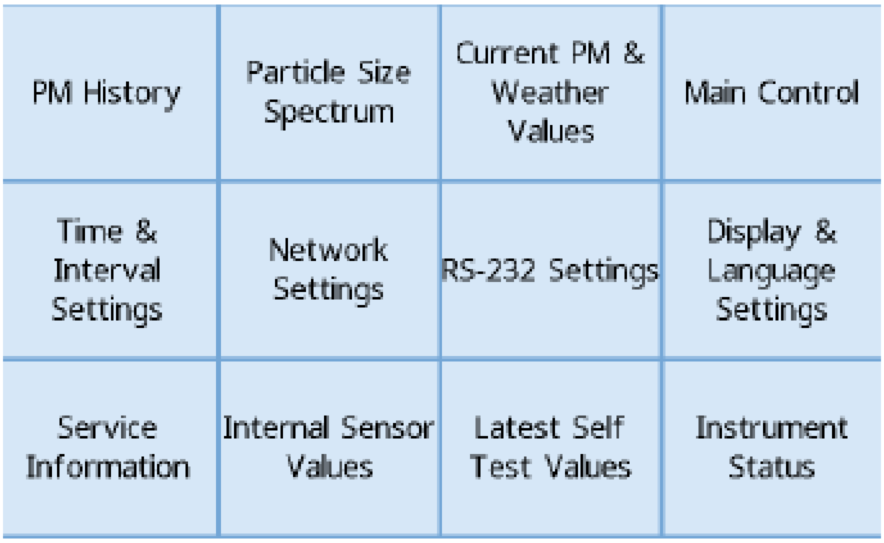

Figure 5: Menu overview with submenus

A total of 8 measured variables can be displayed under the "Current measured values" menu item. The display can be freely configured with the available measured variables by tapping on individual measured variables.

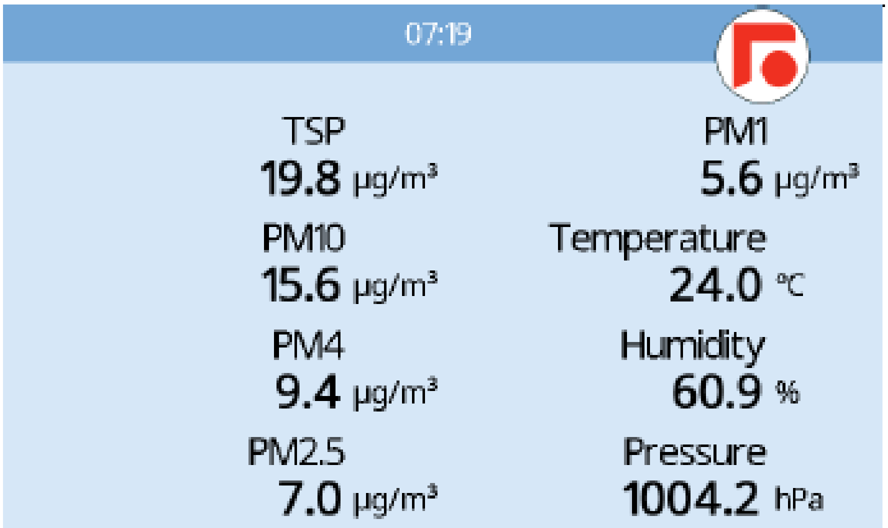

Figure 6: "Current measured values" menu

The status of the measuring equipment can be viewed at any time via various menus (service information, internal sensors, last self-test, status and maintenance) for fault diagnosis or maintenance work.

The measuring system performs a self-test after each start of the measuring operation or at a fixed, definable interval (within the scope of the performance test every 24 h). Here, it is checked, among other things, whether all internal sensors and the weather sensor respond and the DC level of the scattered light signal, the zero classifications and the laser current with dust-free purge air are recorded. In case of irregularities, a warning or error message is displayed.

The EDM 280 field test kit is available for external testing of the measuring system as part of ongoing quality assurance/monitoring in field operation. This kit includes an adapter for the sample inlet (for connecting an external flow meter), a zero air filter and a set for leak testing.

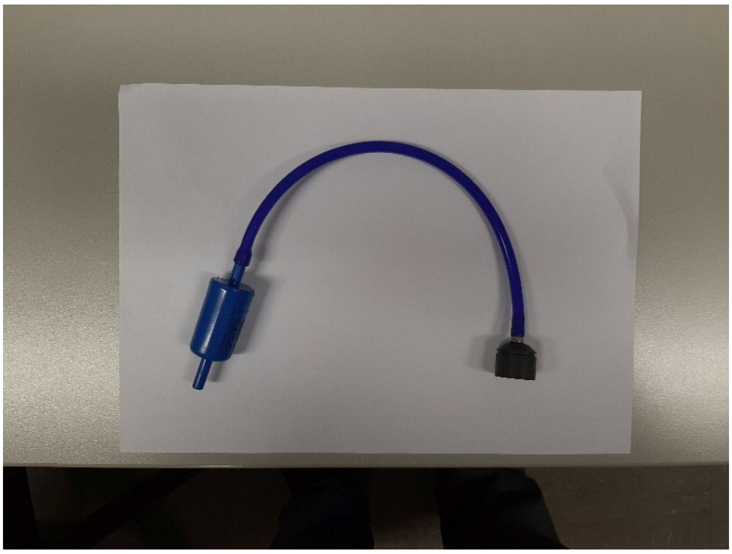

Figure 7: Adapter for sample inlet with mounted zero air filter

Figure 8: Set for leak testing

In addition to the classic installation in a measuring container with a roof bushing, the measuring system can alternatively be used in a fully air-conditioned, weatherproof Model 199 housing.

Figure 9: Fully air-conditioned, weatherproof housing Model 199

It must be ensured that the internal temperature of the housing does not exceed the permissible ambient temperature range of +5°C to +40°C. As part of a previous test by TÜV Rheinland, a Model 199 enclosure (with a built-in aerosol spectrometer) was subjected to a climatic chamber test between -20°C and +60°C and the temperatures inside the Model 199 enclosure were monitored. It could be demonstrated that at no point during the test did the temperatures inside the housing deviate from the permissible ambient temperature range of +5°C to +40°C.

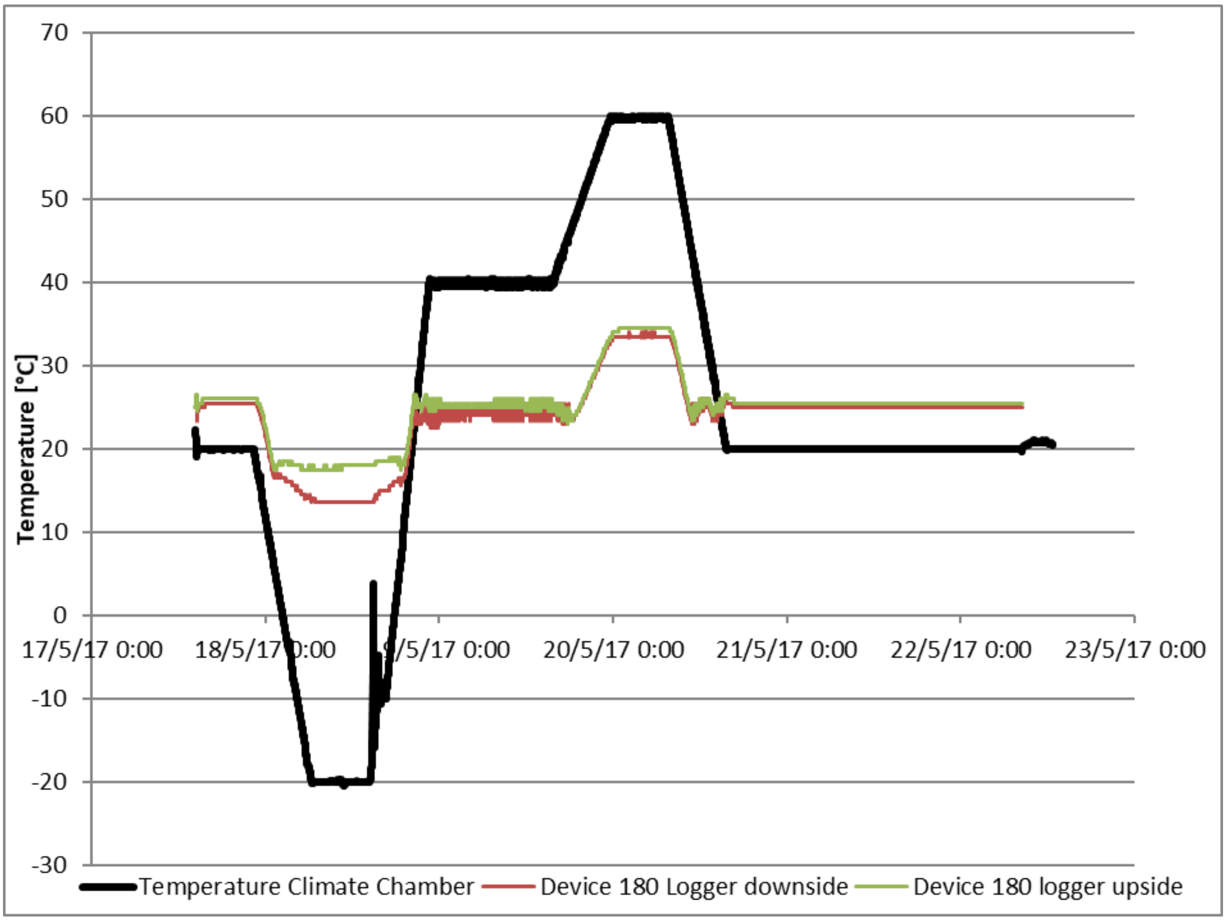

Figure 10: Temperature profile, climate chamber test Model 199

Table 3 contains a list of important instrument-related characteristics of the EDM 280 ambient air measuring system

Table 3: EDM 280 instrument characteristics (manufacturer specification)

Dimension/weight	**EDM 280**
Measuring system	Sampling tube holder: 88.9 mm (H) x 441 mm (W) x 156 mm (D); 2.4 kg Measuring module: 180.5 mm (H) x 434 mm (W) x 320 mm (D); 10.45 kg
Sampling tube	1500 mm (H) ∅ 45 mm tube; 5.3 kg (incl. sampling head)
Sampling head	Sigma-2, non-fractional, Head heating (for outside temperatures < 5°C)
Power supply	100 to 240 VAC at 50 - 60 Hz
Power requirement	Typically < 100 W Maximum approx. 220 W (maximum configuration, all heaters at maximum power).
Installation conditions	
Temperature	+5 to +40 °C
Relative humidity	5-90 %, non-condensing
Sample volume flow	1.2 l/min constant, related to the conditions at the measuring orifice
Sampling tube	Adaptively heated with active control (controlled variable sample air humidity in measuring cell, adjustable variable for sample tube heating capacity)
Aerosol sensor	
Measuring principle	Scattered light measurement, combination of laser and 90° scattered light detection
Measuring range (particle size)	0.178 µm - 29.4 µm (optical latex equivalent diameter)
Size channels	72 logarithmically equidistant gradations, 32 channels per decade
Time resolution	6 s performance test, other configurations possible
Averaging time / storage interval	Non-sliding, in performance test 1 min, other configurations selectable (6 s, 5, 10, 15, 30, 60 min or 1d).

Weather sensor from the company Ott Hydromet (Lufft)	
General	The weather sensors listed are identical in terms of the sensors used. At least version WS300 (T,p,rH) is required to operate the measuring system. The additional sensors of the WS500 and WS600 versions also provide further meteorological measured variables. Within the scope of the performance test, the WS600 weather sensor with maximum number of functions was used.
WS300	Ambient temperature, humidity and pressure
WS500	As WS300, additionally wind speed and wind direction
WS600	As WS500, plus precipitation
Data interfaces	RS-232 Ethernet USB 2.0 USB-B (service interface)
Implemented data protocol (ASCII)	GRIMM protocol Modbus TCP GESYTEC / Bayern-Hessen protocol
Status signals/error messages	Using touch display or via data interface

4. Test programme

4.1. General

Performance testing was carried out using two identical instruments with the following serial numbers:

System 1: 280FE111 (abbreviated to FE111 in the report)
System 2: 280FE114 (abbreviated to FE114 in the report)

At the start of performance testing, the following software versions were installed on the measuring system:

Firmware	1.00
FPGA	0.08
GUI	1.00

The firmware represents the superordinate software and contains, among other things, the control of the measuring device or the measuring system as well as the evaluation algorithm for processing the raw data of the aerosol spectrometer to the output measured values.

The FPGA software is a sublevel software for the evaluation of the raw data of the aerosol spectrometer (particle counting and classification).

The GUI represents the display software.

Relevant functions for ergonomic operation (GUI and DHCP (=Dynamic Host Configuration Protocol)) were missing. In addition, minor errors had been noticed during operation, which also had to be corrected.

The necessary changes (function enhancements (GUI) + bug fixes) were all correctly classified as a type 1 change by the manufacturer. The errors were corrected and the changes were intensively checked internally. No influence on the performance of the measuring system could be determined and thus also not on the results of the performance test achieved so far.

The current software version are:

Firmware	1.01
FPGA	0.08
GUI	1.01

The software version was updated to the current version at the start of the field test in August 2021 and remained unchanged throughout the rest of the test.

4.2 Laboratory testing

Performance testing was carried out using two identical instruments with the following serial numbers:

System 1: 280FE111 (abbreviated to FE111 in the report)
System 2: 280FE114 (abbreviated to FE114 in the report)

Standards [1] and [4] specify the following test programme for the laboratory test:

- Readings
- Negative signals
- Zero level and detection limit
- Flow rate accuracy
- Tightness of the sampling system
- Dependence of the zero point on the ambient temperature
- Dependence of the reading on the ambient temperature
- Effect of mains voltage on the reading
- Effect of failure of mains voltage
- Effect of humidity on the reading

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
- Monodisperse test dust for checking sensitivity

The measured values were recorded internally. The stored raw data sets were continuously saved on a USB stick via the GRIMM protocol, read out as needed and analysed in Excel.

Sensitivity testing was performed using a monodisperse test dust that was placed in otherwise dust-free sample air. The test dust consists of glass spheres with a diameter of approx. 5 µm. It is placed in a dispenser (approx. 100 mg for 5-10 measurements), which is connected to the sample inlet with a tube. The user agitates the particles with the help of small steel balls in the dispenser. The sample air flows from the surrounding area through a filter into the dispenser and is enriched with test dust.

The EDM 280 measuring system classifies the test dust with a special, fine graded classification scale, which must be loaded onto the device before the test. Due to other optical properties, the optical diameter of glass does not match that of PSL, so the mode of distribution is about 4.5 µm. The distribution is used to calculate the mean value of the particle diameter weighted by the number of particles. Ideally, a spherical volume can then be calculated from the particle diameter. A change in sphere volume due to variation in particle diameter is proportional to a change in particle mass (and hence mass concentration) assuming a constant density, and can therefore be used to check sensitivity.

The test with test dust was therefore performed for checking the influence of ambient temperature and voltage supply on the measured value.

Figure 11: EDM 280 in climatic chamber, dispenser connected to sample inlet

However, since significantly higher quantities of dust are introduced into the system when the method is used (compared to normal measuring operation), the method is not suitable for regular use, e.g. in field operation, due to the excessive load / contamination of the measuring equipment (especially the optics).

Instead, the measuring module is to be taken annually to the manufacturer or to a specially trained and equipped service partner for checking and, if necessary, calibration. The method used here relies on a polydisperse test dust in a lower concentration.

The results of the laboratory tests are summarised under point 6 / point 7.

4.3 Field test

Performance testing was carried out using two identical instruments with the following serial numbers:

System 1: 280FE111 (abbreviated to FE111 in the report)
System 2: 280FE114 (abbreviated to FE114 in the report)

Standards [1] and [4] specify the following test programme for the field test:

- Constancy of sample volumetric flow
- Zero checks
- Recording of operational parameters
- Daily values/daily averages
- Availability
- Between-AMS uncertainty
- Expanded uncertainty
- Maintenance interval/period of unattended operation
- Automatic diagnostic check
- Checks of temperature sensors, pressure and/or humidity sensors

The following instruments were used during the field test.

- Measurement container provided by TÜV Rheinland, air-conditioned to about 20 °C (Cologne, Bornheim)
- Fully air-conditioned, weatherproof housing Model 199, air-conditioned to approx. 20 °C (Niederzier, JRC Ispra)
- Weather sensor for recording meteorological parameters such as air temperature, air pressure, air humidity, wind speed, wind direction as well as rainfall (Cologne and Bornheim only)
- 4 reference systems SEQ47/50 (for $PM_{2.5}$ and PM_{10} according to point 5)
- 1 mass flow meter Model 4043 (manufacturer: TSI)
- Field test kit EDM 280 incl. set for leak test and zero filter for external zero point check

In the field test, two EDM 280 systems and four reference instruments (2 for $PM_{2.5}$ and 2 for PM_{10}) were running simultaneously. The SEQ47/50 reference instruments automatically change the filters every 24 h.

Impaction plates on the sampling head were cleaned approximately every two weeks during the test period and greased with silicone grease in order to ensure reliable separation of the particles.

For the candidate systems as well as for the reference devices, the flow rate was checked before and after each change of location using a mass flow meter connected to the air inlet of the system via a hose line. In addition, the leak tightness and the zero point of the candidate systems were checked before and after each change of location.

Sites of measurement and instrument installation

At the field test sites in Cologne and Bornheim, an air pollution measurement station was used in which the candidate systems were installed. The reference instruments were installed outside the container immediately in front of it.

At the field test sites in Niederzier and JRC Ispra tests were carried out without air pollution measurement stations due to the on-site conditions. Candidate systems here were installed in a fully air-conditioned, weatherproof, Model 199 housing from Grimm Aerosol Technik, and the reference instruments were installed on the ground in close proximity to them.

The field test was performed at the following measurement sites:

Table 4: Field test sites

No.	Measurement site	Period	Description
1	Cologne (TÜV car park)	08/2021 – 11/2021	Urban background
2	Bornheim (Motorway A555)	12/2021 – 03/2022	Affected by traffic
3	Niederzier (LANUV (State Agency for Nature, Environment and Consumer Protection) measuring station)	06/2022 – 09/2022	Industrial background
4	JRC Ispra	10/2022 – 01/2023	Rural

Figure 12 to Figure 19 show the PM concentrations measured with the reference systems at the field test sites.

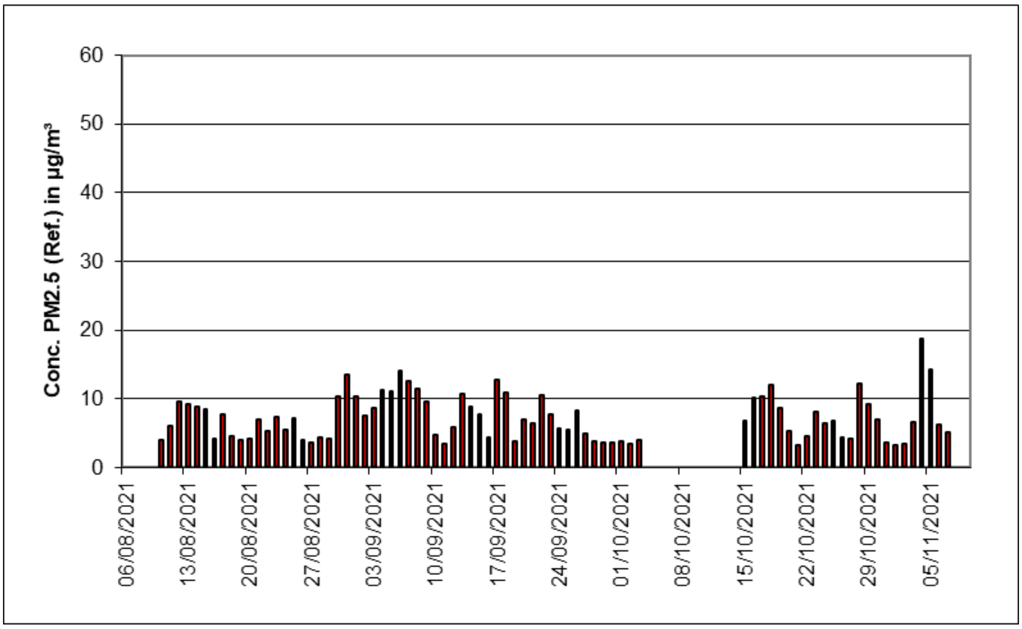

Figure 12: $PM_{2.5}$ concentrations (reference) Cologne

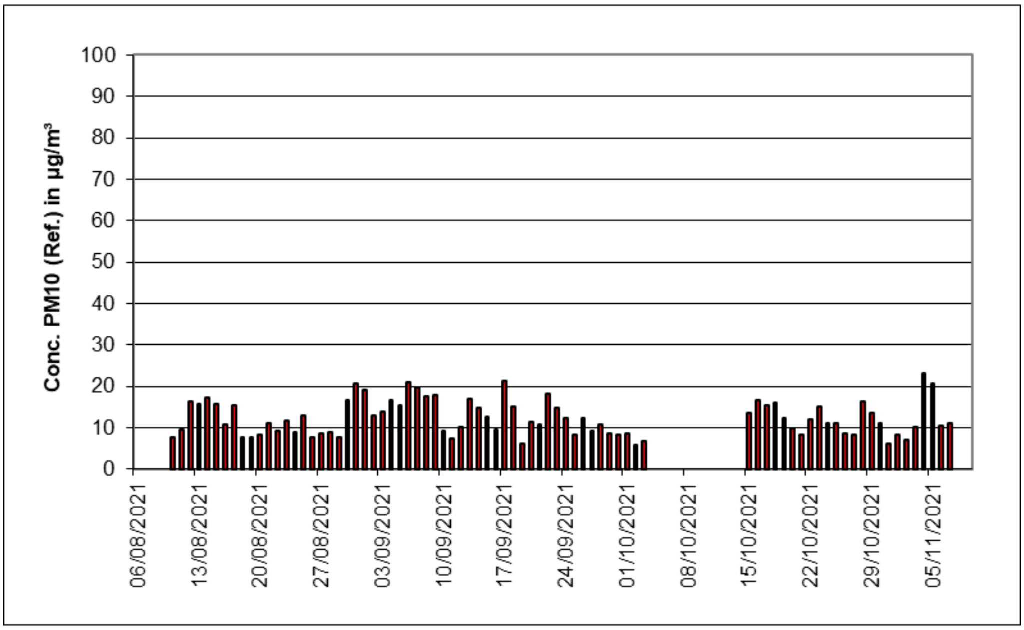

Figure 13: PM_{10} concentrations (reference) Cologne

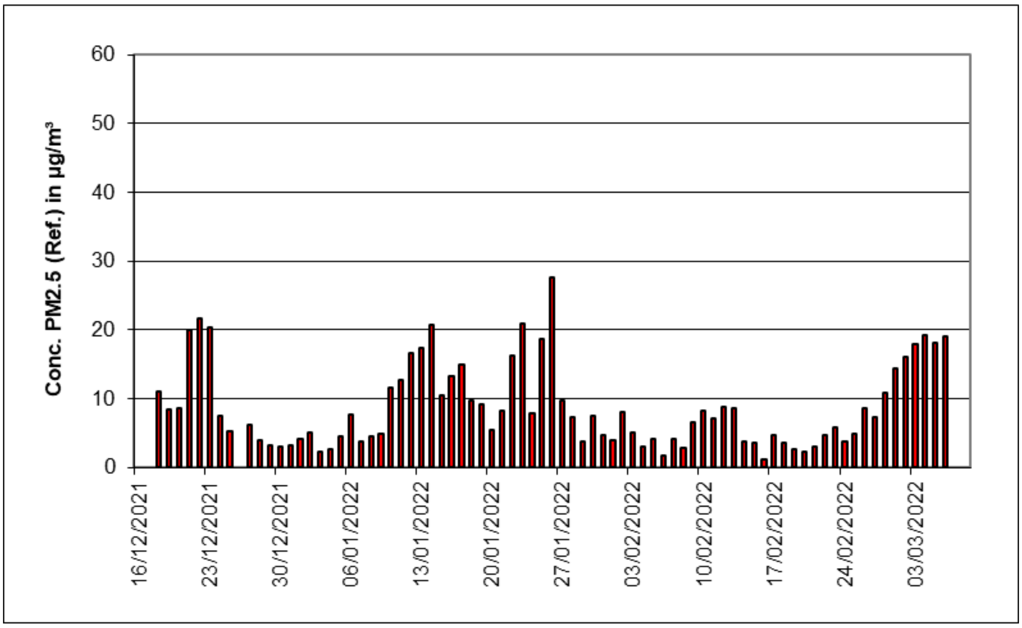

Figure 14: $PM_{2.5}$ concentrations (reference) Bornheim

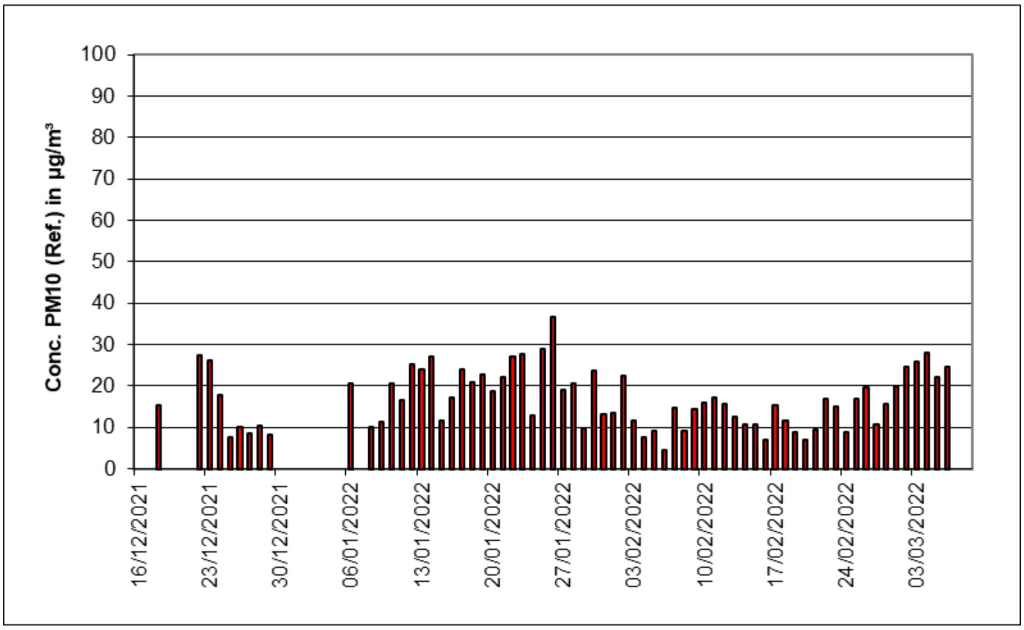

Figure 15: PM_{10} concentrations (reference) Bornheim

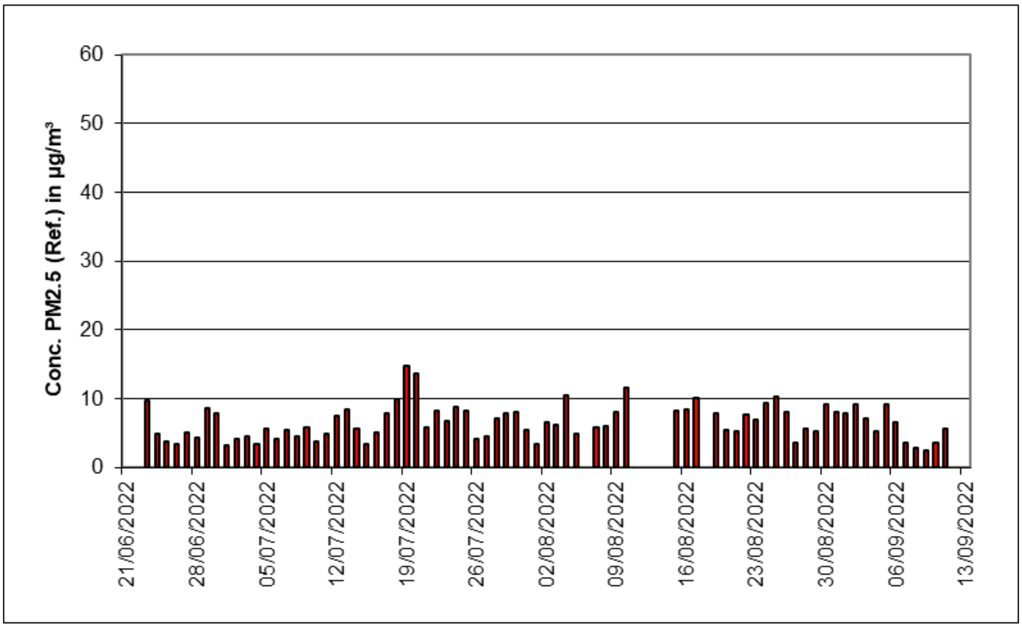

Figure 16: $PM_{2.5}$ concentrations (reference) Niederzier

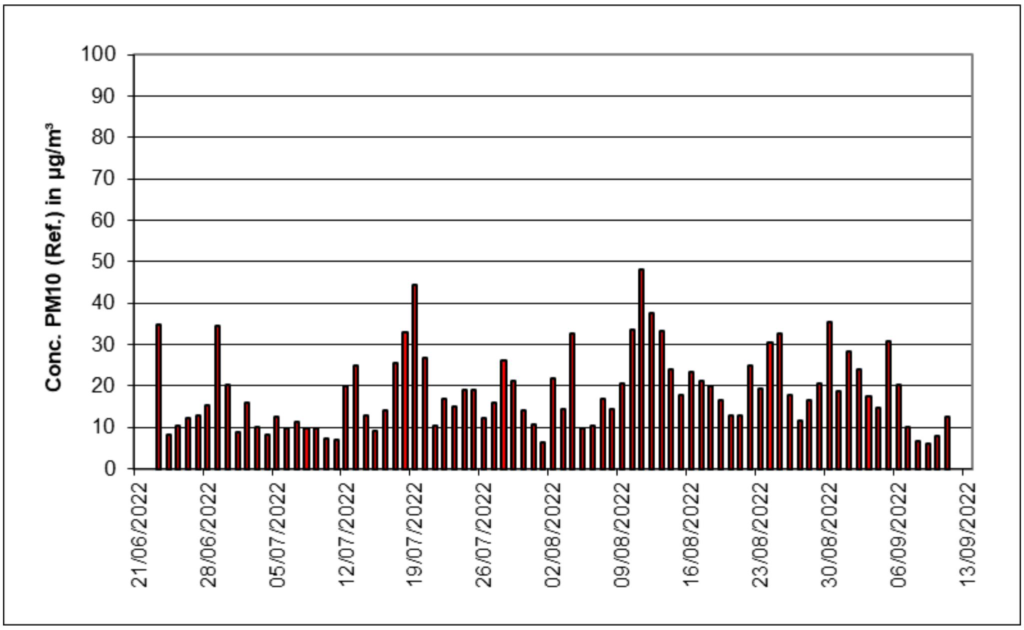

Figure 17: PM_{10} concentrations (reference) Niederzier

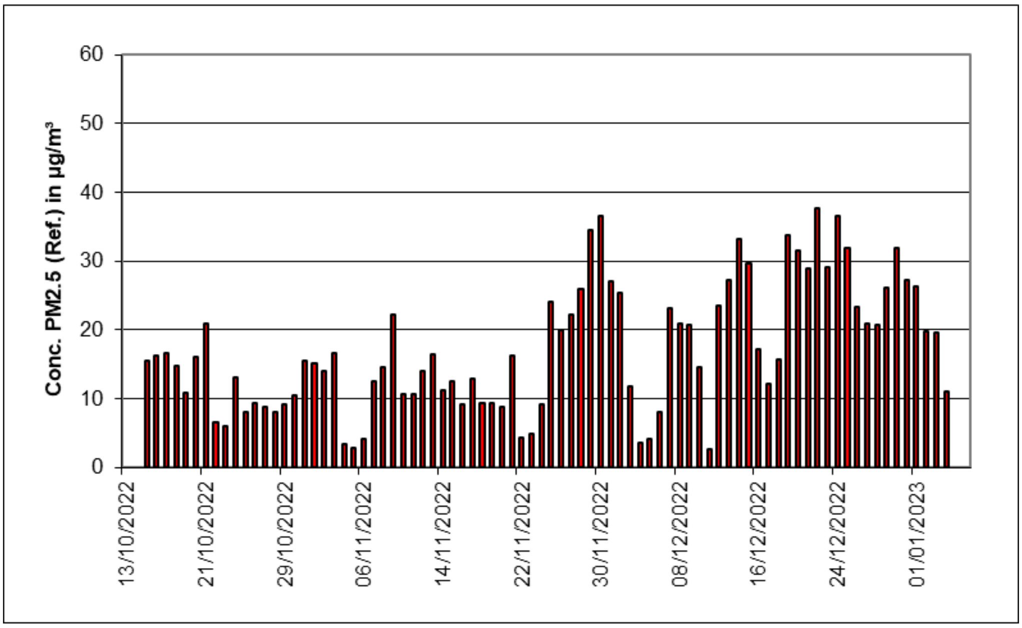

Figure 18: $PM_{2.5}$ concentrations (reference) JRC Ispra

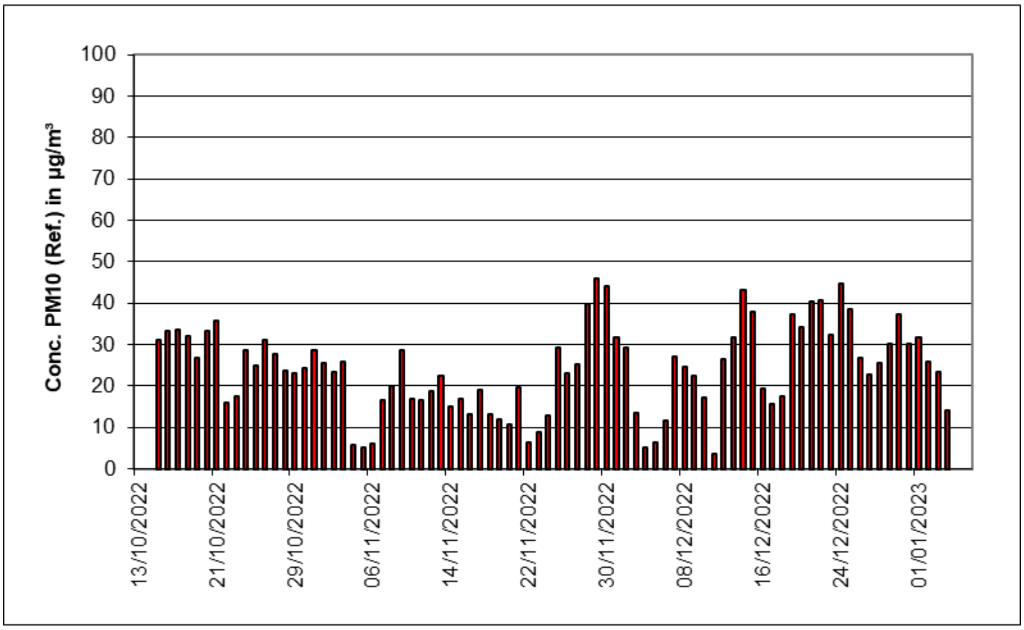

Figure 19: PM_{10} concentrations (reference) JRC Ispra

The following figures show the different field test sites:

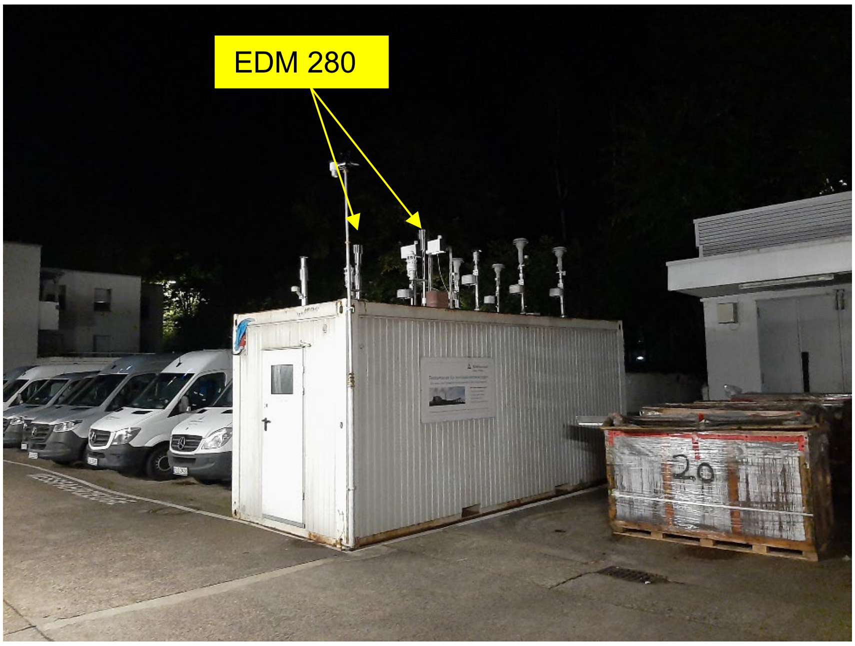

Figure 20: Field test site Cologne

Figure 21: Field test site Bornheim

Figure 22: Field test site Niederzier

Figure 23: Field test site JRC Ispra

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. Air temperature, air pressure, humidity, wind speed, wind direction, and precipitation were recorded continuously (except for Niederzier and JRC Ispra). 1-min average values were recorded.

The structure of the container itself as well as the arrangement of the sampling probes were characterized by the following dimensions:

Cologne und Bornheim

- Height of cabinet roof: 2.5 m
- Height of the sampling system for test system ca. 3.5 m above ground level / ca. 1.0 m above container roof
- Reference system ca. 3.5 m above ground level

Niederzier

- Height of the sampling system for test system ca. 2.5 m above ground level
- Reference system ca. 2.8 m above ground level

JRC Ispra

- Height of the sampling system for test system ca. 2.5 m above ground level
- Reference system ca. 1.5 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 provides information on the concentrations of suspended particulate matter.

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

	Cologne	Bornheim	Niederzier	JRC Ispra
Number of value pairs 2 x reference vs. 2 x candidate	PM_{10}: 73 $PM_{2.5}$: 73	PM_{10}: 68 $PM_{2.5}$: 78	PM_{10}: 81 $PM_{2.5}$: 75	PM_{10}: 82 $PM_{2.5}$: 82
Ratio of $PM_{2.5}$ to PM_{10} [%] Range Average	 35.3 – 80.9 57.1	 16.4 – 90.0 51.0	 24.7 – 69.8 39.5	 30.2 – 92.9 70.6
Air temperature [°C] Range Average	 6.7 – 22.2 15.2	 -1.5 – 14.0 5.6	 16.5 – 28.1 20.5	 -2.7 – 16.7 7.9
Air pressure [hPa] Range Average	 996 – 1025 1013	 989 – 1035 1015	 994 – 1019 1006	 972 – 1009 994
Rel. Humidity [%] Range Average	 61.3 – 92.7 76.0	 53.6 – 98.8 82.5	 36.0 – 86.3 61.5	 28.8 – 99.1 87.5
Wind speed* [m/s] Range Average	 0.0 – 1.7 0.3	 0.3 – 3.7 1.3	 0.3 – 2.0 0.8	 0.1 – 1.2 0.3
Precipitation* [mm] Range Average	 0.0 – 13.0 1.2	 0.0 – 22.1 2.0	Not determined	Not determined

*These data are only indicative measurements

Sampling duration

Standard EN 12341 [3] specifies the sampling time as 24 h ± 1 h.

In the field test, a sampling time of 24 h was always set for all systems. (from 00:00 - 00:00).

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 Grubbs's test for outliers (99%) in order to prevent distortions of the measured results from data, which evidently is implausible. Pairs of measured values detected as significant outliers may be removed from the value pool until the value falls below the critical value of the test variable. In accordance with standard EN 16450 [4], it is permitted to remove up to 2.5% of data pairs that qualify as outliers as long as at least 40 valid data pairs per site remain.

The following pairs of values were identified and removed:

Table 6: Value pairs (reference $PM_{2.5}$) discarded from the data set following Grubbs's test

Location	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]
Bornheim	26.12.2021	13.3	8.8
Niederzier	06.08.2022	9.2	24.0

For PM_{10}, no pairs of measurements were identified as outliers.

Filter handling – Mass measurement

The following filters were used during performance testing:

Table 7: Filter materials used

Filter material, type	Manufacturer
Emfab™, ∅ 47 mm	Pall

Filter handling was performed in compliance with EN 12341.

The filter handling and weighing procedures are described in detail in Appendix 2 to this report.

5. Reference Measurement Method

The following instruments were used for the field test.

1. As reference device $PM_{2.5}$ and PM_{10}:

Standard reference samplers with automatic filter change SEQ47/50-RV
Manufacturer: Sven Leckel Ingenieurbüro GmbH, Berlin
$PM_{2.5}$ and PM_{10} sampling head

During the test, two reference units for $PM_{2.5}$ and two for PM_{10} were operated in parallel with a controlled flow rate of 2.3 m³/h. Under normal conditions the accuracy of flow control is < 1% of the nominal flow rate.

On the reference instruments, the rotary vane vacuum pump takes in sample air via the sampling head. 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.

With the SEQ47/50-RV, a new filter is automatically inserted after 24 hours of sampling and the sampled filter is placed in the filter magazine. The filter magazine for the sampled filters is not actively conditioned / cooled.

The relevant sampling parameters are stored on a storage medium.

The concentration of suspended dust was determined by dividing the amount of suspended dust on the respective filter determined gravimetrically in the laboratory by the associated sample air volume in operating m³.

6. Test results (VDI 4202 Part 3 February 2019)

6.1 6.1 General remarks

The manufacturer's data in the operating instructions of the AMS are not permitted, under any circumstances, to be better than the results of the performance testing.

6.2 Equipment

No additional equipment is required.

6.3 Testing

The manufacturer's operating instructions were checked for completeness and correctness. It was verified whether the manufacturer's specifications in the AMS operating instructions are in no way better than the results of the performance test.

6.4 Evaluation

The operating instructions for the measuring system (status: 1.04 (German) or 1.01 (English)) are complete and correct. The manufacturer's specifications are no better than the results of the performance test.

6.5 Assessment

The operating instructions for the measuring system (status: 1.04 (German) or 1.01 (English)) are complete and correct. The manufacturer's specifications are no better than the results of the performance test.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 6.2 Multicomponent measuring instruments

Multicomponent measuring instruments have to comply with the performance criteria for each separate measured component independently of the other measured components.

6.2 Equipment

No additional equipment is required.

6.3 Testing

The EDM 280 measuring system is an AMS based on aerosol spectrometry. The measured value output for the dust fractions is continuous and simultaneous.

The test was carried out individually for the fractions PM_{10} and $PM_{2.5}$ according to the test specifications .

6.4 Evaluation

Evaluation with regard to performance criteria was carried out for each individual measured component independently of the other measured components.

6.5 Assessment

Evaluation with regard to performance criteria was carried out for each individual measured component independently of the other measured components.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 6.3 General requirements

6.1 6.3.1 Measured value display

The measuring system shall have an operative measured value display as part of the instrument.

6.2 Equipment

No additional equipment is required.

6.3 Testing

It was checked whether the measuring system has a measured value display.

6.4 Evaluation

The measuring system has an operative measured value display at the front of the instrument. A total of 8 measured variables can be displayed under the "Current measured values" menu item. The display can be freely configured with the available measured variables by tapping on individual measured variables.

6.5 Assessment

The measuring system has an operative measured value display at the front of the instrument.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Figure 24 shows the display of measured values on the EDM 280.

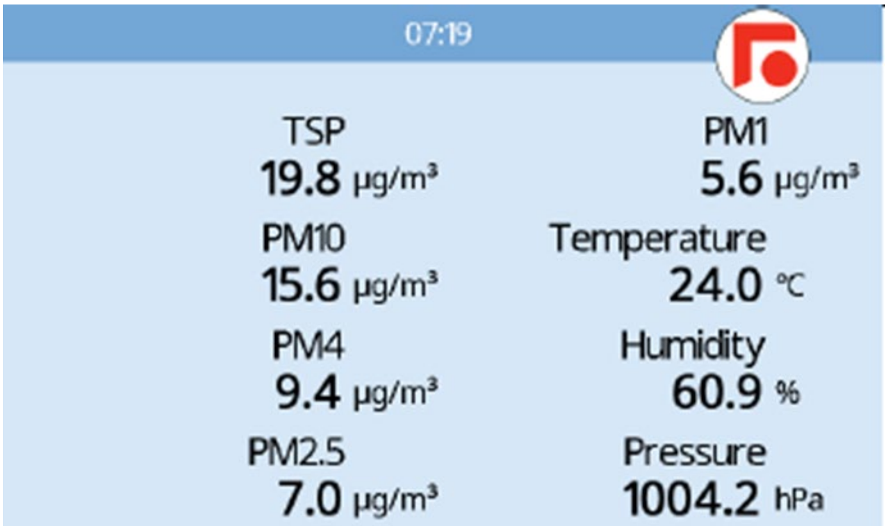

Figure 24: Measured values display EDM 280

6.1 6.3.2 Easy maintenance

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

6.2 Equipment

No additional equipment is required.

6.3 Testing

The necessary regular maintenance was performed in accordance with the instruction manual.

6.4 Evaluation

The manufacturer has prepared a maintenance plan for the measuring system (chapter 7 of the manual for the AMS). The shortest maintenance interval is 3 months (verification of the measuring system according to the specifications of the European standard EN 16450 [4], cleaning of the inlet nozzle and Sigma-2 sampling head).

The measuring module in the measuring system must be sent to Grimm Service or an authorized Grimm service partner at least every 12 months (or when the "Calibration" wear indicator is completely red) for maintenance, including a check of the calibration. As part of the performance test, this maintenance operation was performed in June 2022.

6.5 Assessment

Maintenance work can be carried out externally with standard tools and reasonable effort. The measuring module in the measuring system must be sent to Grimm Service or an authorized Grimm service partner at least every 12 months (or when the "Calibration" wear indicator is completely red) for maintenance, including a check of the calibration.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Work on the equipment was performed during testing based on the work and work procedures described in the manual. Complying with the procedures described in the manual, no difficulties were identified. All maintenance work could be carried out without any problems.

6.1 6.3.3 Functional check

If the operation or the functional check of the measuring system require 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.
The test laboratory shall assess the suitability of the automatic function control belonging to the AMS.

6.2 Equipment

Operating manual.

6.3 Testing

The current operating status of the measuring system is continuously monitored and problems are indicated via a number of different warning and error messages.

The tested device always performs a self-test at the start of measurement operation and, configurable by the user, at regular intervals (in the performance test every 24 h). During the self-test, one of the checks is whether the internal sensors and the weather sensor respond. Dust-free purge air is pumped into the measuring cell and the DC level of the scattered light signal, the zero classifications and the laser current are recorded.

6.4 Evaluation

The current operating status of the measuring system is continuously monitored and problems are indicated via a number of different warning and error messages.

The tested device always performs a self-test at the start of measurement operation and, configurable by the user, at regular intervals (in the performance test every 24 h). During the self-test, one of the checks is whether the internal sensors and the weather sensor respond. Dust-free purge air is pumped into the measuring cell and the DC level of the scattered light signal, the zero classifications and the laser current are recorded. Any warnings or errors are provided in a diagnostic code.

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

6.5 Assessment

The tested device always performs a self-test at the start of measurement operation and, configurable by the user, at regular intervals (in the performance test every 24 h). Any warnings or errors are provided in a diagnostic code.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 6.3.4 Set-up times and warm-up times

The operating instructions have to contain the manufacturer's data relating to the setting-up time and running-in time of the AMS.

6.2 Equipment

User manual.

6.3 Testing

The measuring systems were set up following the manufacturer's instructions. Set-up times and warm-up times were recorded separately.

Necessary structural measures in advance of the installation, such as the installation of roof bushings, are not assessed here.

6.4 Evaluation

The set-up time is primarily determined by the conditions at the installation site. The following steps are necessary for the set-up:

- Unpack the measuring system
- Prepare the rack
- Mount the sampling tube holder
- Prepare the sampling tube
- Install the sampling tube
- Mount the weather sensor
- Seal the roof bushing
- Prepare the measuring module
- Install the measuring module
- Lock the lift, connect the cables, connect the condensate outlet, connect the interface
- Connect the power supply
- Check for leak-tightness

The start-up procedure is described in detail in chapter 5 of the user manual.

The set-up time is approx. 1 h.

After switching on the instrument and starting measuring operation, the sampling tube warms up to the set temperature. During the warm-up phase, the warning 'Sampling assembly is reporting a warning' is displayed. For an acclimatised device, the run-in time is a maximum of 15 minutes.

6.5 Assessment

The set-up time is approx. 1 h. The necessary work is described in the user manual. The warm-up time until valid measured values are available after switching on is approx. 15 min.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 6.3.5 Instrument design

The instruction manual shall include specifications from the manufacturer regarding the design of the measuring system. The main elements are:

- *Instrument shape (e.g. bench mounting, rack mounting, free mounting)*
- *Mounting position (e.g. horizontal or vertical mounting)*
- *Safety requirements*
- *Dimensions*
- *Weight*
- *Power consumption*
- *Preventing condensation within the analyser.*

6.2 Equipment

Operating manual as well as a measuring device for recording energy consumption (Voltcraft Energylogger) and scales.

6.3 Testing

The instrument design of the measuring systems handed over for testing was compared to the description provided in the manual. The energy consumption specified was verified over 24 h during normal operation under field conditions.

6.4 Evaluation

The EDM 280 measuring system must be installed in a horizontal mounting position in a 19" rack in the measuring container or in the fully air-conditioned, weatherproof Model 199 housing.

The dimensions and weight of the measuring system correspond to the information provided in the operating manual and are as follows:

Table 8: Dimensions and weights of the EDM 280 measuring system

Dimension/weight	EDM 280
Measuring system	Sampling tube holder: 88.9 mm (H) x 441 mm (W) x 156 mm (D); 2.4 kg Measuring module: 180.5 mm (H) x 434 mm (W) x 320 mm (D); 10.45 kg
Sampling tube	1500 mm (H) ∅ 45 mm tube; 5.3 kg (incl. sampling head)

The manufacturer specifies a maximum power consumption of 220 W. A significant proportion of this is accounted for by the adaptive heating of the sampling tube.

Typically, the power consumption of the measuring system is less than 100 W. Over 24 hours, a measurement under field conditions on 25.01.2023 resulted in an average power consumption of approx. 46 watts.

To avoid condensation effects on the path of the aerosol to the measuring cell, the adaptive heating in the sampling tube is actively controlled. The heating of the aerosol is kept as low as possible in order to avoid changing the state of the particle fraction of the aerosol as much as possible (avoiding the loss of volatile components). The controlled variable for the heating is the sample air humidity in the measuring cell, the manipulated variable is the sample tube heating power. The control operates in two stages using outdoor temperature, outdoor humidity and measuring cell temperature to determine a nominal value for the sampling tube temperature. The second control loop adjusts the actual temperature to the set temperature.

6.5 Assessment

Specifications made in the instruction manual concerning instrument design are complete and correct.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.3.6 Unintended adjustment

It shall be possible to secure the adjustment of the measuring system against illicit or unintended adjustment during operation. Alternatively, the operating manual shall specifically note that the measuring system may only be installed in a secured area.

6.2 Equipment

The test of this criterion did not require any further equipment.

6.3 Testing

The measuring system is operated via a front display or via an external computer connected directly or via a network and the corresponding data protocols.

Adjustments of the measuring equipment as well as maintenance and service work are divided into a total of 5 levels in a hierarchical design. Functions of a lower service level are also available in the higher service levels.

Service level	User / typical use case	Functions
Service mode 0	Normal measuring operation	Start/stop measurement Display operating time Display firmware and FPGA version Output averages Output serial number Output model name Output data header in GRIMM protocol
Service mode 1	Protected settings that can be changed by the customer	Adjust measurement interval Adjust time and date Output and reset averages Enable/disable measured value output Display thresholds Output data in internal memory IP address configuration GESYTEC configuration
Service mode 2	Field calibration	Calibrate volume flow Configure heating (humidity threshold, factor, offset) Display/configure service register Reference point measurement
Service mode 3	Calibration, service	Advanced settings
Service mode 4	Production	Advanced settings

Table 9: Service Mode - Overview of functions and areas of application

Service mode 0 and 1 are accessible to the user without password protection.
Service mode 1 is actively activated via command line or touch display.

From Service Mode 1 onwards, a USB dongle is required to unlock the service mode. For this purpose, the signed XML file key.xml is located on the dongle, which authenticates the dongle.
For Service Mode 2, explicit instruction/training by the manufacturer is required.
Service Mode 3 and 4 are reserved for Grimm Service or Production.

In order to safely protect the measuring system from unauthorised access during measuring operation, the system must be operated in a locked measuring container (see also section 2.5.1 of the user manual).

6.4 Evaluation

Unintentional adjustment of the calibration is prevented by a hierarchical concept for calibrations of the measuring equipment as well as maintenance and service work.

In order to safely protect the measuring system from unauthorised access during measuring operation, the system must be operated in a locked measuring container.

6.5 Assessment

Unintentional adjustment of the calibration is prevented by a hierarchical concept for calibrations of the measuring equipment as well as maintenance and service work.

In order to safely protect the measuring system from unauthorised access during measuring operation, the system must be operated in a locked measuring container.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.3.7 Data output

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

6.2 Equipment

PC

6.3 Testing

The various outputs are checked and evaluated.

6.4 Evaluation

The measured values are only output digitally. The measuring system has appropriate RS-232, USB and Ethernet interfaces.

6.5 Assessment

The measured signals are provided digitally.

The connection of additional measuring and peripheral devices is possible.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.3.8 Digital interface

The digital interface shall allow the transmission of output signals, status signals, and information like instrument type, measurement range, and measured component and unit. The digital interface shall be described fully in respective standards and guidelines. Access to the measuring system via digital interfaces, e.g. for data transmission, shall be secured against unauthorised access, e.g. by a password.

6.2 Equipment

PC and terminal programme for data transfer, USB stick

6.3 Testing

The measuring system has the following digital transmission paths:

RS-232, USB and Ethernet.

6.4 Evaluation

The measuring system has the following digital transmission paths:

RS-232, USB and Ethernet.

The digital output signals were checked using a PC with terminal programmes connected to the measuring instruments.

All relevant pieces of information such as measured signals, status signals, measured component, measurement range, unit and further instrument information can be transmitted digitally.

The digital transmission protocols GRIMM protocol (GP280 V1.1), Modbus TCP and GESYTEC / Bayern-Hessen protocol are supported.

As part of the performance test, the data were saved directly to a USB stick via the USB interface using the GRIMM protocol.

Transmission to an external computer via USB using the GRIMM protocol, via RS-232 using the GESYTEC / Bayern-Hessen protocol and via Ethernet using Modbus TCP were tested as examples. All digital paths for measured value transmission are functional.

6.5 Assessment

Digital transmission of measured values operates correctly.

In order to safely protect the measuring system from unauthorised access during measuring operation, the system must be operated in a locked measuring container.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.3.9 Data transmission protocol

The measuring system shall contain at minimum one data transmission protocol for the digital transmission of the output signal.
Every data transmission protocol provided by the manufacturer for the measuring system shall allow the correct transmission of the data and detect errors in the transmission. The data transmission protocol including the used commands is to be documented in the instruction manual. The data transmission protocol shall allow to transmit at minimum the following data:

- *identification of the measuring system*
- *identification of measured components*
- *unit*
- *output signal with time signature (date and time)*
- *operation and error status*
- *operating commands for remote control of the measuring systems*

All data are to be transmitted as clear text (ASCII characters).

The AMS has to transmit telemetrically the data of operating states of at least the following parameters:

- *Volumetric flow rate*
- *Pressure drop across the sampling filter (where relevant)*
- *Sampling duration*
- *Sample volume (where relevant)*
- *Mass concentration of the relevant particulate matter fraction(s)*
- *Ambient air temperature*
- *Ambient air pressure*
- *Air temperature in the measuring unit*
- *Temperature of the sample inlet if a heated sample inlet is used*

The results of automated/functional checks have to be recorded, where available.

6.2 Equipment

PC for data transmission

6.3 Testing

The digital transmission protocols GRIMM protocol (GP280 V1.1), Modbus TCP and GESYTEC / Bayern-Hessen protocol are supported.

6.4 Evaluation

The digital transmission protocols GRIMM protocol (GP280 V1.1), Modbus TCP and GESYTEC / Bayern-Hessen protocol are supported.

Chapter 6 of the manual describes the protocols in detail.

In addition to the measured values, all relevant data of operating states as well as status, warning and error messages are transmitted.

6.5 Assessment

The AMS has the digital transmission protocols GRIMM protocol (GP280 V1.1), Modbus TCP and GESYTEC / Bayern-Hessen protocol as standard. Measured and status signals are transmitted correctly.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.3.10 Measuring range

The upper limit of the measuring range of the AMS shall include at least the following ranges of values:

- *up to 1000 µg/m³ as a 24-h mean value*
- *up to 10000 µg/m³ as a 1-h mean value, if applicable*

These concentration ranges correspond to the respective certification range for the performance test.

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Measuring range" is identical to the test point "Measuring ranges" according to Table 1 No. 1 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 1 Measurement ranges.

6.4 Evaluation

The execution, evaluation and assessment for the test point "Measuring range" is identical to the test point "Measuring ranges" according to Table 1 No. 1 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 1 Measurement ranges.

6.5 Assessment

The execution, evaluation and assessment for the test point "Measuring range" is identical to the test point "Measuring ranges" according to Table 1 No. 1 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 1 Measurement ranges.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.3.11 Negative measured signals

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

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Negative measured signals" is identical to the test point "Negative signals" according to Table 1 No. 2 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 2 Negative signals.

6.4 Evaluation

The execution, evaluation and assessment for the test point "Negative measured signals" is identical to the test point "Negative signals" according to Table 1 No. 2 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 2 Negative signals.

6.5 Assessment

The execution, evaluation and assessment for the test point "Negative measured signals" is identical to the test point "Negative signals" according to Table 1 No. 2 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 2 Negative signals.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.3.12 Power failure

In the event of equipment malfunctions and power failure, the equipment parameters shall be protected against loss by buffering. 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 applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Power failure" is identical to the test point "Effect of failure of mains voltage" according to Table 1 No. 10 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 10 Effect of failure of mains voltage.

6.4 Evaluation

The execution, evaluation and assessment for the test point "Power failure" is identical to the test point "Effect of failure of mains voltage" according to Table 1 No. 10 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 10 Effect of failure of mains voltage.

6.5 Assessment

The execution, evaluation and assessment for the test point "Power failure" is identical to the test point "Effect of failure of mains voltage" according to Table 1 No. 10 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 10 Effect of failure of mains voltage.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.3.13 Instrument functions

It shall be possible to monitor the essential device functions by means of status signals that can be transmitted telemetrically.

6.2 Equipment

PC, Modem.

6.3 Testing

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

The digital transmission protocols GRIMM protocol (GP280 V1.1), Modbus TCP and GESYTEC / Bayern-Hessen protocol are supported.

6.4 Evaluation

The measuring system allows for comprehensive telemetric monitoring and control of the measuring device via various routes (Ethernet, RS-232, USB).

6.5 Assessment

The AMS can be comprehensively monitored and controlled from an external computer via a modem or router.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.3.14 Switching

The switching between measurement and function control and/or calibration has to be capable of being triggered telemetrically through computerised control and manually at the AMS.

6.2 Equipment

Not applicable.

6.3 Testing

The measuring system can be monitored and controlled by the operator at the unit or by the telemetric remote control.

6.4 Evaluation

All operating procedures that do not require hands-on operation on site can be monitored or controlled both by the operator at the unit and by telemetric remote control.

6.5 Assessment

In principle, it is possible to monitor all tasks necessary for a functional check on the instrument itself or telemetrically.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.3.15 Instrument software

The version of the instrument's software has to be capable of being displayed by the AMS.

6.2 Equipment

Not applicable.

6.3 Testing

It was tested whether the software version can be displayed on the instrument. The AMS manufacturer has been informed of the obligation to communicate any changes to the instrument software to the test laboratory.

6.4 Evaluation

The current software version can be viewed at any time in the menu under "Service Information".

The implemented system software is as follows.

1.01 (Firmware)

The firmware represents the superordinate software and contains, among other things, the control of the measuring device or the measuring system as well as the evaluation algorithm for processing the raw data of the aerosol spectrometer to the output measured values.

0.08 (FPGA)

The FPGA software is a sublevel software for the evaluation of the raw data of the aerosol spectrometer (particle counting and classification).

1.01 (GUI = display software)

6.5 Assessment

The current software version can be viewed at any time in the menu under "Service Information" (for GUI in the Display and Language menu). Software changes are communicated to the test laboratory.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Figure 25: Software version dispay

6.1 6.4 Requirements on performance characteristics for testing in the laboratory

6.1 6.4.1 General requirements

The performance characteristic to be determined during the tests in the laboratory as well as the associated performance criteria are given in Annex A in Table A1 of VDI 4202-3 for the measured components PM_{10} and $PM_{2.5}$. Table A1 of VDI 4202-3 applies to those areas that are defined as normative in the scope of this standard. The certification range for other components (particle fractions) is to be defined. Performance criteria are to be defined by drawing from Table A1 of VDI 4202-3. These definitions shall be cleared with the relevant body before testing. The determination of the performance characteristics for laboratory testing shall be done according to the procedures described in section 7.4 of VDI 4202-3.

6.2 Equipment

Not applicable.

6.3 Testing

The test was carried out using the performance criteria and requirements of VDI 4202 Part 3 (2019) and EN 16450 (2017).

6.4 Evaluation

Not applicable.

6.5 Assessment

The test was carried out using the performance criteria and requirements of VDI 4202 Part 3 (2019) and EN 16450 (2017).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 6.4.2 Test requirements

Before operating the measuring system, the instruction manual of the manufacturer shall be followed particularly with regard to the set-up of equipment and the quality and quantity of the consumable supplies necessary.
The measuring system shall be allowed to warm up for the duration specified by the manufacturer before undertaking any tests. If the warm-up time is not defined, a minimum period of 4 hours should be maintained.
If auto-scaling or self-correction functions are freely selectable on the instrument, these functions shall be switched off during the laboratory test.
If the autos caling or self-correction functions are not freely selectable and are regarded as “normal operating conditions”, then the times and magnitudes of the self-corrections have to be available to the test laboratory. The magnitudes of the auto-zero and the auto-drift corrections are subject to the same restrictions as they are defined in the performance characteristics.
Zero air and suitable calibration equipment shall be used for the reference point in order to determine the various performance characteristics.
Where an AMS does not have calibration equipment for the reference point or the available equipment is unsuitable, this has to be stated explicitly in the performance test report. In this case, suitable additional quality assurance measures shall be considered.
The possibility of calibrating the sensors for temperature, pressure, and/or air humidity has to be checked and documented.
Before the test and the supply of zero air to the AMS, the equipment used to produce zero air has to be operated for long enough in order to ensure the feeding of zero air into the AMS.
Most AMS can produce the output signal as a moving average over an adjustable time interval. Some instruments adjust this integration time automatically, as a function of the frequency, to the fluctuations of the particulate matter concentrations.
These options are used typically to smooth the output data. For the laboratory tests, the AMS settings have to correspond to the manufacturer’s definitions. This excludes the automated zero adjustment and auto-scaling functions, which have to be switched off during the laboratory tests. All settings have to be recorded in the test report.
Parameters: When testing for individual performance characteristics, the values of the following parameters have to be stable within the range quoted in Table 1 of VDI 4202-3.
Zero air: Zero air is used when determining some of the performance characteristics. The particulate matter concentration in the zero air is not allowed to exceed 1.0 µg/m3.

6.2 Equipment

Not applicable.

6.3 Testing

The test was carried out using the performance criteria and requirements of VDI 4202 Part 3 (2019) and EN 16450 (2017).

6.4 Evaluation

The operating instructions were followed for setting up / installing the system.

The warm-up time described in the manual was observed.

No auto-scaling or self-correction functions are activated on the measuring system.

To determine the performance characteristics at the zero point, the measuring systems are operated with an absolute filter at the system inlet (sampling tube inlet).

A monodisperse test dust is used to determine the performance characteristics at the reference point.

Relevant sensors for temperature, pressure and rel. humidity can be checked, but an adjustment can currently only be made at the manufacturer.

The measuring system produces the output signal as mean value (not moving) and without a smoothing filter. The integration time is set to an interval of 1 min during the test. The only exception are the tests at the reference point, where the interval is set to 6 s.

6.5 Assessment

The test was carried out using the performance criteria and requirements of VDI 4202 Part 3 (2019) and EN 16450 (2017).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 6.4.3 Zero level and detection limit

The zero level and the detection limit have to satisfy the requirements listed in Table A1 of VDI 4202-3.

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Zero level and detection limit" is identical to the test point "Zero level and detection limit" according to point 7.4.3 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 3 Zero level and detection limit (7.4.3).

6.4 Evaluation

The execution, evaluation and assessment for the test point "Zero level and detection limit" is identical to the test point "Zero level and detection limit" according to point 7.4.3 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 3 Zero level and detection limit (7.4.3).

6.5 Assessment

The execution, evaluation and assessment for the test point "Zero level and detection limit" is identical to the test point "Zero level and detection limit" according to point 7.4.3 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 3 Zero level and detection limit (7.4.3).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.4.4 Volumetric flow rate accuracy

The change in the displayed values due to changes in the volumetric flow rate is not allowed to exceed the requirement shown in Table A1 of VDI 4202-3.

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point “Volumetric flow rate accuracy" is identical to the test point “Flow rate accuracy" according to point 7.4.4 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 4 Flow rate accuracy (7.4.4).

6.4 Evaluation

The execution, evaluation and assessment for the test point “Volumetric flow rate accuracy" is identical to the test point “Flow rate accuracy" according to point 7.4.4 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 4 Flow rate accuracy (7.4.4).

6.5 Assessment

The execution, evaluation and assessment for the test point “Volumetric flow rate accuracy" is identical to the test point “Flow rate accuracy" according to point 7.4.4 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 4 Flow rate accuracy (7.4.4).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.4.5 Sample flow rate constancy

The instantaneous value of the volumetric flow rate and the flow rate averaged over the sampling period have to satisfy the requirements shown in Table A1 of VDI 4202-3.

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Sample flow rate constancy" is identical to the test point "Constancy of sample flow rate" according to point 7.4.5 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 5 Constancy of sample flow rate (7.4.5).

6.4 Evaluation

The execution, evaluation and assessment for the test point "Sample flow rate constancy" is identical to the test point "Constancy of sample flow rate" according to point 7.4.5 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 5 Constancy of sample flow rate (7.4.5).

6.5 Assessment

The execution, evaluation and assessment for the test point "Sample flow rate constancy" is identical to the test point "Constancy of sample flow rate" according to point 7.4.5 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 5 Constancy of sample flow rate (7.4.5).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.4.6 Leak tightness of the sampling system

The leakage rate has to satisfy the performance requirement shown in Table A1 of VDI 4202-3 or the AMS manufacturer's specifications while meeting the required data quality targets.

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Leak tightness of the sampling system" is identical to the test point "Leak tightness of the sampling system" according to point 7.4.6 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 6 Leak tightness of the sampling system (7.4.6).

6.4 Evaluation

The execution, evaluation and assessment for the test point "Leak tightness of the sampling system" is identical to the test point "Leak tightness of the sampling system" according to point 7.4.6 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 6 Leak tightness of the sampling system (7.4.6).

6.5 Assessment

The execution, evaluation and assessment for the test point "Leak tightness of the sampling system" is identical to the test point "Leak tightness of the sampling system" according to point 7.4.6 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 6 Leak tightness of the sampling system (7.4.6).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.4.7 Dependence of the zero point and of the reference point on the ambient temperature

The change in the displayed value at the zero point and at the reference point due to changes in the ambient temperature is not allowed to exceed the requirement shown in Table A1 of VDI 4202-3.
The determined differences have to satisfy the performance criteria shown in Table A1 of VDI 4202-3

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Dependence of the zero point and the reference point on the ambient temperature" is identical to the test points "Dependence of the zero point on surrounding temperature" and "Dependence of the measured value on surrounding temperature" according to point 7.4.7 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 7 Dependence of zero on surrounding temperature (7.4.7) and Chapter 7.1 8 Dependence of measured value (span) on surrounding temperature (7.4.7).

6.4 Evaluation

The execution, evaluation and assessment for the test point "Dependence of the zero point and the reference point on the ambient temperature" is identical to the test points "Dependence of the zero point on surrounding temperature" and "Dependence of the measured value on surrounding temperature" according to point 7.4.7 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 7 Dependence of zero on surrounding temperature (7.4.7) and Chapter 7.1 8 Dependence of measured value (span) on surrounding temperature (7.4.7).

6.5 Assessment

The execution, evaluation and assessment for the test point "Dependence of the zero point and the reference point on the ambient temperature" is identical to the test points "Dependence of the zero point on surrounding temperature" and "Dependence of the measured value on surrounding temperature" according to point 7.4.7 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 7 Dependence of zero on surrounding temperature (7.4.7) and Chapter 7.1 8 Dependence of measured value (span) on surrounding temperature (7.4.7).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.4.8 Dependence of the reference point on mains voltage

The change in the displayed value at the reference point due to changes in mains voltage is not allowed to exceed the requirement shown in Table A1 of VDI 4202-3. The determined differences have to satisfy the performance criteria shown in Table A1 of VDI 4202-3.

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Dependence of the reference point on mains voltage" is identical to the test point "Dependence of span on supply voltage" according to point 7.4.8 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 9 Dependence of span on voltage supply (7.4.8).

6.4 Evaluation

The execution, evaluation and assessment for the test point "Dependence of the reference point on mains voltage" is identical to the test point "Dependence of span on supply voltage" according to point 7.4.8 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 9 Dependence of span on voltage supply (7.4.8).

6.5 Assessment

The execution, evaluation and assessment for the test point "Dependence of the reference point on mains voltage" is identical to the test point "Dependence of span on supply voltage" according to point 7.4.8 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 9 Dependence of span on voltage supply (7.4.8).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.4.9 Dependence of the readings on the water vapour concentration

The change in the displayed values due to water vapour concentration has to satisfy the performance criterion shown in Table A1 of VDI 4202-3 in the range from 40 % to 90 % relative humidity.
The largest difference between the readings in the range from 40 % to 90 % relative humidity has to satisfy the performance criterion as per Table A1 of VDI 4202-3.

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Dependence of the readings on the water vapour concentration" is identical to the test point "Dependence of readings on water vapour concentration" according to point 7.4.9 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 11 Dependence of reading on water vapour concentration (7.4.9).

6.4 Evaluation

The execution, evaluation and assessment for the test point "Dependence of the readings on the water vapour concentration" is identical to the test point "Dependence of readings on water vapour concentration" according to point 7.4.9 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 11 Dependence of reading on water vapour concentration (7.4.9).

6.5 Assessment

The execution, evaluation and assessment for the test point "Dependence of the readings on the water vapour concentration" is identical to the test point "Dependence of readings on water vapour concentration" according to point 7.4.9 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 11 Dependence of reading on water vapour concentration (7.4.9).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.5 Requirements relating to performance characteristics for the field test

6.1 6.5.1 General requirements

The performance characteristics that shall be determined in the field tests and the associated performance criteria are listed in Table A1 of VDI 4202-3 for the measured components PM_{10} and $PM_{2.5}$. Table A1 of VDI 4202-3 applies to those areas that are defined as normative in the scope of this standard.
The certification range for other components is to be defined. Performance criteria are to be defined by drawing from Table A1 of VDI 4202-3. These definitions shall be cleared with the relevant body before testing.
The performance characteristics for the field tests shall be determined in accordance with the methods described in section 7.5 of VDI 4202-3.

6.2 Equipment

Not applicable.

6.3 Testing

The test was carried out using the performance criteria and requirements of VDI 4202 Part 3 (2019) and EN 16450 (2017).

6.4 Evaluation

Not applicable.

6.5 Assessment

The test was carried out using the performance criteria and requirements of VDI 4202 Part 3 (2019) and EN 16450 (2017).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 6.5.2 Experimental conditions

The monitoring station for the field test is to be chosen according to the requirements of 39th BImSchV such that the expected concentrations of the measured components to be measured correspond to the designated task. The equipment of the monitoring station shall allow the implementation of the field test and shall fulfil all requirements considered to be necessary during measurement planning.

The AMS shall be built into the monitoring station and commissioned correctly.

The AMS settings have to correspond to the manufacturer's data. All settings have to be recorded in the test report.

The AMS shall be serviced during the field test as specified by the instrument's manufacturer.

If the instrument has an auto-scaling or self-correction function and it is regarded as a "normal operating condition", it shall be operational during the field test. The magnitude of the self-correction has to be available to the testing laboratory. The magnitudes of the auto-zero and the auto-drift corrections over the control interval (long-term drift) are subject to the same restrictions as they are defined in the performance characteristics.

Zero air and suitable calibration equipment shall be used for the reference point in order to determine the various performance characteristics.

Where an AMS does not have calibration equipment for the reference point or the available equipment is unsuitable, this has to be stated explicitly in the performance test report.

In this case, suitable additional quality assurance measures shall be considered.

6.2 Equipment

Not applicable.

6.3 Testing

The test was carried out using the performance criteria and requirements of VDI 4202 Part 3 (2019) and EN 16450 (2017).

6.4 Evaluation

The determination of the installation sites for the comparative campaign was based on the characteristics of the measurement site (urban and rural background, traffic-influenced, industrially influenced) as well as on the availability of an installation option for the measurement station. Due to the relatively low concentrations of suspended particulate matter generally found at the sites in the vicinity of Cologne during the test, the last comparative campaign was carried out at a site in northern Italy (JRC Ispra), which is potentially more highly polluted during the winter months.

The measuring equipment was installed and operated in accordance with the manufacturer's specifications.

The measuring equipment does not have any auto-scaling or self-correction functions.

To determine the performance characteristics at the zero point, the measuring systems are operated with an absolute filter at the unit inlet (inlet to sampling tube) for at least 24 h.

A check of the reference point under field conditions is not intended. The test procedure with test dust used in the laboratory test brings significantly higher amounts of dust into the system (compared to normal measurement operation). Thus, the method is not suitable for regular use, e.g. in field operation, due to the excessive load / contamination of the measuring equipment (especially the optics).

Instead, the measuring module is to be taken annually to the manufacturer or to a specially trained and equipped service partner for checking and, if necessary, calibration. The method used here relies on a polydisperse test dust in a lower concentration.

6.5 Assessment

The test was carried out using the performance criteria and requirements of VDI 4202 Part 3 (2019) and EN 16450 (2017).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 6.5.3 Zero point tests

The long-term drift at the zero point is not allowed to exceed the requirements of Table A1 VDI 4202-3 of in the field test.

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Zero point tests" is identical to the test point "Zero checks" according to point 7.5.3 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 12 Zero checks (7.5.3).

6.4 Evaluation

The execution, evaluation and assessment for the test point "Zero point tests" is identical to the test point "Zero checks" according to point 7.5.3 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 12 Zero checks (7.5.3).

6.5 Assessment

The execution, evaluation and assessment for the test point "Zero point tests" is identical to the test point "Zero checks" according to point 7.5.3 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 12 Zero checks (7.5.3).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.5.4 Recording of operating parameters

During the tests, the AMS has to be capable of transmitting telemetrically data of operating states in accordance with section 6.3.9 Date transmission protocol.

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Recording of operating parameters" is identical to the test point "Recording of operating parameters" according to point 7.5.4 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 13 Recording of operational parameters (7.5.4).

6.4 Evaluation

The execution, evaluation and assessment for the test point "Recording of operating parameters" is identical to the test point "Recording of operating parameters" according to point 7.5.4 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 13 Recording of operational parameters (7.5.4).

6.5 Assessment

The execution, evaluation and assessment for the test point "Recording of operating parameters" is identical to the test point "Recording of operating parameters" according to point 7.5.4 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 13 Recording of operational parameters (7.5.4).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.5.5 Daily means

The AMS has to support the forming of daily means.
If a 24-hour mean is based on results with a shorter averaging period, the percentage of the values available for calculating the 24-hour mean has to be at least 75 %.

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Daily means" is identical to the test point "Daily averages" according to point 7.5.5 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 14 Daily averages (7.5.5).

6.4 Evaluation

The execution, evaluation and assessment for the test point "Daily means" is identical to the test point "Daily averages" according to point 7.5.5 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 14 Daily averages (7.5.5).

6.5 Assessment

The execution, evaluation and assessment for the test point "Daily means" is identical to the test point "Daily averages" according to point 7.5.5 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 14 Daily averages (7.5.5).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.5.6 Availability

The availability of the AMS shall be calculated in the field test and has to be at least 90 % (see Table A1).

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Availability" is identical to the test point "Availability" according to point 7.5.6 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 15 Availability (7.5.6).

6.4 Evaluation

The execution, evaluation and assessment for the test point "Availability" is identical to the test point "Availability" according to point 7.5.6 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 15 Availability (7.5.6).

6.5 Assessment

The execution, evaluation and assessment for the test point "Availability" is identical to the test point "Availability" according to point 7.5.6 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 15 Availability (7.5.6).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.5.7 Inspection interval

The inspection interval of the AMS shall be calculated and stated in the field test. The maintenance interval should be three months, if possible, but at least two weeks.

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point “Inspection interval" is identical to the test point "Maintenance interval" according to point 7.5.7 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 18 Maintenance interval (7.5.7).

6.4 Evaluation

The execution, evaluation and assessment for the test point “Inspection interval" is identical to the test point "Maintenance interval" according to point 7.5.7 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 18 Maintenance interval (7.5.7).

6.5 Assessment

The execution, evaluation and assessment for the test point “Inspection interval" is identical to the test point "Maintenance interval" according to point 7.5.7 of the EN 16450 (2017) standard. Therefore, reference is made here to Chapter 7.1 18 Maintenance interval (7.5.7).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 6.5.8 Data analysis

Comparison measurements with reference instruments shall be performed as part of the field test. The uncertainty between the AMS calculated as part of the data analysis is not allowed to exceed the requirement shown in Table D1 in Annex D of VDI 4202-3. Furthermore, the expanded uncertainty has to satisfy the criterion in Table D1 of VDI 4202-3 .

6.2 Equipment

Not applicable.

6.3 Testing

The execution, evaluation and assessment for the test point "Data analysis" is identical to the test point "Data evaluation" according to point 7.5.8 of the EN 16450 (2017) standard. Therefore, reference is made here to chapters 7.1 Method used for equivalence testing (7.5.8.4 & 7.5.8.8); 7.1 16 Between-AMS uncertainty (7.5.8.4), 7.1 17 Expanded uncertainty (7.5.8.5 – 7.5.8.8) and 7.1 17 Use of correction factors/terms (7.5.8.5–7.5.8.8).

6.4 Evaluation

The execution, evaluation and assessment for the test point "Data analysis" is identical to the test point "Data evaluation" according to point 7.5.8 of the EN 16450 (2017) standard. Therefore, reference is made here to chapters 7.1 Method used for equivalence testing (7.5.8.4 & 7.5.8.8); 7.1 16 Between-AMS uncertainty (7.5.8.4), 7.1 17 Expanded uncertainty (7.5.8.5 – 7.5.8.8) and 7.1 17 Use of correction factors/terms (7.5.8.5–7.5.8.8).

6.5 Assessment

The execution, evaluation and assessment for the test point "Data analysis" is identical to the test point "Data evaluation" according to point 7.5.8 of the EN 16450 (2017) standard. Therefore, reference is made here to chapters 7.1 Method used for equivalence testing (7.5.8.4 & 7.5.8.8); 7.1 16 Between-AMS uncertainty (7.5.8.4), 7.1 17 Expanded uncertainty (7.5.8.5 – 7.5.8.8) and 7.1 17 Use of correction factors/terms (7.5.8.5–7.5.8.8).

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

7. TEST RESULTS (EN 16450 June 2017)

7.1 1 Measurement ranges

The measurement range of the AMS has to comprise at least the following values:
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

7.2 Equipment

The test of this criterion did not require any further equipment.

7.3 Testing

It was tested whether the measuring system's upper limit of measurement meets the requirements.

7.4 Evaluation

The following linear measuring ranges are possible on the measuring system:

$PM_{2.5}$: 0 – 5,100 µg/m³

PM_{10}: 0 – 12,000 µg/m³

These values were determined based on measurements with Arizona Dust A1 ultrafine (with a maximum of 10 % linearity error).

Higher measured values are subject to higher linearity errors and require shorter maintenance intervals.

7.5 Assessment

The linear measuring range is 0 - 5,100 µg/m³ for $PM_{2.5}$ and 0 - 12,000 µg/m³ for PM_{10} for the standardised aerosol Arizona Dust A1 (ultrafine) with max. 10% linearity error. Higher measured values are subject to higher linearity errors and require shorter maintenance intervals.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not required for this performance criterion.

7.1 2 Negative signals

Negative signals shall not be suppressed.

7.2 Equipment

The test of this criterion did not require any further equipment.

7.3 Testing

It was tested in the laboratory as well as in the field whether the measuring system can also output negative measured values.

7.4 Evaluation

The measuring system is able to output negative signals both via its display and its data outputs, however, negative measured values did not occur during the test.

Given the measuring principle and design of the instrument, negative values are not to be expected.

7.5 Assessment

Negative measured signals can be directly displayed by the measuring system and output via the corresponding measured signal outputs, but are not to be expected due to the measuring principle and design.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not required for this performance criterion.

7.1 3 Zero level and detection limit (7.4.3)

Zero level: ≤ 2.0 µg/m³
Detection limit: ≤ 2.0 µg/m³

7.2 Equipment

Zero filter for zero checks

7.3 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 24 h averages.

The zero level and the detection limit were determined with zero filters installed at the AMS inlets of the instruments during normal operation. Air free of suspended particulate matter was applied over a period of 15 days for a duration of 24 h each.

7.4 Evaluation

The detection limit X is calculated from the standard deviation s_{x0} of the measured values sucking air free from suspended particulate matter through both candidate systems. 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.

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

7.5 Assessment

The zero level and the detection limit for both $PM_{2.5}$ and PM_{10} were determined to be 0.00 µg/m³ from the tests for both systems.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 10: Zero level and detection limit $PM_{2.5}$

		Device FE111	Device FE114
Number of values n		15	15
Average of the zero values (Zero level) $\overline{x}_0$	µg/m³	0.00	0.00
Standard deviation of the values s_{x0}	µg/m³	0.00	0.00
Detection limit x	µg/m³	**0.00**	**0.00**

Table 11: Zero level and detection limit PM_{10}

		Device FE111	Device FE114
Number of values n		15	15
Average of the zero values (Zero level) $\overline{x}_0$	µg/m³	0.00	0.00
Standard deviation of the values s_{x0}	µg/m³	0.00	0.00
Detection limit x	µg/m³	**0.00**	**0.00**

Annex 1 in the appendices contains the individual measured values for the determination of the zero level and detection limit.

7.1 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.*

7.2 Equipment

Climatic chamber for the temperature range between +5 °C and +40 °C, a reference flow meter in accordance with item 4.

7.3 Testing

At each temperature, at least ten independent measurements shall be performed over a minimum period of one hour at the operating flow rate specified by the manufacturer. The measurements shall be performed at equal intervals over the measurement period. For each temperature, the mean of the measurement results shall be compared with the operational flow rate.

The EDM 280 measuring system operates with a constant flow rate of 1.2 l/min (measuring orifice conditions).

Using a reference flow meter, the volumetric flow was measured at +5 °C and +40 °C by taking 10 measurements over 1 hour with the operating volumetric flow specified by the manufacturer. To check the accuracy of the flow rate, the measured values of the reference flow meter were therefore related to the conditions at the measuring orifice of the measuring system.

The measurements were performed at equal intervals throughout the measurement period.

7.4 Evaluation

Averages were calculated from the 10 measured values per temperature level and the deviations from the operating volume flow rate specified by the manufacturer were determined.

7.5 Assessment

The maximum relative difference between the average value of the measurement results for the volumetric flow at +5 °C and +40 °C and the nominal value of 1.2 l/min was 0.75 % .

Criterion satisfied? yes

7.6 Detailed presentation of test results

The results of the flow measurements at the permissible ambient temperatures are shown in Table 12.

Table 12: Flow rate accuracy at +5 °C and +40 °C

		Device FE111	Device FE114
Nominal value flow rate	l/min	1.200	1.200
Mean value at 5°C	l/min	1.201	1.209
Dev. from nominal value	%	0.105	0.749
Mean value at 40°C	l/min	1.195	1.193
Dev. from nominal value	%	-0.389	-0.554

Annex 2 in the appendices contains the individual measured values for the determination of the flow rate accuracy.

7.1 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 % of the nominal value of the volume flow (averaged sample flow)
≤ 5 % of the nominal value of the volume flow (instantaneous value of the sample flow)

7.2 Equipment

For this test, an additional reference flow meter in accordance with item 4 was provided.

7.3 Testing

The EDM 280 measuring system operates with a constant flow rate of 1.2 l/min (measuring orifice conditions).

During the field tests, the sampling flow rate was checked for correctness before and after each field test location using a mass flow meter. No readjustment was required at any time during the test.

To determine the constancy of the sample flow rate, the flow rate was recorded and evaluated with the help of a mass flow meter once over a period of 24h.

7.4 Evaluation

The average, standard deviation as well as the maximum and minimum values were determined from the measured values for the flow rate (24-hour average).

7.5 Assessment

The charts illustrating the constancy of the sample flow rate (24h average) demonstrate that all measured values determined during sampling deviate from their respective nominal values by less than 5%. The deviation of the daily averages for the overall flow rate of 1.2 l/min did not exceed 1.00% of the nominal value.

All determined instantaneous values deviate less than 5 %; all averaged values deviate less than 1.00 % from the nominal value.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 13 shows the determined parameters for the flow rate. Figure 26 to Figure 27 provide a chart of the flow rate measurement for both instruments.

Table 13: Key parameters for total flow measurement (24h average)

		Device FE111	Device FE114
Mean value	l/min	1.212	1.207
Dev. from nominal value	%	1.001	0.608
Standard deviation	l/min	0.004	0.007
Minimum value	l/min	1.200	1.193
Maximum value	l/min	1.227	1.238

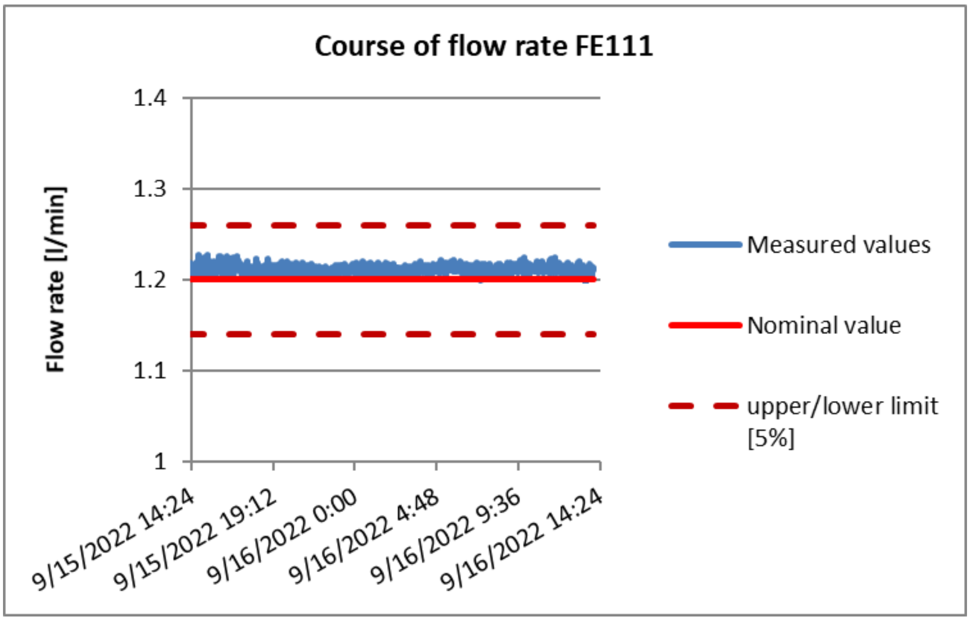

Figure 26: Flow rate for the FE111 candidate

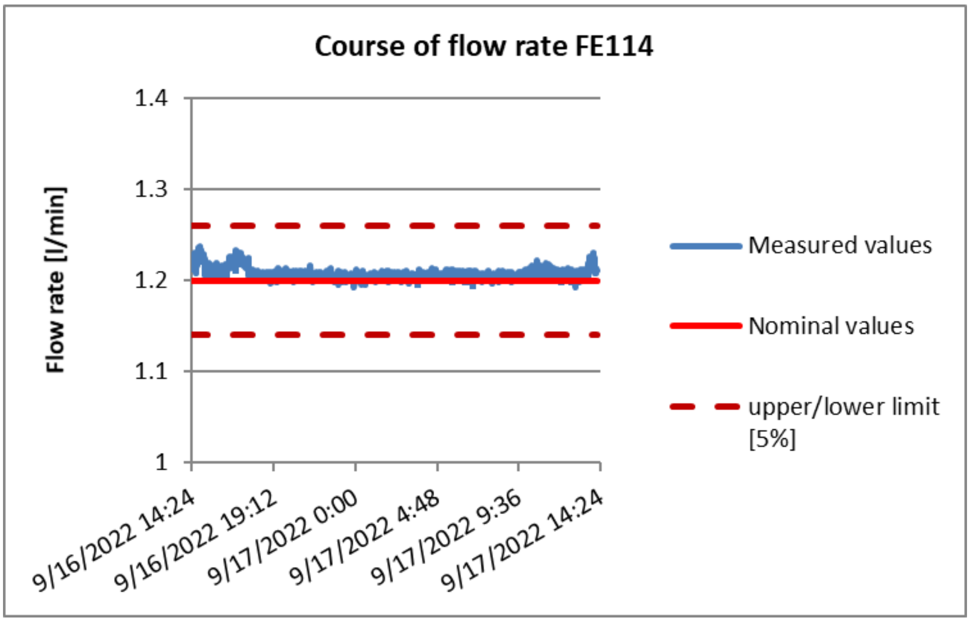

Figure 27: Flow rate for the FE114 candidate

7.1 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).

7.2 Equipment

Field Test Kit

7.3 Testing

The tightness (leakage rate) of the entire flow route of the AMS (sample inlet, sampling tube, measuring system) shall be tested as specified by the manufacturer. A leak test integrated in an AMS can be used, provided that the stringency of such a test is suitable for a proper assessment of the instrument's leak tightness.

If the complete system cannot be tested for technical reasons, the leak rate can be determined separately for each element of the flow path. If proper sealing of the sample inlet is not possible, it may be excluded from the test.

For the EDM 280 measuring system there is a defined procedure to check the tightness (chapter 7.2.4 of the manual). For this purpose, the measuring operation is interrupted and the unit is switched off. The sample air outlet of the unit is closed with a sealing screw from the field test kit. Then the pressure tester from the leak test kit (part of the field test kit) is connected to the sampling tube inlet and the system is pressurised with approx. 100 Torr positive pressure (total volume 330 ml). The drop in pressure must then not exceed 5 Torr within 60 s according to the manufacturer's specification (corresponding to a leakage of 16.5 ml/min at a flow rate of 1200 ml/min).

Calculation of leakage: $L = (p_{fall}/p_{start})/t*V*60$
with

L = Leakage in ml/min
P_{fall} = Drop in pressure in Torr over the test duration
P_{start} = Test pressure at the start of the test in Torr
t = Test duration in s
V = System volume in ml (330 ml for sampling + measuring module)

This procedure was carried out at the beginning and at the end of the field test at every location.

7.4 Evaluation

The leak test was carried out at the beginning and at the end of the field test at every location.

Table 14: Results of the leak test EDM 280

	Leakage in % of sample volume flow			
	FE 111		FE 114	
	At the start	At the end	At the start	At the end
Cologne	0.55	0.00	0.55	0.00
Bornheim	0.41	0.00	0.28	0.55
Niederzier	0.28	0.28	0.00	0.28
JRC Ispra	0.14	0.00	0.14	0.14

The leak test procedure specified by the manufacturer proved to be a suitable method for monitoring the leak tightness of the system in the test.

7.5 Assessment

The leak test procedure specified by the manufacturer proved to be suitable for monitoring the unit's tightness during testing. Leakages of a maximum of 0.55 % were determined during the test.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not applicable in this instance.

7.1 7 Dependence of zero 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.*

7.2 Equipment

Climatic chamber for the temperature range +5 °C to +40 °C, zero filter for zero point check.

7.3 Testing

The dependence of the zero point reading on the ambient temperature must be determined at the following temperatures:

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.

To test the dependence of the zero point on the surrounding temperature, the complete measuring system was operated in a climatic chamber. For the zero point tests, sample air free of suspended dust was applied to the candidates by mounting zero filters at the unit inlet.

At each temperature setting, three separate measurement results shall be recorded at the zero point.

For each temperature setting, the criteria for the warm-up or stabilisation time according to 7.4.2.1 must be fulfilled.

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 for each temperature stage).

7.4 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 $T_{S,n}$ were determined.

7.5 Assessment

The tested ambient temperature range is +5 °C to +40 °C. The maximum deviation from the mean measured value at $T_{S,n}$ was 0.0 µg/m³ for both $PM_{2.5}$ and PM_{10}.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 15: Dependence of the zero point on surrounding temperature, $PM_{2.5}$

Temperature	FE111		FE114	
	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	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0
Mean value at 20°C	0.0	-	0.0	-

Table 16: Dependence of the zero point on surrounding temperature, PM_{10}

Temperature	FE111		FE114	
	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	0.0	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0
20	0.0	0.0	0.0	0.0
Mean value at 20°C	0.0	-	0.0	-

Annex 3 in the appendices contains the individual measured results.

7.1 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.*

7.2 Equipment

Climatic chamber for the temperature range +5 °C to +40 °C, monodisperse test dust for sensitivity testing.

7.3 Testing

The dependence of the span value on the ambient temperature is to be determined at the following temperatures:

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.

To test the dependence of the sensitivity on the ambient temperature, the complete measuring system was operated in the climate chamber.

Sensitivity testing was performed using a monodisperse test dust that was placed in otherwise dust-free sample air. The test dust consists of glass spheres with a diameter of approx. 5 µm. It is placed in a dispenser (approx. 100 mg for 5-10 measurements), which is connected to the sample inlet with a tube. The user agitates the particles with the help of small steel balls in the dispenser. The sample air flows from the surrounding area through a filter into the dispenser and is enriched with test dust.

The EDM 280 measuring system classifies the test dust with a special, fine graded classification scale, which must be loaded onto the device before the test. Due to other optical properties, the optical diameter of glass does not match that of PSL, so the mode of distribution is about 4.5 µm. The distribution is used to calculate the mean value of the particle diameter weighted by the number of particles. Ideally, a spherical volume can then be calculated from the particle diameter. A change in sphere volume due to variation in particle diameter is proportional to a change in particle mass (and hence mass concentration) assuming a constant density, and can therefore be used to check sensitivity.

At each temperature setting, three separate measurement results are recorded at span.

For each temperature setting, the criteria for the warm-up or stabilisation time according to 7.4.2.1 must be fulfilled.

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 span point after an equilibration period of at least 6h for every temperature step (3 readings for each temperature stage).

7.4 Evaluation

The values for the average particle diameter [µm] of the respective individual measurements were determined, converted into a sphere volume [µm³] 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 $T_{S,n}$ were determined.

7.5 Assessment

The tested temperature range was +5 °C to +40 °C. The maximum deviation from the average reading at 20 °C was at -4.5 µg/m³.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 17: Dependence of the sensitivity on the surrounding temperature

Temperature	FE111		FE114	
	Measured value	Deviation to mean value at 20°C	Measured value	Deviation to mean value at 20°C
°C	[µm³]	%	[µm³]	%
20	49.4	0.7	47.8	-0.4
5	48.6	-1.0	47.2	-1.6
20	48.7	-0.7	47.6	-0.8
40	50.9	3.7	45.8	-4.5
20	49.1	0.0	48.6	1.2
Mean value at 20°C	49.1	-	48.0	-

Annex 3 in the appendices contains the results from 3 individual measurements.

7.1 9 Dependence of span on voltage supply (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

7.2 Equipment

Isolation transformer, monodisperse test dust for sensitivity testing.

7.3 Testing

The dependence of the value measured by using calibration equipment on the mains voltage shall be determined at the following voltages, while complying with the manufacturer's specifications:

- at a nominal voltage Vs,n = 230 V;
- at a minimum voltage Vs,1 = 195 V;
- at a maximum voltage Vs,2 = 253 V.

This test item requires the use of calibration equipment for span.

Sensitivity testing was performed using a monodisperse test dust that was placed in otherwise dust-free sample air. The test dust consists of glass spheres with a diameter of approx. 5 µm. It is placed in a dispenser (approx. 100 mg for 5-10 measurements), which is connected to the sample inlet with a tube. The user agitates the particles with the help of small steel balls in the dispenser. The sample air flows from the surrounding area through a filter into the dispenser and is enriched with test dust.

The EDM 280 measuring system classifies the test dust with a special, fine graded classification scale, which must be loaded onto the device before the test. Due to other optical properties, the optical diameter of glass does not match that of PSL, so the mode of distribution is about 4.5 µm. The distribution is used to calculate the mean value of the particle diameter weighted by the number of particles. Ideally, a spherical volume can then be calculated from the particle diameter. A change in sphere volume due to variation in particle diameter is proportional to a change in particle mass (and hence mass concentration) assuming a constant density, and can therefore be used to check sensitivity.

Three individual readings shall be recorded for span at each voltage setting.

At each voltage setting the criteria for warm-up or stabilization time are to be met according to 7.4.2.1.

The tests were performed in the voltage sequence VS,n - VS,1 - VS,n - VS,2 - VS,n.

7.4 Evaluation

The values for the average particle diameter [µm] of the respective individual measurements were determined, converted into a sphere volume [µm³] and evaluated.

In order to rule out a possible drift caused by factors other than voltage, the measured values were averaged at VS,n.

The differences between readings at both extreme voltages and VS,n were determined.

7.5 Assessment

No fluctuations of more than -3.9 %, related to the average value at 230 V, could be detected due to mains voltage changes.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 18: Dependence of the reading on voltage supply

Supply voltage	FE111		FE114	
	Measured value	Deviation to mean value at 230 V	Measured value	Deviation to mean value at 230 V
V	[µm³]	%	[µm³]	%
230	51.3	0.6	47.7	2.8
195	52.3	2.5	46.8	0.8
230	51.2	0.5	46.7	0.6
253	49.0	-3.9	47.1	1.4
230	50.4	-1.2	44.8	-3.4

Annex 4 in the appendices contains the individual results.

7.1 10 Effect of failure of mains voltage

Instrument parameters shall be secured against loss.
On return of mains voltage the instrument shall automatically resume functioning.

7.2 Equipment

Not required for this performance criterion.

7.3 Testing

A simulated failure in the mains voltage served to test whether the instrument remained fully functional, reached operation mode on return of the mains voltage and retained all instrument parameters completely.

7.4 Evaluation

In the event of a mains failure, the measuring system is again in a ready-to-measure state within a few minutes after the voltage has been restored and the operating system has been restarted. All instrument parameters are completely retained.

7.5 Assessment

All instrument parameters are secured against loss. On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not applicable.

7.1 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.

7.2 Equipment

Climatic chamber with humidity control for the range 40 % to 90 % relative humidity, zero filter for zero point verification.

7.3 Testing

The dependence of the reading on the water vapour concentration in the sample air was determined by supplying humidified zero air in the range of 40 % to 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 varied and controlled. Sample air, free of suspended particles was supplied to the instruments after fitting two zero filters at either AMS inlet in order to perform zero point checks.

After stabilising the relative humidity and concentration readings of the AMS, a reading is recorded over the smallest averaging period of the AMS at 40 % relative humidity. The relative humidity was then increased to 90 % at a rate of 25 % per hour. The time taken to reach equilibrium and the average concentration reading were recorded. The relative humidity was then reduced to 40 % at a rate of 25 % per hour. The time taken to reach equilibrium and the average concentration reading were recorded again.

7.4 Evaluation

The measured values for the zero concentrations of the individual measurements at stable humidities were obtained and evaluated. The characteristic concerned is the largest difference in µg/m³ between values in the range of 40% to 90% relative humidity.

7.5 Assessment

No difference was found between the measured values at 40 % and at 90 % relative humidity.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 19: Dependence of the reading on water vapour concentration, $PM_{2.5}$

rel. Humidity	FE111		FE114	
	Measured value	Deviation to previous value	Measured value	Deviation to previous value
%	µg/m³	µg/m³	µg/m³	µg/m³
40	0.0	-	0.0	-
90	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0
Maximum deviation	0.0		0.0	

Table 20: Dependence of the reading on water vapour concentration, PM_{10}

rel. Humidity	FE111		FE114	
	Measured value	Deviation to previous value	Measured value	Deviation to previous value
%	µg/m³	µg/m³	µg/m³	µg/m³
40	0.0	-	0.0	-
90	0.0	0.0	0.0	0.0
40	0.0	0.0	0.0	0.0
Maximum deviation	0.0		0.0	

7.1 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.

7.2 Equipment

Zero filter for zero checks

7.3 Testing

Regular checks of the AMS reading at zero point shall be performed in the field during normal operation over a sufficient time period by using an appropriate method to provide zero air to the AMS. The manufacturer's instructions shall be observed. An appropriate method for generating zero air is to sample ambient air through a zero air filter attached to the inlet of the AMS instead of the usual sampling inlet. The zero check shall be performed for at least 24 h.

The tests shall be performed as a minimum at the beginning and at the end of each of the four comparative campaigns

7.4 Evaluation

During the tests, the absolute measured value of the AMS at zero point defined at 3.0 µg/m³ shall not be exceeded.

7.5 Assessment

The maximum absolute measured value determined at the zero point was 0.0 µg/m³.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 21: Zero checks, $PM_{2.5}$

Date	FE111 Measured Value µg/m³	FE111 Measured value (absolute) ≤ 3.0 µg/m³	Date	FE114 Measured Value µg/m³	FE114 Measured value (absolute) ≤ 3.0 µg/m³
8/6/2021	0.0	ok	8/6/2021	0.0	ok
8/7/2021	0.0	ok	8/7/2021	0.0	ok
8/8/2021	0.0	ok	8/8/2021	0.0	ok
11/9/2021	0.0	ok	11/9/2021	0.0	ok
12/16/2021	0.0	ok	12/16/2021	0.0	ok
3/8/2022	0.0	ok	3/8/2022	0.0	ok
6/21/2022	0.0	ok	6/21/2022	0.0	ok
9/13/2022	0.0	ok	9/13/2022	0.0	ok
10/10/2022	0.0	ok	10/10/2022	0.0	ok
1/6/2023	0.0	ok	1/6/2023	0.0	ok

Table 22: Zero checks, PM_{10}

Date	FE111 Measured Value µg/m³	FE111 Measured value (absolute) ≤ 3.0 µg/m³	Date	FE114 Measured Value µg/m³	FE114 Measured value (absolute) ≤ 3.0 µg/m³
8/6/2021	0.0	ok	8/6/2021	0.0	ok
8/7/2021	0.0	ok	8/7/2021	0.0	ok
8/8/2021	0.0	ok	8/8/2021	0.0	ok
11/9/2021	0.0	ok	11/9/2021	0.0	ok
12/16/2021	0.0	ok	12/16/2021	0.0	ok
3/8/2022	0.0	ok	3/8/2022	0.0	ok
6/21/2022	0.0	ok	6/21/2022	0.0	ok
9/13/2022	0.0	ok	9/13/2022	0.0	ok
10/10/2022	0.0	ok	10/10/2022	0.0	ok
1/6/2023	0.0	ok	1/6/2023	0.0	ok

7.1 13 Recording of operational parameters (7.5.4)

During the tests the AMS shall be able to telemetrically transmit operational states of – at minimum – the following parameters:

- *Volumetric flow rate;*
- *Pressure drop over sample filter (if relevant);*
- *Sampling time;*
- *Sampling volume (if relevant);*
- *Mass concentration of relevant PM fraction(s);*
- *Ambient temperature;*
- *Ambient air pressure;*
- *Air temperature in measuring section;*
- *Temperature of the sampling inlet if a heated inlet is used;*

The results of automated/functional checks have to be recorded, where available.

7.2 Equipment

PC and USB stick for data collection during testing.

7.3 Testing

The measuring system allows for comprehensive telemetric monitoring and control of the measuring instrument via various paths and can also output measured values or status information via various protocols (e.g. GRIMM protocol) according to the manufacturer's specifications.

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

- Ambient temperature, pressure, humidity
- Temperature / rel. humidity in measuring cell and at outlet cover
- Sampling volume
- Sample flow rate
- Nominal/actual value sample conditioning/heating

All values are stored.

7.4 Evaluation

The AMS allows for comprehensive telemetric monitoring and control of the measuring system via various paths. The instrument provides operating statuses and all relevant parameters.

7.5 Assessment

The AMS allows for comprehensive telemetric monitoring and control of the measuring system via various paths. The instrument provides operating statuses and all relevant parameters.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not applicable.

7.1 14 Daily averages (7.5.5)

The AMS shall allow for the formation of daily averages or values.

7.2 Equipment

For this test, a clock was additionally provided.

7.3 Testing

It was checked whether the measuring system allows the formation of a daily average.

7.4 Evaluation

The measuring system continuously determines the suspended dust mass concentration for $PM_{2.5}$ and PM_{10}. The temporal resolution of the measurement is 6 s. The time resolution of the measurement is 6 s, whereby the measured values are output as non-moving average values over the selectable measurement interval (6 s, 1, 5, 10, 15, 30, 60 minutes, daily average). Thus, the formation of 24 h average values is easily possible.

Within the scope of the performance test, the measured value output was set to a measuring interval of 1 min and the measured values were manually condensed to daily average values.

The example of the JRC Ispra site shows that the measuring system allows for the measurement of suspended particulate matter mass concentrations with a high temporal resolution and high reproducibility (see Figure 28 to Figure 33). The uncertainty between AMS is well below the 2.5 µg/m³ required for 24-hour measurements for both a 1 min and 60 min measurement interval.

Table 23: Uncertainties between AMS, JRC Ispra, 1 min & 60 min averages

	$PM_{2.5}$		PM_{10}	
Average	1 min	60 min	1 min	60 min
Number of readings	118739	1980	118739	1980
u_{bs}, AMS [µg/m³]	0.88	0.83	1.35	1.00

7.5 Assessment

The measuring system enables the measurement of the suspended dust mass concentrations in high temporal resolution with high reproducibility. The formation of valid daily average values is easily possible.

Criterion satisfied? yes

7.6 Detailed presentation of test results

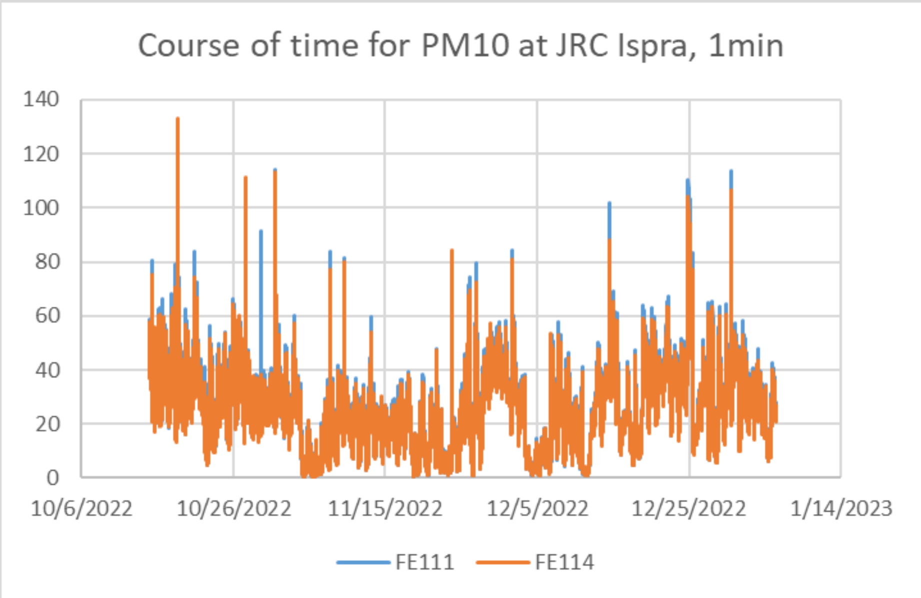

Figure 28: PM_{10} concentrations, JRC Ispra, 1 min measuring interval

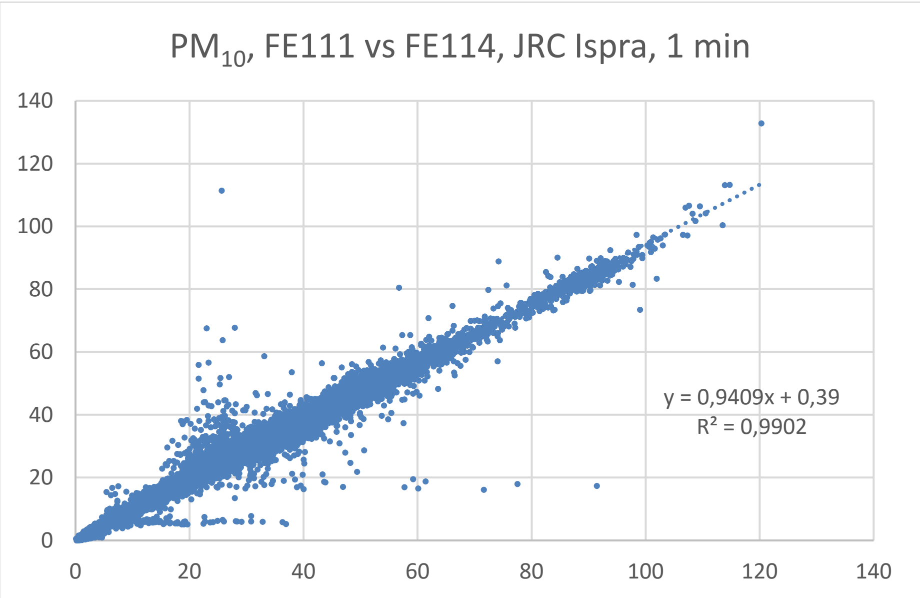

Figure 29: Comparison FE111 vs FE114, PM10, JRC Ispra, 1 min measuring interval

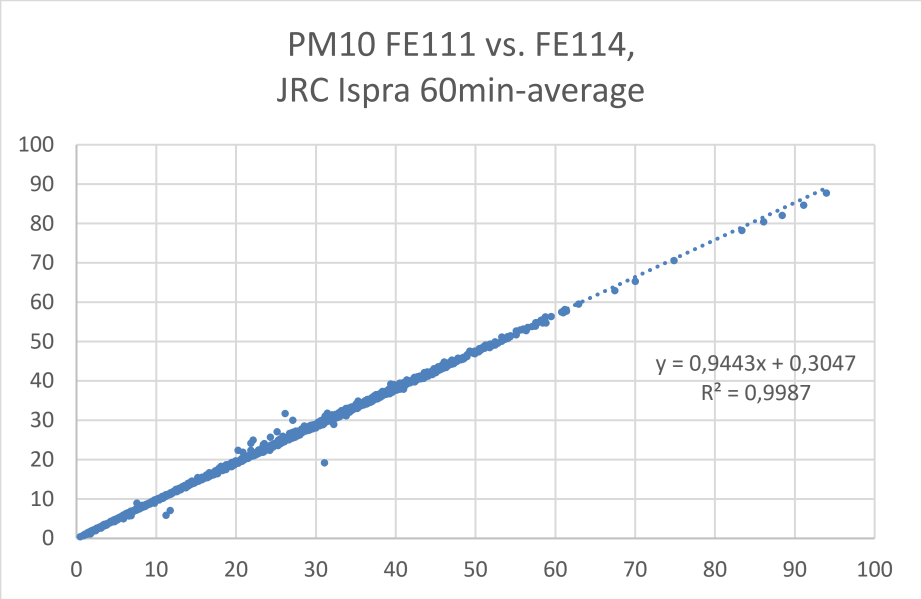

Figure 30: Comparison FE111 vs FE114, PM_{10}, JRC Ispra, 60 min measuring interval

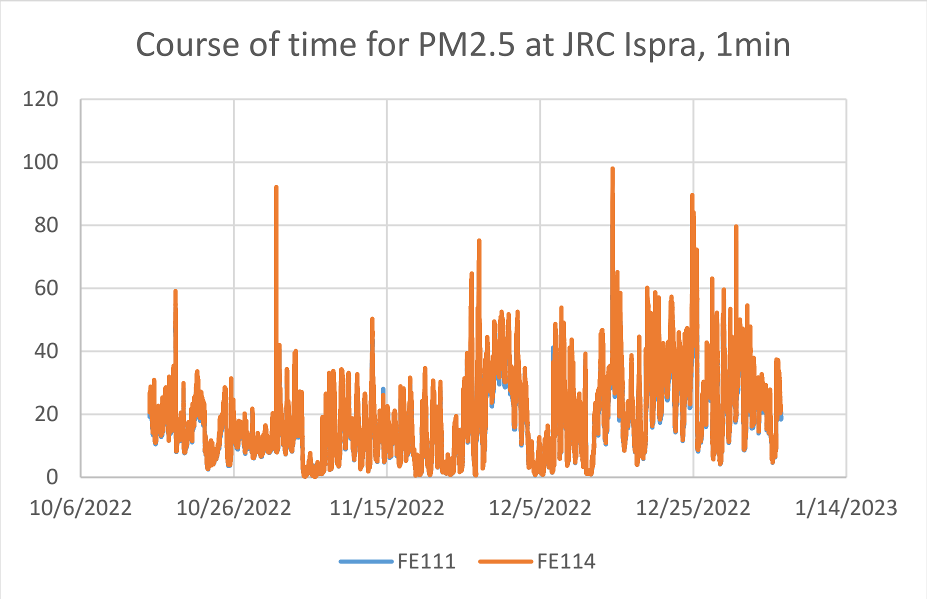

Figure 31: $PM_{2.5}$ concentrations, JRC Ispra, 1 min measuring interval

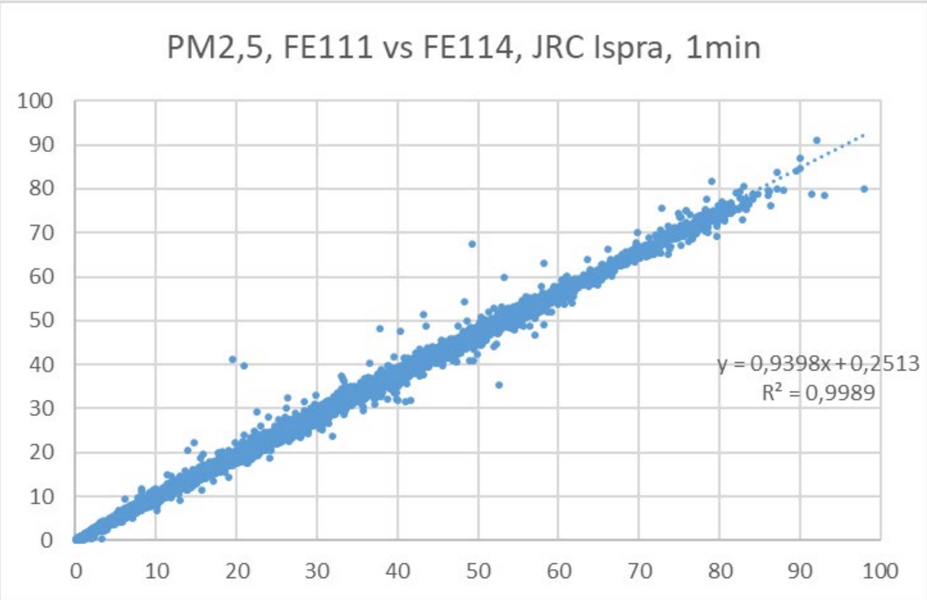

Figure 32: Comparison FE111 vs FE114, $PM_{2.5}$, JRC Ispra, 1 min measuring interval

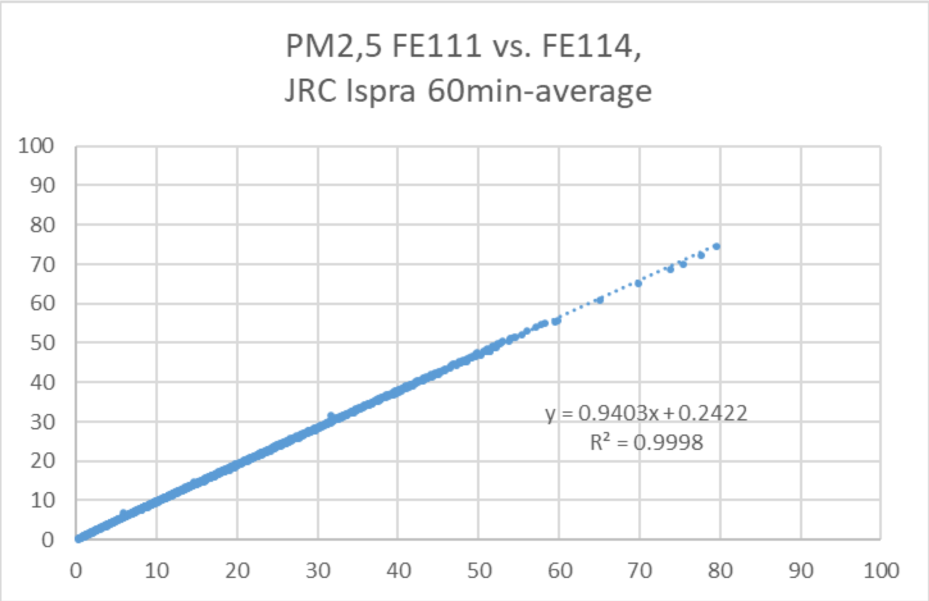

Figure 33: Comparison FE111 vs FE114, $PM_{2.5}$, JRC Ispra, 60 min measuring interval

7.1 15 Availability (7.5.6)

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

7.2 Equipment

Not required for this performance criterion.

7.3 Testing

The start and end times of the availability tests are determined by the start and end times, respectively, at each of the six field test sites. The proper operation of the measuring systems was checked during each on-site visit or via remote monitoring (usually every work day). This daily check consisted of plausibility checks on the measured values, status signals and other relevant parameters (see 7.5.4). Time, duration and nature of any error in functioning are to be 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.

7.4 Evaluation

Table 24 shows a list of operating, maintenance and malfunction times. During the field test, the measuring systems were operated for a total of 350 measuring days. This period includes 18 days of zero filter operation (or days affected by switching between zero filter and sampling head).

No outages due to external influences were recorded during the entire field test period.

While no equipment outages were recorded for device FE111 during the test, there were outages for device FE114 on a total of 6 days. The outages were caused by a bug in the communication between the WS600 weather sensor and the measuring system and required a software update for the weather sensor by the manufacturer Ott Hydromet / Lufft.

7.5 Assessment

Availability was 100% for system FE111 and 98.3% for system FE114.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 24: Determination of the availability

		System 1 (SN FE111)	System 2 (SN FE114)
Operation time (t_{field})	d	350	350
Outage time	d	0	6
Maintenance time incl. zero filter ($t_{cal,maint}$)	d	18	18
Actual operating time (t_{valid})	d	332	326
Availability	%	100	98.3

7.1 Method used for equivalence testing (7.5.8.4 & 7.5.8.8)

Standard EN 16450 [4] requires compliance with the following five criteria:

1. Of the full data set, at least 20% of the concentration values (determined with the reference method) shall be greater than 28 µg/m³ for PM_{10} and 17 µg/m³ for $PM_{2.5}$. When, due to low concentration levels, the criteria for 20 % of results to be greater than 28 µg/m3 for PM_{10}, or to be greater than 17 µg/m3 for $PM_{2.5}$ cannot be obtained, a minimum of 32 data points higher than these thresholds 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 for PM_{10} and 18 µg/m³ for $PM_{2.5}$.
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:
   - Data sets 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;
   - Data sets for each individual site
5. Preconditions for acceptance of the full dataset are that the slope b is insignificantly different from 1: $\left| b-1 \right| \leq 2 \cdot u(b)$ and the intercept a is insignificantly different from 0: $\left| a \right| \leq 2 \cdot u(a)$. If these requirements are not met, then the candidate systems can be calibrated with the values of the total data set for the slope and/or for the axis section.

The following chapters address the issue of verifying compliance with the five criteria.

Chapter 7.1 16 Between-AMS uncertainty (7.5.8.4) addresses verification of criteria 1 and 2.

Verification of criteria 3, 4 and 5 is reported on in chapter 7.1 17 Expanded uncertainty (7.5.8.5 – 7.5.8.8)

Chapter 7.1 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.

7.1 16 Between-AMS uncertainty (7.5.8.4)

The between-AMS uncertainty u_{bs} shall be ≤ 2.5 µg/m³.

7.2 Equipment

Not required for this performance criterion.

7.3 Testing

The test was performed as part of the field test with four separate comparison campaigns. Different seasons as well as different levels of PM concentrations were considered.

Of the total data set, at least 20% of the concentration values determined by the reference method must be greater than 17 µg/m³ for $PM_{2.5}$ or greater than 28 µg/m³ for PM_{10}. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.

For each comparison campaign, at least 40 valid value pairs were determined. Of the entire data set, a total of 46 readings are above 17 µg/m³ for $PM_{2.5}$ and 46 readings are above 28 µg/m³ for PM_{10}. The concentrations measured were related to the ambient conditions.

7.4 Evaluation

Chapter 7.5.8.4 of standard EN 16450 specifies that:

The between-AMS uncertainty u_{bs} shall be ≤ 2.5 µg/m³. A between-AMS uncertainty > 2.5 µg/m^3 is an indication of unsuitable performance of one or both instruments, and equivalence should not be stated.

Uncertainty is determined for:

- All results combined (complete data set)
- 1 data set with measured values ≥ 18 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)
- 1 data set with measured values ≥ 30 µg/m³ for PM_{10} (basis: averages reference measurement)

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

7.5 Assessment

At no more than 1.19 µg/m³ the uncertainty between the candidate systems u_{bs} remains well below the permissible maximum of 2.5 µg/m³.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Table 25: Between-AMS uncertainty $u_{bs,AMS}$.

Location	**Number of measure-ments**	**Uncertainty $u_{bs,AMS}$ µg/m³**	
		$PM_{2.5}$	**PM_{10}**
All locations	326 ($PM_{2.5}$) 326 (PM_{10})	0.44	0.61
Classification via reference values			
Values ≥ 18 µg/m³ ($PM_{2.5}$) Values ≥ 30 µg/m³ (PM_{10})	43 (PM2.5) 39 (PM10)	1.04	1.19

Please note: In the charts below, CM1 corresponds to the FE111 unit and CM2 to the FE114 unit.

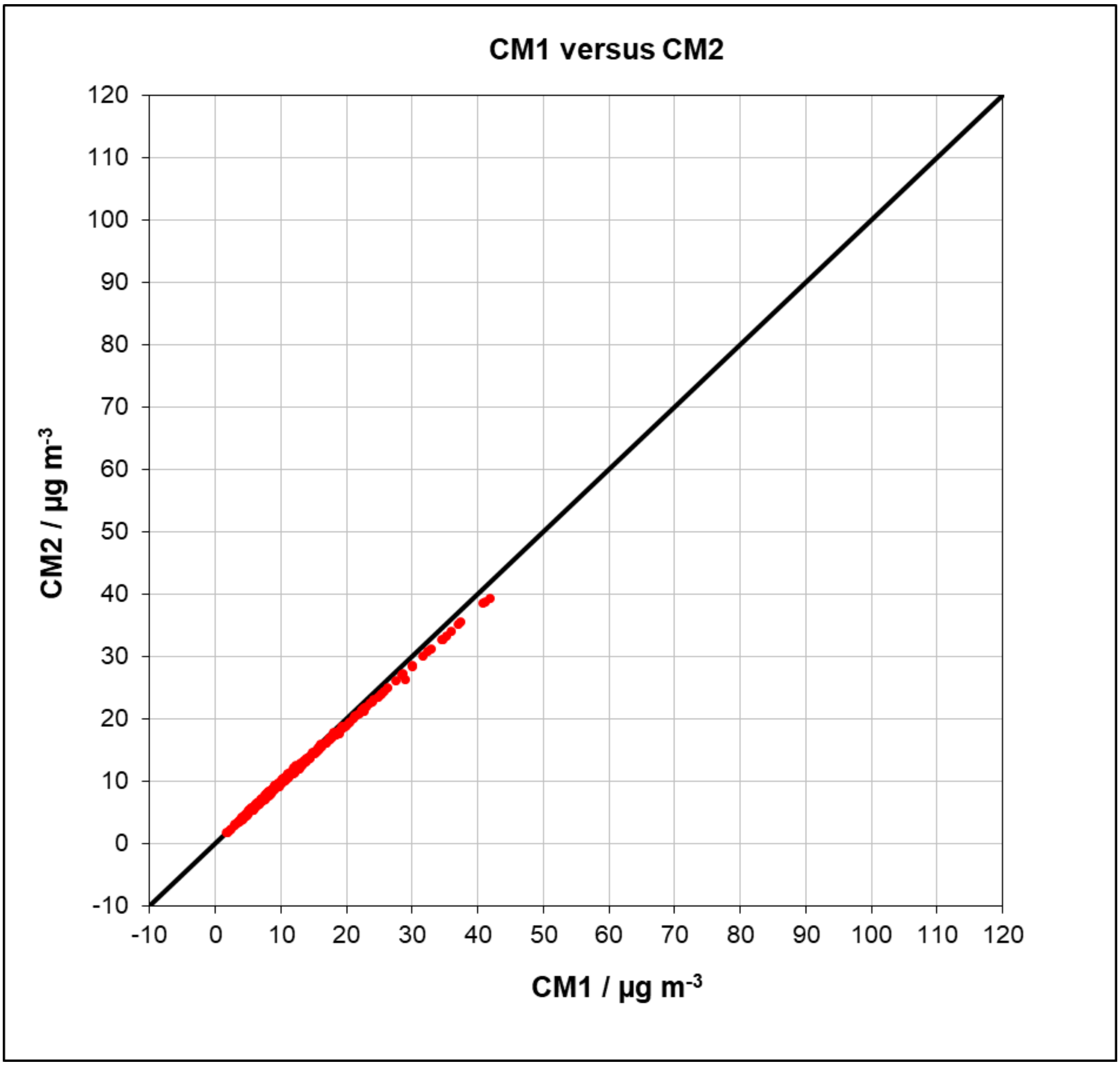

Figure 34: Results of parallel measurements, all sites, $PM_{2.5}$

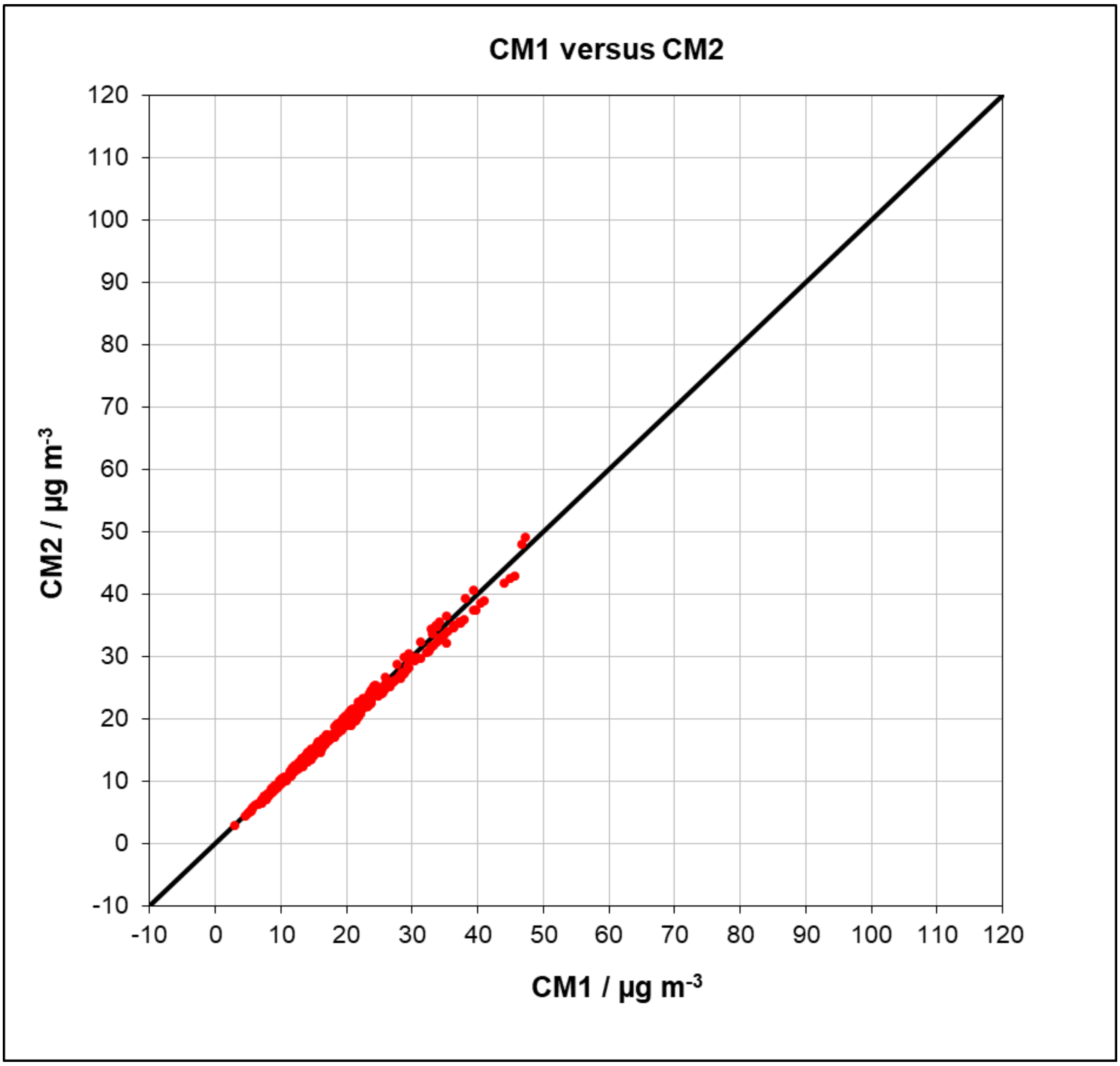

Figure 35: Results of parallel measurements, all sites, PM_{10}

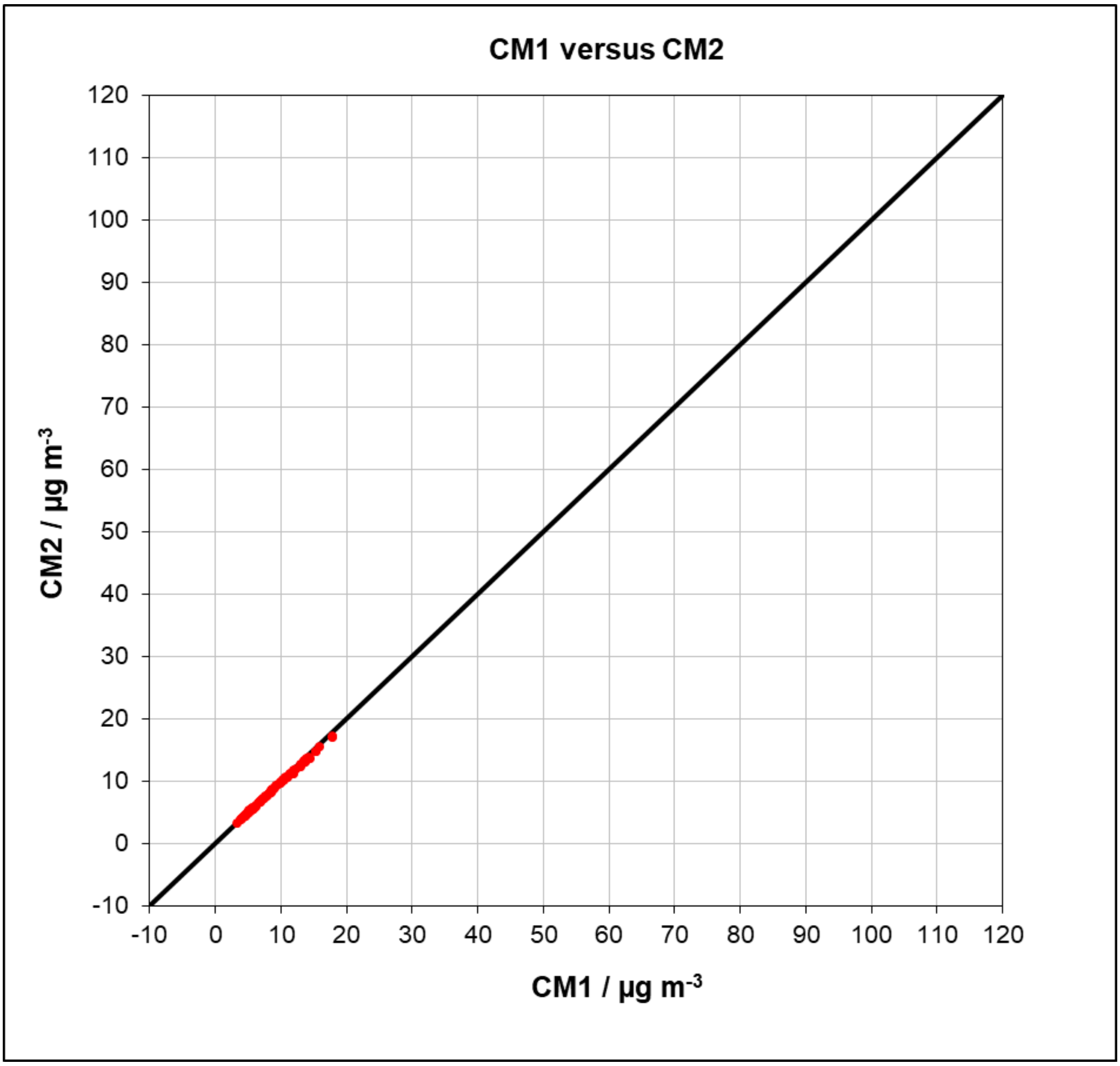

Figure 36: Results of parallel measurements, Cologne, $PM_{2.5}$

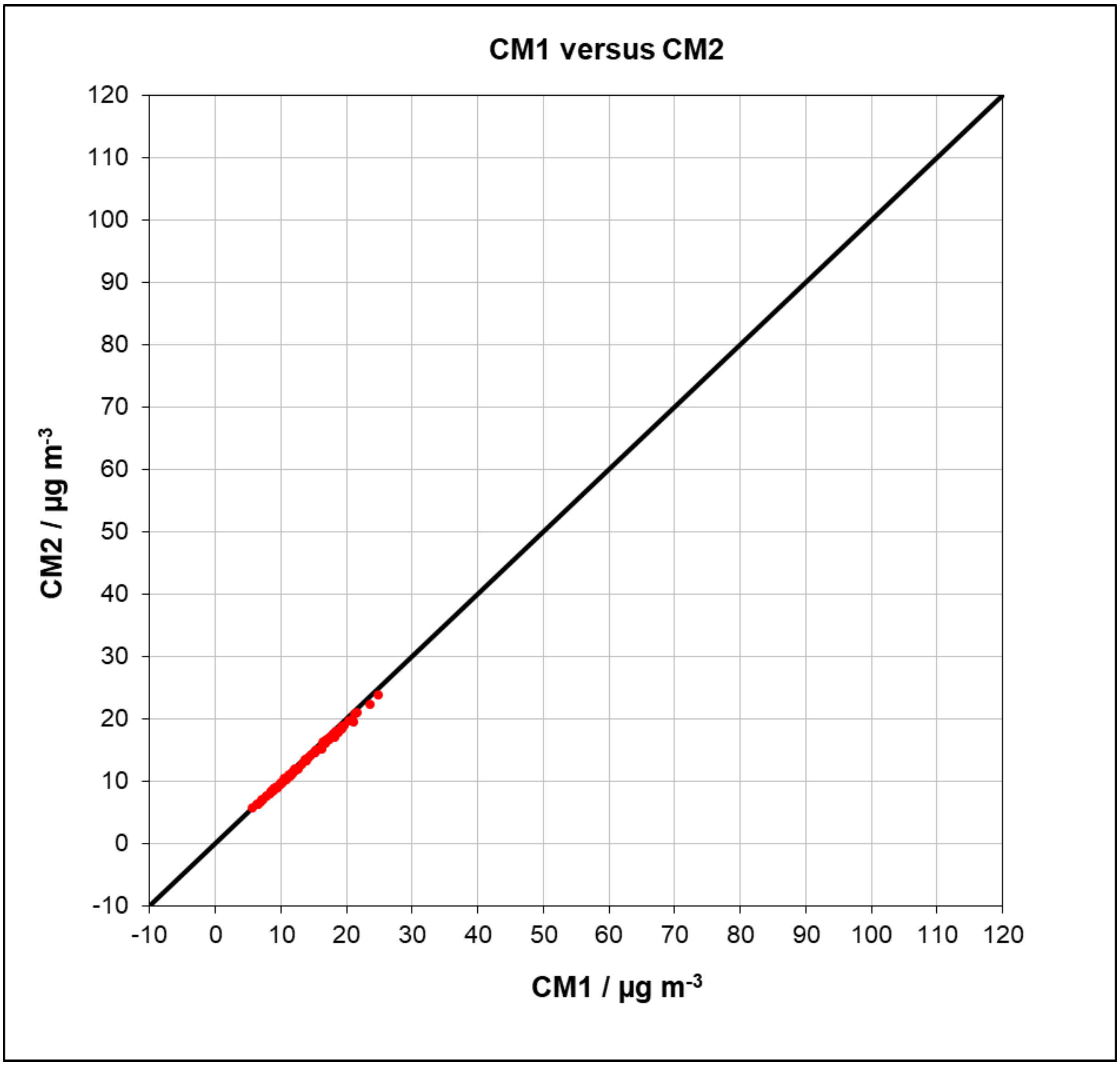

Figure 37: Results of parallel measurements, Cologne, PM_{10}

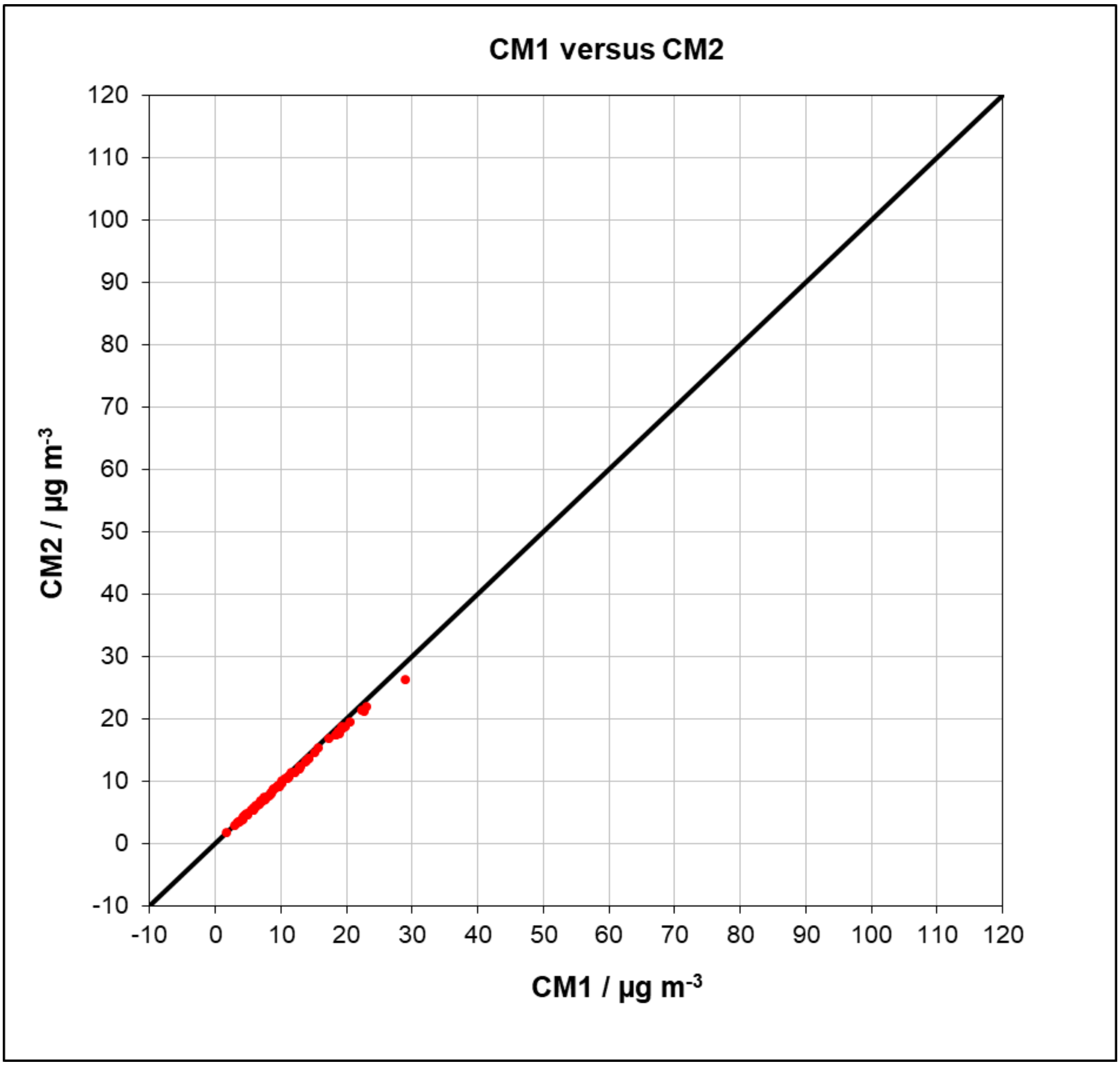

Figure 38: Results of parallel measurements, Bornheim, $PM_{2.5}$

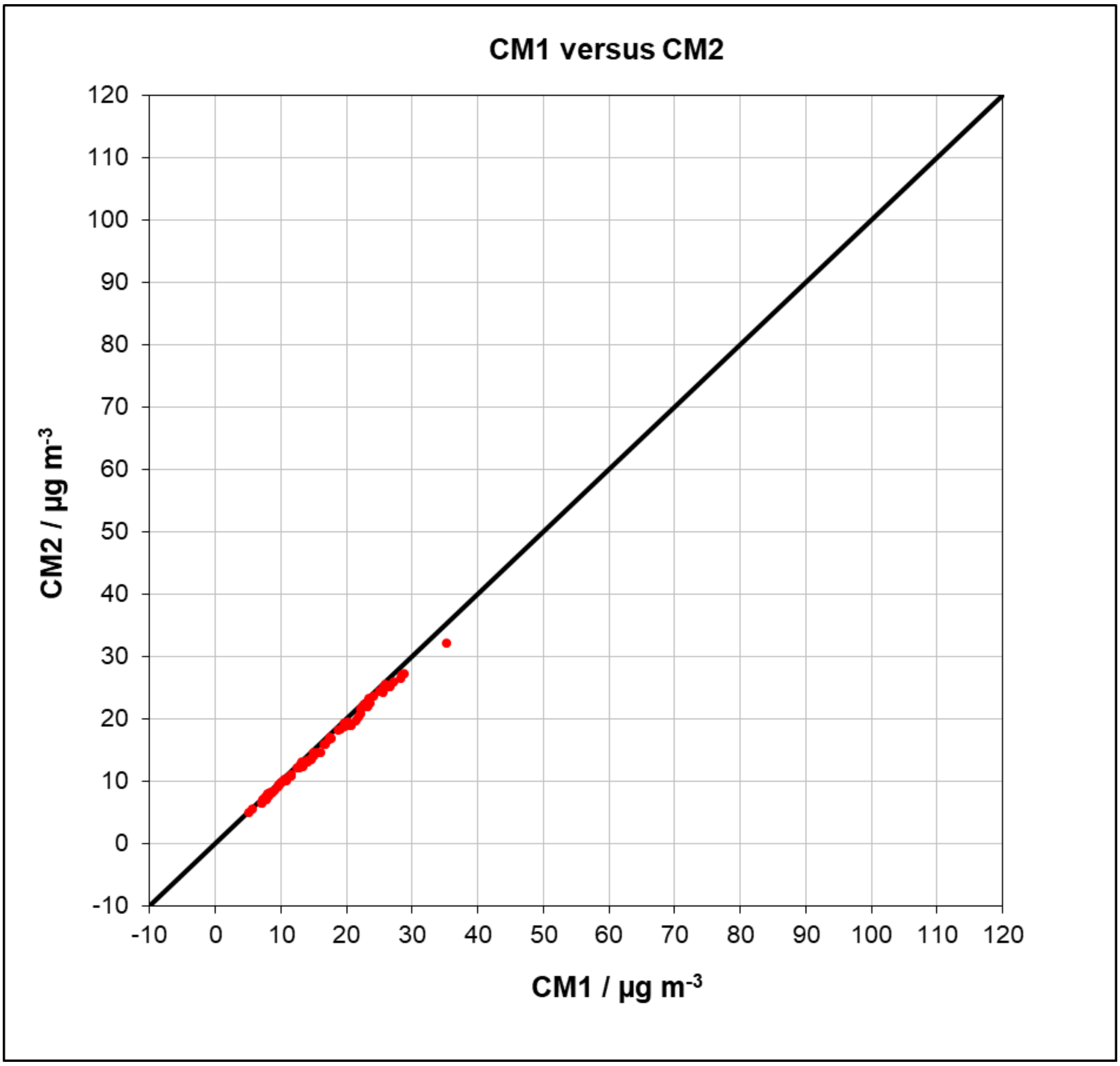

Figure 39: Results of parallel measurements, Bornheim, PM_{10}

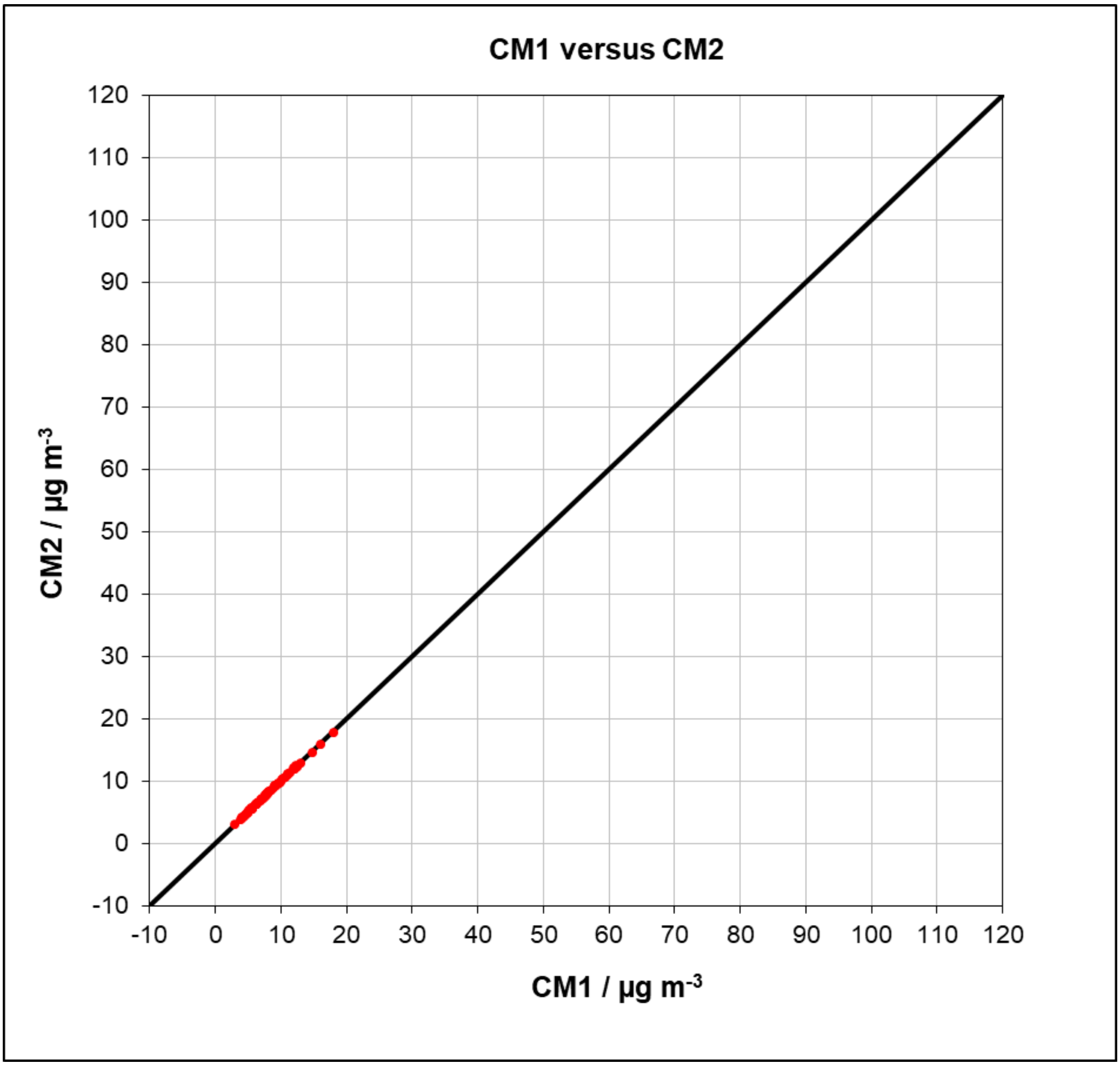

Figure 40: Results of parallel measurements, Niederzier, $PM_{2.5}$

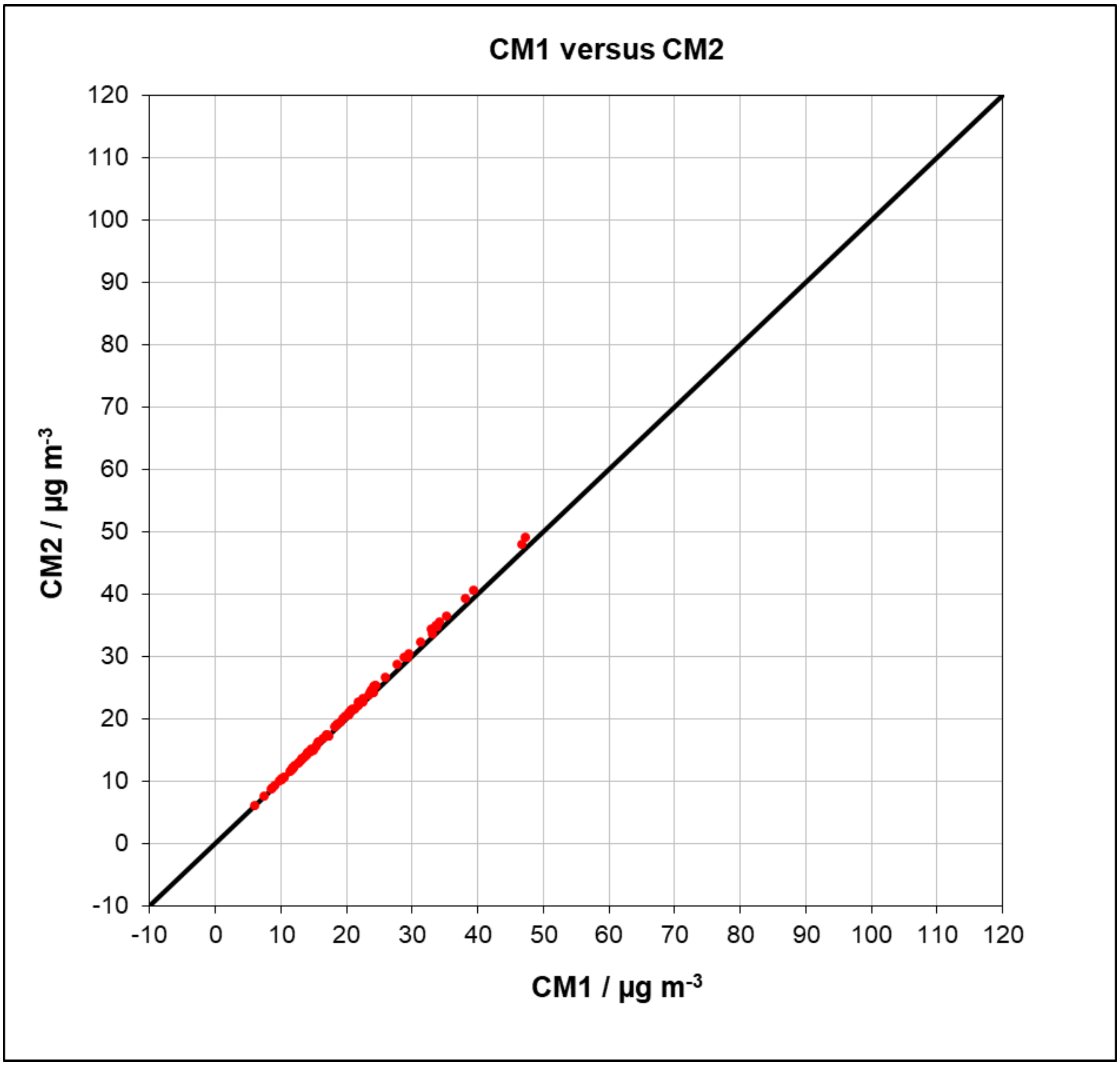

Figure 41: Results of parallel measurements, Niederzier, PM_{10}

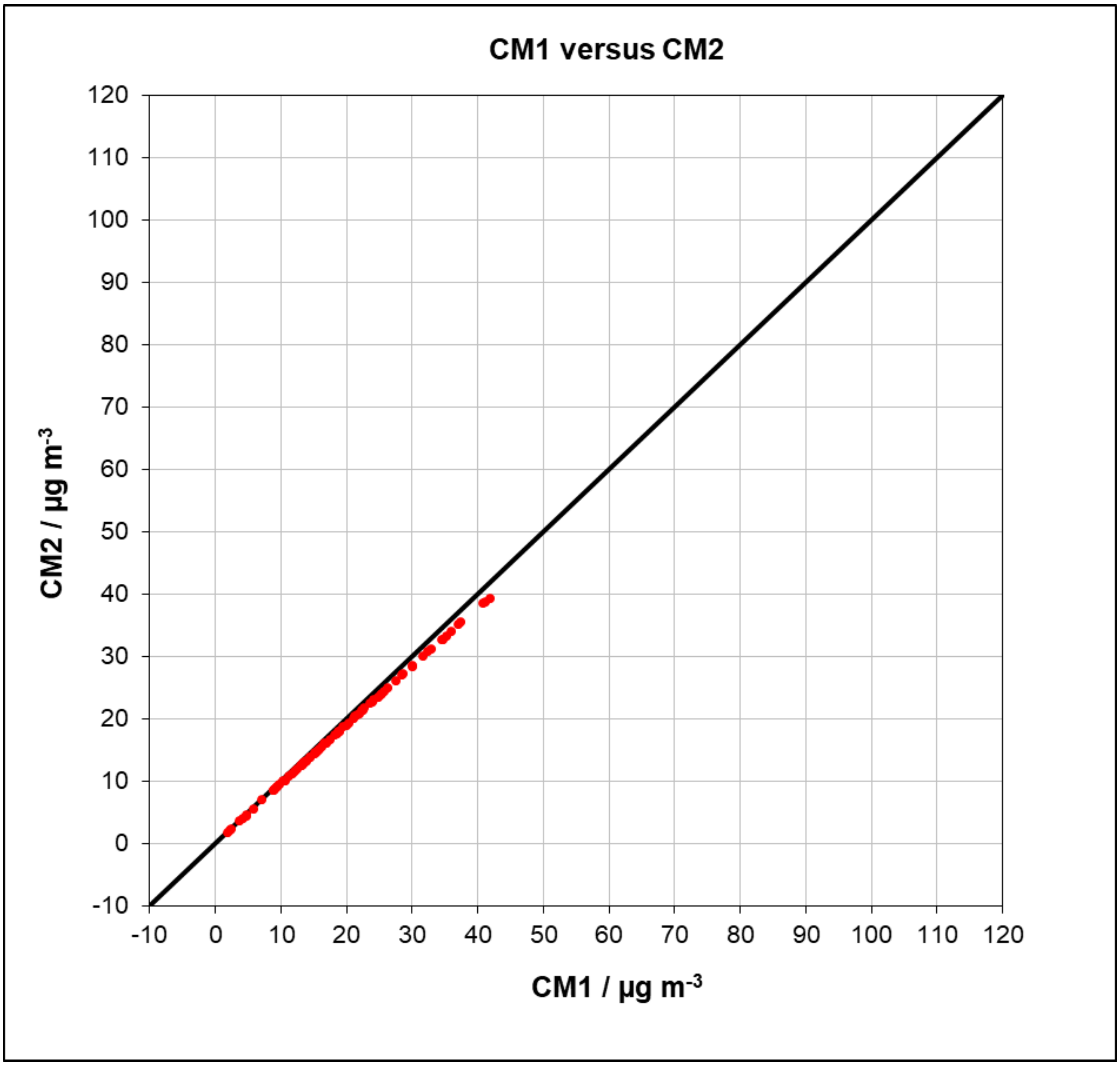

Figure 42: Results of parallel measurements, JRC Ispra, $PM_{2.5}$

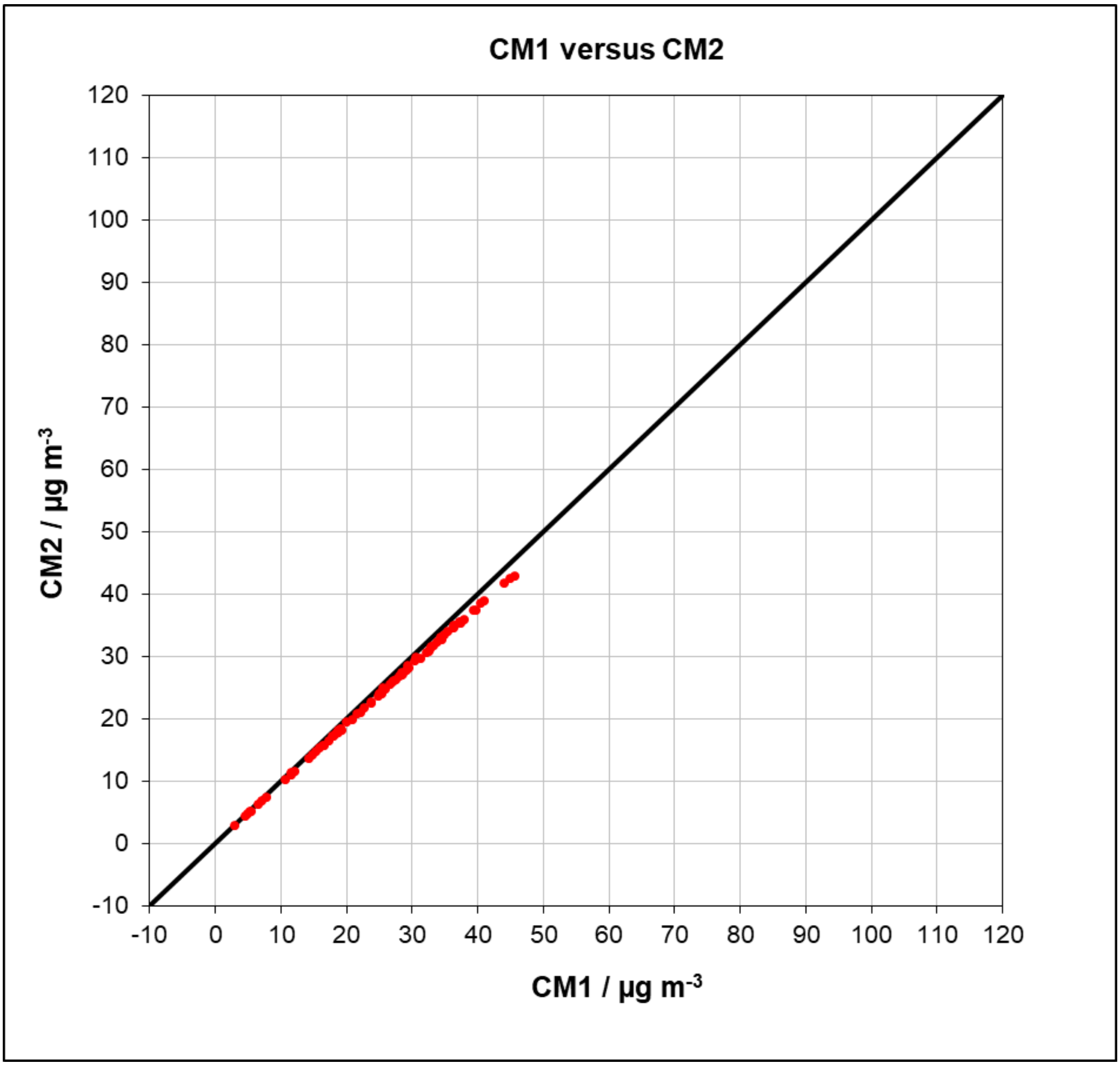

Figure 43: Results of parallel measurements, JRC Ispra, PM_{10}

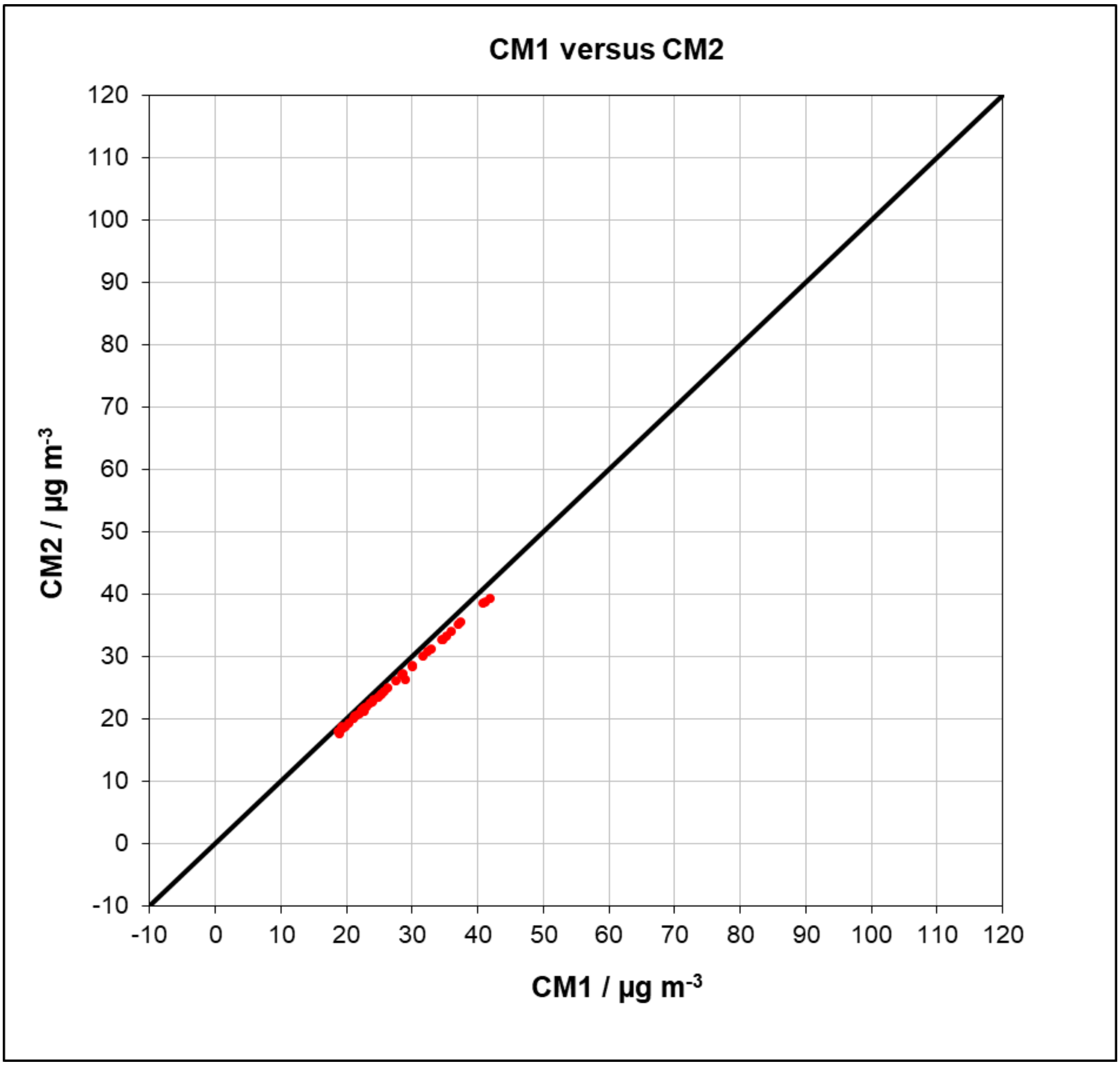

Figure 44: Results of parallel measurements, all sites ≥ 18 µg/m³, $PM_{2.5}$

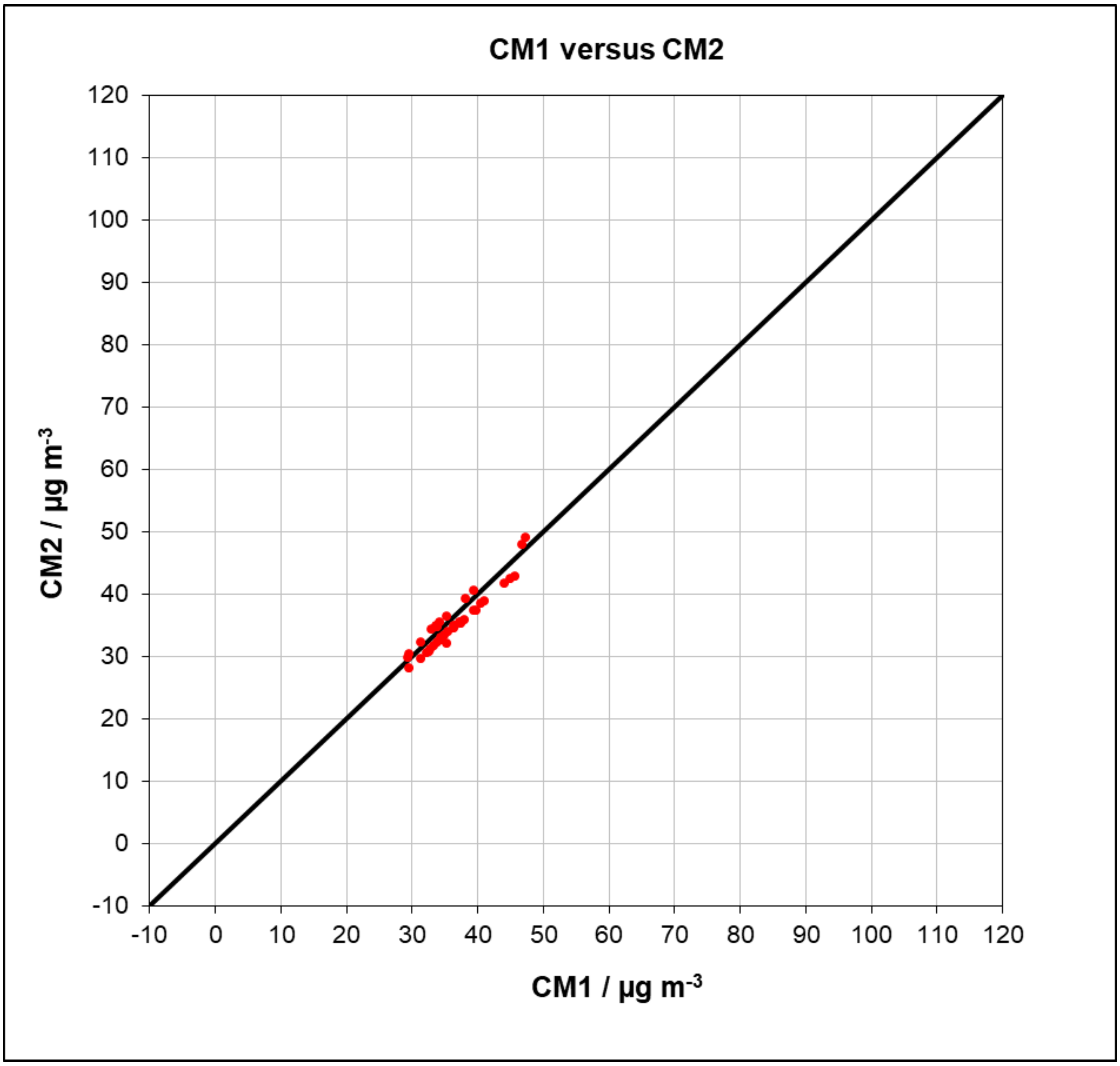

Figure 45: Results of parallel measurements, all sites ≥ 30 µg/m³, PM_{10}

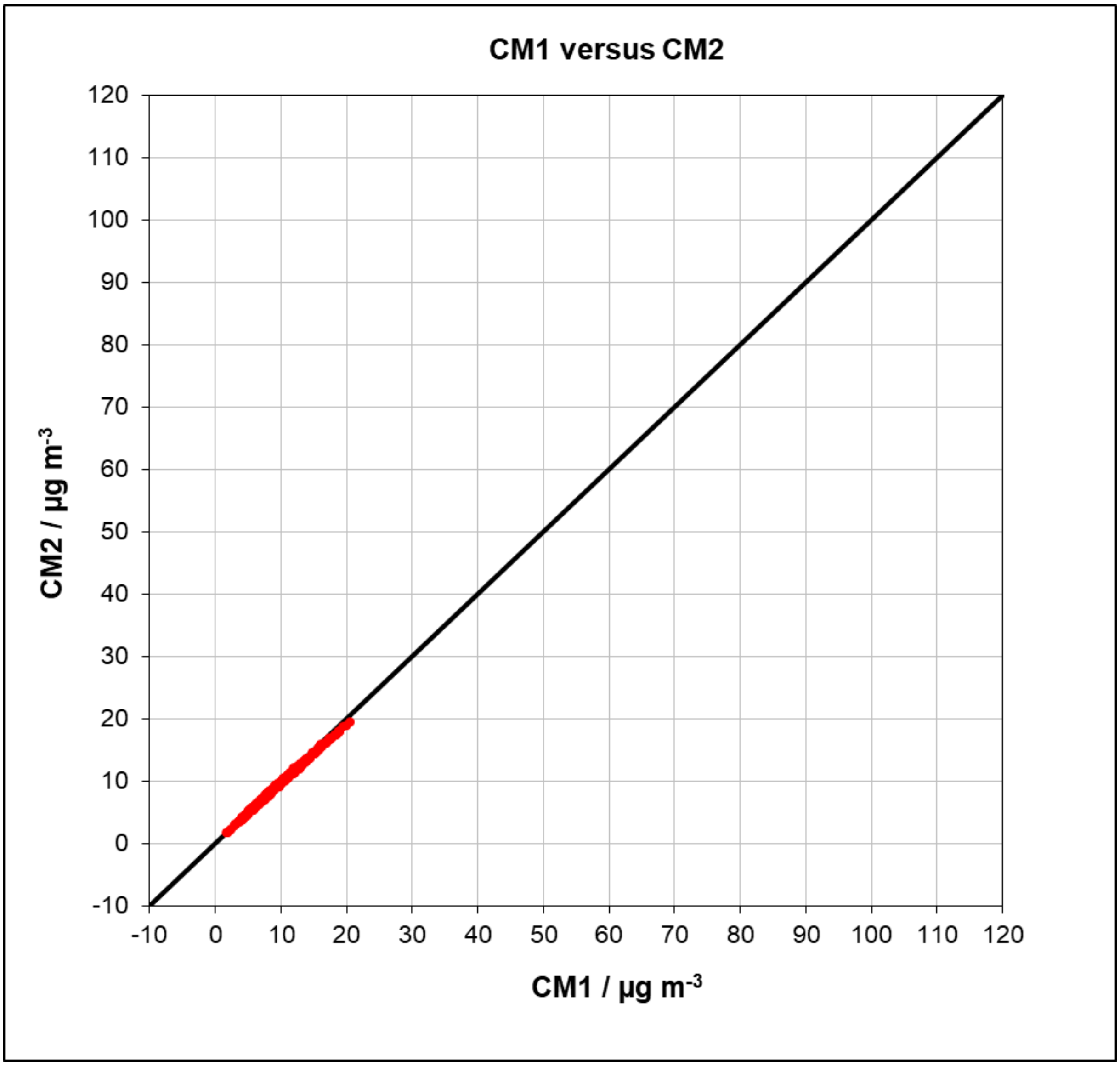

Figure 46: Results of parallel measurements, all sites < 18 µg/m³, $PM_{2.5}$

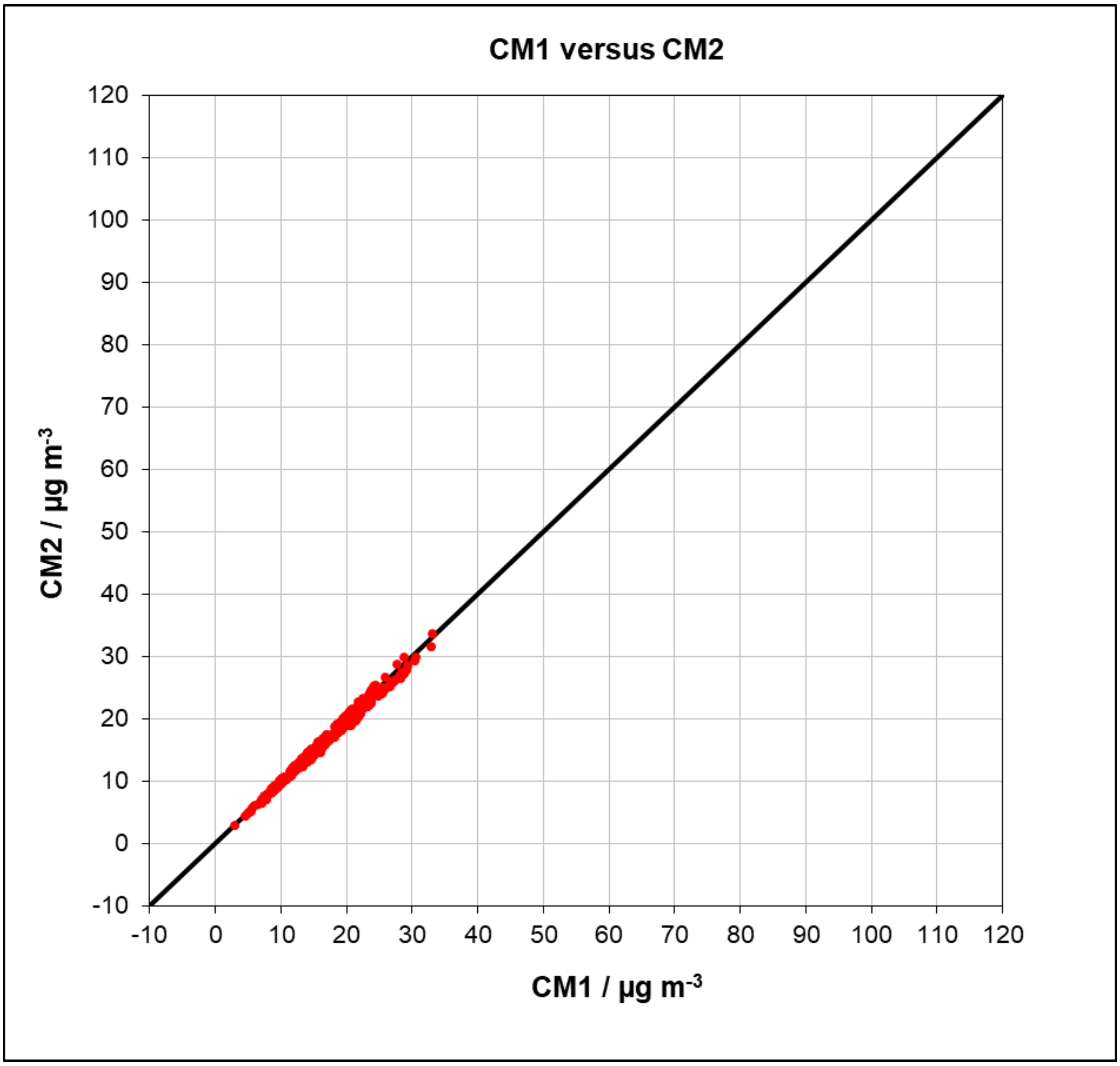

Figure 47: Results of parallel measurements, all sites < 30 µg/m³, PM_{10}

7.1 17 Expanded uncertainty (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.

7.2 Equipment

Additional reference measurement systems as described in section 5 of this report were used for this test.

7.3 Testing

The test was performed as part of the field test with four separate comparison campaigns. Different seasons as well as different concentrations of $PM_{2.5}$ and PM_{10} were taken into consideration.

Of the total data set, at least 20% of the concentration values determined by the reference method must be greater than 17 µg/m³ for $PM_{2.5}$ or greater than 28 µg/m³ for PM_{10}. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.

For each comparison campaign, at least 40 valid value pairs were determined. Of the entire data set, a total of 46 readings are above 17 µg/m³ for $PM_{2.5}$ and 46 readings are above 28 µg/m³ for PM_{10}. The concentrations measured were related to the ambient conditions.

7.4 Evaluation

[EN 16450, 7.5.8.3]

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

The uncertainty between the reference units $u_{bs,RM}$ operated in parallel shall be determined analogously to the uncertainty between the test items and shall be ≤ 2.0 µg/m³.

Results of the evaluation are summarised in section 7.6.

[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 averages 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 together
- Every location or comparison separately
- For a reduced data set that only considers dust concentrations greater than or equal to 18 µg/m3 for $PM_{2.5}$ or 30 µg/m³ for PM_{10}, provided the subset contains at least 40 valid data pairs.

  Please note: The partial data set for PM_{10} contains only 39 valid data pairs instead of the required 40 valid data pairs. The evaluation for the data set greater than or equal to 30 µg/m³ for PM_{10} was nevertheless carried out for information purposes.

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

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

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

u_{RM} =random uncertainty of the reference method; u_{RM} is calculated as $u_{bs,RM}/\sqrt{2}$, where $u_{bs,RM}$ is the between RM uncertainty of two reference instruments operated in parallel.

L = daily limit value for PM_{10} (50 µg/m³) or replacement daily limit value for $PM_{2.5}$ (30 µg/m³)

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 B to [4].

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_y is calculated for:

- All sites or comparisons together
- Every location or comparison separately
- For a reduced data set considering only dust concentrations greater than or equal to 18 µg/m3 for $PM_{2.5}$ or greater than or equal to 30 µg/m3 for PM_{10}, provided that the subset contains at least 40 valid data pairs.

  Please note: The partial data set for PM_{10} contains only 39 valid data pairs instead of the required 40 valid data pairs. The evaluation for the data set greater than or equal to 30 µg/m³ for PM_{10} was nevertheless carried out for information purposes.

The Guideline states the following prerequisites 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 the Guideline 7.5.8.6 [4] (also see 7.1 17 Use of correction factors/terms). The calibration may only be performed for the full data set.

[EN 16450 section 7.5.8.7] The combined uncertainty of the tested instruments for all data sets w^2_{AMS} is calculated as follows:

$$w_{AMS}^2 = \frac{u_{yi=L}^2}{L^2}$$

For each data set the uncertainty w_{AMS} is calculated at a level of L = 30 µg/m³ for $PM_{2.5}$ and L = 50 µg/m³ for PM_{10}.

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

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

Considering the large number of available test results, an expansion factor k=2 must be used.

7.5 Assessment

The determined uncertainties W_{AMS} are already below the permissible expanded relative uncertainty Wdqo of 25 % for particulate matter for all considered data sets for the component PM_{10} without applying correction factors. For the $PM_{2.5}$ component, without applying correction factors, some of the data sets are still above the allowable expanded relative uncertainty W_{dqo} of 25% for fine dust. Since for both $PM_{2.5}$ and PM_{10} the intercept is significantly different from 0 and the slope is significantly different from 1, the application of correction factors shall be made appropriately in accordance with Section 7.1 17 Use of correction factors/terms . After applying correction factors and terms, all considered data sets are below the specified expanded relative uncertainty W_{dqo} of 25%.

Criterion satisfied? yes

Table 26 and Table 27 below summarise all results for the equivalence tests. Where a criterion was not satisfied, the corresponding line is marked in red.

Table 26: Equivalence test for $PM_{2.5}$

Standard EN 16450:2017					
Candidate	EDM 280		SN	FE111 & FE114	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**0.44**	**µg/m³**			
	FE111 & FE114				
Number of data pairs	**308**				
Slope b	**1.022**	**not significant**			
Uncertainty of b	**0.012**				
Ordinate intercept a	**1.032**	**significant**			
Uncertainty of a	**0.152**				
Expanded meas. uncertainty W_{CM}	**15.31**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.49**	**µg/m³**			
Uncertainty between Candidates	**1.04**	**µg/m³**			
	FE111 & FE114				
Number of data pairs	**43**				
Slope b	**1.165**				
Uncertainty of b	**0.054**				
Ordinate intercept a	**-3.095**				
Uncertainty of a	**1.388**				
Expanded meas. uncertainty W_{CM}	**17.92**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.54**	**µg/m³**			
Uncertainty between Candidates	**0.25**	**µg/m³**			
	FE111 & FE114				
Number of data pairs	**265**				
Slope b	**1.077**				
Uncertainty of b	**0.024**				
Ordinate intercept a	**0.703**				
Uncertainty of a	**0.206**				
Expanded meas. uncertainty W_{CM}	**22.33**	**%**			

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	EDM 280		SN	FE111 & FE114	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
Cologne					
Uncertainty between Reference	**0.37**	**µg/m³**			
Uncertainty between Candidates	**0.20**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**79**			**73**	
Slope b	**1.161**			**1.116**	
Uncertainty of b	**0.038**			**0.040**	
Ordinate intercept a	**0.470**			**0.607**	
Uncertainty of a	**0.299**			**0.308**	
Expanded meas. uncertainty W_{CM}	**36.02**	%		**28.07**	%
Bornheim					
Uncertainty between Reference	**0.48**	**µg/m³**			
Uncertainty between Candidates	**0.43**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**78**			**78**	
Slope b	**0.977**			**0.914**	
Uncertainty of b	**0.022**			**0.020**	
Ordinate intercept a	**1.830**			**1.944**	
Uncertainty of a	**0.238**			**0.212**	
Expanded meas. uncertainty W_{CM}	**10.84**	%		**7.97**	%
Niederzier					
Uncertainty between Reference	**0.72**	**µg/m³**			
Uncertainty between Candidates	**0.08**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**75**			**75**	
Slope b	**1.101**			**1.082**	
Uncertainty of b	**0.089**			**0.086**	
Ordinate intercept a	**0.128**			**0.334**	
Uncertainty of a	**0.622**			**0.606**	
Expanded meas. uncertainty W_{CM}	**25.07**	%		**22.82**	%
JRC Ispra					
Uncertainty between Reference	**0.50**	**µg/m³**			
Uncertainty between Candidates	**0.75**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**82**			**82**	
Slope b	**1.081**			**1.018**	
Uncertainty of b	**0.022**			**0.021**	
Ordinate intercept a	**0.325**			**0.518**	
Uncertainty of a	**0.430**			**0.402**	
Expanded meas. uncertainty W_{CM}	**21.87**	%		**13.21**	%
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.49**	**µg/m³**			
Uncertainty between Candidates	**1.04**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**44**			**43**	
Slope b	**1.194**			**1.126**	
Uncertainty of b	**0.055**			**0.052**	
Ordinate intercept a	**-3.067**			**-2.799**	
Uncertainty of a	**1.414**			**1.34**	
Expanded meas. uncertainty W_{CM}	**22.77**	%		**14.09**	%
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.54**	**µg/m³**			
Uncertainty between Candidates	**0.25**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**270**			**265**	
Slope b	**1.109**			**1.044**	
Uncertainty of b	**0.025**			**0.023**	
Ordinate intercept a	**0.565**			**0.847**	
Uncertainty of a	**0.211**			**0.198**	
Expanded meas. uncertainty W_{CM}	**27.56**	%		**17.30**	%
All comparisons					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**0.44**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**314**			**308**	
Slope b	**1.057**	**significant**		**0.989**	**not significant**
Uncertainty of b	**0.013**			**0.012**	
Ordinate intercept a	**0.881**	**significant**		**1.186**	**significant**
Uncertainty of a	**0.156**			**0.146**	
Expanded meas. uncertainty W_{CM}	**20.25**	%		**11.36**	%

Table 27: Equivalence test for PM_{10}

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	EDM 280		SN	FE111 & FE114	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.72**	**µg/m³**			
Uncertainty between Candidates	**0.61**	**µg/m³**			
	FE111 & FE114				
Number of data pairs	**304**				
Slope b	**0.982**	**not significant**			
Uncertainty of b	**0.011**				
Ordinate intercept a	**0.951**	significant			
Uncertainty of a	**0.215**				
Expanded measured uncertainty WCM	**6.54**	**%**			
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	**1.06**	**µg/m³**			
Uncertainty between Candidates	**1.19**	**µg/m³**			
	FE111 & FE114				
Number of data pairs	**39**				
Slope b	**0.937**				
Uncertainty of b	**0.061**				
Ordinate intercept a	**2.344**				
Uncertainty of a	**2.194**				
Expanded measured uncertainty WCM	**7.54**	**%**			
All comparisons, <30 µg/m³					
Uncertainty between Reference	**0.65**	**µg/m³**			
Uncertainty between Candidates	**0.49**	**µg/m³**			
	FE111 & FE114				
Number of data pairs	**265**				
Slope b	**1.003**				
Uncertainty of b	**0.016**				
Ordinate intercept a	**0.663**				
Uncertainty of a	**0.271**				
Expanded measured uncertainty WCM	**7.29**	**%**			

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	EDM 280		SN	FE111 & FE114	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
Cologne					
Uncertainty between Reference	**0.52**	**µg/m³**			
Uncertainty between Candidates	**0.38**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**79**			**73**	
Slope b	**1.047**			**0.999**	
Uncertainty of b	**0.031**			**0.032**	
Ordinate intercept a	**0.522**			**0.672**	
Uncertainty of a	**0.400**			**0.406**	
Expanded measured uncertainty W_{CM}	**12.29**	**%**		**4.90**	**%**
Bornheim					
Uncertainty between Reference	**0.71**	**µg/m³**			
Uncertainty between Candidates	**0.60**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**68**			**68**	
Slope b	**0.991**			**0.941**	
Uncertainty of b	**0.024**			**0.024**	
Ordinate intercept a	**-0.011**			**0.099**	
Uncertainty of a	**0.437**			**0.436**	
Expanded measured uncertainty W_{CM}	**5.51**	**%**		**12.59**	**%**
Niederzier					
Uncertainty between Reference	**0.89**	**µg/m³**			
Uncertainty between Candidates	**0.49**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**81**			**81**	
Slope b	**0.956**			**0.992**	
Uncertainty of b	**0.022**			**0.021**	
Ordinate intercept a	**2.246**			**2.164**	
Uncertainty of a	**0.458**			**0.445**	
Expanded measured uncertainty W_{CM}	**6.97**	**%**		**9.72**	**%**
JRC Ispra					
Uncertainty between Reference	**0.69**	**µg/m³**			
Uncertainty between Candidates	**0.87**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**82**			**82**	
Slope b	**1.009**			**0.956**	
Uncertainty of b	**0.017**			**0.017**	
Ordinate intercept a	**0.618**			**0.812**	
Uncertainty of a	**0.438**			**0.445**	
Expanded measured uncertainty W_{CM}	**7.29**	**%**		**8.25**	**%**
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	**1.06**	**µg/m³**			
Uncertainty between Candidates	**1.19**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**39**			**39**	
Slope b	**0.951**			**0.949**	
Uncertainty of b	**0.056**			**0.074**	
Ordinate intercept a	**2.260**			**1.514**	
Uncertainty of a	**2.022**			**2.68**	
Expanded measured uncertainty W_{CM}	**6.22**	**%**		**9.61**	**%**
All comparisons, <30 µg/m³					
Uncertainty between Reference	**0.65**	**µg/m³**			
Uncertainty between Candidates	**0.49**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**271**			**265**	
Slope b	**1.016**			**0.993**	
Uncertainty of b	**0.015**			**0.017**	
Ordinate intercept a	**0.635**			**0.651**	
Uncertainty of a	**0.257**			**0.286**	
Expanded measured uncertainty W_{CM}	**8.52**	**%**		**7.02**	**%**
All comparisons					
Uncertainty between Reference	**0.72**	**µg/m³**			
Uncertainty between Candidates	**0.61**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**310**			**304**	
Slope b	**0.994**	**not significant**		**0.972**	**significant**
Uncertainty of b	**0.010**			**0.011**	
Ordinate intercept a	**0.937**	**significant**		**0.929**	**significant**
Uncertainty of a	**0.204**			**0.233**	
Expanded measured uncertainty W_{CM}	**6.74**	**%**		**7.35**	**%**

Results for testing the five criteria from point 7.1 Method used for equivalence testing were as follows:

Criterion 1: More than 32 value pairs were greater than 17 µg/m³ ($PM_{2.5}$) or 28 µg/m³ (PM_{10}).

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: For $PM_{2.5}$, not all expanded uncertainties were below 25%.
For PM_{10}, all expanded uncertainties were below 25%.

Criterion 5: For $PM_{2.5}$, for candidate FE111, the slope and intercept were significantly greater than allowed when evaluating the total data set; for candidate FE114, the intercept was significantly greater than allowed when evaluating the total data-set.
For PM_{10}, for candidate FE111, the intercept was significantly greater than allowed when evaluating the total data set; for candidate FE114, the slope and intercept were significantly greater than allowed when evaluating the total data-set.

Further: The total data set for both candidates together shows a slope of 1.022 ($PM_{2.5}$) and 0.982 (PM_{10}) and an intercept of 1.032 ($PM_{2.5}$) and 0.951 (PM_{10}), respectively, with a total expanded uncertainty of 15.31% ($PM_{2.5}$) and 6.54% (PM_{10}).

The result is that for both $PM_{2.5}$ and PM_{10} the intercept is significantly different from 0 and the slope is significantly different from 1. Therefore, an additional evaluation is carried out under chapter 7.1 17 Use of correction factors/terms by applying the corresponding correction factors/terms to the data sets.

7.6 Detailed presentation of test results

Table 28 provides an overview of the between RM uncertainties $u_{bs,RM}$ determined during the field tests.

Table 28: Between RM uncertainty $u_{bs,RM}$, $PM_{2.5}$

Reference instruments	Location	Number of values*	Uncertainty $u_{bs,RM}$
No.			µg/m³
1 / 2	Cologne	73	0.37
1 / 2	Bornheim	78	0.48
1 / 2	Niederzier	75	0.72
1 / 2	JRC Ispra	82	0.50
1 / 2	All sites	308	0.53

Table 29: Between RM uncertainty $u_{bs,RM}$, PM_{10}

Reference instruments	Location	Number of values*	Uncertainty $u_{bs,RM}$
No.			µg/m³
1 / 2	Cologne	73	0.52
1 / 2	Bornheim	68	0.71
1 / 2	Niederzier	81	0.89
1 / 2	JRC Ispra	82	0.69
1 / 2	All sites	304	0.72

*Note: Number of values corresponds to the number of pairs of measured values when two reference values and both candidates are presented.

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

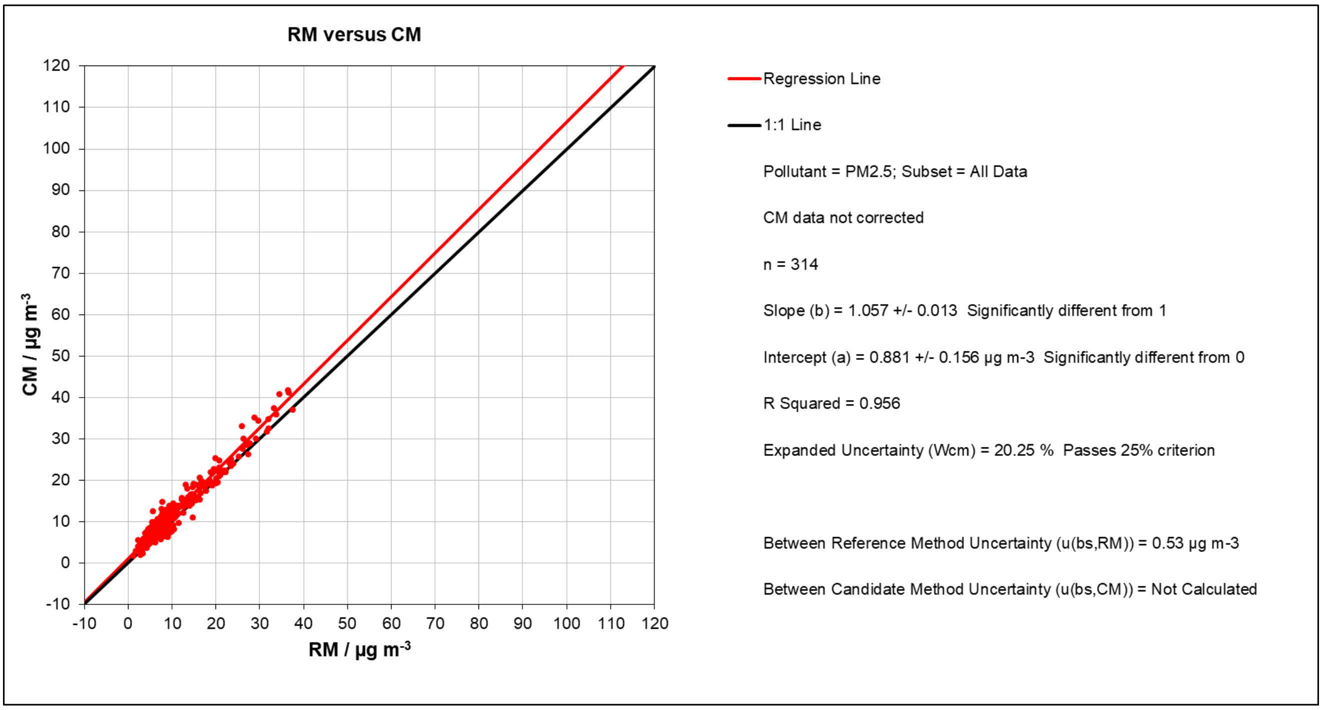

Figure 48: Reference vs candidate, SN FE111, all sites, $PM_{2.5}$

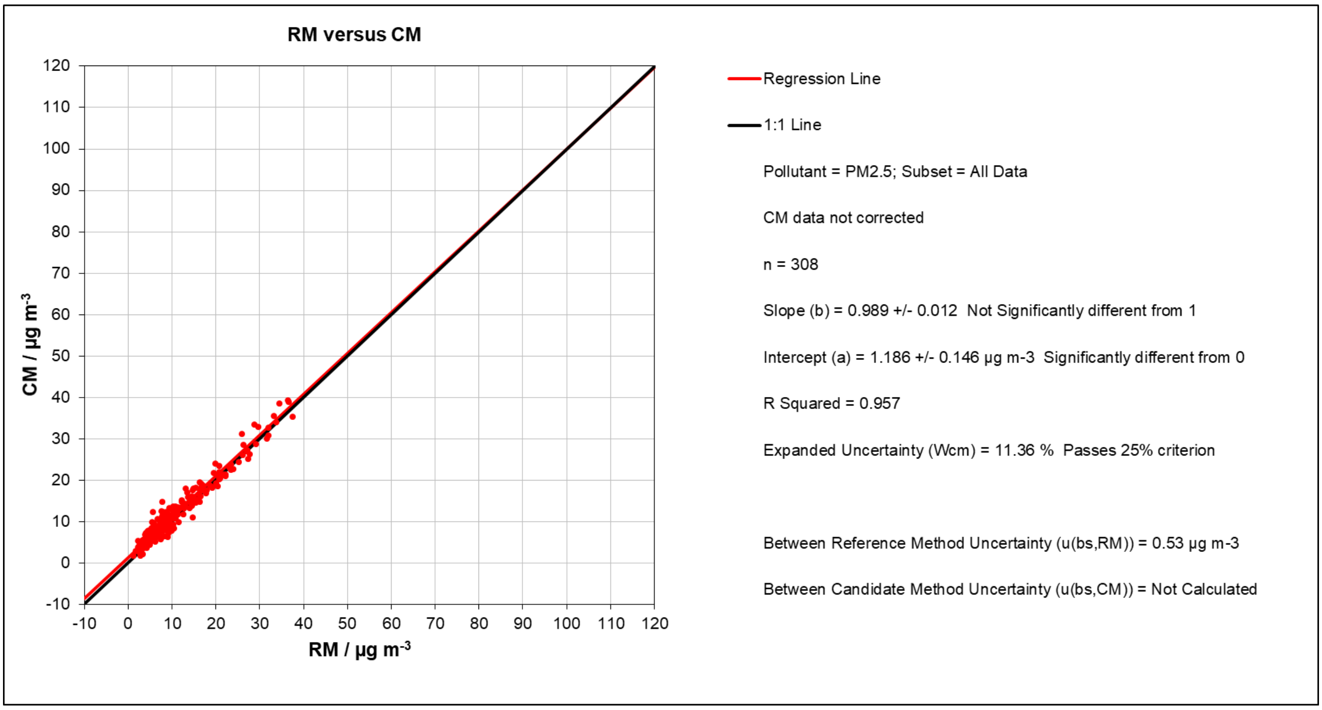

Figure 49: Reference vs candidate, SN FE114, all sites, $PM_{2.5}$

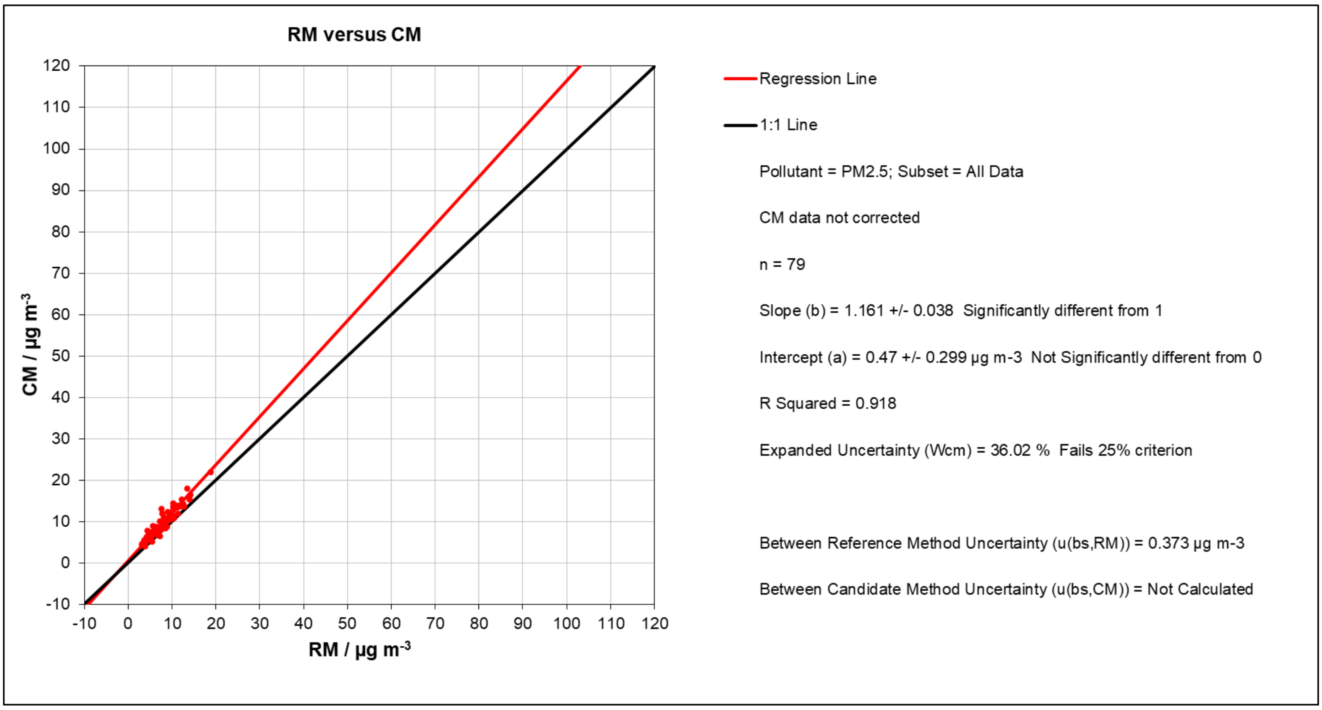

Figure 50: Reference vs candidate, SN FE111, Cologne, $PM_{2.5}$

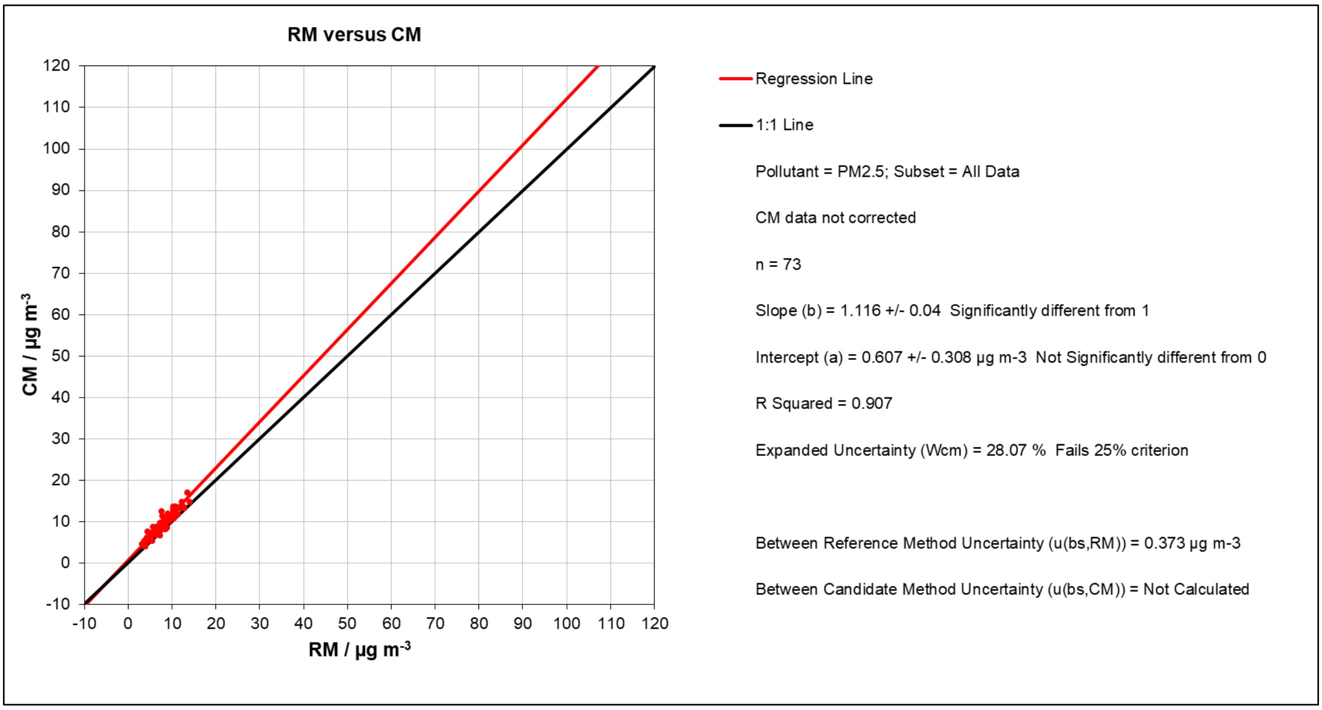

Figure 51: Reference vs candidate, SN FE114, Cologne, $PM_{2.5}$

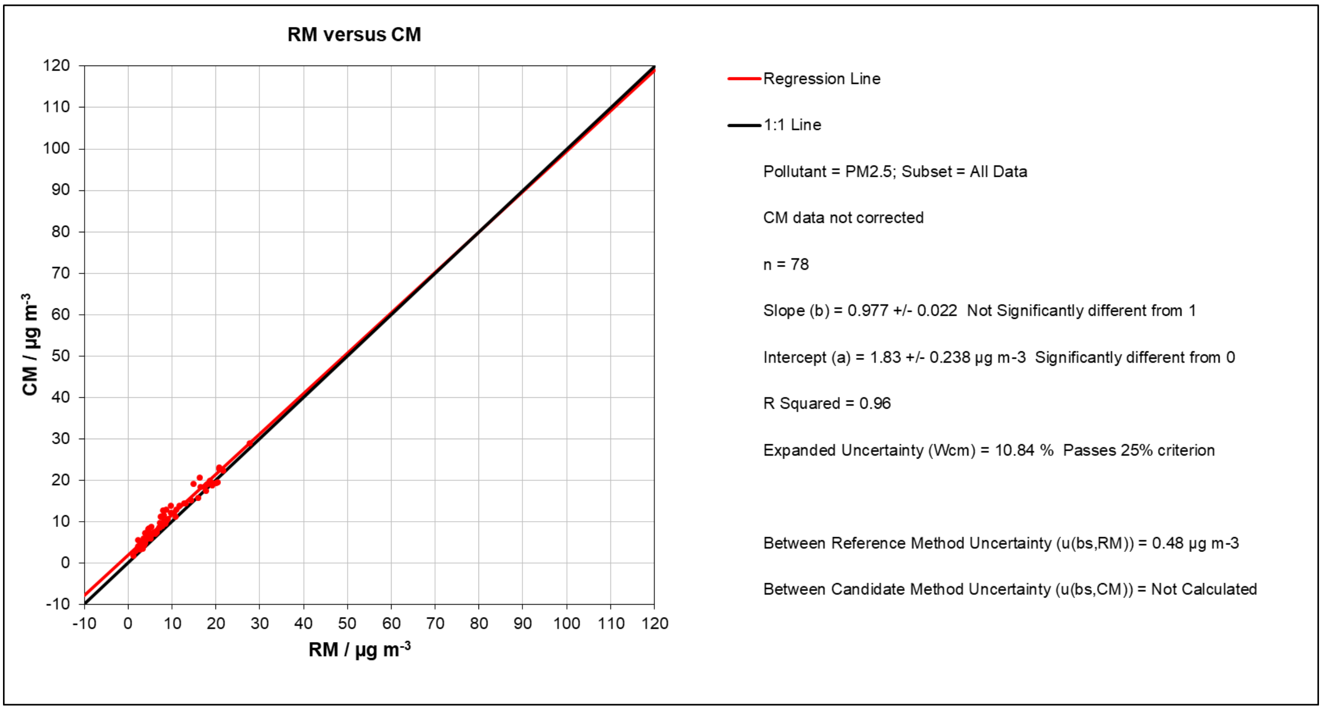

Figure 52: Reference vs candidate, SN FE111, Bornheim, $PM_{2.5}$

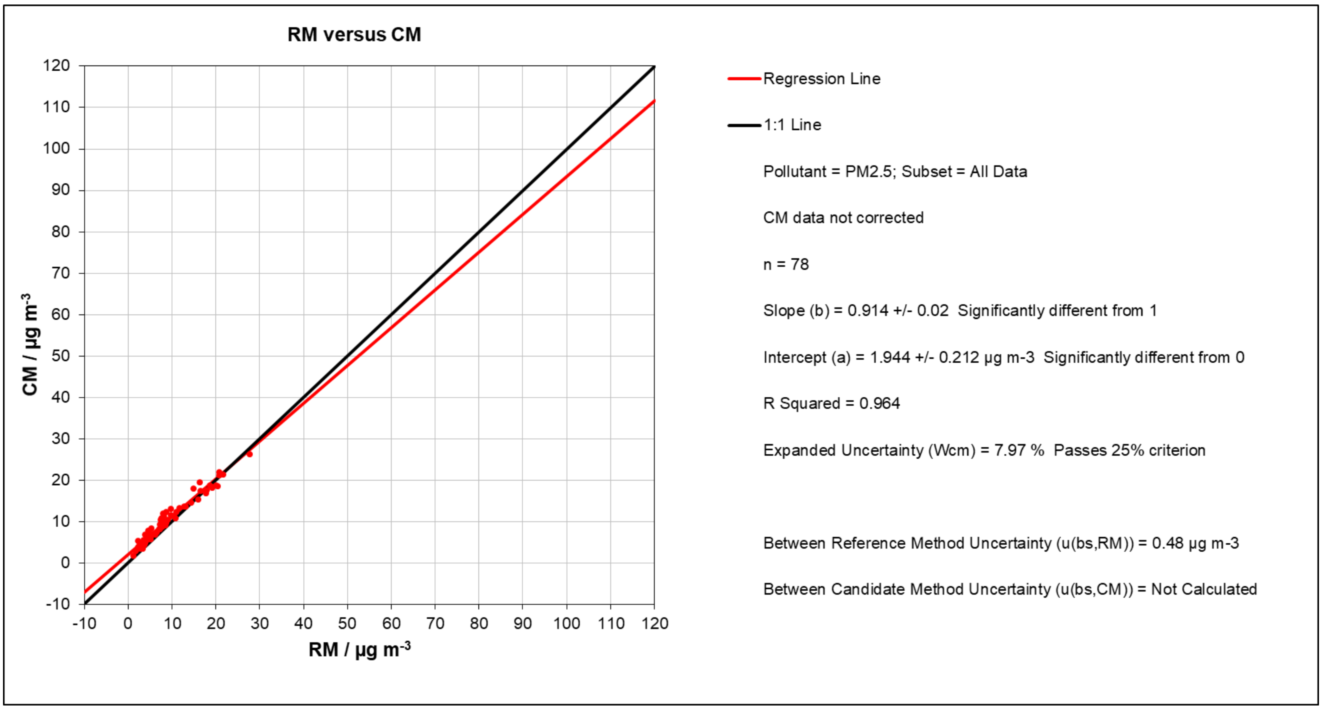

Figure 53: Reference vs candidate, SN FE114, Bornheim, $PM_{2.5}$

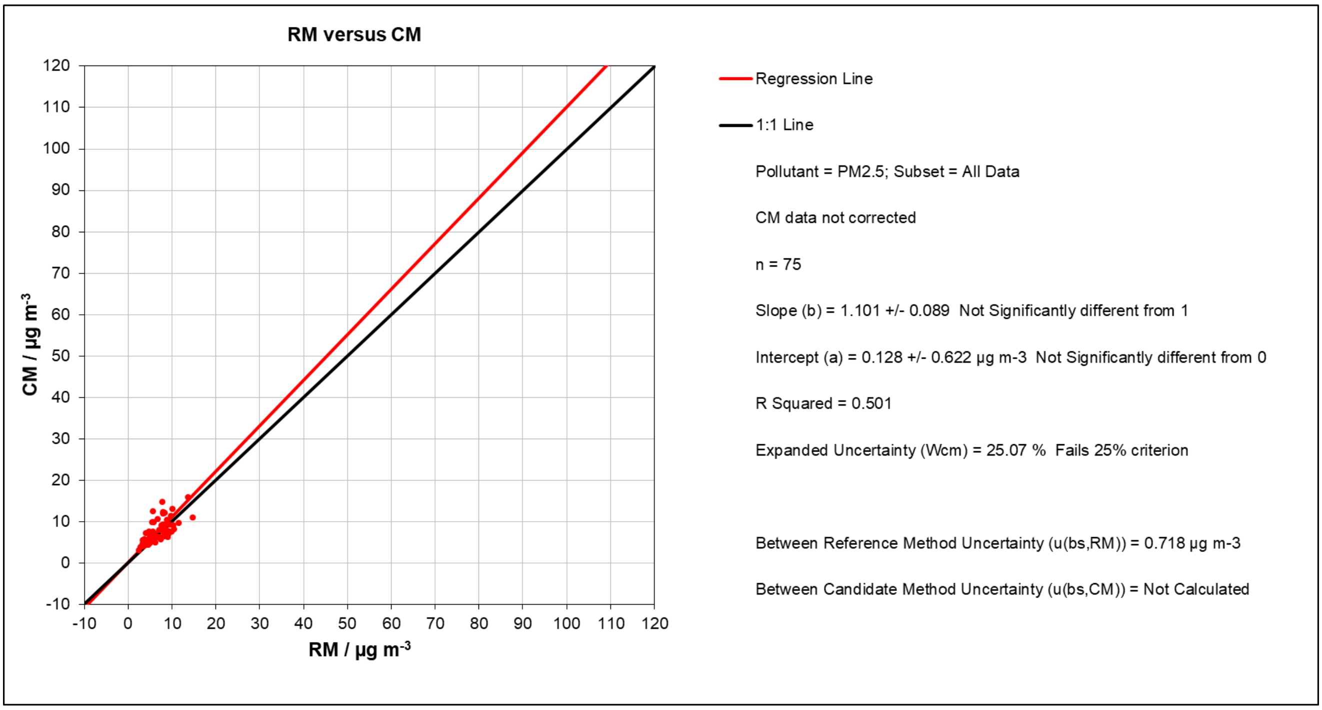

Figure 54: Reference vs candidate, SN FE111, Niederzier, $PM_{2.5}$

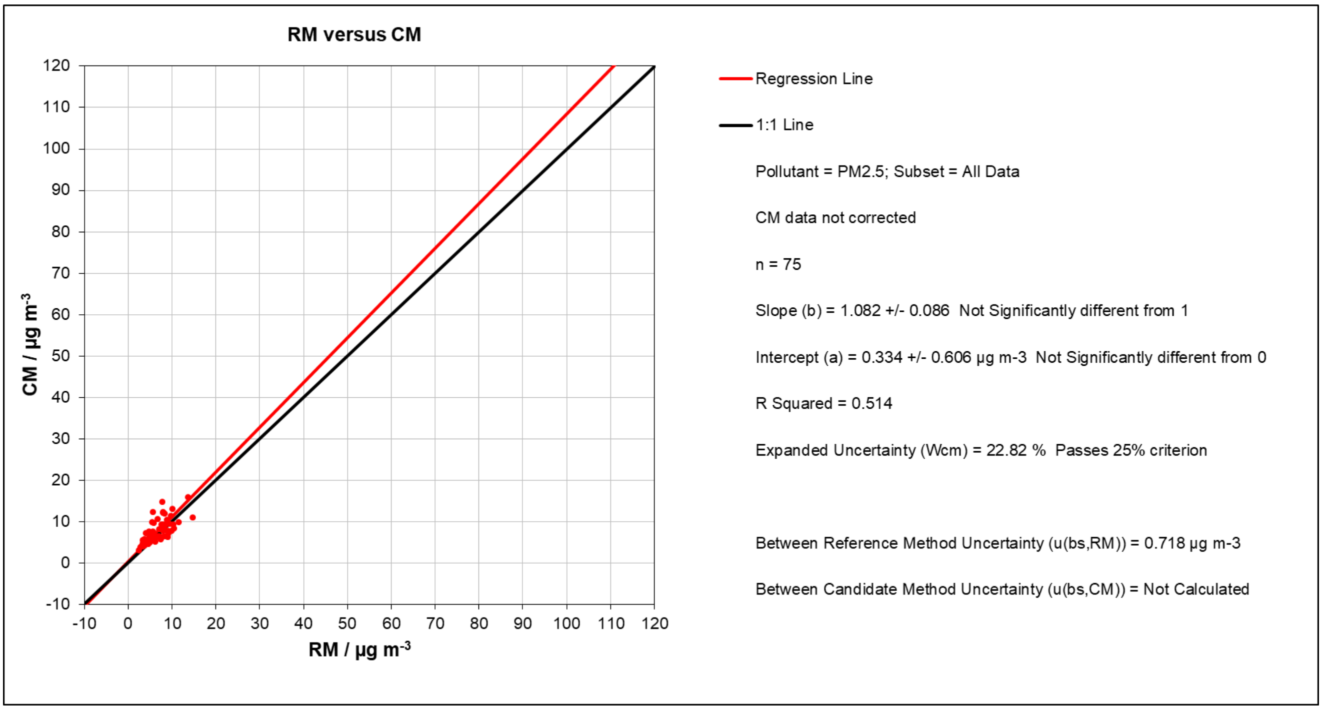

Figure 55: Reference vs candidate, SN FE114, Niederzier, $PM_{2.5}$

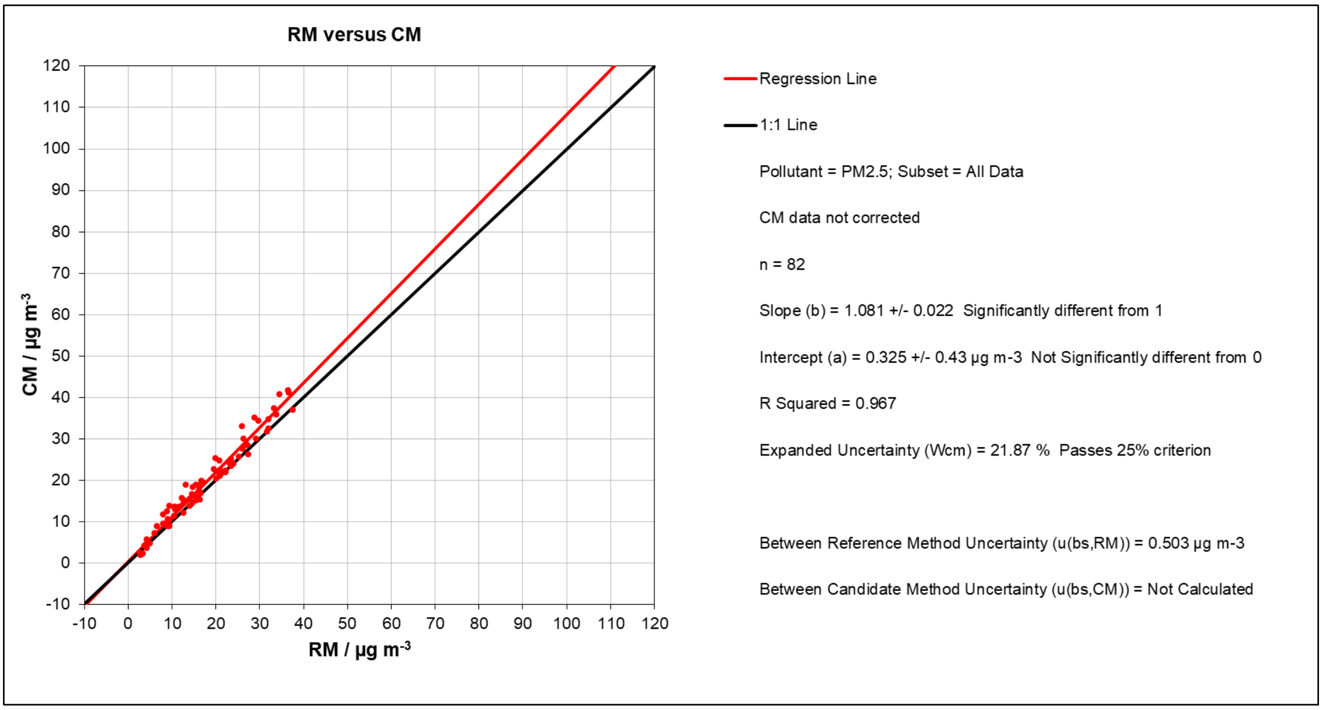

Figure 56: Reference vs candidate, SN FE111, JRC Ispra, $PM_{2.5}$

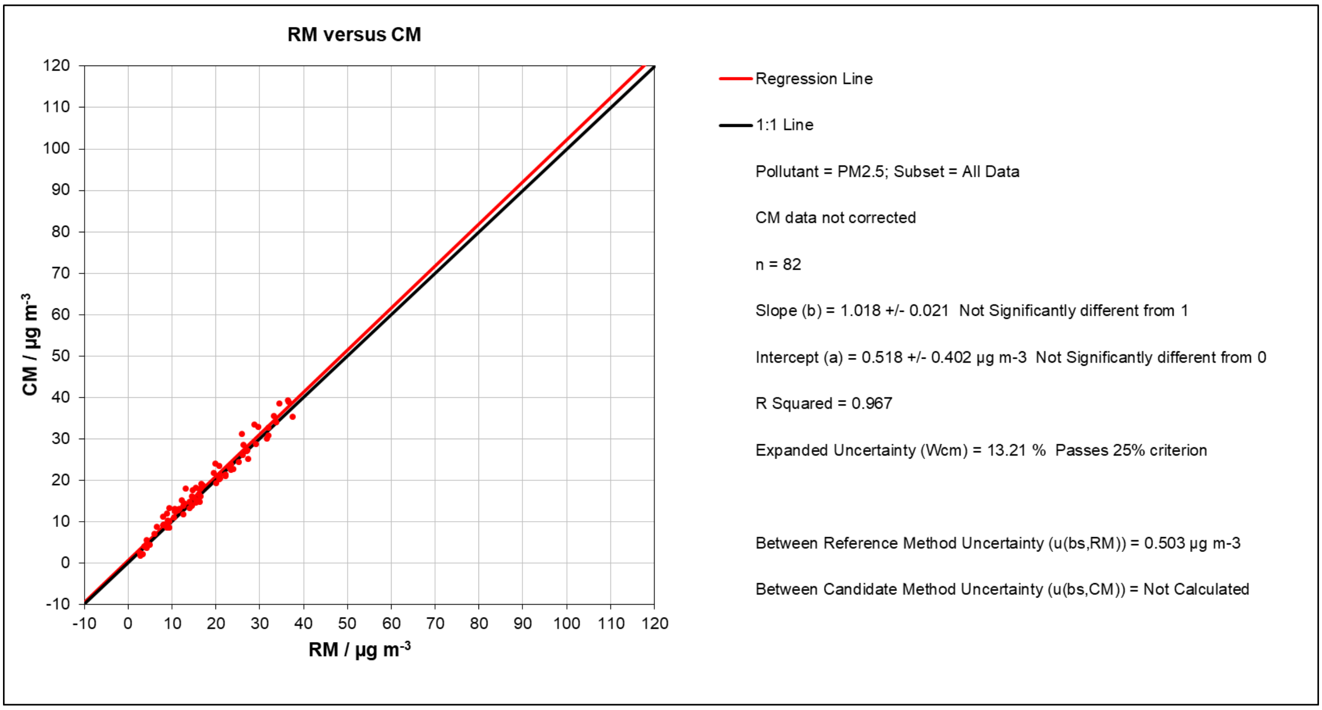

Figure 57: Reference vs candidate, SN FE114, JRC Ispra, $PM_{2.5}$

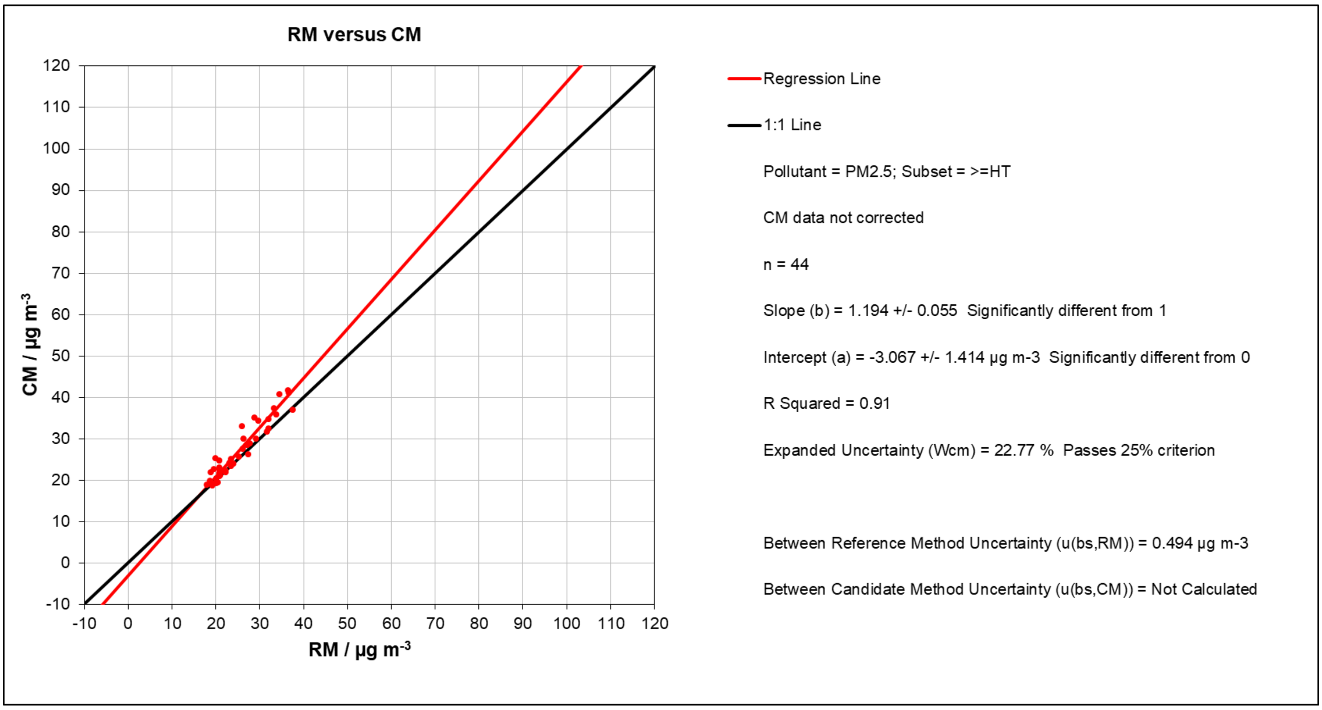

Figure 58: Reference vs candidate, SN FE111, all sites ≥18 µg/m³, $PM_{2.5}$

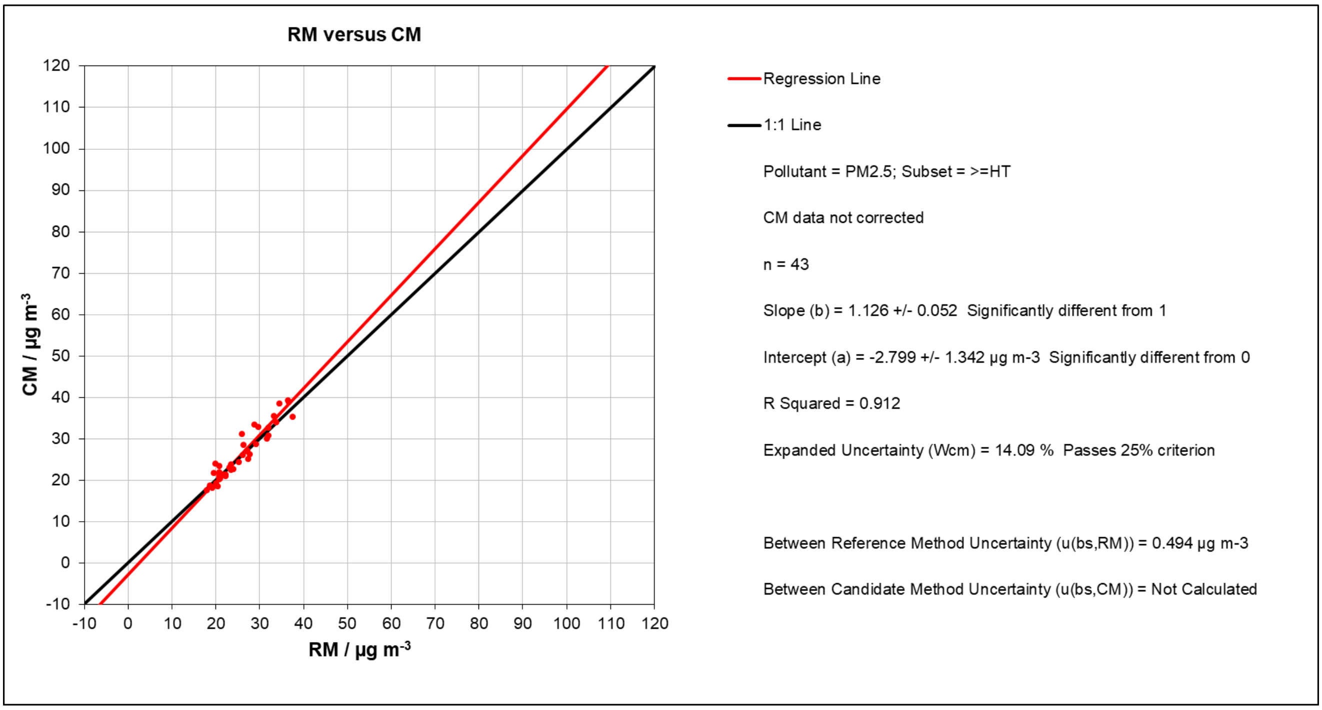

Figure 59: Reference vs candidate, SN FE114, all sites ≥18 µg/m³, $PM_{2.5}$

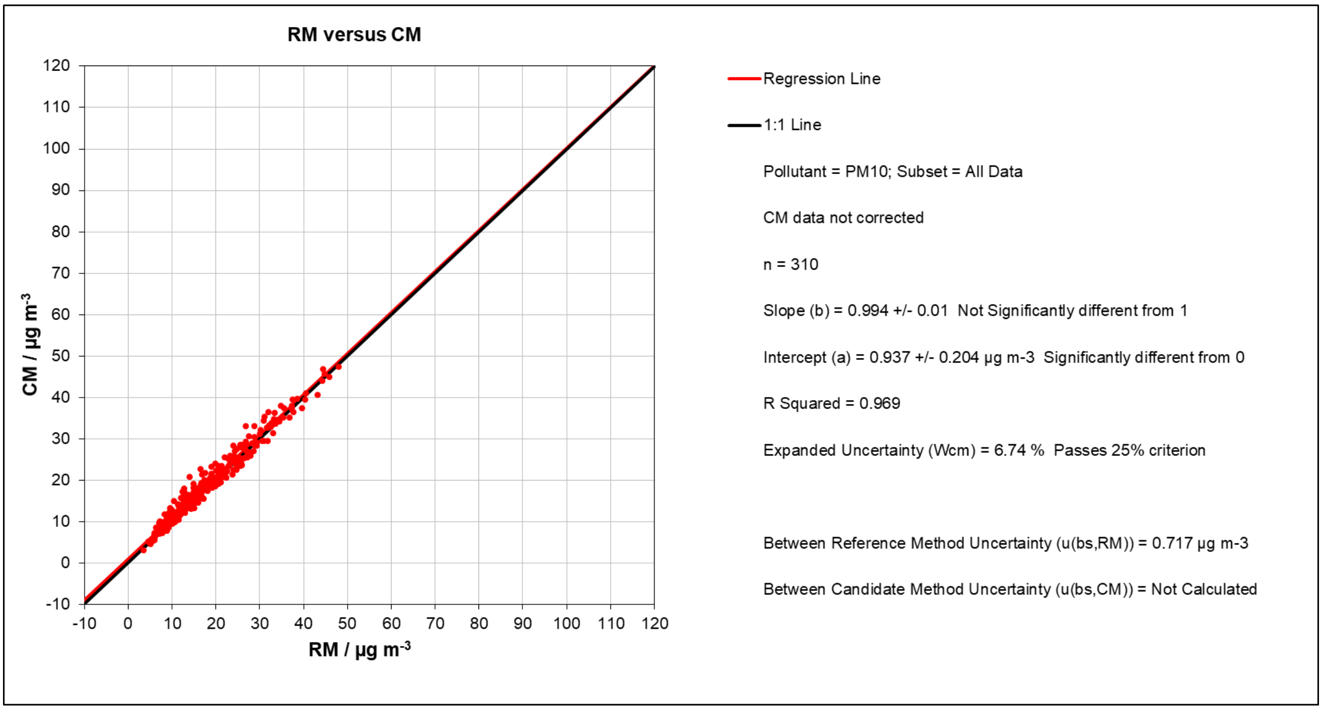

Figure 60: Reference vs candidate, SN FE111, all sites, PM_{10}

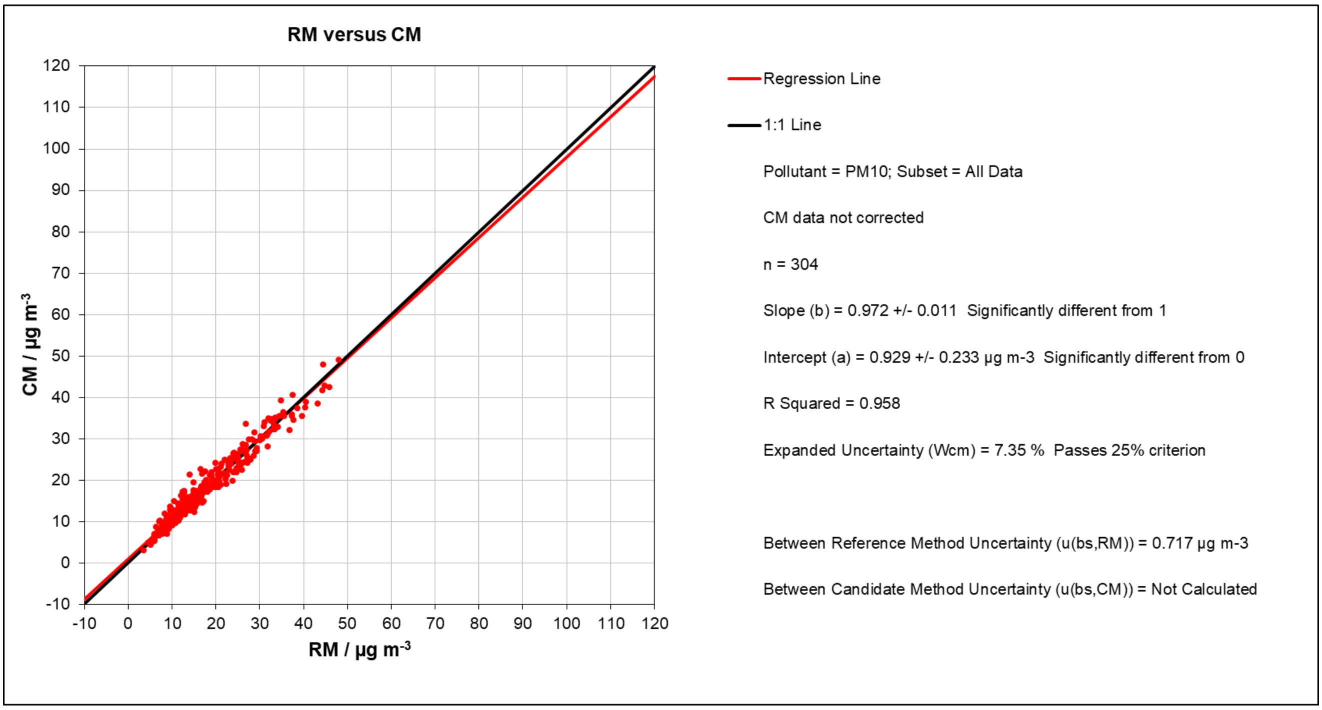

Figure 61: Reference vs candidate, SN FE114, all sites, PM_{10}

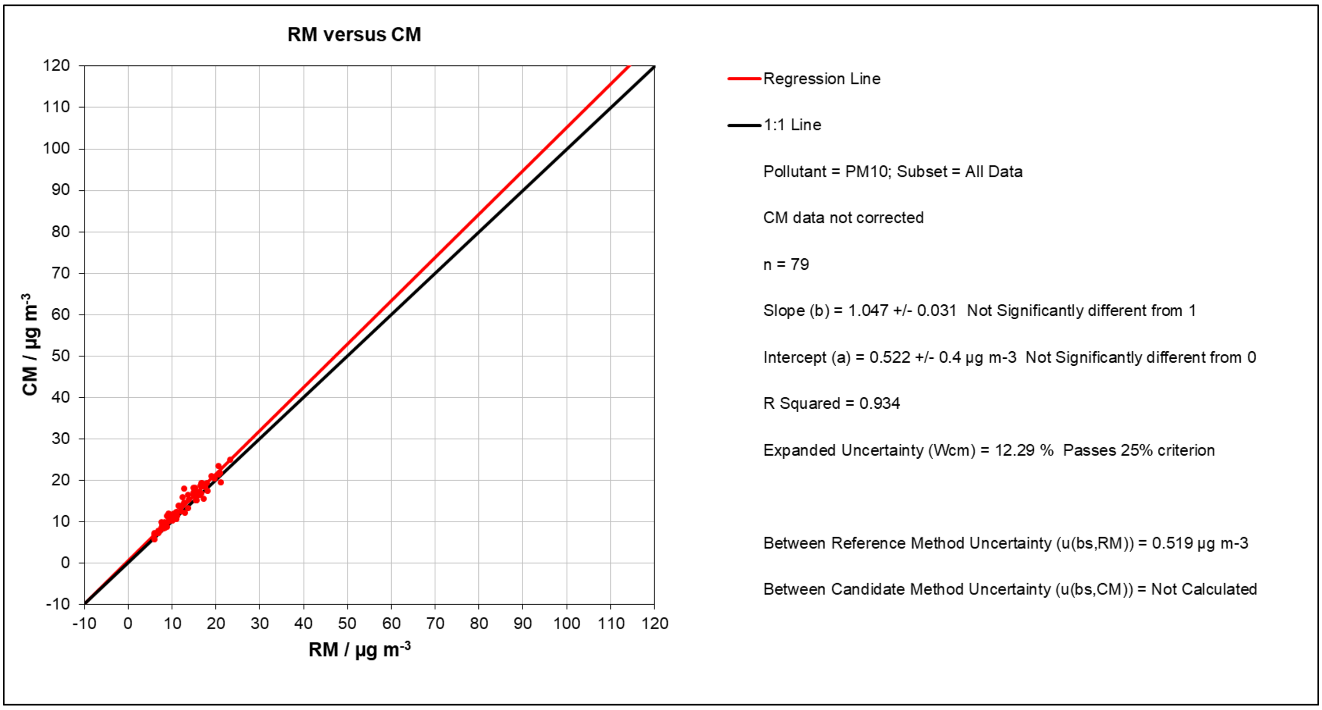

Figure 62: Reference vs candidate, SN FE111, Cologne, PM_{10}

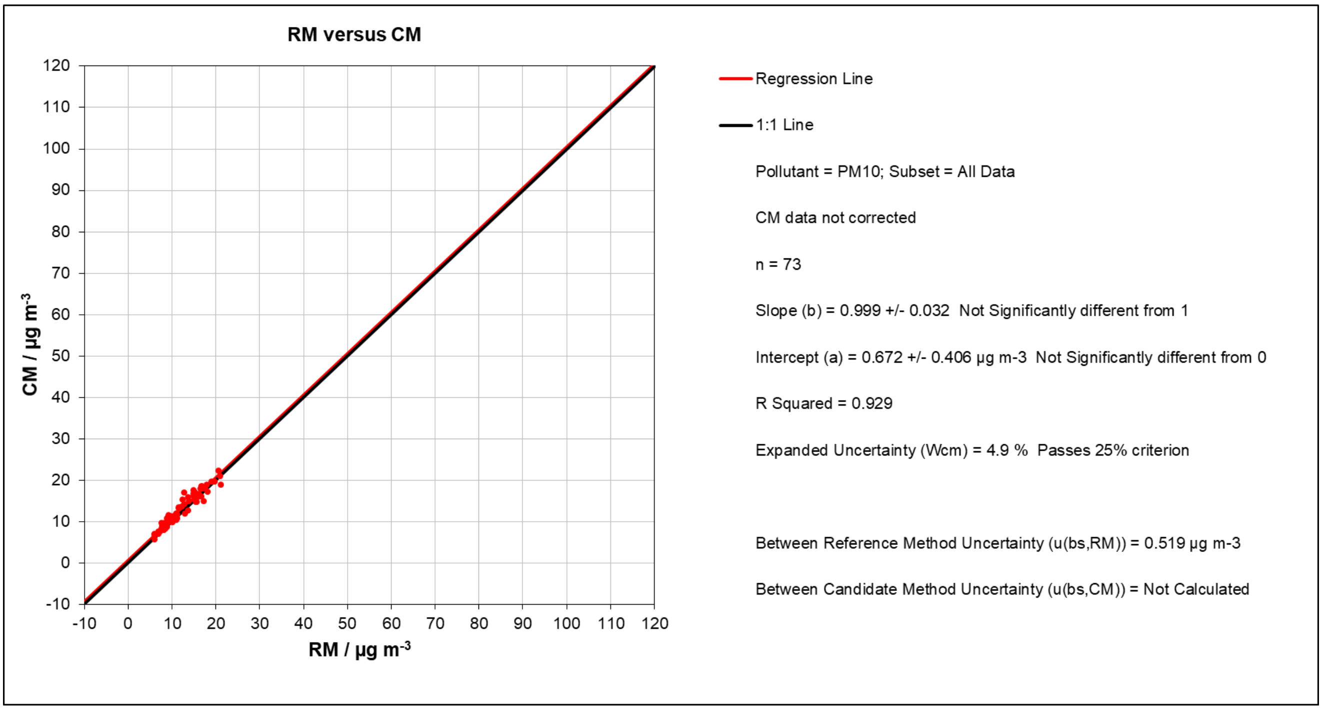

Figure 63: Reference vs candidate, SN FE114, Cologne, PM_{10}

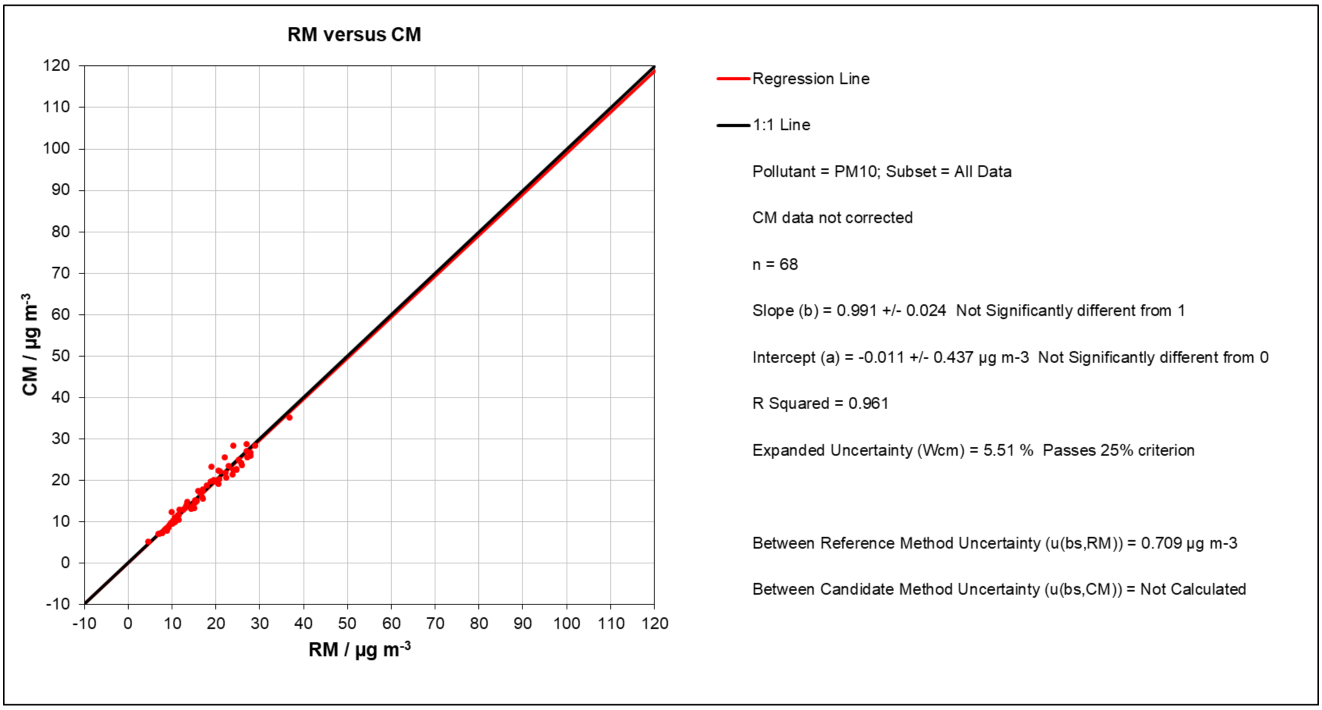

Figure 64: Reference vs candidate, SN FE111, Bornheim, PM_{10}

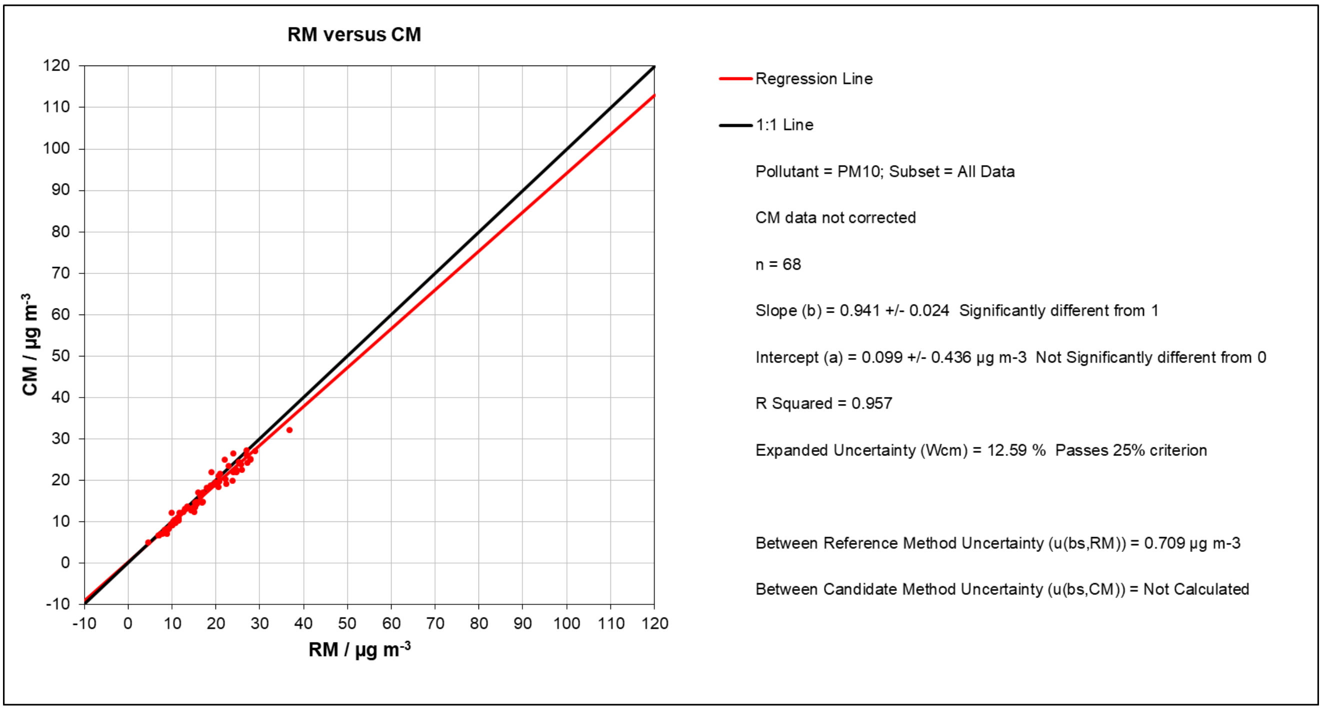

Figure 65: Reference vs candidate, SN FE114, Bornheim, PM_{10}

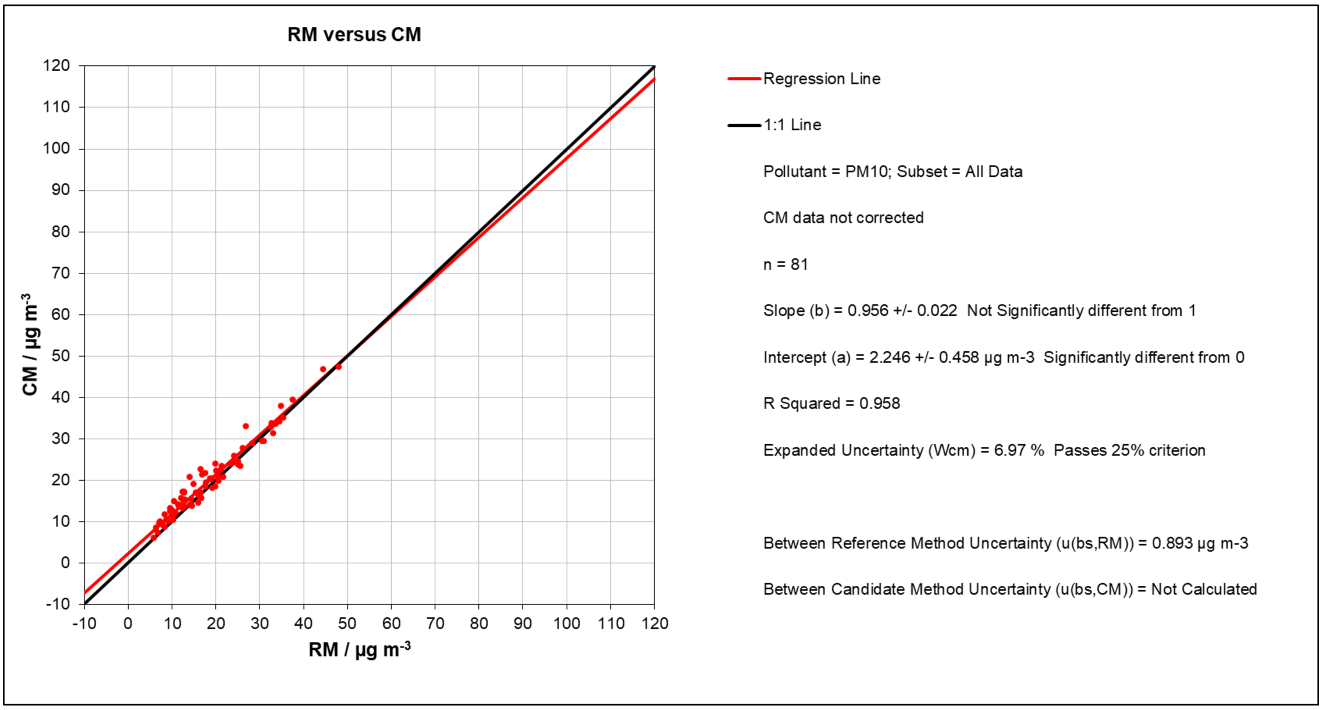

Figure 66: Reference vs candidate, SN FE111, Niederzier, PM_{10}

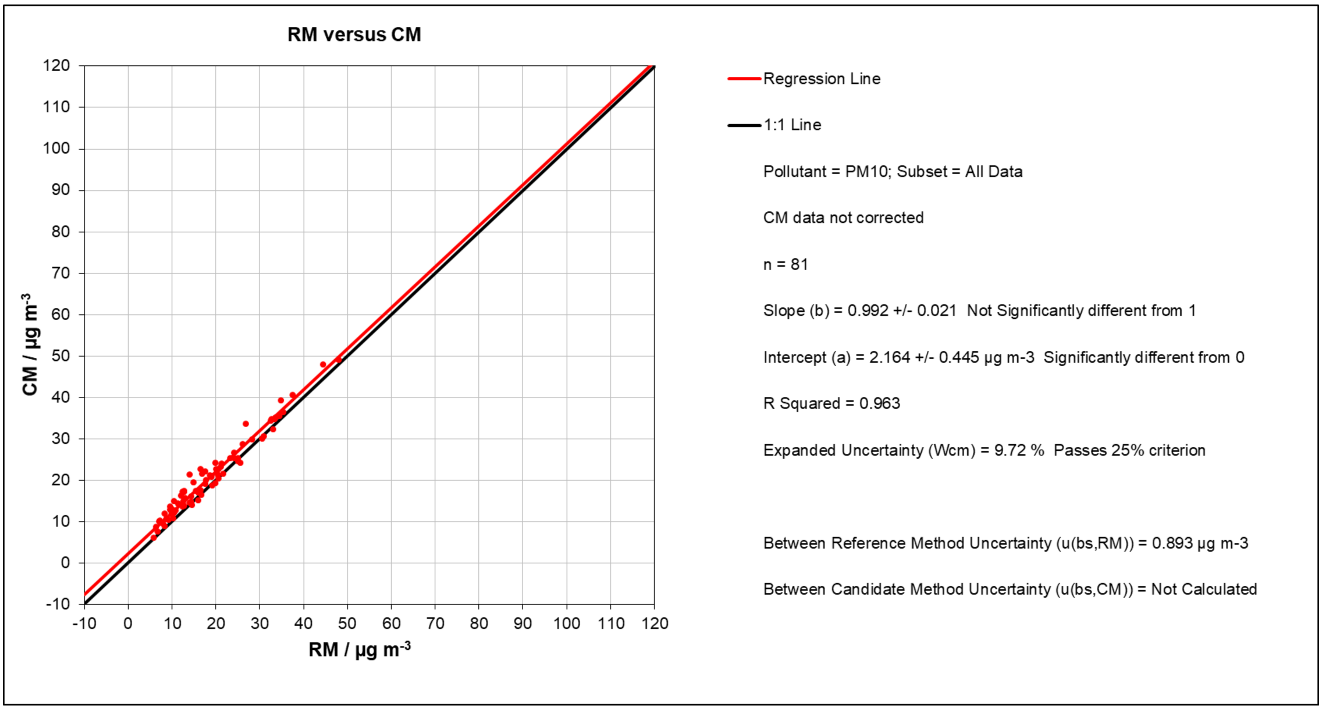

Figure 67: Reference vs candidate, SN FE114, Niederzier, PM_{10}

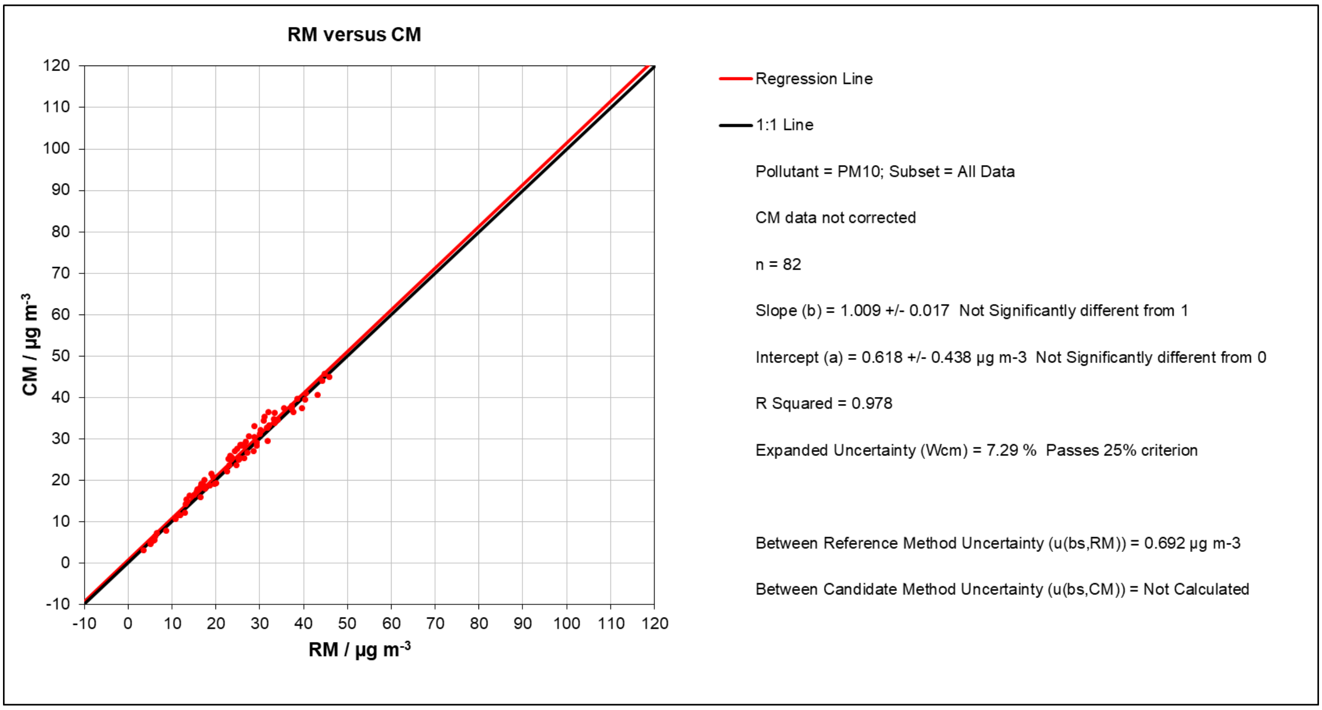

Figure 68: Reference vs candidate, SN FE111, JRC Ispra, PM_{10}

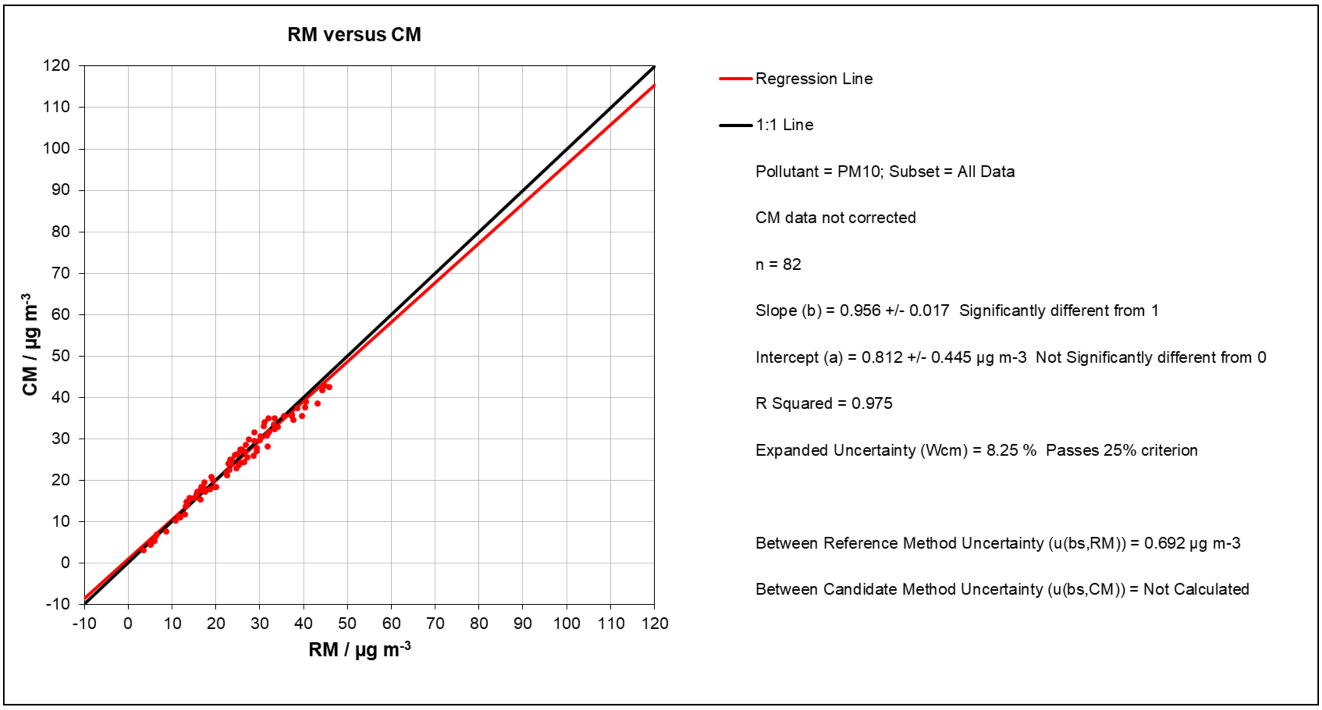

Figure 69: Reference vs candidate, SN FE114, JRC Ispra, PM_{10}

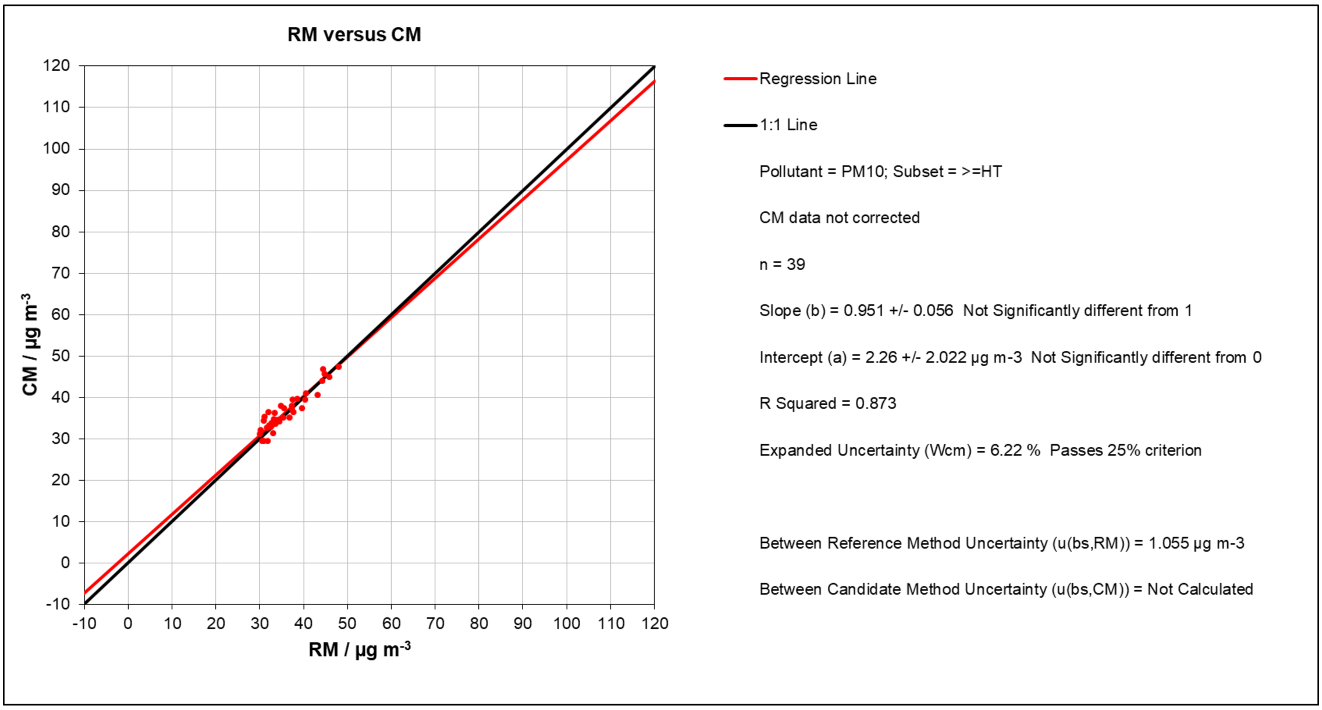

Figure 70: Reference vs candidate, SN FE111, all sites ≥30 µg/m³, PM_{10}

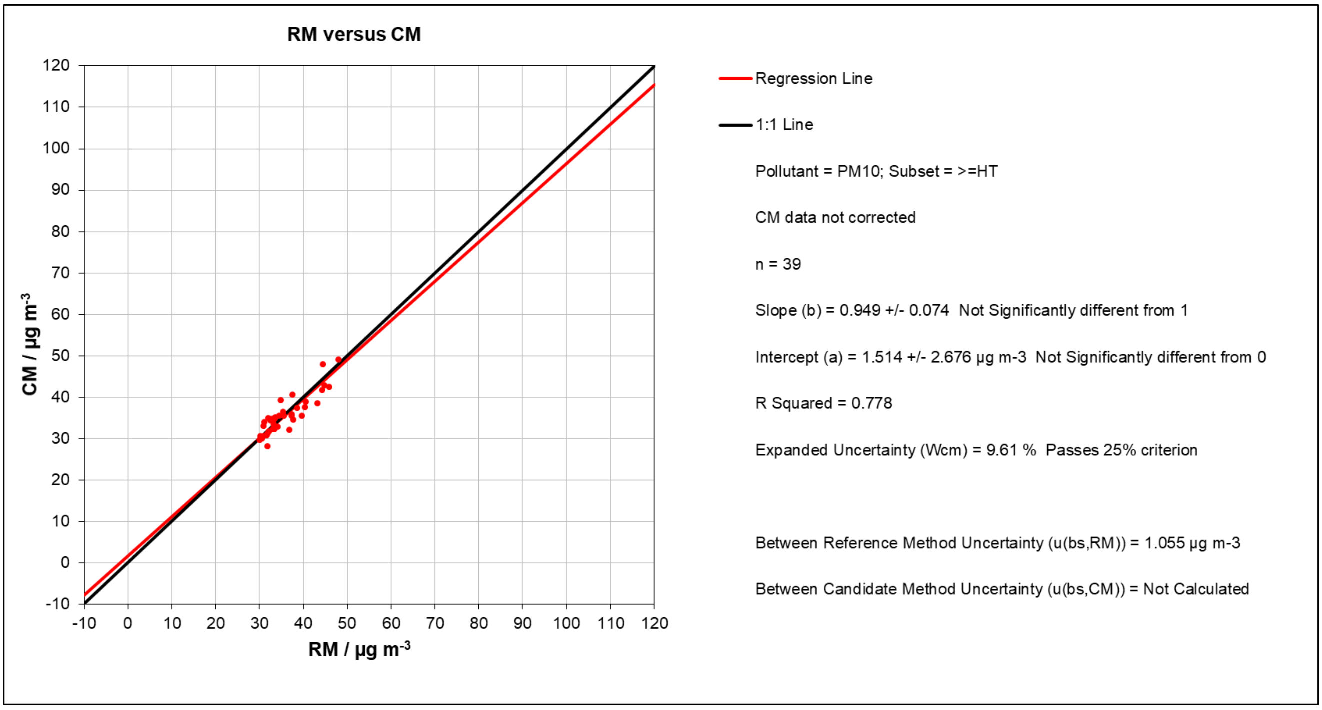

Figure 71: Reference vs candidate, SN FE114, all sites ≥30 µg/m³, PM_{10}

7.1 17 Use of correction factors/terms (7.5.8.5–7.5.8.8)

Correction factors/terms (=calibration) shall be applied if the highest expanded uncertainty calculated for the tested instruments exceeds the relative expanded uncertainty specified under the 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.

7.2 Equipment

Not required for this performance criterion.

7.3 Testing

See section
7.1 17 Expanded uncertainty (7.5.8.5 – 7.5.8.8)

7.4 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. AMS uncertainty > 25%) i.e. the tested instrument is not found to be equivalent with the reference method, then it is permissible to use a correction factor or term which results from the regression equation for the full data set. The corrected values have to meet the requirements for all data sets or sub data sets. Moreover, a correction may also be used for the case that $W_{AMS} \leq W_{dqo}$ in order to improve the accuracy of the tested instruments.

Three different situations may occur:

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

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

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

concerning a)

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

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

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

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

and

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

where u(a) = uncertainty of the axis intercept a, whose value was used to determine $y_{i,corr}$.

The algorithms for calculating axis intercepts and slopes as well as their variance by means of orthogonal regression are described in detail in the annex to [4].

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 [4].

concerning c)

The values of the slope b and the axis 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 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

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

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 [4].

The values for $u_{c\_s,corr}$ are then used to calculate the combined relative uncertainty of the AMS after correction in accordance with the following equation:

$$w^2_{AMS,corr} = \frac{u^2_{corr,yi=L}}{L^2}$$

The uncertainty $w_{AMS,corr}$ for the corrected data set is calculated at the 24h limit value using y_i as concentration at the limit value.

The relative expanded uncertainty $W_{AMS,corr}$ is calculated using the following equation:

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

Considering the large number of available test results, an expansion factor k=2 must be used.

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%.

7.5 Assessment

After the use of correction factors, the candidate systems met the requirements for data quality of ambient air monitors for all data sets.

Criterion satisfied? yes

The analysis of the total data set shows that for both $PM_{2.5}$ and PM_{10} the intercept is significantly different from 0 and the slope is significantly different from 1.

Axis intercept and slope correction of the entire data set (each for $PM_{2.5}$ and PM_{10}) was performed and all data sets were re-evaluated using the corrected values.

All data sets meet the data quality requirements after correction.

When a measuring system is operated in the context of a measurement grid, the EN 16450 standard requires that the instruments are tested annually at a number of sites which in turn depends on the highest expanded uncertainty determined during equivalence testing. The criterion used for specifying the number of sites for annual testing is grouped into 5% steps (EN 16450 [4], chapter 8.6.2, Table 5). It should be noted that the highest calculated expanded uncertainty after correction for $PM_{2.5}$ is in the range 20 % to 25 % and for PM_{10} in the range 10 % to 15 %.

The monitoring network operator or the competent authority of a member state is responsible for compliant implementation of the requirements for regular tests as described above. However, TÜV Rheinland recommends that the expanded uncertainty of the total data set (of all data) be used for this purpose, in this case 15.31 % ($PM_{2.5}$) and 6.54 % (PM_{10}) (uncorrected data set) and 10.36 % ($PM_{2.5}$) and % 7.04 (PM_{10}) (data set after axis intercept correction), respectively, which would require annual verification at 3 ($PM_{2.5}$) or 2 (PM_{10}) measurement locations.

7.6 Detailed presentation of test results

Table 30 and Table 31 show the evaluation results of the equivalence test after applying the correction factor to the full data set.

Table 30: Summary of equivalence test results after intercept and slope correction, $PM_{2.5}$

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	EDM 280		SN	FE111 & FE114	
			Limit value	30	µg/m³
Status of measured values	Slope and offset corrected		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**0.43**	**µg/m³**			
	FE111 & FE114				
Number of data pairs	**308**				
Slope b	**1.000**	**not significant**			
Uncertainty of b	**0.012**				
Ordinate intercept a	**0.005**	**not significant**			
Uncertainty of a	**0.149**				
Expanded meas. uncertainty W_{CM}	**10.36**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.49**	**µg/m³**			
Uncertainty between Candidates	**1.02**	**µg/m³**			
	FE111 & FE114				
Number of data pairs	**43**				
Slope b	**1.138**				
Uncertainty of b	**0.052**				
Ordinate intercept a	**-4.007**				
Uncertainty of a	**1.358**				
Expanded meas. uncertainty W_{CM}	**12.96**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.54**	**µg/m³**			
Uncertainty between Candidates	**0.25**	**µg/m³**			
	FE111 & FE114				
Number of data pairs	**265**				
Slope b	**1.051**				
Uncertainty of b	**0.024**				
Ordinate intercept a	**-0.309**				
Uncertainty of a	**0.202**				
Expanded meas. uncertainty W_{CM}	**12.92**	**%**			

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	EDM 280		SN	FE111 & FE114	
			Limit value	30	µg/m³
Status of measured values	Slope and offset corrected		Allowed uncertainty	25	%
Cologne					
Uncertainty between Reference	**0.37**	**µg/m³**			
Uncertainty between Candidates	**0.19**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**79**			**73**	
Slope b	**1.134**			**1.091**	
Uncertainty of b	**0.037**			**0.039**	
Ordinate intercept a	**-0.542**			**-0.408**	
Uncertainty of a	**0.292**			**0.301**	
Expanded meas. uncertainty W_{CM}	**24.42**	**%**		**16.90**	**%**
Bornheim					
Uncertainty between Reference	**0.48**	**µg/m³**			
Uncertainty between Candidates	**0.42**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**78**			**78**	
Slope b	**0.955**			**0.894**	
Uncertainty of b	**0.022**			**0.019**	
Ordinate intercept a	**0.785**			**0.895**	
Uncertainty of a	**0.232**			**0.207**	
Expanded meas. uncertainty W_{CM}	**8.75**	**%**		**16.89**	**%**
Niederzier					
Uncertainty between Reference	**0.72**	**µg/m³**			
Uncertainty between Candidates	**0.08**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**75**			**75**	
Slope b	**1.067**			**1.049**	
Uncertainty of b	**0.087**			**0.084**	
Ordinate intercept a	**-0.820**			**-0.622**	
Uncertainty of a	**0.608**			**0.593**	
Expanded meas. uncertainty W_{CM}	**15.62**	**%**		**14.20**	**%**
JRC Ispra					
Uncertainty between Reference	**0.50**	**µg/m³**			
Uncertainty between Candidates	**0.73**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**82**			**82**	
Slope b	**1.056**			**0.995**	
Uncertainty of b	**0.022**			**0.020**	
Ordinate intercept a	**-0.685**			**-0.496**	
Uncertainty of a	**0.420**			**0.393**	
Expanded meas. uncertainty W_{CM}	**13.78**	**%**		**12.05**	**%**
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.49**	**µg/m³**			
Uncertainty between Candidates	**1.02**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**44**			**43**	
Slope b	**1.166**			**1.100**	
Uncertainty of b	**0.054**			**0.051**	
Ordinate intercept a	**-3.978**			**-3.718**	
Uncertainty of a	**1.383**			**1.31**	
Expanded meas. uncertainty W_{CM}	**15.06**	**%**		**13.36**	**%**
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.54**	**µg/m³**			
Uncertainty between Candidates	**0.25**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**270**			**265**	
Slope b	**1.083**			**1.020**	
Uncertainty of b	**0.024**			**0.023**	
Ordinate intercept a	**-0.443**			**-0.168**	
Uncertainty of a	**0.206**			**0.194**	
Expanded meas. uncertainty W_{CM}	**17.11**	**%**		**9.98**	**%**
All comparisons					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**0.43**	**µg/m³**			
	FE111			**FE114**	
Number of data pairs	**314**			**308**	
Slope b	**1.033**	**significant**		**0.967**	**significant**
Uncertainty of b	**0.012**			**0.011**	
Ordinate intercept a	**-0.142**	**not significant**		**0.155**	**not significant**
Uncertainty of a	**0.152**			**0.143**	
Expanded meas. uncertainty W_{CM}	**12.11**	**%**		**11.46**	**%**

Table 31: Summary of equivalence test results after intercept and slope correction, PM_{10}

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010					
Candidate	EDM 280		SN	FE111 & FE114	
			Limit value	50	µg/m³
Status of measured values	Slope and offset corrected		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.72**	**µg/m³**			
Uncertainty between Candidates	**0.62**	**µg/m³**			
	FE111 & FE114				
Number of data pairs	**304**				
Slope b	**1.000**	**not significant**			
Uncertainty of b	**0.011**				
Ordinate intercept a	**-0.006**	**not significant**			
Uncertainty of a	**0.219**				
Expanded measured uncertainty WCM	**7.04**	**%**			
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	**1.06**	**µg/m³**			
Uncertainty between Candidates	**1.21**	**µg/m³**			
	FE111 & FE114				
Number of data pairs	**39**				
Slope b	**0.955**				
Uncertainty of b	**0.062**				
Ordinate intercept a	**1.366**				
Uncertainty of a	**2.233**				
Expanded measured uncertainty WCM	**8.12**	**%**			
All comparisons, <30 µg/m³					
Uncertainty between Reference	**0.65**	**µg/m³**			
Uncertainty between Candidates	**0.50**	**µg/m³**			
	FE111 & FE114				
Number of data pairs	**265**				
Slope b	**1.022**				
Uncertainty of b	**0.016**				
Ordinate intercept a	**-0.303**				
Uncertainty of a	**0.275**				
Expanded measured uncertainty WCM	**7.70**	**%**			

Comparison candidate with reference according to Guide "Demonstration of Equivalence Of Ambient Air Monitoring Methods", January 2010				
Candidate	EDM 280	SN	FE111 & FE114	
		Limit value	50	µg/m³
Status of measured values	Slope and offset corrected	Allowed uncertainty	25	%
Cologne				
Uncertainty between Reference	0.52	µg/m³		
Uncertainty between Candidates	0.39	µg/m³		
	FE111		FE114	
Number of data pairs	79		73	
Slope b	1.066		1.018	
Uncertainty of b	0.031		0.032	
Ordinate intercept a	-0.445		-0.292	
Uncertainty of a	0.407		0.414	
Expanded measured uncertainty W_{CM}	12.56	%	5.42	%
Bornheim				
Uncertainty between Reference	0.71	µg/m³		
Uncertainty between Candidates	0.61	µg/m³		
	FE111		FE114	
Number of data pairs	68		68	
Slope b	1.009		0.958	
Uncertainty of b	0.024		0.024	
Ordinate intercept a	-0.985		-0.874	
Uncertainty of a	0.445		0.444	
Expanded measured uncertainty W_{CM}	6.14	%	13.22	%
Niederzier				
Uncertainty between Reference	0.89	µg/m³		
Uncertainty between Candidates	0.50	µg/m³		
	FE111		FE114	
Number of data pairs	81		81	
Slope b	0.974		1.010	
Uncertainty of b	0.022		0.022	
Ordinate intercept a	1.312		1.229	
Uncertainty of a	0.466		0.453	
Expanded measured uncertainty W_{CM}	7.47	%	10.01	%
JRC Ispra				
Uncertainty between Reference	0.69	µg/m³		
Uncertainty between Candidates	0.88	µg/m³		
	FE111		FE114	
Number of data pairs	82		82	
Slope b	1.027		0.973	
Uncertainty of b	0.017		0.017	
Ordinate intercept a	-0.343		-0.147	
Uncertainty of a	0.446		0.453	
Expanded measured uncertainty W_{CM}	7.64	%	8.88	%
All comparisons, ≥30 µg/m³				
Uncertainty between Reference	1.06	µg/m³		
Uncertainty between Candidates	1.21	µg/m³		
	FE111		FE114	
Number of data pairs	39		39	
Slope b	0.969		0.968	
Uncertainty of b	0.057		0.075	
Ordinate intercept a	1.289		0.491	
Uncertainty of a	2.058		2.72	
Expanded measured uncertainty W_{CM}	6.79	%	10.13	%
All comparisons, <30 µg/m³				
Uncertainty between Reference	0.65	µg/m³		
Uncertainty between Candidates	0.50	µg/m³		
	FE111		FE114	
Number of data pairs	271		265	
Slope b	1.035		1.011	
Uncertainty of b	0.016		0.017	
Ordinate intercept a	-0.331		-0.316	
Uncertainty of a	0.262		0.291	
Expanded measured uncertainty W_{CM}	8.85	%	7.49	%
All comparisons				
Uncertainty between Reference	0.72	µg/m³		
Uncertainty between Candidates	0.62	µg/m³		
	FE111		FE114	
Number of data pairs	310		304	
Slope b	1.013	not significant	0.990	not significant
Uncertainty of b	0.010		0.012	
Ordinate intercept a	-0.019	not significant	-0.029	not significant
Uncertainty of a	0.207		0.237	
Expanded measured uncertainty W_{CM}	7.16	%	7.89	%

7.1 18 Maintenance interval (7.5.7)

The maintenance interval of the AMS shall be at least 14 days.

7.2 Equipment

Not required for this performance criterion.

7.3 Testing

The maintenance interval is the longest time period without intervention as recommended by the manufacturer. The relevant body shall ensure that during this period the AMS does not need any maintenance or adjustment.

7.4 Evaluation

The manufacturer has prepared a maintenance plan for the measuring system (see manual chapter 7). The shortest maintenance interval is 3 months (verification of the measuring system according to the specifications of the European standard EN 16450 [4], cleaning of the inlet nozzle and Sigma-2 sampling head).

The measuring module in the measuring system must be sent to Grimm Service or an authorized Grimm service partner at least every 12 months (or when the "Calibration" wear indicator is completely red) for maintenance, including a check of the calibration.

7.5 Assessment

The maintenance interval is three months.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Chapter 7 of the manual lists the necessary maintenance work.

7.1 19 Automatic diagnostic check (7.5.4)

Automatic checks must be possible.

7.2 Equipment

Operating manual.

7.3 Testing

The current operating status of the measuring system is continuously monitored and problems are indicated via a number of different warning and error messages.

The tested device always performs a self-test at the start of measurement operation and, configurable by the user, at regular intervals (in the performance test every 24 h). During the self-test, one of the checks is whether the internal sensors and the weather sensor respond. Dust-free purge air is pumped into the measuring cell and the DC level of the scattered light signal, the zero classifications and the laser current are recorded.

7.4 Evaluation

The current operating status of the measuring system is continuously monitored and problems are indicated via a number of different warning and error messages.

The tested device always performs a self-test at the start of measurement operation and, configurable by the user, at regular intervals (in the performance test every 24 h). During the self-test, one of the checks is whether the internal sensors and the weather sensor respond. Dust-free purge air is pumped into the measuring cell and the DC level of the scattered light signal, the zero classifications and the laser current are recorded. Any warnings or errors are provided in a diagnostic code.

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

7.5 Assessment

The tested device always performs a self-test at the start of measurement operation and, configurable by the user, at regular intervals (in the performance test every 24 h). Any warnings or errors are provided in a diagnostic code.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not applicable.

7.1 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 %

7.2 Equipment

Barometer, thermometer and hygrometer.

7.3 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. AMS sensors were checked at the beginning and at the end of each field test.

7.4 Evaluation

The measuring system uses a combined weather sensor from Ott Hydromet / Lufft to record the outdoor temperature, relative humidity and air pressure. The following versions are available:

Version	Measurements
WS300	Ambient temperature, humidity and pressure
WS500	As WS300, plus wind speed and wind direction
WS600	As WS500, plus precipitation

The weather sensors listed are identical in terms of the sensors used. At least version WS300 (T,p,rH) is required to operate the measuring system. The additional sensors of the WS500 and WS600 versions also provide further meteorological measured variables. Within the scope of the performance test, the WS600 weather sensor with maximum number of functions was used.

Relying on transfer standards, it is easily possible to perform comparison measurements on site at any time. The variations of the sensors were within the requirements at all times.

7.5 Assessment

The sensors for recording the ambient temperature, air pressure and relative humidity can be easily checked on site. The deviations of the sensors were within the requirements at all times.

Criterion satisfied? yes

7.6 Detailed presentation of test results

Not required for this performance criterion.

8. Recommendations for use in practice

8.1 Work in the maintenance interval

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

Every 3 months:

- Clean the Sigma-2 sampling head
- Clean the inlet nozzle
- Verify the measuring equipment (flow rate, tightness, zero point, check the temperature, pressure and humidity sensors)

Every 12 months:

- Clean the sampling tube
- The measuring module in the measuring system must be sent to Grimm Service or an authorized Grimm service partner at least every 12 months (or when the "Calibration" wear indicator is completely red) for maintenance, including a check of the calibration.

Further details can be found in chapter 7 of the user manual.

Environmental Protection /
Air Pollution Control

Dipl.-Ing. Guido Baum

Dipl.-Ing. Karsten Pletscher

Cologne, 03 February 2023
936/21252222/A

9. Bibliography

[1] VDI Standard 4202, Part 3, "Automated measuring systems for air quality monitoring - Performance test, declaration of suitability and certification of measuring systems for point-related measurement of mass concentration for particulate air pollutants", February 2019

[2] VDI standard 4203, Part 1, "Automated measuring systems and data evaluation systems for emission monitoring – Performance test, declaration of suitability and certification of stationary automated measuring systems and check of the quality management system of the manufacturer", July 2017

[3] European standard EN 12341 "Ambient air - Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2.5}$ mass concentration of suspended particulate matter." German version EN 12341:2014

[4] European standard EN 16450 "Ambient air – Automated measuring systems for the measurement of the concentration of particulate matter (PM_{10}; $PM_{2.5}$)", German version dated July 2017

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

[6] Operating manual EDM 280, version 1.04 (German) respectively 1.01 (English)

[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

10. Appendices

Appendix 1 **Measured and calculated values**

Annex 1: Zero level and detection limit

Annex 2: Flow rate accuracy

Annex 3: Temperature dependence of the zero point and sensitivity

Annex 4: Dependence on voltage supply

Annex 5: Measured values from the field test sites

Annex 6: Ambient condition at the field test locations

Appendix 2 **Methods used for filter weighing**

Appendix 3 **Certificate of Accreditation**

Appendix 4 **Operation manual**

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

Manufacturer GRIMM Aerosol Technik

Type EDM 280

Standards ZP Measured values with zero filter

Serial-No. FE111 / FE114

No.	Date	Measured values [µg/m³] FE111	Date	Measured values [µg/m³] FE114
1	4/22/2021	0.0	4/22/2021	0.0
2	4/23/2021	0.0	4/23/2021	0.0
3	4/24/2021	0.0	4/24/2021	0.0
4	4/25/2021	0.0	4/25/2021	0.0
5	4/26/2021	0.0	4/26/2021	0.0
6	4/27/2021	0.0	4/27/2021	0.0
7	4/28/2021	0.0	4/28/2021	0.0
8	4/29/2021	0.0	4/29/2021	0.0
9	4/30/2021	0.0	4/30/2021	0.0
10	5/1/2021	0.0	5/1/2021	0.0
11	5/2/2021	0.0	5/2/2021	0.0
12	5/3/2021	0.0	5/3/2021	0.0
13	5/4/2021	0.0	5/4/2021	0.0
14	5/5/2021	0.0	5/5/2021	0.0
15	5/6/2021	0.0	5/6/2021	0.0
	No. of values	15	No. of values	15
	Mean	0.00	Mean	0.00
	Standard deviation s_{x0}	0.00	Standard deviation s_{x0}	0.00
	Detection limit x	0.00	Detection limit x	0.00

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

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

Manufacturer: Grimm Aerosol Technik

Type: EDM 280

Serial-No.: FE111 / FE114

Nominal flow rate [l/min]: 1.2

		FE111			FE114		
Temperature 1	5°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
		1	6/18/2021 5:10	1.199	1	6/18/2021 5:12	1.210
		2	6/18/2021 5:16	1.201	2	6/18/2021 5:18	1.210
		3	6/18/2021 5:22	1.201	3	6/18/2021 5:23	1.209
		4	6/18/2021 5:28	1.201	4	6/18/2021 5:29	1.209
		5	6/18/2021 5:34	1.201	5	6/18/2021 5:35	1.208
		6	6/18/2021 5:39	1.206	6	6/18/2021 5:41	1.207
		7	6/18/2021 5:45	1.201	7	6/18/2021 5:46	1.211
		8	6/18/2021 5:52	1.201	8	6/18/2021 5:54	1.209
		9	6/18/2021 5:59	1.200	9	6/18/2021 6:01	1.209
		10	6/18/2021 6:04	1.201	10	6/18/2021 6:08	1.209
			Mean	**1.201**		**Mean**	**1.209**

		FE111			FE114		
Temperature 2	40°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
		1	6/18/2021 12:10	1.194	1	6/18/2021 12:11	1.192
		2	6/18/2021 12:15	1.194	2	6/18/2021 12:16	1.193
		3	6/18/2021 12:21	1.195	3	6/18/2021 12:23	1.194
		4	6/18/2021 12:27	1.195	4	6/18/2021 12:28	1.193
		5	6/18/2021 12:33	1.196	5	6/18/2021 12:34	1.194
		6	6/18/2021 12:39	1.196	6	6/18/2021 12:41	1.193
		7	6/18/2021 12:45	1.195	7	6/18/2021 12:47	1.194
		8	6/18/2021 12:51	1.196	8	6/18/2021 12:52	1.193
		9	6/18/2021 12:58	1.196	9	6/18/2021 12:59	1.194
		10	6/18/2021 13:04	1.195	10	6/18/2021 13:05	1.194
			Mean	**1.195**		**Mean**	**1.193**

Annex 3 — Dependence of zero point on surrounding temperature, PM2.5 — Page 1 of 3

Manufacturer: Grimm Aerosol Technik

Type: EDM 280

Serial-No.: FE111 / FE114

			Measurement 1	Measurement 2	Measurement 3		
FE111	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	0.0	0.0	0.0	0.0	0.0
	2	5	0.0	0.0	0.0	0.0	
	3	20	0.0	0.0	0.0	0.0	
	4	40	0.0	0.0	0.0	0.0	
	5	20	0.0	0.0	0.0	0.0	
FE114	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	0.0	0.0	0.0	0.0	0.0
	2	5	0.0	0.0	0.0	0.0	
	3	20	0.0	0.0	0.0	0.0	
	4	40	0.0	0.0	0.0	0.0	
	5	20	0.0	0.0	0.0	0.0	

Annex 3 **Dependence of zero point on surrounding temperature, PM10** **Page 2 of 3**

Manufacturer Grimm Aerosol Technik

Type EDM 280

Serial-No. FE111 / FE114

			Measurement 1	Measurement 2	Measurement 3		
FE111	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	0.0	0.0	0.0	0.0	0.0
	2	5	0.0	0.0	0.0	0.0	
	3	20	0.0	0.0	0.0	0.0	
	4	40	0.0	0.0	0.0	0.0	
	5	20	0.0	0.0	0.0	0.0	
FE114	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	0.0	0.0	0.0	0.0	0.0
	2	5	0.0	0.0	0.0	0.0	
	3	20	0.0	0.0	0.0	0.0	
	4	40	0.0	0.0	0.0	0.0	
	5	20	0.0	0.0	0.0	0.0	

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

Manufacturer Grimm Aerosol Technik

Used test standard Test with reference dust

Type EDM 280

Serial-No. FE111 / FE114

			Measurement 1	Measurement 2	Meaurement 3		
FE111	No.	Temperature [°C]	Measured value [µm³]	Measured value [µm³]	Measured value [µm³]	Mean value of 3 measurements [µm³]	Mean value at 20°C [µm³]
Span	1	20	49.6	50.0	48.6	49.4	49.1
	2	5	48.5	47.8	49.4	48.6	
	3	20	49.1	46.9	50.2	48.7	
	4	40	50.9	51.2	50.4	50.9	
	5	20	49.4	49.1	48.7	49.1	
FE114	No.	Temperature [°C]	Measured value [µm³]	Measured value [µm³]	Measured value [µm³]	Mean value of 3 measurements [µm³]	Mean value at 20°C [µm³]
Span	1	20	48.3	47.1	48.0	47.8	48.0
	2	5	45.5	47.1	49.1	47.2	
	3	20	48.0	47.5	47.3	47.6	
	4	40	46.4	45.7	45.5	45.8	
	5	20	47.9	48.7	49.2	48.6	

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

Manufacturer Grimm Aerosol Technik

Used test standard Test with reference dust

Type EDM 280

Serial-No. FE111 / FE114

FE111	No.	Mains voltage [V]	Measurement 1 Measured value [µm³]	Measurement 2 Measured value [µm³]	Measurement 3 Measured value [µm³]	Mean value of 3 measurements [µm³]
Span	1	230	51.2	50.8	51.8	51.3
	2	195	52.6	52.6	51.6	52.3
	3	230	51.9	51.5	50.3	51.2
	4	253	49.6	48.9	48.5	49.0
	5	230	50.5	49.9	50.7	50.4
FE114	**No.**	**Mains voltage [V]**	**Measured value [µm³]**	**Measured value [µm³]**	**Measured value [µm³]**	**Mean value of 3 measurements [µm³]**
Span	1	230	48.3	46.8	48.2	47.7
	2	195	46.1	45.5	48.8	46.8
	3	230	47.0	47.6	45.5	46.7
	4	253	47.0	47.6	46.6	47.1
	5	230	45.3	44.9	44.4	44.8

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 1 of 12**

Manufacturer: Grimm Aerosol Technik

Type of instrument: EDM 280

Serial-No.: FE111 / FE114

PM10 & 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 [%]	FE111 PM2,5 [µg/m³]	FE114 PM2,5 [µg/m³]	FE111 PM10 [µg/m³]	FE114 PM10 [µg/m³]	Remark	Test site
1	8/6/2021										Zero filter	Cologne
2	8/7/2021										Zero filter	
3	8/8/2021										Zero filter	
4	8/9/2021										Zero → Inlet	
5	8/10/2021	4.1	3.9	7.3	7.9	52.7	5.1	5.0	8.5	8.3		
6	8/11/2021	6.3	5.7	9.4	9.6	62.9	8.0	7.8	11.7	11.4		
7	8/12/2021	9.7	9.5	16.1	16.4	59.1	10.4	10.3	16.5	16.2		
8	8/13/2021	8.9	9.7	15.8	15.8	58.9	10.3	10.0	16.3	15.9		
9	8/14/2021	9.3	8.3	17.4	17.1	50.9	8.8	8.6	15.6	15.0		
10	8/15/2021	9.0	8.0	15.7	15.6	54.2	8.4	8.2	15.1	14.7		
11	8/16/2021	4.2	4.1	10.3	11.5	37.9	5.7	5.5	11.7	11.2		
12	8/17/2021	7.9	7.6	15.4	15.1	50.7	12.0	11.3	18.2	17.1		
13	8/18/2021	4.2	4.7	8.4	6.7	59.2	6.2	6.0	9.9	9.6		
14	8/19/2021	3.8	4.3	7.5	8.0	52.6	5.4	5.3	9.1	8.8		
15	8/20/2021	4.0	4.4	7.6	9.3	49.9	5.3	5.2	8.6	8.4		
16	8/21/2021	6.9	7.0	10.8	11.1	63.6	6.7	6.8	10.5	10.4		
17	8/22/2021	5.7	5.1	8.8	9.7	58.0	7.3	7.1	11.0	10.6		
18	8/23/2021	7.1	7.5	11.5	11.7	62.9	9.9	9.6	13.8	13.3		
19	8/24/2021	5.6	5.5	8.6	9.2	62.2	5.2	5.3	8.8	8.8		
20	8/25/2021	7.7	6.7	12.9	13.1	55.7	6.5	6.6	12.0	11.9		
21	8/26/2021	3.9	4.0	7.4	8.1	51.3	5.8	5.5	9.5	8.9		
22	8/27/2021	3.6	3.4	8.4	8.6	41.5	4.9	4.8	9.5	9.1		
23	8/28/2021	4.5	4.3	9.3	8.4	49.5	7.8	7.5	11.3	10.8		
24	8/29/2021	4.5	3.9	8.1	7.6	53.8	6.2	6.0	9.4	8.9		
25	8/30/2021	10.5	10.0	16.7	16.6	61.6	13.6	13.1	19.3	18.5		
26	8/31/2021	14.0	13.2	21.0	20.3	65.7	17.9	16.9	23.5	22.3		
27	9/1/2021	10.5	10.2	19.4	18.7	54.3	14.4	13.6	21.0	19.6		
28	9/2/2021	7.6	7.5	12.6	13.1	59.0	13.0	12.4	17.9	17.0		
29	9/3/2021	9.1	8.3	13.7	14.0	62.9	10.7	10.5	15.3	14.9		
30	9/4/2021	11.5	11.2	16.6	16.6	68.3	13.8	13.4	18.6	18.0		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 2 of 12**

Manufacturer	Grimm Aerosol Technik	PM10 & PM2,5
Type of instrument	EDM 280	Measured values in µg/m³ (ACT)
Serial-No.	FE111 / FE114	

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 [%]	FE111 PM2,5 [µg/m³]	FE114 PM2,5 [µg/m³]	FE111 PM10 [µg/m³]	FE114 PM10 [µg/m³]	Remark	Test site
31	9/5/2021	11.3	11.0	15.3	15.2	73.0	13.4	13.0	17.3	16.6		Cologne
32	9/6/2021	14.3	13.9	21.0	21.0	67.0	15.3	14.8	21.7	20.9		
33	9/7/2021	12.5	12.7	19.4	20.0	64.1	14.1	13.7	20.4	19.7		
34	9/8/2021	11.5	11.3	17.6	17.7	64.8	11.9	11.7	18.4	17.9		
35	9/9/2021	9.4	9.8	17.5	18.2	53.8	11.3	11.1	19.3	18.8		
36	9/10/2021	4.8	4.7	9.3	9.0	52.0	5.7	5.6	10.1	9.8		
37	9/11/2021	3.2	3.7	7.4	7.3	47.1	4.5	4.5	7.8	7.6		
38	9/12/2021	5.8	5.8	10.1	10.2	57.5	7.0	7.0	10.8	10.5		
39	9/13/2021	11.1	10.3	16.6	17.2	63.2	13.6	13.3	19.2	18.5		
40	9/14/2021	9.0	8.7	14.8	15.0	59.4	10.3	10.3	16.9	16.7		
41	9/15/2021	8.0	7.5	12.4	13.1	60.8	9.6	9.5	14.6	14.1		
42	9/16/2021	4.3	4.3	9.4	9.8	44.7	5.5	5.5	10.8	10.2		
43	9/17/2021	12.9	12.6	20.6	21.7	60.4	13.5	13.2	19.5	18.8		
44	9/18/2021	11.3	10.4	14.7	15.2	72.2	13.9	13.6	18.0	17.5		
45	9/19/2021	4.3	3.5	6.2	5.8	64.6	3.9	3.9	5.7	5.6		
46	9/20/2021	7.3	6.7	11.4	11.7	60.8	7.8	7.7	13.7	13.4		
47	9/21/2021	6.7	5.9	10.9	10.9	58.1	6.8	6.8	11.3	11.0		
48	9/22/2021	10.7	10.3	17.8	18.4	58.0	10.8	10.7	17.4	17.1		
49	9/23/2021	8.0	7.4	14.8	15.1	51.5	8.1	8.0	16.4	16.3		
50	9/24/2021	5.8	5.6	12.0	12.9	45.8	8.9	8.7	15.8	15.2		
51	9/25/2021	5.8	5.0	8.5	8.4	64.0	5.7	5.6	8.5	8.4		
52	9/26/2021	8.7	7.8	12.1	12.5	66.9	9.3	9.2	13.8	13.5		
53	9/27/2021	4.9	5.0	9.2	9.4	53.6	7.4	7.2	11.9	11.5		
54	9/28/2021	3.8	3.8	10.5	10.7	35.3	5.5	5.4	11.6	11.0		
55	9/29/2021	3.6	3.6	8.2	8.9	42.7	5.0	5.0	9.4	9.1		
56	9/30/2021	4.1	3.3	8.6	7.9	44.6	5.1	5.1	9.9	9.6		
57	10/1/2021	4.3	3.4	8.8	8.2	44.8	4.3	4.4	9.0	8.9		
58	10/2/2021	3.4	3.5	5.2	6.7	58.1	4.2	4.2	6.8	6.7		
59	10/3/2021	4.2	3.6	6.9	6.9	56.7	4.1	4.1	7.8	7.6		
60	10/4/2021						3.2	3.3	6.4	6.3		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 3 of 12**

Manufacturer: Grimm Aerosol Technik

Type of instrument: EDM 280

Serial-No.: FE111 / FE114

PM10 & 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 [%]	FE111 PM2,5 [µg/m³]	FE114 PM2,5 [µg/m³]	FE111 PM10 [µg/m³]	FE114 PM10 [µg/m³]	Remark	Test site
61	10/5/2021						3.8	3.8	6.4	6.3		Cologne
62	10/6/2021						3.9	3.9	6.6	6.3		
63	10/7/2021						12.0	11.4	16.3	15.3		
64	10/8/2021						9.9	9.8	14.3	13.9		
65	10/9/2021						17.9	17.3	24.8	23.8		
66	10/10/2021						15.8	15.6	21.3	20.8		
67	10/11/2021						14.3	13.8	20.9	19.9		
68	10/12/2021						8.4	8.2	12.6	12.0		
69	10/13/2021						9.1	9.0	15.1	14.6		
70	10/14/2021						10.5	10.3	16.7	16.0		
71	10/15/2021	6.9	6.6	13.2	14.2	49.3	8.2	8.2	13.2	12.7		
72	10/16/2021	10.3	10.1	16.5	16.7	61.3	12.9	12.6	16.8	16.1		
73	10/17/2021	10.4	10.4	15.1	15.9	66.9	11.4	11.3	15.1	14.7		
74	10/18/2021	12.3	11.6	16.0	16.2	74.3	13.6	13.2	17.2	16.7		
75	10/19/2021	9.2	8.3	12.0	12.4	71.7	10.5		13.7		Outage FE114 (weather sensor)	
76	10/20/2021	5.4	5.4	10.2	9.3	54.6	6.7		10.7		Outage FE114 (weather sensor)	
77	10/21/2021	3.3	3.1	8.8	7.7	38.5	4.3		8.6		Outage FE114 (weather sensor)	
78	10/22/2021	4.5	4.7	12.6	11.3	38.6	6.6		12.4		Outage FE114 (weather sensor)	
79	10/23/2021	8.4	7.8	15.3	14.7	54.1	11.0	10.6	16.3	15.2		
80	10/24/2021	6.1	6.8	11.6	10.9	57.3	8.8	8.7	12.3	11.8		
81	10/25/2021	6.7	6.7	11.3	10.7	60.9	8.5	8.5	12.2	11.9		
82	10/26/2021	4.4	4.3	8.6	8.4	50.5	5.6	5.6	8.9	8.5		
83	10/27/2021	4.0	4.5	8.7	7.6	52.2	5.5	5.5	8.9	8.6		
84	10/28/2021	11.9	12.4	16.9	16.1	73.8	15.4	14.8	18.7	17.9		
85	10/29/2021	9.2	9.1	14.3	13.1	66.6	12.3	12.0	16.4	15.9		
86	10/30/2021	6.9	7.0	11.9	10.3	62.7	8.5	8.4	12.1	11.8		
87	10/31/2021	3.4	3.9	6.8	5.4	60.4	4.8	4.8	7.1	7.0		
88	11/1/2021	3.4	3.1	8.9	7.5	39.2	4.5	4.5	8.3	7.9		
89	11/2/2021	3.9	3.0	7.4	6.4	49.7	4.6	4.6	7.3	7.1		
90	11/3/2021	6.6	6.6	10.4	9.7	65.8	7.7	7.5	10.2	9.9		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 4 of 12**

Manufacturer: Grimm Aerosol Technik

Type of instrument: EDM 280

Serial-No.: FE111 / FE114

PM10 & 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 [%]	FE111 PM2,5 [µg/m³]	FE114 PM2,5 [µg/m³]	FE111 PM10 [µg/m³]	FE114 PM10 [µg/m³]	Remark	Test site
91	11/4/2021	18.2	19.4	23.8	22.6	80.9	22.0		25.0		Outage FE114 (weather sensor)	Cologne
92	11/5/2021	13.8	14.7	21.0	20.1	69.5	16.4		21.3		Outage FE114 (weather sensor)	
93	11/6/2021	5.9	6.5	10.6	10.3	59.3	8.6	8.4	11.8	11.3		
94	11/7/2021	5.0	5.2	10.9	11.4	45.9	6.9	6.8	11.4	10.8		
95	11/8/2021										Inlet → Zero	
96	11/9/2021										Zero filter	
97	12/16/2021										Zero filter	Bornheim
98	12/17/2021										Zero → Inlet	
99	12/18/2021	11.5	10.4	15.6	14.7	71.9	12.9	12.2	15.0	14.5		
100	12/19/2021	9.4	7.6	13.3			9.8	9.2	12.9	12.3	Outage RM2 PM10	
101	12/20/2021	9.9	7.4	20.0			10.0	9.6	16.5	15.9	Outage RM2 PM10	
102	12/21/2021	19.3	20.8	31.6			19.3	18.8	25.8	25.6	Outage RM2 PM10	
103	12/22/2021	21.5	21.9	28.0	26.6	79.6	22.3	21.3	25.5	24.2		
104	12/23/2021	20.4	20.3	26.2	25.8	78.2	19.5	18.6	23.6	22.5		
105	12/24/2021	7.3	7.7	18.6	17.1	41.9	8.9	8.7	18.8	18.1		
106	12/25/2021	5.4	5.0	7.4	7.6	69.7	6.1	6.0	7.2	7.0		
107	12/26/2021			10.4	9.9		9.1	8.8	9.5	9.1	Outlier RM PM2,5	
108	12/27/2021	6.0	6.2	8.5	8.7	71.0	7.0	6.9	7.9	7.8		
109	12/28/2021	3.5	4.3	10.2	10.3	38.0	5.5	5.4	10.2	10.0		
110	12/29/2021	3.2	3.3	8.3	8.4	39.1	4.6	4.6	8.0	8.0		
111	12/30/2021	3.1	2.9	8.3			3.6	3.5	7.6	7.5	Outage RM2 PM10	
112	12/31/2021	3.6	2.9	6.6			3.5	3.5	5.7	5.5	Outage RM2 PM10	
113	1/1/2022	4.1	4.3	9.1			5.8	5.6	8.1	7.6	Outage RM2 PM10	
114	1/2/2022	5.5	4.8	10.2			5.9	5.7	10.4	10.0	Outage RM2 PM10	
115	1/3/2022	2.6	1.9	10.1			5.6	5.4	11.6	11.0	Outage RM2 PM10	
116	1/4/2022	2.7	2.5	6.1			4.2	4.3	7.9	7.8	Outage RM2 PM10	
117	1/5/2022	4.6	4.2	10.1			6.9	6.7	10.7	10.0		
118	1/6/2022	7.6	7.7	20.7	20.6	37.2	11.2	10.7	22.2	20.9		
119	1/7/2022	4.2	3.4	9.2			4.7	4.7	9.7	9.5	Outage RM2 PM10	
120	1/8/2022	4.5	4.4	9.8	10.1	44.8	5.9	5.8	12.4	12.1		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 5 of 12**

Manufacturer: Grimm Aerosol Technik
Type of instrument: EDM 280
Serial-No.: FE111 / FE114

PM10 & 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 [%]	FE111 PM2,5 [µg/m³]	FE114 PM2,5 [µg/m³]	FE111 PM10 [µg/m³]	FE114 PM10 [µg/m³]	Remark	Test site
121	1/9/2022	4.9	4.8	11.2	11.5	42.7	6.6	6.4	11.6	11.0		Bornheim
122	1/10/2022	12.1	11.3	20.7	20.8	56.3	13.8	13.3	20.2	19.6		
123	1/11/2022	13.1	12.4	16.3	16.6	77.4	14.3	13.6	16.8	16.0		
124	1/12/2022	17.0	16.2	25.3	25.0	65.8	18.3	17.4	25.0	24.4		
125	1/13/2022	17.9	16.9	24.5	23.3	72.7	18.3	17.4	22.5	21.9		
126	1/14/2022	21.0	20.5	27.8	26.2	76.8	23.1	21.9	27.1	26.0		
127	1/15/2022	10.7	10.4	11.7	11.7	90.0	12.0	11.4	12.8	12.1		
128	1/16/2022	13.3	13.1	17.4	16.7	77.2	14.3	13.7	17.7	16.9		
129	1/17/2022	15.1	14.6	25.2	22.6	62.1	19.0	17.9	28.2	26.4		
130	1/18/2022	9.7	9.7	21.9	20.0	46.4	13.7	13.1	22.1	21.5		
131	1/19/2022	8.9	9.3	23.9	21.8	39.7	10.6	10.4	23.5	23.3		
132	1/20/2022	5.3	5.4	19.8	17.9	28.3	8.7	8.3	19.7	18.8		
133	1/21/2022	8.2	8.1	23.2	21.0	36.9	11.6	11.3	25.5	25.0		
134	1/22/2022	16.5	16.1	27.8	26.4	60.2	20.5	19.5	28.7	27.2		
135	1/23/2022	19.8	21.8	26.5	29.2	74.9	22.6	21.2	26.7	25.1		
136	1/24/2022	7.9	7.9	12.8	13.0	60.7	8.8	8.7	13.2	13.0		
137	1/25/2022	18.8	18.5	29.3	28.8	64.2	19.8	18.7	28.4	27.0		
138	1/26/2022	27.7	27.6	37.3	36.2	75.1	28.9	26.2	35.2	32.1		
139	1/27/2022	9.9	9.5	19.2	18.6	51.3	12.1	11.4	23.2	22.0		
140	1/28/2022	7.6	6.8	21.1	20.1	35.1	9.7	9.3	19.1	18.3		
141	1/29/2022	4.4	3.3	9.4	9.9	39.6	5.6	5.4	9.6	9.3		
142	1/30/2022	7.9	7.0	23.8	23.7	31.4	11.1	10.4	21.4	19.8		
143	1/31/2022	4.7	4.5	12.8	13.8	34.5	8.1	7.7	14.0	13.1		
144	2/1/2022	3.9	4.0	13.6	13.3	29.3	7.2	6.9	14.6	13.6		
145	2/2/2022	8.3	7.7	22.4	22.3	35.9	12.7	11.9	20.7	19.0		
146	2/3/2022	4.9	5.4	12.0	11.0	44.7	6.2	6.1	10.4	10.3		
147	2/4/2022	3.0	3.0	7.0	8.4	38.9	3.5	3.5	7.3	7.0		
148	2/5/2022	4.0	4.2	9.1	9.4	44.3	5.4	5.3	8.8	8.2		
149	2/6/2022	1.6	1.9	4.2	4.9	38.9	2.8	2.8	5.2	4.9		
150	2/7/2022	4.3	4.0	15.3	14.4	28.1	6.3	6.0	13.8	13.2		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 6 of 12**

Manufacturer	Grimm Aerosol Technik
Type of instrument	EDM 280
Serial-No.	FE111 / FE114

PM10 & 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 [%]	FE111 PM2,5 [µg/m³]	FE114 PM2,5 [µg/m³]	FE111 PM10 [µg/m³]	FE114 PM10 [µg/m³]	Remark	Test site
151	2/8/2022	3.0	2.8	9.6	8.6	31.6	3.3	3.3	8.5	8.2		Bornheim
152	2/9/2022	6.6	6.4	14.5	14.1	45.6	7.4	7.3	13.0	12.6		
153	2/10/2022	8.2	8.3	15.9	16.0	51.4	10.1	10.0	17.4	17.1		
154	2/11/2022	7.0	7.1	17.0	17.1	41.2	8.4	8.1	15.5	14.6		
155	2/12/2022	9.0	8.4	15.2	16.1	55.6	10.2	9.7	15.0	14.1		
156	2/13/2022	8.3	8.8	12.6	12.6	67.6	9.4	9.2	12.9	12.4		
157	2/14/2022	3.5	4.0	10.6	10.7	35.3	4.4	4.4	9.9	9.7		
158	2/15/2022	3.1	4.2	10.9	10.8	33.4	4.9	4.8	10.0	9.7		
159	2/16/2022	1.2	1.1	7.1	6.8	16.4	1.7	1.7	7.1	6.6		
160	2/17/2022	4.7	4.6	16.1	14.4	30.6	7.7	7.1	14.5	13.5		
161	2/18/2022	3.9	3.1	12.0	11.1	30.5	5.8	5.4	11.6	10.8		
162	2/19/2022	2.2	3.1	9.2	8.4	30.3	4.1	3.9	7.7	7.1		
163	2/20/2022	2.5	2.1	7.3	7.0	31.8	3.9	3.7	7.0	6.6		
164	2/21/2022	2.8	3.1	9.4	9.4	31.2	4.9	4.6	9.1	8.5		
165	2/22/2022	4.9	4.5	17.0	16.7	28.0	8.3	7.7	16.0	14.6		
166	2/23/2022	5.8	5.9	14.7	15.3	38.9	7.4	7.0	13.3	12.3		
167	2/24/2022	3.6	3.7	8.6	8.9	41.9	4.4	4.4	8.3	8.2		
168	2/25/2022	5.2	4.5	17.2	16.4	28.8	7.0	6.8	17.2	16.6		
169	2/26/2022	9.3	8.1	20.0	19.0	44.4	12.9	12.3	20.1	18.9		
170	2/27/2022	7.7	6.7	11.2	10.0	67.9	8.5	8.2	10.9	10.4		
171	2/28/2022	10.8	10.8	16.3	15.1	68.8	11.1	10.8	15.0	14.7		
172	3/1/2022	14.9	14.0	20.2	19.7	72.3	15.2	14.6	19.7	19.4		
173	3/2/2022	15.8	16.1	25.1	24.3	64.6	15.7	15.3	22.7	22.4		
174	3/3/2022	17.9	17.8	26.2	25.5	69.0	17.3	16.8	24.1	23.7		
175	3/4/2022	19.2	19.0	28.2	27.7	68.5	19.2	18.4	25.8	25.0		
176	3/5/2022	18.0	18.1	22.7	21.6	81.4	19.0	17.6	21.7	20.2		
177	3/6/2022	19.0	19.2	25.2	24.2	77.2	18.7	18.0	22.5	22.0		
178	3/7/2022										Inlet → Zero	
179	3/8/2022										Zero filter	
180	6/21/2022										Zero filter	Niederzier

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 7 of 12**

Manufacturer: Grimm Aerosol Technik
Type of instrument: EDM 280
Serial-No.: FE111 / FE114

PM10 & 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 [%]	FE111 PM2,5 [µg/m³]	FE114 PM2,5 [µg/m³]	FE111 PM10 [µg/m³]	FE114 PM10 [µg/m³]	Remark	Test site
181	6/22/2022	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	Zero → Inlet	Niederzier
182	6/23/2022	8.5	11.0	35.1	34.5	28.0	11.4	11.4	38.0	39.3		
183	6/24/2022	5.1	4.6	8.4	8.2	58.8	6.2	6.3	11.7	12.0		
184	6/25/2022	3.4	4.1	10.7	10.3	35.4	4.8	4.9	11.9	12.1		
185	6/26/2022	3.4	3.4	12.1	12.7	27.1	5.5	5.5	13.2	13.5		
186	6/27/2022	4.6	5.6	13.6	12.2	39.7	7.4	7.4	15.3	15.6		
187	6/28/2022	3.9	4.5	15.3	15.5	27.4	4.7	4.7	16.9	17.4		
188	6/29/2022	7.4	9.6	35.6	33.4	24.7	7.8	7.9	34.2	35.5		
189	6/30/2022	7.3	8.5	20.6	19.6	39.1	8.9	9.0	22.3	22.7		
190	7/1/2022	3.1	3.3	9.1	8.4	36.7	4.2	4.2	10.5	10.7		
191	7/2/2022	3.7	4.6	16.5	15.3	26.1	4.5	4.6	16.4	16.9		
192	7/3/2022	4.5	4.5	10.6	9.4	44.9	5.4	5.6	11.3	11.6		
193	7/4/2022	3.0	3.7	8.7	7.8	40.9	3.9	4.0	8.7	8.9		
194	7/5/2022	5.2	6.0	12.1	13.2	44.5	7.2	7.3	14.6	14.8		
195	7/6/2022	3.8	4.6	10.0	9.7	42.5	5.0	5.1	11.6	11.8		
196	7/7/2022	5.7	5.0	10.9	11.9	47.2	5.6	5.7	14.1	14.4		
197	7/8/2022	3.9	5.1	9.0	10.3	46.3	5.6	5.6	12.6	12.8		
198	7/9/2022	5.4	6.3	9.2	10.6	59.3	6.8	6.9	12.8	13.0		
199	7/10/2022	3.5	4.0	6.5	8.0	51.4	5.0	5.0	10.0	10.3		
200	7/11/2022	5.1	4.8	5.6	8.5	69.8	4.8	4.9	9.7	10.0		
201	7/12/2022	7.4	7.5	18.8	21.1	37.3	5.7	5.8	18.5	19.2		
202	7/13/2022	8.1	8.6	24.5	25.5	33.4	6.4	6.4	23.7	24.6		
203	7/14/2022	4.2	7.0	12.8	12.8	44.0	7.5	7.6	17.1	17.4		
204	7/15/2022	2.3	4.3	9.0	9.2	36.5	4.3	4.4	10.1	10.4		
205	7/16/2022	4.1	6.1	13.8	14.1	36.6	5.1	5.3	14.0	14.5		
206	7/17/2022	6.3	9.2	25.8	25.5	30.3	6.2	6.3	23.5	24.1		
207	7/18/2022	9.3	10.5	33.6	32.5	29.9	7.6	7.8	31.3	32.3		
208	7/19/2022	13.9	15.6	44.6	44.3	33.2	10.9	11.0	46.7	48.0		
209	7/20/2022	12.8	14.4	26.5	27.1	50.8	15.9	16.0	33.1	33.7		
210	7/21/2022	5.4	6.3	10.0	11.1	55.7	9.8	9.7	14.9	14.9		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 8 of 12**

Manufacturer: Grimm Aerosol Technik

Type of instrument: EDM 280

Serial-No.: FE111 / FE114

PM10 & 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 [%]	FE111 PM2,5 [µg/m³]	FE114 PM2,5 [µg/m³]	FE111 PM10 [µg/m³]	FE114 PM10 [µg/m³]	Remark	Test site
211	7/22/2022	7.7	8.8	17.4	16.3	49.0	12.0	11.9	21.3	21.5		Niederzier
212	7/23/2022	6.4	7.2	15.4	14.3	45.5	10.6	10.6	19.0	19.5		
213	7/24/2022	8.2	9.4	19.7	18.3	46.3	10.3	10.3	20.3	20.7		
214	7/25/2022	8.2	8.2	19.8	18.2	43.4	8.2	8.3	20.4	21.0		
215	7/26/2022	4.2	3.9	12.1	12.1	33.4	7.1	7.2	15.8	16.3		
216	7/27/2022	4.4	4.6	16.2	15.7	28.2	4.4	4.5	14.5	15.1		
217	7/28/2022	7.2	7.0	26.7	25.4	27.3	6.2	6.3	27.7	28.7		
218	7/29/2022	8.2	7.5	21.4	20.8	37.2	8.0	8.2	22.5	23.3		
219	7/30/2022	8.2	7.8	14.7	13.4	57.1	11.9	12.1	20.8	21.3		
220	7/31/2022	6.1	4.7	11.2	10.3	50.1	5.5	5.7	12.1	12.6		
221	8/1/2022	3.8	2.8	6.3	6.3	52.1	4.7	4.8	8.5	8.7		
222	8/2/2022	7.0	6.3	22.2	21.1	30.5	6.4	6.5	20.8	21.6		
223	8/3/2022	6.2	6.3	15.0	13.8	43.4	4.9	5.0	14.1	14.7		
224	8/4/2022	10.1	10.6	34.0	31.2	31.8	8.1	8.3	32.9	34.4		
225	8/5/2022	4.8	4.9	10.3	9.0	50.2	7.5	7.6	13.2	13.6		
226	8/6/2022			11.2	9.7		5.4	5.6	11.7	12.2	Outlier RM PM2,5	
227	8/7/2022	5.6	6.2	17.4	16.1	35.2	5.4	5.6	15.7	16.4		
228	8/8/2022	6.0	6.0	15.1	13.5	42.0	6.4	6.6	15.5	16.0		
229	8/9/2022	7.6	8.3	21.1	20.0	38.8	7.7	7.8	21.9	22.6		
230	8/10/2022	10.8	12.2	34.2	33.0	34.2	9.6	9.7	33.7	35.0		
231	8/11/2022			48.5	47.5		12.1	12.1	47.3	49.1	No measurement PM2,5	
232	8/12/2022			37.8	37.2		12.3	12.4	39.4	40.6	No measurement PM2,5	
233	8/13/2022			33.9	33.0		11.0	11.1	33.7	34.8	No measurement PM2,5	
234	8/14/2022			24.4	23.8		10.1	10.2	25.9	26.6	No measurement PM2,5	
235	8/15/2022	8.0	8.4	18.0	17.5	46.2	7.9	7.9	19.4	20.0		
236	8/16/2022	7.7	9.1	23.5	23.1	36.1	9.2	9.3	24.1	25.2		
237	8/17/2022	10.0	10.2	21.5	21.0	47.5	13.0	13.0	23.5	23.9		
238	8/18/2022			20.0	19.6		17.9	17.7	24.0	24.1	No measurement PM2,5	
239	8/19/2022	7.9	7.6	16.6	16.3	47.3	14.7	14.6	22.6	22.7		
240	8/20/2022	6.2	4.7	13.2	12.4	42.6	9.8	9.9	17.0	17.2		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 9 of 12**

Manufacturer	Grimm Aerosol Technik	
Type of instrument	EDM 280	PM10 & PM2,5 Measured values in µg/m³ (ACT)
Serial-No.	FE111 / FE114	

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 [%]	FE111 PM2,5 [µg/m³]	FE114 PM2,5 [µg/m³]	FE111 PM10 [µg/m³]	FE114 PM10 [µg/m³]	Remark	Test site
241	8/21/2022	5.5	5.0	12.9	12.6	41.3	7.2	7.3	13.6	13.9		Niederzier
242	8/22/2022	7.8	7.6	26.3	23.7	30.7	9.1	9.3	24.5	25.3		
243	8/23/2022	7.1	6.9	20.4	18.0	36.5	8.0	8.1	18.1	18.7		
244	8/24/2022	9.5	9.1	32.2	28.9	30.5	9.3	9.5	29.4	30.0		
245	8/25/2022	10.9	9.5	34.0	31.5	31.2	9.1	9.2	33.8	34.8		
246	8/26/2022	8.2	7.7	19.3	16.0	45.0	12.4	12.3	21.8	22.1		
247	8/27/2022	4.1	3.1	11.9	11.1	31.6	5.6	5.7	13.9	14.1		
248	8/28/2022	5.1	6.0	16.9	15.9	34.0	6.3	6.4	16.9	17.5		
249	8/29/2022	5.1	5.5	21.0	20.1	25.9	5.5	5.6	19.8	20.5		
250	8/30/2022	9.3	8.9	36.1	34.5	25.7	7.8	7.8	35.1	36.4		
251	8/31/2022	8.4	7.7	18.7	18.7	43.0	9.2	9.3	20.5	21.1		
252	9/1/2022	7.6	8.2	28.4	28.0	28.0	8.4	8.5	28.9	29.9		
253	9/2/2022	9.3	9.1	24.9	23.3	38.3	6.9	7.1	24.4	25.3		
254	9/3/2022	7.0	7.3	17.9	17.1	41.0	6.1	6.3	18.5	19.1		
255	9/4/2022	4.8	5.7	14.7	14.5	35.9	5.6	5.7	13.7	14.1		
256	9/5/2022	8.9	9.3	31.7	30.0	29.5	6.2	6.3	29.4	30.5		
257	9/6/2022	6.1	7.0	21.0	19.8	32.0	6.2	6.3	20.7	21.3		
258	9/7/2022	3.6	3.6	10.2	10.2	35.6	4.1	4.1	10.4	10.7		
259	9/8/2022	2.3	3.2	6.8	6.7	40.3	3.8	3.9	7.3	7.5		
260	9/9/2022	2.4	2.4	5.9	5.9	41.5	3.0	3.1	6.0	6.1		
261	9/10/2022	3.3	4.0	7.8	8.0	46.0	5.6	5.7	9.1	9.4		
262	9/11/2022	5.5	5.6	12.5	12.4	44.7	12.5	12.4	17.2	17.2		
263	9/12/2022										Inlet → Zero	
264	9/13/2022										Zero filter	
265	10/13/2022										Zero filter	JRC Ispra
266	10/14/2022										Zero → Inlet	
267	10/15/2022	15.8	15.2	30.4	31.4	50.1	18.9	18.1	34.3	33.1		
268	10/16/2022	16.5	16.1	32.4	34.1	49.0	18.5	17.7	34.8	33.4		
269	10/17/2022	17.6	15.6	32.3	34.6	49.7	19.9	19.0	36.3	34.9		
270	10/18/2022	15.1	14.4	31.4	32.5	46.0	18.3	17.5	36.4	35.0		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 10 of 12**

Manufacturer Grimm Aerosol Technik

Type of instrument EDM 280

Serial-No. FE111 / FE114

PM10 & 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 [%]	FE111 PM2,5 [µg/m³]	FE114 PM2,5 [µg/m³]	FE111 PM10 [µg/m³]	FE114 PM10 [µg/m³]	Remark	Test site
271	10/19/2022	11.1	10.5	25.9	27.8	40.1	12.9	12.5	29.2	28.5		JRC Ispra
272	10/20/2022	16.4	15.7	32.3	34.5	48.2	17.5	16.6	33.9	32.3		
273	10/21/2022	21.3	20.4	34.4	36.9	58.5	24.7	23.4	37.3	35.5		
274	10/22/2022	7.4	5.6	15.0	16.7	40.8	9.0	8.7	17.8	17.2		
275	10/23/2022	6.1	6.0	17.2	17.6	34.8	7.1	7.0	20.0	19.5		
276	10/24/2022	13.3	12.8	28.3	29.3	45.4	18.8	17.9	32.9	31.5		
277	10/25/2022	8.1	7.8	24.6	25.3	32.0	11.7	11.1	27.5	26.3		
278	10/26/2022	9.6	9.2	30.9	31.3	30.2	13.9	13.3	35.4	34.0		
279	10/27/2022	8.8	8.8	27.4	27.7	32.0	12.4	11.9	30.6	29.9		
280	10/28/2022	8.0	8.2	23.5	23.5	34.3	9.5	9.2	25.5	24.9		
281	10/29/2022	8.4	9.8	22.6	23.4	39.5	9.8	9.5	25.1	23.9		
282	10/30/2022	10.2	10.7	24.4	24.2	43.0	11.3	10.9	27.1	26.1		
283	10/31/2022	15.2	15.7	29.0	28.5	53.8	15.1	14.5	30.4	29.4		
284	11/1/2022	14.8	15.5	25.6	25.7	59.1	16.2	15.6	28.5	27.4		
285	11/2/2022	13.4	14.6	24.4	22.5	59.7	15.5	14.8	25.0	24.0		
286	11/3/2022	16.5	16.7	25.7	26.2	63.8	18.9	18.0	28.6	27.3		
287	11/4/2022	2.6	4.1	6.0	5.5	58.8	2.2	2.1	5.3	5.1		
288	11/5/2022	1.9	3.9	5.4	4.8	56.3	1.8	1.8	4.6	4.4		
289	11/6/2022	3.9	4.5	5.9	6.3	68.8	3.7	3.6	5.4	5.2		
290	11/7/2022	12.5	12.6	16.1	16.9	75.8	12.1	11.7	15.9	15.3		
291	11/8/2022	14.4	14.8	19.4	20.7	72.9	14.4	13.8	19.3	18.2		
292	11/9/2022	22.2	22.1	27.9	29.3	77.4	22.3	21.3	27.0	25.8		
293	11/10/2022	10.6	10.6	16.7	16.8	63.5	13.7	13.1	19.1	18.4		
294	11/11/2022	10.3	11.0	16.6	16.5	64.2	13.1	12.5	18.4	17.6		
295	11/12/2022	14.1	14.0	18.7	18.4	75.6	13.8	13.2	18.7	17.8		
296	11/13/2022	16.7	16.3	22.5	22.6	73.1	16.9	16.1	22.0	21.1		
297	11/14/2022	11.2	11.4	15.1	15.1	74.7	13.3	12.6	16.5	15.7		
298	11/15/2022	12.1	13.0	16.9	16.6	74.9	14.4	13.8	18.5	17.7		
299	11/16/2022	9.3	8.8	13.4	13.3	68.0	10.6	10.1	15.3	14.8		
300	11/17/2022	13.0	12.6	18.5	19.6	67.2	15.1	14.4	21.6	20.8		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 11 of 12**

Manufacturer	Grimm Aerosol Technik
Type of instrument	EDM 280
Serial-No.	FE111 / FE114

PM10 & 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 [%]	FE111 PM2,5 [µg/m³]	FE114 PM2,5 [µg/m³]	FE111 PM10 [µg/m³]	FE114 PM10 [µg/m³]	Remark	Test site
301	11/18/2022	9.2	9.6	13.3	13.0	71.7	10.4	10.0	14.1	13.7		JRC Ispra
302	11/19/2022	8.9	9.8	12.0	11.8	78.7	8.9	8.5	11.5	11.0		
303	11/20/2022	8.9	8.7	10.7	10.8	81.9	8.9	8.6	10.6	10.2		
304	11/21/2022	16.5	16.1	19.4	19.9	82.9	15.3	14.7	19.1	18.4		
305	11/22/2022	4.4	4.2	6.5	6.0	68.7	4.8	4.6	6.5	6.3		
306	11/23/2022	5.3	4.6	8.8	8.6	56.4	4.7	4.4	7.8	7.5		
307	11/24/2022	9.0	9.4	12.3	13.6	71.2	9.1	8.7	12.0	11.7		
308	11/25/2022	24.4	23.7	29.0	29.6	82.0	23.9	22.7	28.4	27.0		
309	11/26/2022	20.2	19.8	22.5	23.7	86.6	20.4	19.3	23.7	22.5		
310	11/27/2022	21.9	22.5	24.7	25.8	87.8	22.0	20.9	24.8	23.6		
311	11/28/2022	25.6	26.2	39.2	40.1	65.3	33.0	31.2	37.4	35.4		
312	11/29/2022	34.3	34.7	45.3	46.5	75.1	40.8	38.5	44.9	42.4		
313	11/30/2022	36.3	36.8	43.4	45.0	82.7	41.1	38.8	44.1	41.7		
314	12/1/2022	26.7	27.3	31.6	31.9	85.1	28.4	27.1	32.6	31.2		
315	12/2/2022	25.3	25.3	28.9	29.8	86.1	25.7	24.4	29.1	27.8		
316	12/3/2022	11.9	11.7	13.2	13.9	86.9	13.6	13.0	14.7	14.1		
317	12/4/2022	3.8	3.4	4.9	5.4	70.8	4.2	4.1	4.8	4.7		
318	12/5/2022	4.4	3.9	6.4	6.5	64.1	5.8	5.6	7.1	6.9		
319	12/6/2022	7.9	8.1	11.5	11.6	68.9	9.4	9.1	11.6	11.3		
320	12/7/2022	22.8	23.5	26.6	27.7	85.1	24.1	23.1	26.6	25.6		
321	12/8/2022	20.8	20.9	24.1	25.2	84.7	21.2	20.4	23.7	22.8		
322	12/9/2022	20.9	20.6	21.8	22.9	92.9	21.0	20.1	22.6	21.7		
323	12/10/2022	14.1	15.0	17.0	17.6	84.6	16.6	16.0	18.7	18.1		
324	12/11/2022	2.3	3.1	3.4	3.7	75.6	2.4	2.4	3.0	2.9		
325	12/12/2022	23.0	23.8	26.3	26.5	88.6	23.5	22.5	25.4	24.3		
326	12/13/2022	27.4	27.2	31.2	32.4	85.8	26.3	25.0	29.5	28.2		
327	12/14/2022	32.9	33.5	42.2	44.1	76.9	37.4	35.5	40.5	38.5		
328	12/15/2022	29.9	29.5	37.2	38.3	78.6	34.4	32.8	36.4	34.6		
329	12/16/2022	16.9	17.2	19.1	19.7	88.1	19.5	18.7	20.9	20.0		
330	12/17/2022	12.0	12.4	15.3	16.0	77.8	15.7	15.0	17.3	16.5		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 12 of 12**

Manufacturer: Grimm Aerosol Technik

Type of instrument: EDM 280

Serial-No.: FE111 / FE114

PM10 & 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 [%]	FE111 PM2,5 [µg/m³]	FE114 PM2,5 [µg/m³]	FE111 PM10 [µg/m³]	FE114 PM10 [µg/m³]	Remark	Test site
331	12/18/2022	16.2	15.2	17.2	17.9	89.5	15.8	15.2	17.9	17.2		JRC Ispra
332	12/19/2022	34.2	33.3	36.6	38.0	90.4	35.9	34.0	37.8	35.8		
333	12/20/2022	32.2	31.0	33.5	34.6	92.8	31.7	30.1	34.5	32.8		
334	12/21/2022	28.8	28.9	39.5	41.1	71.6	35.1	33.3	39.4	37.5		
335	12/22/2022	38.0	37.2	39.7	41.5	92.6	37.1	35.2	40.9	39.0		
336	12/23/2022	28.8	29.4	31.9	32.6	90.3	30.1	28.6	33.3	31.7		
337	12/24/2022	36.3	36.7	44.3	45.4	81.4	41.8	39.3	45.6	42.9		
338	12/25/2022	31.6	32.4	38.3	38.8	82.9	34.7	32.6	39.6	37.3		
339	12/26/2022	23.2	23.6	26.4	26.8	87.9	25.1	23.8	28.1	26.8		
340	12/27/2022	21.0	21.0	22.6	23.1	91.7	22.5	21.4	25.1	24.0		
341	12/28/2022	20.0	21.5	25.2	25.8	81.4	21.7	20.6	25.3	24.1		
342	12/29/2022	25.4	26.8	29.8	30.3	86.7	27.5	26.1	31.2	29.7		
343	12/30/2022	32.0	31.8	36.7	37.7	85.7	32.4	30.8	37.1	35.5		
344	12/31/2022	27.1	27.2	29.9	30.5	90.1	28.6	27.2	32.1	30.7		
345	1/1/2023	26.2	26.5	31.9	31.5	83.1	30.1	28.4	32.6	30.8		
346	1/2/2023	20.0	19.8	25.4	26.2	77.0	25.3	24.1	28.4	27.0		
347	1/3/2023	19.7	19.3	23.2	23.3	83.8	22.7	21.7	25.9	24.9		
348	1/4/2023	11.2	10.8	14.0	14.1	78.3	13.4	12.9	16.3	15.7		
349	1/5/2023										Inlet → Zero	
350	1/6/2023										Zero filter	

Annex 6 **Ambient conditions at the field test sites** **Page 1 of 12**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity* [m/s]	Wind direction* [°]	Precipitation* [mm]
1	8/6/2021	Cologne	19.2	23.4	999.4	77.7	0.5	165.0	0.0
2	8/7/2021		19.2	24.2	998.8	68.6	0.4	162.0	0.2
3	8/8/2021		18.3	22.8	1004.9	65.3	0.4	140.3	3.1
4	8/9/2021		17.9	22.9	1011.4	71.5	0.3	146.2	1.5
5	8/10/2021		18.2	25.0	1012.0	84.2	0.1	121.8	0.0
6	8/11/2021		20.0	25.9	1014.3	78.4	0.1	120.8	0.0
7	8/12/2021		21.4	27.8	1014.6	71.9	0.1	122.9	0.0
8	8/13/2021		21.6	27.2	1016.0	72.4	0.0	106.2	0.0
9	8/14/2021		21.1	28.2	1015.6	65.8	0.1	107.5	0.0
10	8/15/2021		22.2	30.8	1009.3	65.8	0.2	131.1	0.0
11	8/16/2021		17.0	21.8	1008.0	77.8	0.2	118.9	4.3
12	8/17/2021		14.8	18.3	1013.2	83.8	0.1	117.6	2.0
13	8/18/2021		17.0	19.5	1011.1	86.6	0.0	112.3	2.6
14	8/19/2021		18.7	21.5	1009.8	79.3	0.1	111.6	0.0
15	8/20/2021		18.9	25.0	1012.1	76.1	0.1	110.1	0.2
16	8/21/2021		20.5	27.0	1012.5	73.2	0.3	123.7	0.3
17	8/22/2021		19.5	23.7	1011.1	81.8	0.1	107.7	0.0
18	8/23/2021		18.5	21.4	1016.9	80.8	0.2	113.9	0.0
19	8/24/2021		17.8	22.7	1021.2	63.7	0.4	142.1	0.0
20	8/25/2021		17.9	24.6	1017.1	64.4	0.1	102.4	0.0
21	8/26/2021		16.2	19.7	1010.1	83.2	0.0	97.3	5.1
22	8/27/2021		14.8	19.2	1012.0	89.5	0.0	98.8	0.0
23	8/28/2021		16.1	20.0	1013.5	87.8	0.1	105.8	0.0
24	8/29/2021		15.6	17.1	1013.4	92.7	0.0	94.6	6.1
25	8/30/2021		17.4	20.4	1014.2	86.4	0.0	106.1	0.2
26	8/31/2021		16.9	22.1	1019.1	79.7	0.0	102.3	0.0
27	9/1/2021		15.9	17.8	1022.9	80.1	0.0	97.3	0.0
28	9/2/2021		16.9	23.8	1021.2	76.3	0.2	110.0	0.0
29	9/3/2021		19.0	26.7	1015.5	71.2	0.2	117.7	0.0
30	9/4/2021		19.3	27.5	1012.8	73.3	0.1	97.9	0.0

* Indicative only

Annex 6 **Ambient conditions at the field test sites** **Page 2 of 12**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity* [m/s]	Wind direction* [°]	Precipitation* [mm]
31	9/5/2021	Cologne	19.9	28.3	1015.1	68.9	0.1	110.5	0.0
32	9/6/2021		19.8	27.4	1018.4	67.6	0.1	107.8	0.0
34	9/7/2021		19.5	27.3	1018.1	68.5	0.2	113.6	0.0
34	9/8/2021		21.0	27.8	1011.8	62.3	0.7	138.3	0.0
35	9/9/2021		21.0	29.5	1006.4	71.5	0.2	119.1	3.6
36	9/10/2021		20.9	24.6	1008.6	80.0	0.1	110.1	0.7
37	9/11/2021		19.8	23.1	1012.2	73.9	0.1	110.7	0.0
38	9/12/2021		18.5	23.5	1013.4	71.3	0.1	106.3	0.0
39	9/13/2021		16.8	23.2	1013.4	75.1	0.1	106.7	0.0
40	9/14/2021		19.4	25.4	1009.5	72.9	0.4	136.4	0.0
41	9/15/2021		20.3	22.5	1006.7	80.9	0.1	117.4	3.1
42	9/16/2021		17.3	21.7	1011.8	72.0	0.0	96.3	0.0
43	9/17/2021		16.9	22.4	1011.6	77.8	0.1	107.6	0.0
44	9/18/2021		17.4	24.1	1011.3	73.1	0.1	112.4	0.0
45	9/19/2021		15.8	20.0	1010.4	71.0	0.5	134.5	0.0
46	9/20/2021		14.3	17.2	1015.2	65.0	0.4	123.8	0.0
47	9/21/2021		14.6	18.4	1023.9	61.3	0.2	113.2	0.0
48	9/22/2021		13.6	21.3	1023.7	73.1	0.1	109.8	0.0
49	9/23/2021		16.2	23.2	1015.1	69.1	0.1	109.9	0.0
50	9/24/2021		18.5	22.2	1012.1	70.5	0.1	112.1	0.0
51	9/25/2021		17.6	24.0	1011.4	71.5	0.2	127.1	0.0
52	9/26/2021		19.2	25.8	1010.6	72.2	0.4	147.8	0.0
53	9/27/2021		17.0	22.2	1011.5	80.6	0.7	163.3	4.3
54	9/28/2021		13.7	18.3	1017.4	79.3	0.4	141.5	0.0
55	9/29/2021		12.3	16.3	1013.6	77.3	0.5	155.1	5.9
56	9/30/2021		12.5	17.4	1020.6	66.4	0.3	139.3	0.0
57	10/1/2021		14.2	20.0	1013.1	61.8	1.1	198.0	0.2
58	10/2/2021		15.3	19.5	1004.7	77.7	1.0	197.9	4.5
59	10/3/2021		18.3	22.0	997.5	67.8	1.4	173.7	2.6
60	10/4/2021		14.3	19.3	1011.2	68.7	0.5	159.7	0.0

* Indicative only

Annex 6 **Ambient conditions at the field test sites** **Page 3 of 12**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity* [m/s]	Wind direction* [°]	Precipitation* [mm]
61	10/5/2021	Cologne	13.3	18.7	1004.2	75.9	1.1	179.0	3.3
62	10/6/2021		12.0	13.4	1010.4	79.3	0.4	128.7	5.1
63	10/7/2021		12.9	18.0	1021.8	81.7	0.1	109.5	0.2
64	10/8/2021		11.8	19.0	1025.1	79.5	0.1	109.6	0.0
65	10/9/2021		11.7	18.7	1023.7	75.0	0.1	108.6	0.0
66	10/10/2021		10.3	17.4	1022.2	72.5	0.2	120.9	0.0
67	10/11/2021		11.5	16.7	1021.2	79.5	0.0	104.7	0.0
68	10/12/2021		10.5	13.2	1016.1	88.7	0.0	106.0	10.4
69	10/13/2021		9.3	15.0	1020.1	83.3	0.0	103.3	0.3
70	10/14/2021		12.5	15.6	1019.7	79.7	0.0	107.8	0.0
71	10/15/2021		11.2	13.7	1013.8	78.2	0.1	108.8	1.0
72	10/16/2021		7.7	13.8	1017.4	83.8	0.1	114.2	0.0
73	10/17/2021		8.7	15.0	1016.4	76.7	0.1	118.3	0.0
74	10/18/2021		10.0	14.8	1018.1	77.6	1.2	183.2	0.0
75	10/19/2021		13.8	17.9	1014.0	85.3	0.9	194.3	6.1
76	10/20/2021		16.2	18.4	1002.7	72.4	0.7	167.8	0.0
77	10/21/2021		11.8	17.6	997.5	75.7	0.7	132.9	9.6
78	10/22/2021		8.9	13.3	1012.9	75.5	0.2	113.8	1.1
79	10/23/2021		9.5	12.2	1022.4	81.3	0.1	114.3	0.0
80	10/24/2021		8.6	14.3	1019.7	72.4	1.1	179.6	0.0
81	10/25/2021		10.0	16.7	1014.6	77.3	0.4	154.6	1.0
82	10/26/2021		12.8	17.4	1016.5	75.4	0.1	116.0	0.5
83	10/27/2021		13.3	17.9	1018.9	76.4	0.3	135.0	0.0
84	10/28/2021		10.9	15.7	1013.2	81.1	1.7	214.5	0.0
85	10/29/2021		12.3	17.6	1005.1	72.5	1.7	213.6	0.0
86	10/30/2021		12.8	13.9	999.9	72.4	1.6	210.2	1.0
87	10/31/2021		13.4	17.8	998.8	84.5	0.7	157.3	13.0
88	11/1/2021		11.4	15.7	996.1	71.6	0.4	136.9	0.0
89	11/2/2021		8.1	10.2	996.0	84.7	0.3	143.9	3.8
90	11/3/2021		6.7	8.0	996.2	88.2	0.1	99.2	7.3

* Indicative only

Annex 6 **Ambient conditions at the field test sites** **Page 4 of 12**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity* [m/s]	Wind direction* [°]	Precipitation* [mm]
91	11/4/2021	Cologne	7.5	9.4	1002.1	88.0	0.0	93.2	1.8
92	11/5/2021		8.9	11.8	1017.5	86.0	0.0	96.3	0.3
93	11/6/2021		9.0	13.4	1022.4	77.5	0.3	126.8	0.0
94	11/7/2021		10.4	12.4	1013.0	75.1	0.3	105.5	0.2
95	11/8/2021								
96	11/9/2021								
97	12/16/2021	Bornheim	9.2	11.0	1030.8	91.5	0.5	161.5	0.0
98	12/17/2021		7.9	9.0	1033.2	92.2	0.5	159.5	0.0
99	12/18/2021		4.1	5.6	1032.3	98.8	0.5	161.2	0.5
100	12/19/2021		5.8	6.5	1025.0	96.9	1.1	224.8	0.3
101	12/20/2021		4.1	6.9	1021.1	81.7	0.6	150.2	0.0
102	12/21/2021		-1.4	2.4	1020.4	90.3	0.3	156.7	0.0
103	12/22/2021		-1.5	2.1	1018.2	88.2	0.5	143.9	0.0
104	12/23/2021		2.9	9.7	1005.8	82.5	1.0	143.6	0.2
105	12/24/2021		9.2	11.5	999.3	84.9	1.2	194.5	0.0
106	12/25/2021		3.5	7.5	1000.6	92.9	0.9	104.3	11.4
107	12/26/2021		2.0	3.3	1000.6	89.0	0.9	131.9	0.3
108	12/27/2021		5.6	7.7	994.7	95.5	0.5	143.8	1.3
109	12/28/2021		8.7	12.3	989.3	92.7	1.3	173.9	22.1
110	12/29/2021		10.0	12.9	1000.7	89.6	1.3	188.6	3.0
111	12/30/2021		13.7	15.9	1010.4	86.9	1.1	179.2	2.0
112	12/31/2021		14.0	16.7	1014.4	79.2	1.3	173.7	0.0
113	1/1/2022		12.6	15.1	1017.9	82.5	0.9	154.9	0.0
114	1/2/2022		11.5	14.7	1009.2	82.0	1.4	170.0	3.9
115	1/3/2022		9.7	11.7	1005.4	84.5	1.4	181.7	7.6
116	1/4/2022		6.8	8.4	993.0	96.7	0.9	169.9	15.7
117	1/5/2022		3.6	5.5	1001.2	87.9	2.3	228.8	5.4
118	1/6/2022		3.2	6.3	1012.5	90.4	0.9	181.1	0.2
119	1/7/2022		3.7	6.5	1007.2	83.0	1.2	158.1	0.5
120	1/8/2022		2.7	4.7	1000.7	89.3	1.0	156.3	0.8

* Indicative only

Annex 6 **Ambient conditions at the field test sites** **Page 5 of 12**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity* [m/s]	Wind direction* [°]	Precipitation* [mm]
121	1/9/2022	Bornheim	4.7	6.5	994.4	85.3	1.7	205.6	7.9
122	1/10/2022		2.0	6.7	1015.6	90.7	0.5	150.9	0.0
123	1/11/2022		0.6	4.4	1027.6	94.8	0.5	143.3	0.0
124	1/12/2022		1.6	3.7	1033.1	93.5	0.4	161.2	0.0
125	1/13/2022		2.5	6.4	1034.5	88.8	0.5	153.9	0.0
126	1/14/2022		1.5	5.2	1029.8	96.4	0.4	146.7	0.0
127	1/15/2022		1.8	2.8	1022.7	97.2	0.9	121.8	0.0
128	1/16/2022		4.0	6.0	1019.9	89.4	1.1	180.1	0.0
129	1/17/2022		5.8	7.0	1027.3	92.5	1.7	230.8	0.5
130	1/18/2022		6.3	8.4	1030.8	89.1	0.5	170.5	0.0
131	1/19/2022		4.2	5.6	1019.6	87.4	1.2	177.0	1.0
132	1/20/2022		3.3	5.3	1021.3	85.6	2.1	247.0	0.2
134	1/21/2022		3.0	5.2	1027.2	91.2	1.3	223.6	1.0
134	1/22/2022		4.8	6.0	1027.8	94.0	1.4	230.5	0.6
135	1/23/2022		4.8	5.6	1029.3	91.1	0.3	166.7	0.0
136	1/24/2022		3.6	4.9	1028.1	85.5	0.7	144.9	0.0
137	1/25/2022		2.7	3.5	1027.4	90.4	0.7	161.9	0.0
138	1/26/2022		2.2	2.8	1026.3	88.5	1.3	188.2	0.0
139	1/27/2022		5.3	7.8	1020.1	88.0	1.7	203.5	2.0
140	1/28/2022		5.5	8.6	1026.8	83.7	1.3	212.1	0.0
141	1/29/2022		8.6	11.6	1019.8	82.8	2.0	213.1	0.5
142	1/30/2022		5.5	8.4	1021.2	75.6	1.9	229.1	0.0
143	1/31/2022		4.4	6.1	1006.7	88.6	3.2	241.1	11.9
144	2/1/2022		5.8	8.8	1010.7	87.4	2.4	228.2	3.3
145	2/2/2022		8.5	10.9	1013.0	82.4	1.8	224.3	0.8
146	2/3/2022		7.5	8.8	1011.2	88.6	0.9	169.0	0.2
147	2/4/2022		7.1	9.6	1006.2	79.8	1.9	182.4	0.8
148	2/5/2022		5.6	8.4	1014.0	73.0	2.0	193.3	0.0
149	2/6/2022		6.7	8.7	1001.2	83.0	3.0	206.4	15.8
150	2/7/2022		5.0	7.8	1015.7	78.2	2.2	227.0	1.0

* Indicative only

Annex 6 **Ambient conditions at the field test sites** **Page 6 of 12**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity* [m/s]	Wind direction* [°]	Precipitation* [mm]
151	2/8/2022	Bornheim	8.7	11.3	1022.3	81.8	1.2	178.5	0.2
152	2/9/2022		9.1	11.7	1020.1	80.4	0.9	160.7	0.0
153	2/10/2022		5.4	9.6	1015.0	91.8	0.9	178.0	8.9
154	2/11/2022		3.6	7.3	1022.9	79.2	1.6	215.1	1.3
155	2/12/2022		1.8	6.8	1022.7	78.6	0.5	145.7	0.0
156	2/13/2022		5.3	12.2	1008.0	68.8	1.1	142.6	0.0
157	2/14/2022		9.6	13.1	997.9	68.5	1.9	157.5	0.0
158	2/15/2022		7.9	10.7	1004.5	72.2	1.6	174.9	0.0
159	2/16/2022		12.1	15.5	994.4	77.2	2.9	181.7	1.0
160	2/17/2022		10.5	15.0	999.5	66.4	3.6	234.4	2.0
161	2/18/2022		9.6	14.6	997.7	70.9	3.0	186.4	1.3
162	2/19/2022		6.8	9.3	1006.4	60.6	3.4	202.9	0.0
163	2/20/2022		9.4	12.2	1001.7	77.2	3.0	193.0	3.6
164	2/21/2022		6.2	11.6	997.9	76.3	3.7	236.8	11.4
165	2/22/2022		7.4	10.9	1012.2	81.1	1.9	203.2	1.0
166	2/23/2022		8.2	13.0	1018.1	69.6	1.3	174.7	0.0
167	2/24/2022		7.4	12.3	1007.6	75.0	1.7	175.0	3.1
168	2/25/2022		3.9	8.0	1017.3	82.4	1.3	196.5	3.8
169	2/26/2022		3.4	7.6	1027.9	83.4	0.4	143.7	0.0
170	2/27/2022		3.4	10.0	1025.8	71.6	0.8	143.8	0.0
171	2/28/2022		4.5	11.7	1024.7	61.3	0.8	146.4	0.0
172	3/1/2022		4.2	9.6	1022.4	61.5	0.4	145.0	0.0
173	3/2/2022		5.7	12.3	1017.3	53.6	0.3	148.7	0.0
174	3/3/2022		4.8	13.0	1012.9	57.0	0.4	142.8	0.0
175	3/4/2022		3.9	11.0	1014.5	59.6	0.4	137.4	0.0
176	3/5/2022		3.0	9.5	1015.0	64.1	0.4	138.9	0.0
177	3/6/2022		1.8	8.8	1018.4	65.0	0.8	130.4	0.0
178	3/7/2022								
179	3/8/2022								
180	6/21/2022	Niederzier							

* Indicative only

Annex 6 **Ambient conditions at the field test sites** **Page 7 of 12**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity* [m/s]	Wind direction* [°]	Precipitation* [mm]
181	6/22/2022	Niederzier							Not recorded
182	6/23/2022		24.0	32.0	998.8	58.5	0.9	108.2	
183	6/24/2022		20.7	25.7	996.1	77.3	1.0	202.6	
184	6/25/2022		20.6	25.9	999.8	67.5	0.8	164.5	
185	6/26/2022		17.9	20.2	1003.5	79.0	0.7	148.7	
186	6/27/2022		17.5	23.0	1005.2	79.1	0.5	188.4	
187	6/28/2022		18.0	25.4	1008.6	64.1	0.8	81.6	
188	6/29/2022		19.9	28.8	1002.4	64.7	0.5	66.7	
189	6/30/2022		19.4	30.0	1000.1	73.7	0.7	167.8	
190	7/1/2022		16.9	22.4	1006.7	67.7	1.1	209.1	
191	7/2/2022		19.1	27.9	1009.0	59.1	0.6	125.9	
192	7/3/2022		19.4	25.8	1006.7	62.0	0.6	183.0	
193	7/4/2022		17.9	25.9	1008.7	61.3	0.5	146.6	
194	7/5/2022		19.1	25.6	1010.6	59.4	0.5	208.7	
195	7/6/2022		16.5	22.8	1013.4	60.0	0.5	194.1	
196	7/7/2022		17.8	21.1	1011.7	68.8	0.9	225.3	
197	7/8/2022		18.4	25.6	1018.7	62.0	0.5	188.8	
198	7/9/2022		18.8	25.3	1015.2	66.2	0.6	178.2	
199	7/10/2022		16.7	21.9	1014.2	68.5	0.4	218.4	
200	7/11/2022		18.0	22.0	1012.4	75.2	0.3	183.2	
201	7/12/2022		20.4	30.3	1012.6	62.2	0.4	67.0	
202	7/13/2022		24.5	31.3	1009.0	51.6	0.6	156.1	
203	7/14/2022		20.7	26.9	1008.3	58.7	0.6	200.0	
204	7/15/2022		17.7	23.8	1010.8	57.3	0.5	180.2	
205	7/16/2022		18.1	25.5	1011.9	56.0	0.5	173.6	
206	7/17/2022		18.7	28.2	1014.5	51.6	0.5	99.5	
207	7/18/2022		24.2	36.1	1010.5	42.6	0.5	100.9	
208	7/19/2022		28.1	38.4	1005.1	37.0	1.2	66.6	
209	7/20/2022		25.6	31.8	1005.0	49.2	1.0	192.4	
210	7/21/2022		18.7	22.5	1007.9	86.3	1.1	212.4	

* Indicative only

Annex 6 **Ambient conditions at the field test sites** **Page 8 of 12**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity* [m/s]	Wind direction* [°]	Precipitation* [mm]
211	7/22/2022	Niederzier	19.0	23.4	1008.2	74.7	0.6	122.6	Not recorded
212	7/23/2022		19.7	26.5	1007.3	72.8	0.5	134.9	
213	7/24/2022		23.4	32.0	1005.8	60.0	0.5	137.6	
214	7/25/2022		22.7	28.2	999.3	59.9	0.7	164.8	
215	7/26/2022		19.4	25.1	1004.7	68.6	1.1	216.9	
216	7/27/2022		17.1	22.4	1007.9	57.9	0.6	128.0	
217	7/28/2022		19.2	24.8	1005.4	52.9	1.0	45.6	
218	7/29/2022		20.6	26.6	1004.5	58.9	0.6	131.3	
219	7/30/2022		20.4	27.7	1007.1	62.5	0.6	179.5	
220	7/31/2022		22.3	27.3	1005.3	61.5	1.3	196.1	
221	8/1/2022		21.6	26.7	1006.0	68.5	0.7	195.0	
222	8/2/2022		22.0	30.4	1005.9	60.6	0.7	139.3	
223	8/3/2022		25.6	34.5	1003.5	52.9	0.5	147.5	
224	8/4/2022		25.0	34.0	1001.5	59.3	0.4	140.4	
225	8/5/2022		19.1	23.2	1006.2	74.6	0.6	177.0	
226	8/6/2022		16.6	23.8	1015.0	58.6	0.7	115.6	
227	8/7/2022		18.3	26.7	1012.7	52.9	0.7	122.9	
228	8/8/2022		19.7	27.5	1012.9	55.3	0.7	135.1	
229	8/9/2022		22.4	29.4	1014.2	50.9	1.0	58.5	
230	8/10/2022		24.2	31.8	1012.5	43.3	1.0	44.5	
231	8/11/2022		24.4	32.6	1009.3	40.5	1.0	72.2	
232	8/12/2022		24.9	32.8	1006.4	36.0	1.2	74.3	
234	8/13/2022		24.4	32.8	1004.0	36.8	0.9	73.4	
234	8/14/2022		25.1	33.3	996.7	42.6	1.0	74.1	
235	8/15/2022		22.5	25.6	993.6	62.8	1.0	164.5	
236	8/16/2022		23.7	30.5	996.7	57.9	0.5	137.2	
237	8/17/2022		20.8	25.4	999.1	70.5	0.6	167.1	
238	8/18/2022		19.3	25.8	1001.8	78.8	0.5	168.0	
239	8/19/2022		20.5	27.0	1002.8	72.4	0.8	183.9	
240	8/20/2022		19.9	25.4	1005.4	75.2	0.7	183.1	

* Indicative only

Annex 6 **Ambient conditions at the field test sites** **Page 9 of 12**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity* [m/s]	Wind direction* [°]	Precipitation* [mm]
241	8/21/2022	Niederzier	18.9	26.1	1005.2	64.0	0.4	150.2	Not recorded
242	8/22/2022		21.1	28.3	1003.3	58.0	0.5	106.9	
243	8/23/2022		22.0	30.9	1003.9	60.4	0.4	112.7	
244	8/24/2022		24.5	33.3	1005.8	53.8	0.6	65.5	
245	8/25/2022		25.5	33.8	1003.4	43.8	0.8	76.9	
246	8/26/2022		20.8	23.5	1004.0	77.4	0.6	232.2	
247	8/27/2022		18.2	20.6	1005.3	75.6	0.5	207.1	
248	8/28/2022		19.3	24.3	1007.7	56.4	1.2	65.9	
249	8/29/2022		17.8	24.5	1009.2	56.7	0.6	84.9	
250	8/30/2022		21.7	28.6	1007.6	50.7	1.2	42.1	
251	8/31/2022		19.6	24.9	1008.5	69.8	0.9	59.8	
252	9/1/2022		20.2	26.8	1007.5	53.7	1.1	65.4	
253	9/2/2022		21.2	27.1	1003.0	41.5	2.0	75.2	
254	9/3/2022		19.7	26.8	1000.1	54.4	1.2	77.3	
255	9/4/2022		20.2	28.6	1005.8	65.6	0.4	117.1	
256	9/5/2022		22.5	31.5	1007.0	50.6	0.7	74.0	
257	9/6/2022		23.1	31.0	1003.4	59.2	0.8	126.5	
258	9/7/2022		20.1	26.5	1000.9	74.4	0.7	171.6	
259	9/8/2022		18.1	22.5	997.4	76.0	1.2	191.4	
260	9/9/2022		17.4	20.9	997.5	74.0	1.9	207.5	
261	9/10/2022		16.6	19.4	1000.4	82.4	1.9	212.1	
262	9/11/2022		17.2	22.8	1006.8	80.5	0.5	185.3	
263	9/12/2022								
264	9/13/2022								
265	10/13/2022	JRC Ispra							Not recorded
266	10/14/2022								
267	10/15/2022		13.9	22.0	992.3	89.2	0.2	94.2	
268	10/16/2022		15.3	22.0	998.4	89.5	0.2	100.1	
269	10/17/2022		14.6	22.4	1004.2	89.3	0.2	90.2	
270	10/18/2022		15.0	23.9	1002.2	87.3	0.3	119.3	

* Indicative only

Annex 6 **Ambient conditions at the field test sites** **Page 10 of 12**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity* [m/s]	Wind direction* [°]	Precipitation* [mm]
271	10/19/2022	JRC Ispra	14.9	24.1	997.7	86.5	0.2	111.9	Not recorded
272	10/20/2022		14.8	20.1	997.4	90.8	0.2	119.1	
273	10/21/2022		15.5	16.6	994.0	97.1	0.4	231.8	
274	10/22/2022		16.7	21.6	992.8	93.6	0.4	186.5	
275	10/23/2022		16.1	17.4	997.1	97.6	0.3	140.2	
276	10/24/2022		16.6	17.4	993.8	99.1	0.3	136.2	
277	10/25/2022		16.1	20.8	995.0	91.5	0.4	141.2	
278	10/26/2022		16.0	22.4	998.1	91.0	0.3	131.8	
279	10/27/2022		14.4	21.8	1003.0	90.5	0.3	127.6	
280	10/28/2022		14.0	23.0	1003.7	89.1	0.3	124.8	
281	10/29/2022		13.7	23.4	1001.7	88.5	0.3	118.8	
282	10/30/2022		12.9	20.8	998.9	89.0	0.2	103.8	
283	10/31/2022		13.1	22.5	998.0	88.8	0.2	108.8	
284	11/1/2022		11.4	16.7	998.7	95.0	0.2	96.1	
285	11/2/2022		10.9	17.8	999.1	91.8	0.3	113.9	
286	11/3/2022		12.6	16.0	994.4	95.1	0.2	90.5	
287	11/4/2022		11.3	16.7	981.0	84.1	0.7	170.1	
288	11/5/2022		11.2	20.0	987.6	62.1	0.7	173.1	
289	11/6/2022		9.0	15.4	993.3	70.1	0.4	146.4	
290	11/7/2022		6.6	15.4	995.9	83.1	0.3	119.2	
291	11/8/2022		7.1	14.0	996.9	88.4	0.3	96.0	
292	11/9/2022		10.0	13.4	995.4	93.0	0.1	59.4	
293	11/10/2022		11.2	17.3	1000.4	93.1	0.3	109.9	
294	11/11/2022		9.6	17.4	1008.8	91.2	0.3	123.2	
295	11/12/2022		8.3	14.9	1005.6	91.2	0.3	120.4	
296	11/13/2022		8.8	16.4	1000.8	83.2	0.3	111.8	
297	11/14/2022		8.6	10.4	998.4	95.3	0.2	108.9	
298	11/15/2022		6.7	9.3	992.4	98.2	0.2	80.6	
299	11/16/2022		9.7	13.6	981.1	93.5	0.3	105.5	
300	11/17/2022		9.2	14.6	978.2	91.6	0.3	120.2	

* Indicative only

Annex 6 **Ambient conditions at the field test sites** **Page 11 of 12**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity* [m/s]	Wind direction* [°]	Precipitation* [mm]
301	11/18/2022	JRC Ispra	10.7	16.1	977.1	81.7	0.5	175.3	Not recorded
302	11/19/2022		7.6	14.0	982.0	71.3	0.4	173.4	
303	11/20/2022		5.0	15.3	985.8	73.8	0.4	148.9	
304	11/21/2022		4.6	12.5	983.2	82.0	0.4	119.7	
305	11/22/2022		7.5	12.8	972.3	82.6	0.5	174.9	
306	11/23/2022		6.1	13.8	978.5	69.8	0.4	163.1	
307	11/24/2022		5.1	15.4	988.6	80.5	0.5	156.3	
308	11/25/2022		5.9	13.5	994.3	83.1	0.3	122.8	
309	11/26/2022		7.4	16.9	1000.6	72.8	0.5	178.7	
310	11/27/2022		4.0	11.8	1002.5	80.5	0.4	137.7	
311	11/28/2022		5.3	8.6	994.5	87.3	0.2	84.6	
312	11/29/2022		4.6	8.4	992.1	90.7	0.2	90.3	
313	11/30/2022		4.0	6.6	993.4	94.5	0.2	89.0	
314	12/1/2022		3.3	10.6	993.4	87.3	0.3	111.1	
315	12/2/2022		5.1	7.9	993.7	87.2	0.2	96.2	
316	12/3/2022		5.7	7.7	992.8	91.0	0.6	180.9	
317	12/4/2022		6.7	8.5	989.6	93.2	0.7	205.3	
318	12/5/2022		6.0	7.6	992.7	95.9	0.5	137.4	
319	12/6/2022		3.1	9.8	991.4	85.7	0.5	147.2	
320	12/7/2022		1.2	9.9	988.6	88.7	0.3	122.6	
321	12/8/2022		2.3	8.1	986.4	89.0	0.3	108.2	
322	12/9/2022		2.9	4.0	980.1	95.7	0.3	103.6	
323	12/10/2022		4.4	10.2	974.8	90.1	0.4	140.0	
324	12/11/2022		5.9	10.3	976.9	28.8	1.2	108.5	
325	12/12/2022		-2.7	4.8	984.3	82.3	0.4	121.4	
326	12/13/2022		1.0	4.4	985.8	76.5	0.3	106.1	
327	12/14/2022		0.6	5.4	982.1	86.4	0.2	94.9	
328	12/15/2022		-0.6	2.6	981.7	93.6	0.4	123.0	
329	12/16/2022		3.1	6.6	980.1	95.7	0.2	97.0	
330	12/17/2022		3.8	11.2	991.8	88.6	0.3	123.3	

* Indicative only

Annex 6 **Ambient conditions at the field test sites** **Page 12 of 12**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. temperature (max) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity* [m/s]	Wind direction* [°]	Precipitation* [mm]
331	12/18/2022	JRC Ispra	4.2	8.1	1006.4	78.3	0.3	97.9	Not recorded
332	12/19/2022		1.3	6.2	1008.4	94.2	0.2	111.7	
333	12/20/2022		1.9	8.2	1003.4	90.9	0.2	86.4	
334	12/21/2022		4.9	10.4	996.4	87.6	0.3	115.4	
335	12/22/2022		2.2	9.1	992.8	92.3	0.4	128.5	
336	12/23/2022		4.5	12.1	990.8	90.0	0.4	136.7	
337	12/24/2022		6.0	9.7	992.7	94.8	0.3	126.0	
338	12/25/2022		8.1	11.1	999.1	88.4	0.3	152.9	
339	12/26/2022		7.5	10.6	1000.3	90.1	0.3	112.8	
340	12/27/2022		4.6	13.1	1000.4	88.4	0.4	144.2	
341	12/28/2022		6.3	10.3	1001.2	80.6	0.3	136.8	
342	12/29/2022		5.2	10.8	997.3	86.4	0.3	120.0	
343	12/30/2022		6.4	8.7	997.0	85.9	0.2	93.2	
344	12/31/2022		6.3	10.5	1004.1	88.5	0.3	131.7	
345	1/1/2023		8.7	10.3	1006.1	96.3	0.1	90.1	
346	1/2/2023		9.5	10.3	1004.6	98.7	0.1	90.5	
347	1/3/2023		9.7	10.8	1004.3	98.7	0.1	74.8	
348	1/4/2023		7.3	12.3	1004.8	93.8	0.3	131.1	
349	1/5/2023								
350	1/6/2023								

* Indicative only

Appendix 2:

Methods used for filter weighing

Performance of weighing and handling of the filters

Weighing takes place in an air-conditioned weighing chamber. Conditions are as follows: 20 °C ±1 °C and 45% ± 50% rel. humidity and thus meet the requirements of EN 12341.

Filters for the field test are weighed manually. For further processing, filters incl. the control filters are placed on sieves to avoid cross-loading.
Conditions for initial and back weighing had previously been defined and are in line with the specifications of standard EN 12341.

Before sampling = pre-weighing	After sampling = post-weighing
Conditioning > 48 hours	Conditioning > 48 hours
Filter weighing	Filter weighing
Repeated conditioning > 12 hours	Repeated conditioning 24 to 72 hours
Filter weighing and immediate packing	Filter weighing

Blank value samples both from the weighing chamber and the field are used for the purpose of quality assurance. In doing so, the requirements of standard EN 12341 are taken into account.

Weighed filters are kept separately 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. Unloaded filters shall be stored no longer than 2 months before sampling. Should this period be exceeded, initial weighing will be repeated.

Loaded filters must be brought to the weighing chamber within a month. They are then weighed within a month.

Appendix 3 Certificate of Accreditation

DAkkS
Deutsche
Akkreditierungsstelle

Akkreditierung

Die Deutsche Akkreditierungsstelle bestätigt mit dieser **Teil-Akkreditierungsurkunde,** dass das Prüflaboratorium

TÜV Rheinland Energy GmbH
Am Grauen Stein, 51105 Köln

die Mindestanforderungen gemäß DIN EN ISO/IEC 17025:2018 für die in der Anlage zu dieser Urkunde aufgeführten Konformitätsbewertungstätigkeiten erfüllt.
Dies schließt zusätzliche bestehende gesetzliche und normative Anforderungen ein, einschließlich solcher in relevanten sektoralen Programmen.

Die Anforderungen an das Managementsystem in der DIN EN ISO/IEC 17025 sind in einer für Prüflaboratorien relevanten Sprache verfasst und stehen insgesamt in Übereinstimmung mit den Prinzipien der DIN EN ISO 9001.

Diese Akkreditierung wurde gemäß Art. 5 Abs. 1 Satz 2 VO (EG) 765/2008, nach Durchführung eines Akkreditierungsverfahrens unter Beachtung der Mindestanforderungen der DIN EN ISO/IEC 17011 und auf Grundlage einer Bewertung und Entscheidung durch den eingesetzten Akkreditierungsausschuss ausgestellt.

Diese Teil-Akkreditierungsurkunde gilt nur in Verbindung mit dem Bescheid vom 18.11.2022 mit der Akkreditierungsnummer D-PL-11120-02.
Sie besteht aus diesem Deckblatt, der Rückseite des Deckblatts und der folgenden Anlage mit insgesamt 33 Seiten.

Registrierungsnummer der Teil-Akkreditierungsurkunde: **D-PL-1112-02-01**
Sie ist Bestandteil der Akkreditierungsurkunde D-PL-11120-02-00.

Berlin, 18.11.2022

Im Auftrag Dr. Heike Manke
Abteilungsleitung

Diese Urkunde gibt den Stand zum Zeitpunkt des Ausstellungsdatums wieder. Der jeweils aktuelle Stand der gültigen und überwachten Akkreditierung ist der Datenbank akkreditierter Stellen der Deutschen Akkreditierungsstelle zu entnehmen (www.dakks.de).

Siehe Hinweise auf der Rückseite

Figure 72: Certificate of accreditation according to EN ISO/IEC 17025:2018 - Page 1

Deutsche Akkreditierungsstelle

Standort Berlin
Spittelmarkt 10
10117 Berlin

Standort Frankfurt am Main
Europa-Allee 52
60327 Frankfurt am Main

Standort Braunschweig
Bundesallee 100
38116 Braunschweig

Die Deutsche Akkreditierungsstelle GmbH (DAkkS) ist die beliehene nationale Akkreditierungsstelle der Bundesrepublik Deutschland gemäß § 8 Absatz 1 AkkStelleG i. V. m. § 1 Absatz 1 AkkStelleGBV. Die DAkkS ist als nationale Akkreditierungsbehörde gemäß Art. 4 Abs. 4 VO (EG) 765/2008 und Tz. 4.7 DIN EN ISO/IEC 17000 durch Deutschland benannt.

Die Akkreditierungsurkunde ist gemäß Art. 11 Abs. 2 VO (EG) 765/2008 im Geltungsbereich dieser Verordnung von den nationalen Behörden als gleichwertig anzuerkennen sowie von den WTO-Mitgliedsstaaten, die sich in bilateralen- oder multilateralen Gegenseitigkeitsabkommen verpflichtet haben, die Urkunden von Akkreditierungsstellen, die Mitglied bei ILAC oder IAF sind, als gleichwertig anzuerkennen.

Die DAkkS ist Unterzeichnerin der Multilateralen Abkommen zur gegenseitigen Anerkennung der European co-operation for Accreditation (EA), des International Accreditation Forum (IAF) und der International Laboratory Accreditation Cooperation (ILAC).

Der aktuelle Stand der Mitgliedschaft kann folgenden Webseiten entnommen werden:
EA: www.european-accreditation.org
ILAC: www.ilac.org
IAF: www.iaf.nu

Diese Akkreditierungsurkunde ist Eigentum der Deutschen Akkreditierungsstelle.

Figure 73: Certificate of accreditation according to EN ISO/IEC 17025:2018 - Page 2

Appendix 4: Operation manual

USER MANUAL

EDM 280
Environmental dust monitor 19 inch rack version

For continuous outdoor measurements

MANUFACTURER INFORMATION

User manual for environmental dust monitor, 19-inch rack version, EDM 280

Version: 1.01

Previous version: 0.00

Production date: 17.07.2022

Document scope: 70 Pages

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Please read the operating manual carefully before putting the device into operation. The manufacturer is not liable for damage resulting from improper installation, use, cleaning or handling.

TRADEMARK AND COPYRIGHT INFORMATION

In many cases, the software and hardware names referred to in this document are registered trademarks and should be treated as such.

For reasons of technical development or clarity, illustrations may differ from the actual appearance. No claims to the delivery of identical products may therefore be derived from the illustrations.

This document, **Manual_E_EDM280_V1-01_(Stand-02-05-2023).docx**, refers to the complete environmental dust monitor model EDM 280 as a 19″ rack version, even if individual programme modules or device components have not been purchased.

The document refers to the current device design status at the time this documentation was created (see page 2 above for production date).

CONTENTS

ILLUSTRATIONS

TABLES

ABBREVIATIONS

- A   Ampere; unit of electrical current
- °C   Degrees Celsius; unit of temperature
- CEN   European Committee for Standardization (French: Comité Européen de Normalisation)
- cm   Centimetre; unit of length; 1 cm = 0.01 m
- DIN   German Institute for Standardization (German: Deutsches Institut für Normung). DIN standards can be national standards (DIN), European standards (DIN EN) or international standards (DIN EN ISO)
- EMC   Electromagnetic compatibility. Interference from electrical or electromagnetic effects on or by other devices
- EN European standard. Rule developed through a public standardisation process and put into effect by a European committee for standardisation (e.g. CEN)
- °F   Degrees Fahrenheit; unit of temperature
- ISO   International Organization for Standardization. Association of standardisation organisations that develops international standards
- l/min   Litres per minute; unit of volume flow
- LAN   A local area network or LAN is a computer network in which a wide range of different devices (computers, printers, etc.) are connected locally.
- LED   Light-emitting diode (LED)
- Modbus   Communication protocol with master/slave architecture (master = PC, slave = measuring system)
- MTBF   Mean time between failures; a term for wear parts that need to be serviced or can be repaired
- mV   Millivolt; derived unit of electrical potential; 1 mV = 10^{-3} V
- mW   Milliwatt; unit of power; 1 mW = 10^{-3}W
- nm   Nanometre; unit of length; 1 nm = 10^{-9} m
- µm   Micrometre; unit of length; 1 µm = 10^{-6} m
- OVC   Overvoltage category; determines the required insulation strength of the components used in the low-voltage power supply network
- p/l   Particles per litre; unit of number concentration
- PD   Pollution degree; classification depending on the amount of dry pollution and condensation in the environment
- PM   Particulate matter
- RoHS   Restriction of Hazardous Substances, directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment
- TC   Total counts, total particle concentration
- TCP/IP   Transmission Control Protocol/Internet Protocol, network protocol
- TSP   Total suspended particles, dust mass fraction without standard reference. Takes into account all particles suspended in the air, typically particle sizes up to approx. 100 µm aerodynamic diameter
- USB   Universal serial bus. Interface for data transfer between a computer and external devices
- VAC   Volts AC (alternating current)
- VDC   Volts DC (direct current)

1 | Introduction

The EDM 280 is a stationary environmental dust monitor used to determine dust mass fractions and the particle number size distribution in outdoor air. It consists of a sampling system, a weather sensor, a sampling tube holder (19-inch installation) and a measuring module (19-inch slide-in module). The measuring module contains the aerosol spectrometer, the centrepiece of the measurement technology. Operation is intuitive using a touch display. The EDM 280 is the latest development in GRIMM's successful series of stationary environmental dust monitors. It combines the advantages of its predecessors, the EDM 180 and EDM 180+, with significant improvements to the hardware and software.

Advantages of the EDM 280 include:

- Improved optical measuring cell, 72 logarithmically equidistant size channels
- Improved lower detection limit of particle size at 178 nm
- PSL traceable particle size determination in accordance with ISO 21501-1
- Conformity in accordance with DIN EN 16450, VDI 4202 Blatt 3
- New low-maintenance sampling design with improved inlet efficiency at high wind speeds and adaptive heating for optimised sample air conditioning, including for high dust loads and for aerosols with a high proportion of ionic components
- Improved electronics
- Low energy requirement
- Output of six dust mass fractions TSP, PM_{10}, PM_4, $PM_{2.5}$, PM_1 and PM_{coarse} of the total particle concentration and particle number size distribution, as well as weather data
- Measurement of temperature and calculation of relative humidity in the measuring cell
- Condensate trap in the sample air path with automatic condensate drainage
- Digital volume flow control and flow sensor
- Easy operation with a graphical user interface on the integrated touch display
- Extended diagnostics in self test and during measuring operation, descriptive error messages and easy-to-understand wear indicators
- Flexible interfaces (RS-232, USB-B, Ethernet, USB memory)
- Flexible data protocols such as GRIMM protocol, Modbus/TCP, GESYTEC / Bayern-Hessen protocol

The proven advantages of the previous models have also been retained. These include:

- Aerodynamic focusing of the sample volume flow in accordance with ISO 21501-1
- Full flow analysis of the entire sample volume flow
- Internal particle-free purge air circuit to protect the optical components
- Verification of the functionality of all optical, pneumatic and electronic components by self test at the beginning of the measurement and optionally at adjustable intervals
- Robust design and low maintenance
- Quiet operation

2 | Basic operating requirements

2.1 Explanation of symbols

The following graphic symbols are used to indicate important information.

	This symbol indicates useful tips for easy operation of the device.
	**Attention** This symbol indicates a situation which if not avoided may result in damage to property and the environment.
	**Caution** Risk of blindness from laser radiation inside the device
	**Danger** Touching live parts poses an immediate risk of fatal injury.
CE	Marking for products in the extended internal market of the European Economic Area that meet safety, health and environmental protection requirements.
	Protection class I. All exposed parts are earthed with the mains-side protective conductor to ensure that they cannot receive dangerous voltage in the event of an error with uncontrolled current flow.
	Mandatory action symbol "Read the operating manual"
IP20	Degree of protection. The sequence of digits defines the degree of protection against the ingress of foreign bodies (first digit) and water (second digit) into the housing or system.

2.2 General information

Grimm Aerosol Technik GmbH (referred to as GRIMM below) has made every effort to ensure the accuracy and completeness of this document. We accept no liability for errors, omissions or future changes in the information provided and assume no responsibility for any damage caused directly or indirectly by use of this information and/or use of hardware or software.

GRIMM is not liable for damage resulting from misuse of patent rights or rights against third parties.

Because our ongoing development efforts continuously improve the functions of our hardware and software, the descriptions and illustrations in the manual may differ from the versions available to you. If necessary, please request the current version of this document.

2.3 Warranty

GRIMM warrants that the device described in this document has been designed and manufactured in accordance with existing technical requirements for the application described and that our strict quality control ensures that it is free from defects in material or assembly.

However, we provide no further guarantee or warranty for any application-specific function or for damage due to defects in material or assembly. Each instrument is recorded during production technology and precisely logged, in particular calibration. In the event of a material defect or defect of title at the time of the transfer of risk, GRIMM will provide, at GRIMM's discretion, a replacement delivery or rectification within a reasonable period of time. This does not apply to operating errors. GRIMM will carry out the repair or repairs free of charge at its factory, with only the transport and associated costs to be borne by the customer. On-site repairs will only be undertaken against reimbursement of travel and service costs. If the repair is not successful or the replacement delivery is defective, the customer expressly reserves the right to reduce or withdraw at the customer's discretion. However, there is no right of withdrawal for insignificant defects. The costs of any further claims that may arise from the warranty will not be borne by GRIMM.

GRIMM provides the warranty for the goods sold only if they are used under normal conditions and in accordance with the instructions in this manual.

The warranty expires after 12 months from the date of delivery ex works. The costs of returns for warranty work will be borne by the customer.

This warranty does not apply for the following exceptions:

- We assume liability for 90 days for spare parts that are replaced or repaired during the warranty period in order to enable further operation of the device, assuming that it is only used normally.
- The supplier is not liable for subcontractor products or batteries or consumables, only the original warranty remains valid.
- Without written confirmation from GRIMM, GRIMM provides no warranty for parts from subcontractors that have been modified or have been removed or installed by untrained personnel.
- All of the above supersedes any other warranty agreements or limitations. No further liability claims are granted, in particular regarding use beyond normal use.
- The purchaser is responsible for use or operation. The purchaser must observe the legal requirements and obligations and operate the device in accordance with the legal and operational regulations. Any deviations from this will lead to the exclusion of warranty.
- All legal measures against GRIMM cease to be valid after more than 12 months, regardless of the party initiating them.
- Both purchaser and seller agree that this limitation of warranty, which sets out the requirements and limitations, shall not be called into question. Both partners are registered traders under German law.

Irrespective of the legal grounds, GRIMM and its agents (employees, representatives, bodies) are liable for damages only on the basis of intent and gross negligence and for the negligent breach of fundamental contractual obligations (the fulfilment of which is essential to enable proper performance of the contract and on the fulfilment of which the customer regularly relies and may rely). In the latter case, liability is limited to foreseeable damage typical for the contract. In the event of ordinary negligence, liability for indirect and unforeseen damage, loss of production and use, loss of profit, loss of savings and financial loss arising from claims by third parties is excluded. The above limitations of liability and exclusions of liability do not apply to damages arising from injury to life, limb or health and damages under product liability law. With the exception of cases of intent, claims arising from injury to life, limb or health or claims arising under product liability law, the period set out above (12 months) applies mutatis mutandis to the period of limitation for claims for damages; in this respect, the respective statutory limitation period applies.

In the event of any dispute, the place of jurisdiction is Hamburg, Germany.

2.4 Safety regulations

The manufacturer accepts no liability, direct or indirect, if the operator opens or manipulates the device. To ensure safe operation, the user must follow the instructions in the user manual.

If it can be assumed that safe operation is no longer possible, the device must be shut down and secured against unintentional operation. It can be assumed that safe operation is no longer possible if:

- The mains cable or mains plug are damaged
- The device shows visible damage
- The device has been stored under adverse conditions for an extended period, or
- After heavy operational demands

Cold devices, for example after transport at low temperature, must be acclimatised for at least four hours before starting operation. Disregarding this acclimatisation time can cause damage to internal components and electronics from condensation.

2.4.1 Electrical safety

Within the framework of the EMC Directive, the device meets the requirements of EN 61326-1 (2013), the requirements for radio frequency disturbance of EN 55011 (2016) +A1 (2017) and EN 61000-3-2 (2019) and discharge immunity of EN 61000-4-2 (2009), EN 61000-4-4 (2012), EN 61000-4-5 (2014) + A1 (2017) and EN 61000-4-11 (2004) + A1 (2017), as well as the requirements for electrical safety of EN 61010-1 (2020).

Before using the EDM 280, check to ensure that the mains voltage is within the permitted range for the device. The wide-range power supply unit is designed for AC voltages from 100 to 240 VAC at 50 to 60 Hz. The EDM 280 may only be operated on a circuit with an installed residual current circuit breaker.

The device is protected by electronic overcurrent fuses. The fuse (4 A delay fuse) trips only in the event of a serious error.

Risk of electric shock
Before starting any work in the measuring module, the IEC connector on the back of the device must be disconnected. The fuses installed inside the module may only be replaced by trained service personnel.

2.4.2 Testing of electrical devices in accordance with VDE 0701, VDE 0702, EN 50678 and EN 50699

At some installation locations, the operator is required to carry out an annual test of electrical equipment in accordance with the VDE 0702 or EN 50699 standard. The operator is also responsible for electrical safety after opening the measuring module (for example for maintenance work). In these cases, a repeat test in accordance with VDE 0701 or EN 50678 is usually required.

The following is recommended for the test

The measuring module is supplied with mains voltage via the IEC connector. It should therefore be tested in accordance with the specifications for protection class I. The anodised front is a design element and has no protective effect. The switch on the front does not switch the mains voltage. It is therefore sufficient to check the sheet steel sides of the housing to measure the protective conductor resistance.

The sampling tube holder and the sampling tube are supplied with protective extra-low voltage (24 VDC) from the measuring module and connected to the functional earth. If required, an insulation measurement can be made on the conductive screws on the top of the sampling tube holder and on the sampling tube jacket.

2.4.3 Laser safety

In normal operation, the device meets the requirement for class 1 lasers as per EN 60825-1 (2022). Class 1 lasers meet the highest protection class, which means that no potentially hazardous radiation is accessible during normal operation.

The laser diode used in the EDM 280 is optically encapsulated within the measuring cell during operation. If the measuring cell is damaged or open, the laser protection class is 3B as per EN 60825-1 (2022).

Caution Risk of blindness from laser radiation inside the measuring cell
Never operate the measuring module with an open or damaged measuring cell.
Never operate with the inlet nozzle unscrewed.

2.4.4 General workplace safety

The EDM 280 housing is equivalent to degree of protection IP20. There is no protection against water, which is why the instructions for installation in measuring containers or indoors must be followed. During installation, ensure that the measuring module is guided by both handles. Installation of the sampling tube through the roof bushing into the 19″ assembly should be carried out by two people. When operating the lift to connect the sampling tube to the measuring module, do not grip the sampling assembly. The double-walled design of the sampling tube keeps the outside cool. Exposed surfaces of the sampling tube can heat up slightly. To prevent injury and health hazards, appropriate work clothing such as work boots with steel toecaps and non-slip soles must be worn during all installation and maintenance work, particularly when working on the roof of a measuring container or in wet conditions.

2.5 Areas of application and suitable use

2.5.1 Areas of application and general information

The EDM 280 model environmental dust monitor is suitable for all types of aerosol measurements, and especially for continuous or automated measurements provided that the stated specifications are met. Measurements of this kind can be: Continuous measurement of the particulate matter fractions PM_{10} and $PM_{2.5}$, measurements of other particulate matter fractions such as TSP, PM_4, PM_1 or PM_{coarse}, either indoors or outdoors, determination of particle size distribution, questions arising in aerosol research.

To protect the EDM 280 from unauthorised access during measuring operation in measurement networks, the system must be operated in a locked container or a locked measuring station.

2.5.2 Volume flow measurement and control

The sample volume flow is automatically set to the set value of 1.2 litres per minute under the conditions inside the measuring module. The sample volume flow displayed and output is converted to the ambient conditions of the weather sensor at the inlet. It therefore generally deviates from 1.2 litres per minute. All concentration values displayed and output are also output to the ambient conditions, i.e. to the measured values of the weather sensor. Digital volume flow control ensures the specified accuracy for every operation within the technical specifications set out in Table 3-1 in section 0 at the measuring location.

2.5.3 Information about operation and remote control

The EDM 280 can be controlled via various interfaces such as RS-232, USB-B, Ethernet or wirelessly via WLAN. Data transfer is limited only by the maximum cable length or the range of the radio connection.

2.5.4 Notes on starting and stopping the measuring operation

To start and stop measuring operation, the EDM 280 must be supplied with voltage by the power supply unit. Permitted mains voltages are documented in the technical specifications. The measurement starts once the device has completed the self test. Measuring operation can be started or stopped at any time.

2.5.5 Memory functions on interruption of the mains voltage

The EDM 280 has a memory function in the event of a power failure. If the power supply is interrupted, the measurement continues automatically when the voltage is restored.

2.5.6 Preparatory workflows and checks

Each new measurement starts with a self test, which provides information about the device status. After successfully completing the self test, the EDM 280 switches to measuring operation.

2.6 Restrictions of the area of application

To ensure that the EDM 280 functions correctly, the conditions for temperature, relative humidity and ambient pressure listed in Table 3-1 in section 0 must be adhered to. In case of doubt and for questions regarding use of the EDM 280, please contact your dealer or sales representative at GRIMM.

2.7 Transport

The EDM 280 may only be transported in its original packaging. The aerosol inlet must be closed with the protective cap and the dust cover must be pushed over the opening. The transport lock must be screwed into the transport position, as otherwise internal components are easily damaged by knocks.

2.8 Storage

For storage of the device, the original packaging should be used and the temperature and humidity as specified for storage and transport in section 0 should be adhered to. During storage, the aerosol inlet must be closed with the protective cap and the dust cover must be pushed over the opening.

2.9 Disposal

2.9.1 Recommendations for disposal of waste

The filters used can be disposed of in household waste after use. The button cell used in the EDM 280 should be disposed of properly.

2.9.2 Expected life time of the device

When used as intended and with regular maintenance by GRIMM Service or authorised service technicians, the EDM 280 has a service life of many years. It is not possible to say what is a normal life time as it depends on the application in question.

2.10 Repairs

In the knowledge that defective or inactive devices are detrimental to the customer, GRIMM's policy is to address these customer issues as quickly as possible. If a device is found to have stopped or failed, please contact the nearest GRIMM sales office or relevant dealer without delay. Before sending in any of our devices for servicing, please contact the GRIMM Service department by e-mail at: service@grimm.durag.com and provide the following data:

- Device model (on the rating plate on the back of the device)
- Serial number (on the rating plate on the back of the device)
- Detailed error description, where possible with the status message displayed and the last data log from the USB flash drive
- Order date and your order number (except when under warranty)
- Your billing address
- Your shipping address

Attention
Before sending the device in for servicing, please ensure that it is free from contamination that is hazardous to health and please include the completed contamination declaration.

3 | Technical information

3.1 Overview of components and measuring principle

The EDM 280 is a stationary aerosol spectrometer for the simultaneous detection of airborne particulate matter concentrations in outdoor air. Among the measured values it records are: dust mass fractions TSP, PM_{10}, PM_4, $PM_{2.5}$, PM_1 and PM_{coarse}, total particle concentration (TC) and particle number size distribution in 72 size channels. In addition, ambient temperature, humidity and ambient pressure can also be output, as well as wind speed, wind direction and precipitation intensity, depending on the version.

The schematic structure of the EDM 280 is shown in Figure 3-1.

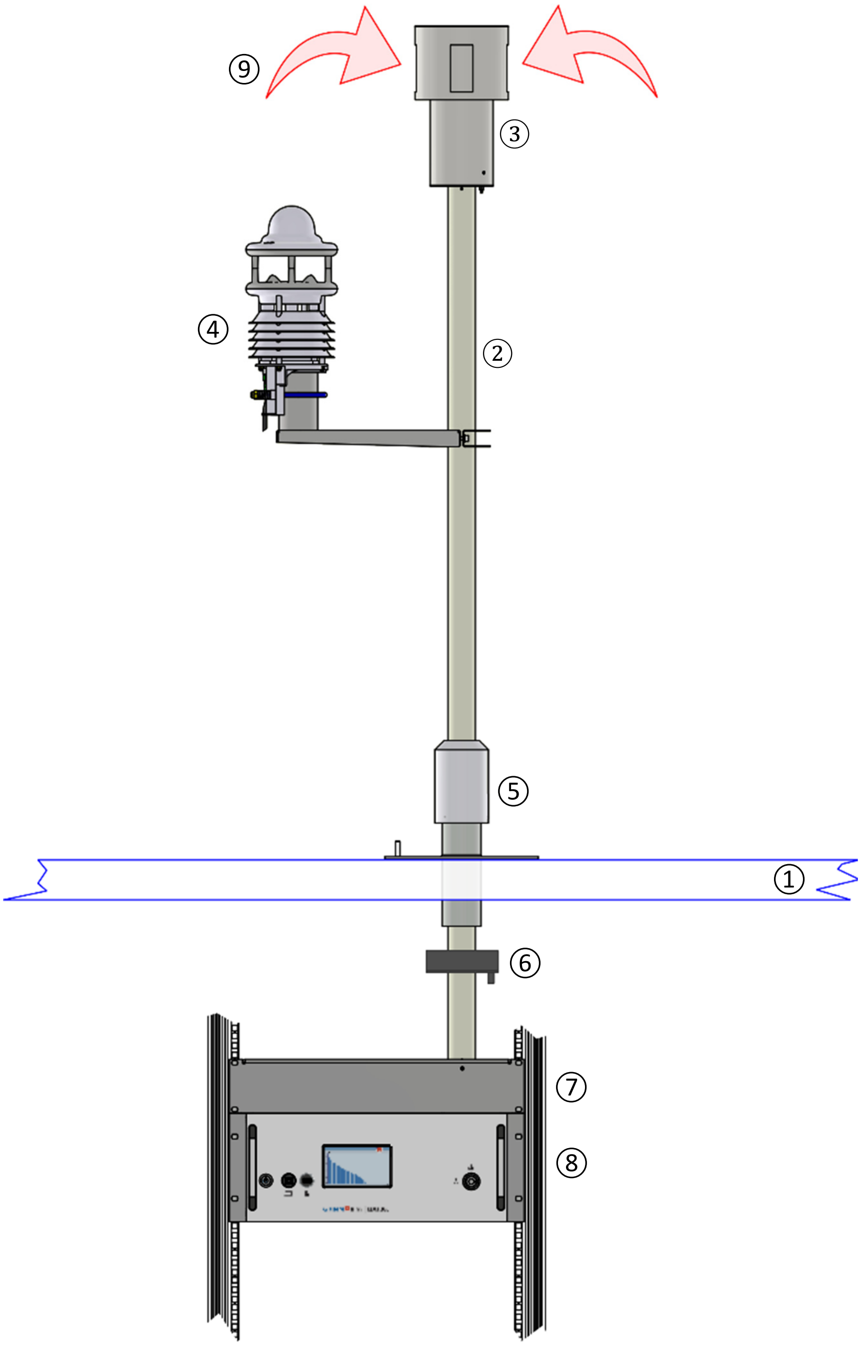


Figure 3-1: Schematic structure of the EDM 280

The EDM 280 is designed for installation in a measuring container with a roof bushing ①. It essentially consists of the sampling assembly and measuring module. The sampling assembly is designed for permanent installation in a 19" rack and is made up of a sampling tube ② with the sampling head ③ and weather sensor ④, a roof flange with a rain deflector ⑤, and on the inside the water trap ⑥ and sampling tube holder ⑦. The measuring module ⑧ is mounted in the rack under the sampling tube holder and connected to the sampling assembly in just a few steps. It contains the aerosol spectrometer and all components prone to wear, so it can be easily removed for maintenance and calibration. The touch display can be used to control measuring operation on site, allowing you to view the measured values and device status and to make settings.

The sample air ⑨ is drawn in by the Sigma-2 sampling head and fed vertically through the sampling tube for sample air conditioning into the optical measuring cell in the measuring module. Adaptive heating in the sampling tube is actively adjusted to ensure that condensation cannot be formed as the aerosol passes through to the measuring cell, at the same time ensuring that there is as little warming of the aerosol as possible.

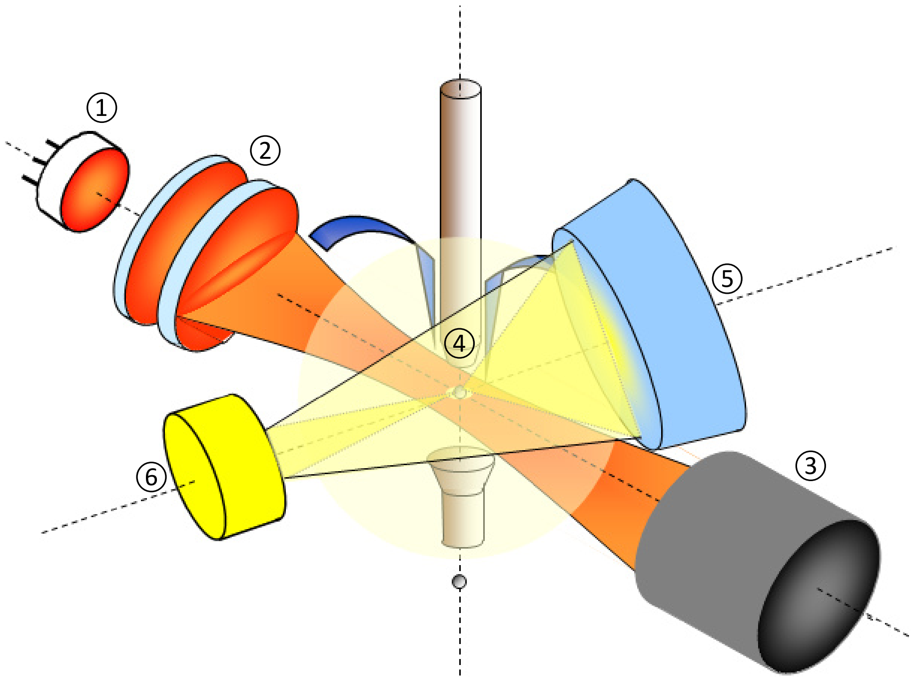


Figure 3-2: Schematic structure of the optical measuring cell

The device works using the principle of scattered light measurement on single particles. A laser diode ① serves as the light source. An illumination optics unit ② is used to focus the light as a narrow laser band into the measuring cell and then channel it to the measuring field in a light trap ③. All sample air is aerodynamically focussed into the focal point of the laser band ④, as set out in Annex A.3 "Definition of the sensing zone", ISO 21501-1 (2009). When a particle crosses through the laser beam, it is illuminated by the laser beam. This produces scattered light. The scattered light is collected by a wide-range lens ⑤ on a photodetector ⑥. The position of the detector is perpendicular to the laser beam. Each electrical signal from the detector is counted and classified after appropriate amplification. The count events are output in 72 size increments. The size scale of the classification channels was determined on the basis of a unique, logarithmically equidistant allocation in diameter for polystyrene latex (PSL) spheres. This means that the diameter corresponds to a “light scattering equivalent particle diameter” for polystyrene latex spheres as defined in ISO 21501-1 (2009).

The dust mass fractions are calculated on the basis of the measured particle number size distribution. Assuming spherical particles, a volume distribution is calculated and, in a further step, a mass distribution is calculated by multiplication with size-dependent density factors. For the calculation of the PM fractions, results from comparative measurements in outdoor air with gravimetric dust collectors are included.

The optical measuring cell is followed by a condensate trap, which is automatically emptied during the self test, and a two-stage dust filter with a pre-filter and a residual dust filter. The sample volume flow is adjusted automatically. The sample air pump also conveys the purge air, which is taken from the pump outlet air in the device through an ultrafine filter and kept constant by a purge air controller. The purge air prevents contamination of the illumination and detection optics and is used as particle-free reference air during the device self test.

The device is controlled using either the touch display on the front of the device or via one of the interfaces (RS-232, USB-B, Ethernet) and one of the data protocols (GRIMM protocol, Modbus TCP, GESYTEC / Bayern-Hessen protocol).

3.2 Technical data

Table 3-1: Technical data EDM 280

Specification	Description
Measuring principle	Light scattering on single particles, aerodynamically focused measuring volume
Sample volume flow	1.2 l/min, accuracy ≤ ± 2%, controlled to be constant at the measuring orifice
Particle size range	0.178 µm < Do < 29.4 µm (Do = optical latex equivalent diameter)
Size channels	72 logarithmically equidistant gradations, 32 channels per decade
Mass calculation	PM values Optimised for best correlation to the reference method filter collector with gravimetric mass determination (EN 12341:2014)
Mass concentration	0 … 12,000 µg/m³ for PM_{10} (with 10% linearity error for the measurement of 0 … 5,100 µg/m³ for $PM_{2.5}$ Arizona Dust A1 ultrafine)
Limit of detection	0.1 µg/m³ for TSP
Zero level	≤ 0.1 µg/m³ for TSP
Data output	TSP, PM_{10}, PM_4, $PM_{2.5}$, PM_1, PM_{coarse} as well as sensor data and status information on the touch display, via interface or USB flash drive
Weather sensor measuring range	Temperature: -50 … 60 °C, ± 0.2 °C (-20 … 50 °C), otherwise ± 0.5 °C (> - 30 °C) Rel. humidity: 0 … 100% RH, ± 2% RH Air pressure: 300 … 1200 hPa, ± 0.5 hPa (0 … 40 °C)
Time resolution	6 seconds
Storage interval	Selectable, 6 seconds, 1, 5, 10, 15, 30, 60 minutes, daily average value
Data interfaces	RS-232 (selectable with 9600, 19200, 57600, 115200 baud) Ethernet (10BASE-T/100BASE-TX) USB flash drive (USB 2.0), FAT32 formatted, max 500 mA current consumption USB-B (service interface with 115200 baud/s)
Data protocol (ASCII)	GRIMM protocol Modbus TCP GESYTEC / Bayern-Hessen protocol
Self-diagnosis	At every start and automatically at configurable intervals
Operation	Using touch display or via data interface
Power supply	Wide-range input 100 to 240 VAC at 50 to 60 Hz 250 VA connected load, fuse 4 A delayed action
Power consumption	Typical 25 W (continental warm) Typical 40 W (tropical humid) Typical 80 W (polar cold). Typical 220 W (maximum configuration, all heaters at maximum power)
Overvoltage category	OVC II
Sample air conditions at the installation location	Temperature: -40 … 60°C Max relative humidity: 100% (-40 °C) … 30% (60 °C) Max absolute humidity: 60 g/m³ Air pressure: 530 … 1080 hPa
Conditions in the measuring container	Temperature: 5 … 40 °C Relative humidity: 5 … 90%, non-condensing
Degree of protection	IP20, pollution degree PD: 2
Transport and storage	Temperature: -20 … +50 °C, relative humidity: < 95% (non-condensing)
Dimensions	Sampling tube: 1500 mm (H) x Ø 45 mm (tube) / Ø 105 mm (sample inlet) Sampling tube holder: 88.9 mm (H) x 441 mm (W) x 156 mm (D) Measuring module: 180.5 mm (H) x 434 mm (W) x 320 mm (D)
Weight	Total: 20.5 kg (with weather sensor WS300, holder and cables) Sampling tube with sampling head: 5.3 kg Sampling tube holder: 2.4 kg Measuring module: 10.45 kg

3.3 Scope of delivery and optional accessories

3.3.1 Scope of delivery

The following list sets out the scope of delivery for the EDM 280 set, item number 4019844, with item numbers and product names. To verify one or more systems, an EDM 280 field test kit, item number 4031934, is required.

Table 3-2: Scope of delivery for EDM 280 set

Item no.	Name
4019843	EDM 280 4019845 19″ measuring module EDM 280 4034841 Mounting kit EDM 280 4019846 Packaging EDM 280 1201650 USB flash drive 2 GB 4033774 Hex key 8 mm straight 4035325 DB9 Null-modem cable 2 metres
4020436	Sampling tube holder 19″ heated complete 4020438 Packaging PNR Sigma-2 head
4019859	282L-1.5 PNR heated for LUFFT sensor (with Sigma-2 head PNS)
1200097	159L LUFFT sensor WS 600
1200010	189 roof flange for PNR d45 mm complete
1204636	USB cable 2.0 A connector to B connector
1200654	Mains cable 250 VAC 10 A C13/EU connector 1.8 m
Accessories required for verification	
4031934	Test – field test kit accessories EDM 280 with adapter for sample inlet, zero air filter, leak test set

3.3.2 Optional accessories

The following list contains optional accessories for the EDM 280 with the item number and product name.

Table 3-3: Optional accessories

Item no.	Name
1200092	157L LUFFT sensor WS 300 (instead of 1200097 WS 600)
1200094	158L LUFFT sensor WS 500 (instead of 1200097 WS 600)
4027424	Data logger access point EDM 280 (remote connection to GRIMM network via mobile radio, or local connection via existing WLAN)
4027428	Data logger EDM 280 (remote connection to GRIMM network via mobile radio)
4027429	Access point EDM 280 (local connection via existing WLAN)
4025195	199 fully air-conditioned, weatherproof housing for 19″ devices TÜV-tested for temperatures from -20 °C to + 60 °C

4 | Device description

In the following illustrations and tables, the controls on the 19″ measuring module and on the sampling tube holder are marked and their function is described in the text that follows.

4.1 Controls on the 19″ measuring module

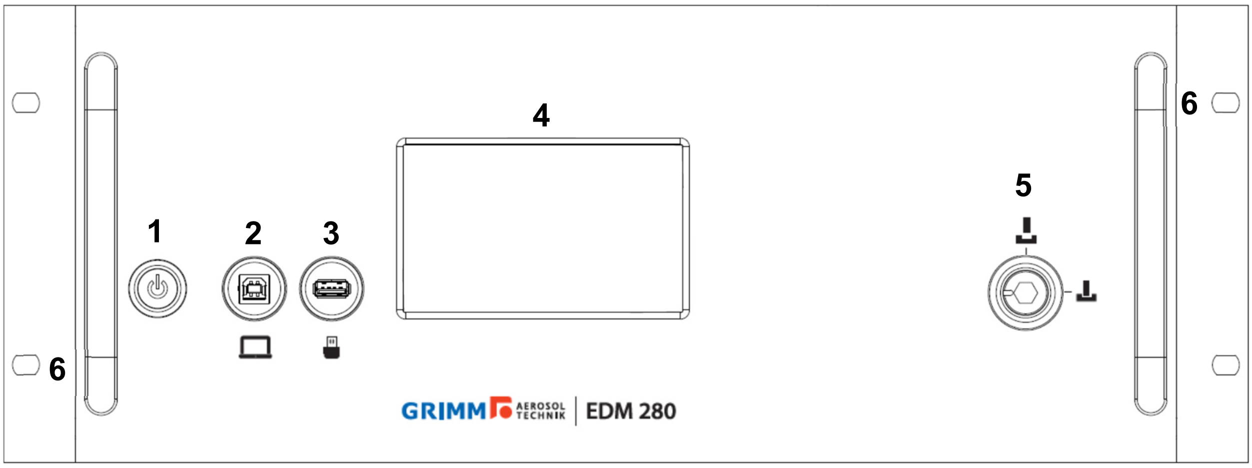


Figure 4-1: Measuring module front

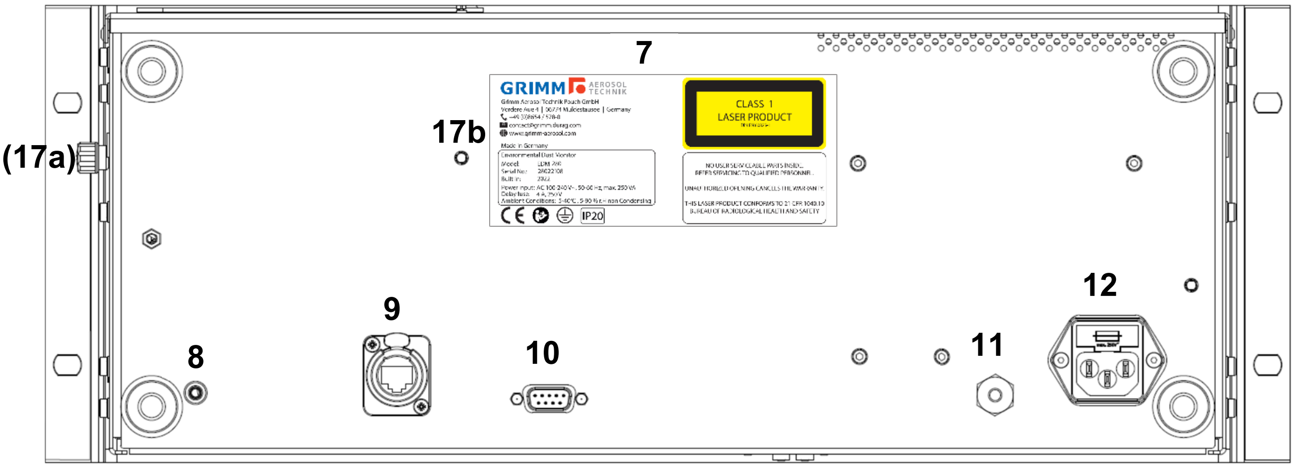


Figure 4-2: Measuring module back

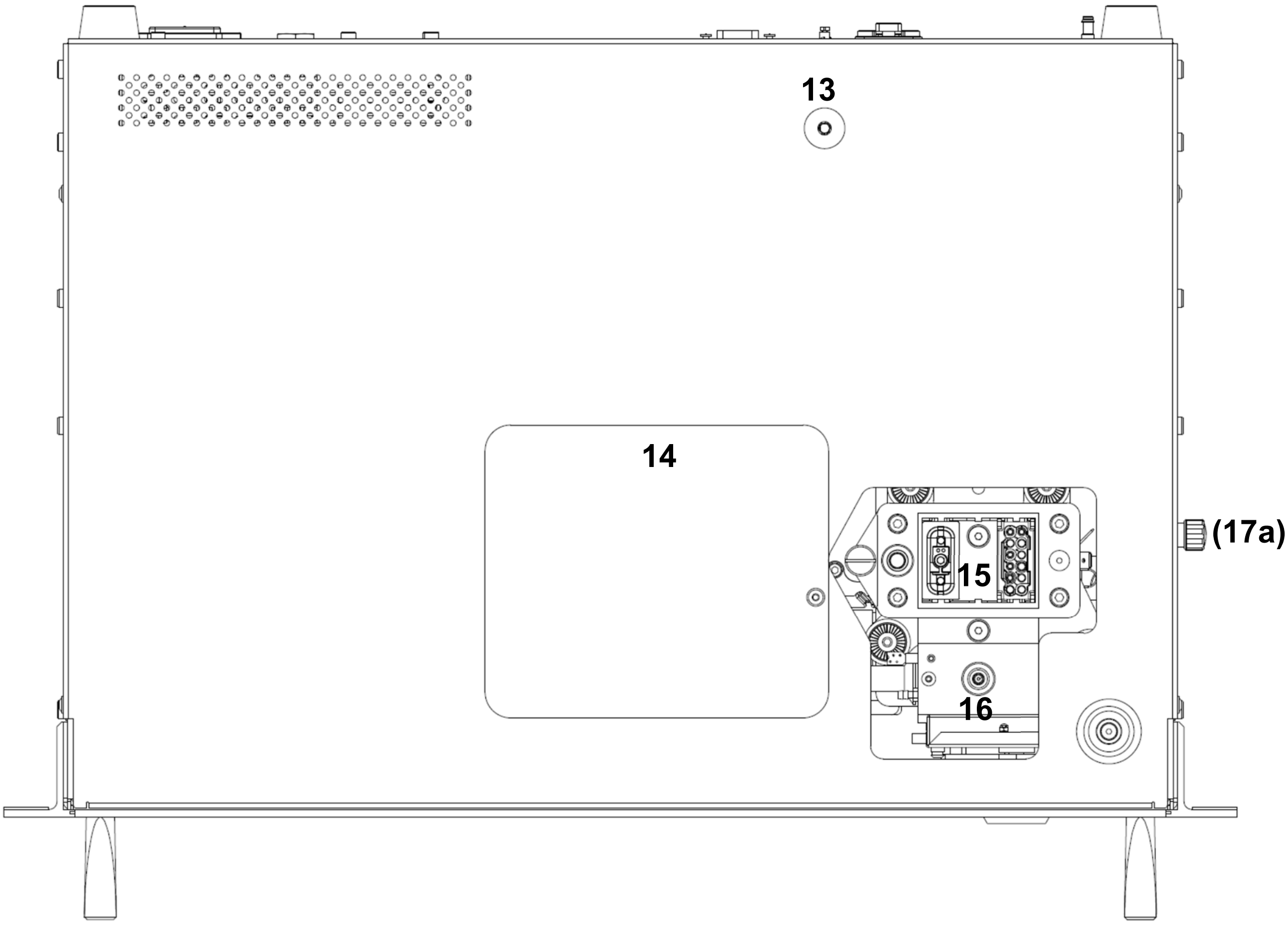


Figure 4-3: Measuring module top

Table 4-1: Measuring module controls, numbers refer to Figure 4-1 to Figure 4-3

Number	Name
Front	
1	On/off switch with LED
2	USB-B service interface
3	USB flash drive
4	Touch display
5	Lift lock
6	Handles and holes for mounting screws
Back	
7	Rating plate, calibration sticker and safety label
8	Condensate outlet
9	RJ45 Ethernet interface
10	RS-232 serial interface
11	Sample air outlet
12	Fuse and mains connection IEC socket
17b	Keep transport lock for lift, during operation (see also 17a)
Top	
13	Earthing rivet
14	Sample inlet cover
15	Lift contacts
16	Inlet nozzle

Right side	
17a	Transport lock for lift, during transport (see also 17b)

The following section explains the controls on the measuring module and their function.

4.1.1 On/off switch with LED

The on/off switch turns the 24 V DC power supply in the EDM 280 on or off. When switched on, the ring on the push button is blue. To properly disconnect the EDM 280 from the power supply, for example for work inside the measuring module, switching off with the on/off switch is not enough. The IEC connector on the back of the device also needs to be disconnected (see section 2.4.1 Electrical safety).

4.1.2 USB-B service interface

The USB-B service interface on the front of the device can be used for communication with a PC (e.g. for settings in the GESYTEC / Bayern-Hessen protocol). It always uses the GRIMM protocol GP280. The service interface is marked with a PC symbol. Once the settings and service work have been completed, the USB cable can simply be removed from the service interface.

4.1.3 USB flash drive

A USB flash drive can be used for saving when not connected to a PC or as a backup. The USB flash drive is plugged into the front of the device. The socket is marked with a USB flash drive symbol.

	The USB flash drive can be inserted and removed during operation.

USB 2.0 compatible USB flash drives with more than 2 GB can be used with the EDM 280. The data is written to text files in the GRIMM protocol GP-280. Each time measuring operation is started, a new file is created and named with a serial number and continuous index. The interval for saving should be adjusted to the duration of the measurement, see also section 5.3 Data log on the USB flash drive .

4.1.4 Touch display

The EDM 280 has a touch display with interactive menu navigation. The display shows measured values, sensor data and status parameters. Operation and the menus are described in section 5.6 Display of measured values on the touch display.

4.1.5 Lift lock

The lift in the EDM 280 connects the 19″ module to the sampling tube with the sampling tube holder. It can be closed and opened with the lift lock on the front of the device using an 8 mm hex key. The lift lock can be opened for service work or to remove the 19″ module, symbol up. The lift is closed in measuring operation, indicated by the symbol to the right of the lift lock. The lift is held in place in the end positions by a magnet, causing a slight jolt. For more information on the lift, see also section 5.1.2 and Figure 5-2.

The lift allows quick removal (and reinstallation) of the EDM 280 measuring module for maintenance, calibration or cross-exchange. The sampling assembly remains installed and can be serviced while installed.

4.1.6 Handles and holes for mounting screws

The measuring module has two handles and four holes on the front. The holes are slotted to allow easy installation in the 19" rack with screws.

4.1.7 Rating plate, calibration sticker and safety label

The rating plate on the back of the device contains all relevant device information and safety instructions.

- Manufacturer information
- Model name
- Serial number
- Year of manufacture
- Operating voltage, apparent power, main fuse
- Protection class
- Laser safety warning

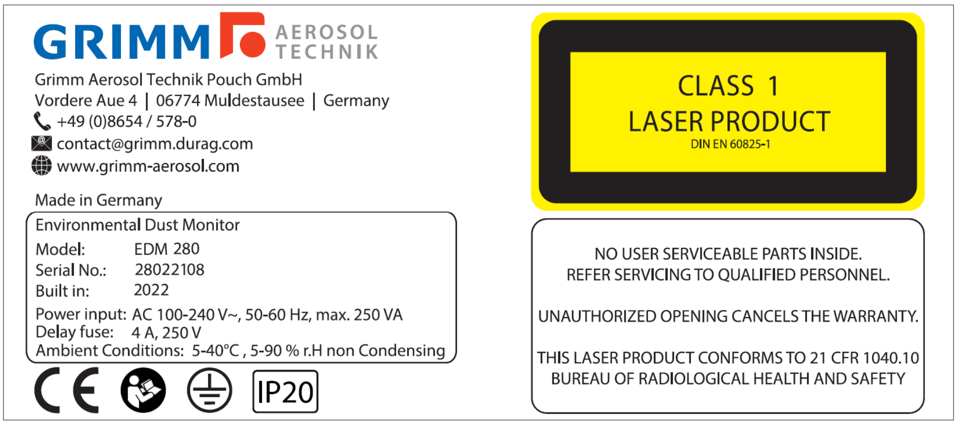


Figure 4-4: EDM 280 rating plate

The calibration label is in the form of a safety label. It provides information about the time of the next calibration and is destroyed if the device is opened without authorisation. A device with a damaged or removed calibration sticker loses all warranty claims.

4.1.8 Condensate outlet

The outlet (8, Figure 4-2) from the condensate trap is on the back of the device on the left. The condensate trap is emptied automatically during each self test. The condensate is not actively pumped out, it is drained by gravity. The condensate outlet must be connected to a suitable collecting vessel or a drain in the container. It is important to ensure that the hose is not higher than the condensate outlet.

Attention
Water collects in the condensate trap, especially when the air is warm and humid and the measuring container is cold. It must be drained regularly during the self test.

	The setting for the automatic self test should therefore be as follows: ■ Every 24 hours for average temperatures between 10 °C and 30 °C ■ Every 12 hours for average temperatures between 30°C and 45°C ■ Every 6 hours for average temperatures between 45 °C and 60 °C

⚠	**Attention** Dripping water can damage devices and equipment below. The condensate outlet should therefore always be connected to the drain with a hose.

4.1.9 RJ45 Ethernet interface

The RJ45 socket for the Ethernet interface (10BASE-T/100BASE-TX) is on the back of the device. It is required for example for communication using the Modbus data protocol.

4.1.10 RS-232 serial interface

There is a serial RS-232 interface on the back of the device. It is required for example for communication using the GESYTEC / Bayern-Hessen protocol. See also section 5.5.

4.1.11 Sample air outlet

The sample volume flow of 1.2 l/min leaves the device at the sample air outlet (11, Figure 4-2). The air is filtered and dried and can be used for further analyses (e.g. gases).

4.1.12 Fuse and mains connection IEC socket

The mains connection for an IEC device cable (12, Figure 4-2) is on the back of the device on the right and the fuse (4 A delay fuse) is above the socket. Before plugging in the cable, check to ensure that the mains voltage is within the permitted range for the device (see information on rating plate). The EDM 280 may only be operated on a circuit with an installed residual current circuit breaker.

⚡	**Danger** Touching live parts inside the measuring module poses a risk of fatal injury, so always remove the mains plug before opening the measuring module.

4.1.13 Earthing rivet

An earth for the entire system can be fixed to the earthing rivet (13, Figure 4-3).

4.1.14 Lift contact cover and inlet nozzle

The lift contact and the inlet nozzle are protected by a cover during transport. To open it, turn the cover cap 180 degrees. The cover is held in place in the positions (open or closed) by two magnets in the housing plate.

⚠	**Attention** In measuring operation, the sensitive optics are protected from contamination with purge air. In standby mode or in the event of a power failure, particles accumulate there and moisture or insects get into the measuring cell through the sample inlet and soil or damage it.

	Therefore: If measuring operation is interrupted for an extended period, open the lift and seal the inlet nozzle with the protective cap and the lift opening with the cover.

4.1.15 Lift contacts

As part of the lift in the measuring module, the lift contacts (15, Figure 4-3) monitor the lift to ensure that it is in the correct position, and with it all electrical connections that are relevant for the supply and function of the sampling tube. The lift contacts are closed or opened by the lift lock (see 4.1.5).

When closed, the lift is extended upwards out of the 19″ measuring module (see illustration on right). The lift contacts are then firmly connected to the counterpiece in the sampling tube holder. When open, for example to remove the 19" module, the lift is recessed in the 19″ measuring module.

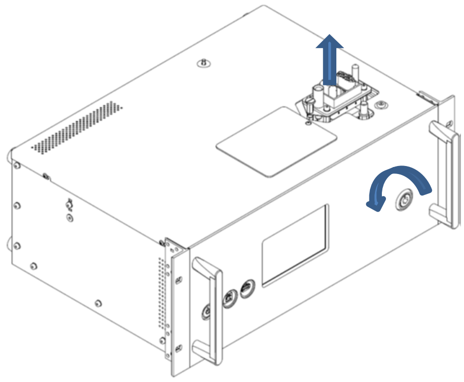


Figure 4-5: Measuring module with lift extended (closed position)

4.1.16 Inlet nozzle

Like the lift contacts, the inlet nozzle (16, Figure 4-3), which is also part of the lift, is extended upwards when the lift is closed and connects with the counterpiece in the sampling tube holder. This seals the sample air path pneumatically and the EDM 280 is ready for measurement.

4.1.17 Transport lock

The lift mechanism is secured during transport with a knurled screw that is screwed in on the right-hand side (17a). During installation and operation, the knurled screw is unscrewed and stored on the back of the device (17b).

4.2 Sampling tube holder controls

Figure 4-6: Sampling tube holder front

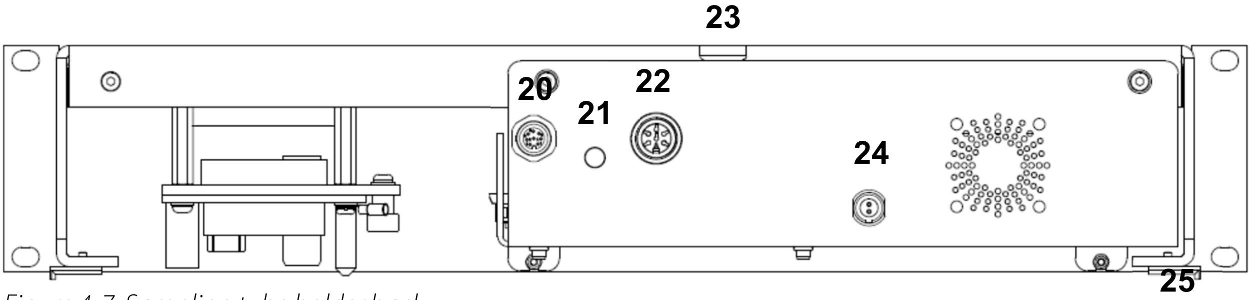


Figure 4-7: Sampling tube holder back

Table 4-2: Sampling tube holder controls, numbers refer to Figure 4-6 and Figure 4-7

Number	Name
Top	
(18)	Sampling tube slot
Front	
18	Sampling tube lock
19	Holes for mounting screws
Back	
20	Weather station connection
21	Sampling head heater connection
22	Sampling tube heater connection
23	Fixture for optional data logger access point
24	24 VDC power supply (for optional data logger access point)
25	Detents and guide grooves

The sampling tube holder connects the measuring module and the sampling tube. After installation, it remains permanently in the 19″ rack. The following section explains the controls on the sampling tube holder and their function.

4.2.1 Sampling tube slot

The hole on the top of the sampling tube holder is referred to as the sampling tube slot. All lines on the sampling tube and the sampling tube itself go into the sampling tube slot. The steps required to do this are described in detail in section 5.1.2.

⚠	**Attention** When lowering the sampling tube, be careful not to squeeze the cables.

4.2.2 Sampling tube lock

When the sampling tube is correctly positioned in the sampling tube holder (marked with a red dot towards the front), the sampling tube is fixed with the grub screw for the sampling tube lock (18, Figure 4-6) on the front of the sampling tube holder. Tighten the grub screw only slightly.

4.2.3 Holes for mounting screws

As with the 19″ measuring module, the sampling tube holder is also fixed in the 19″ rack with four screws through slotted holes that make it easier to align.

The connections for the weather station, the sampling head heater and the sampling tube heater are located next to each other on the back of the sampling tube holder. All three cables for these connections must be threaded through the sampling tube holder when installing the sampling tube. Figure 5-2 shows the three connected cables.

4.2.4 Weather station connection

Item 20 in Figure 4-7 indicates the connection for the weather station. The EDM 280 can be operated with different weather sensors. They all use a three-metre cable with an 8-pin connector.

4.2.5 Sampling head heater connection

Item 21 in Figure 4-7 indicates the connection for the sampling head heater. A heating cartridge on the Sigma-2 head prevents ice formation or freezing of the inlet openings in harsh weather conditions. The sampling head heater switches on when the outside temperature drops below 5 °C.

4.2.6 Sampling tube heater connection

Item 22 in Figure 4-7 indicates the connection for the sampling tube heater. Adaptive heating in the sampling tube is actively adjusted to ensure that condensation cannot be formed as the aerosol passes through to the measuring cell, at the same time ensuring that there is as little warming of the aerosol as possible so as not to change the status of the particle fraction of the aerosol.

4.2.7 Fixture for optional data logger access point

If the EDM 280 is operated with a data logger, it can be easily mounted on a rail. The rail is fixed into its designated position (23 in Figure 4-7) on the back of the sampling tube holder. Section 8, Appendix, contains an illustration of the fixture.

4.2.8 24 VDC power supply (for optional data logger access point)

Below the fixture for the optional data logger access point, there is a 24 VDC voltage output (24 in Figure 4-7). This can be used to supply the data logger with up to 2 A.

4.2.9 Detents and guide grooves

On the underside of the sampling tube holder, there are detents and guide grooves on the right and left. When installing the sampling tube holder, they guarantee precise positioning above the measuring module.

5 | Installation in the measuring container and starting operation

The setup time is the time required for setting up the measuring system until starting operation. The EDM 280 must be installed so that it is not affected by changes in the weather, for example in an air-conditioned measuring container. Passing the sampling tube through the roof requires additional measures at the installation location. If the EDM 280 is replacing an EDM 180 that is already in place, the existing roof bushing can be used. For non-stationary use, the model 199 fully air-conditioned, weatherproof housing for 19″ devices is recommended, (see Table 3-3, Optional accessories). Here again, a roof bushing is already in place.

To set up the measuring system, the following steps are required:

- Unpack the measuring device
- Prepare the rack
- Mount the sampling tube holder
- Prepare the sampling tube
- Install the sampling tube
- Mount the weather sensor
- Seal the roof bushing
- Prepare the measuring module
- Install the measuring module
- Lock the lift, connect the cables, connect the condensate outlet, connect the interface
- Connect the power supply
- Check for leak-tightness

The time needed to complete this work, i.e. the setup time for an EDM 280, is one hour.

Attention
Before starting operation, the measuring device must have acclimatised to the required operating conditions. We recommend storing the device at the place of operation for at least four hours.

The run-in time is the time required from starting operation of the measuring system until it is ready to measure. After starting measuring operation, the sampling tube warms up to the set temperature. During this time, the measured values may be compromised by high humidity. This process can take up to ten minutes. During the warm-up phase, the warning ‘Sampling assembly is reporting a warning’ is displayed. The current temperature can be displayed in the ‘Internal sensors’ menu (see Figure 5-11).

For an acclimatised device (see section 2.4), the run-in time is a maximum of 15 minutes.

5.1 Installation of the EDM 280 in a 19″ rack system

For continuous measuring operation, the EDM 280 should be permanently installed in a 19″ rack in the measuring container, or alternatively in the model 199 fully air-conditioned, weatherproof housing for 19″ devices (item number 4025195). Figure 5-1 shows a schematic diagram of a fully installed EDM 280.

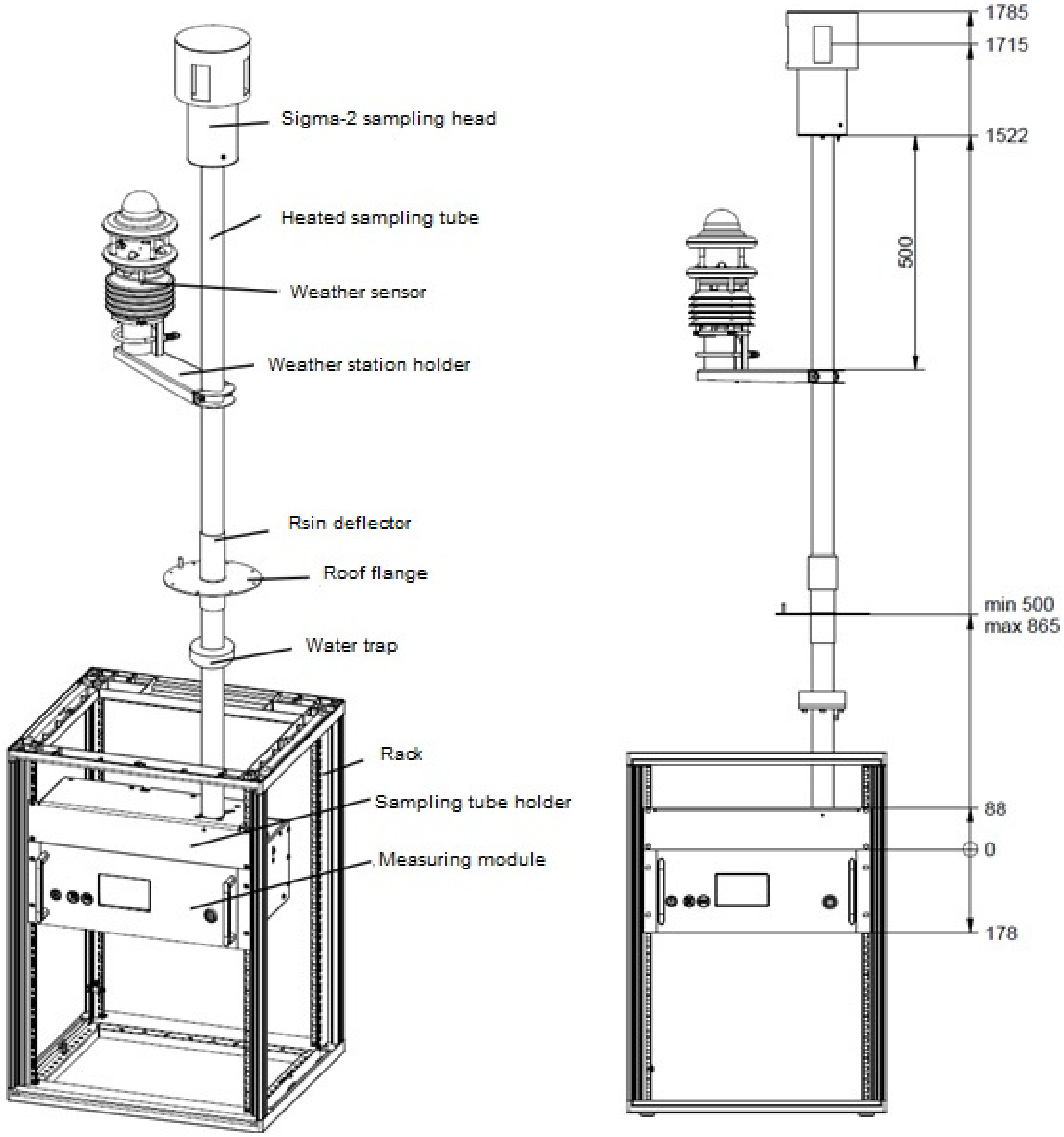


Figure 5-1: Overall view of the EDM 280 system

5.1.1 Preparation and tools

For installation in a 19″ rack in a measuring container, the following tools are required:

- Allen hex key set, 8 mm …2 mm (for various screws)
- Size 13 open-end spanner (for the weather station holder)
- Pliers, side cutter (to cut hoses)
- Plumb bob (for vertical positioning of the sampling tube holder under the roof bushing)
- Short spirit level (for horizontal positioning of the sampling tube holder and measuring module)
- Compass (for alignment of the wind sensor)
- Cable ties (for laying the cables)
- Laptop (helpful with terminal programme)

5.1.2 Steps for installation in a measuring container

1. **To set up the rack:**
    a. Set up the rack components.
    b. Mount the rack rails.
    c. Clip in the rack nuts.
    d. Roughly align the rack under the roof flange.

2. **To mount the sampling tube holder:**
    a. Insert the measuring module.
    b. Place the sampling tube holder on the measuring module.

> **Attention**
> Check the detents/guide grooves, they must engage with each other.
> If there is a gap (> 1 mm) remaining between the sampling tube holder and the measuring module or if the housing edges are not flush, please check the installation positions.

    c. Screw the sampling tube holder into the rack.
    d. Remove the measuring module again.
    e. Adjust the rack's feet so the sampling tube holder is level.

3. **To prepare for mounting of the sampling tube:**
    a. Fit the rain separator on to the sampling tube.
    b. Pull out the cable for the weather sensor in the sampling tube to the required length.
    c. Loosen the clamping screws in the water trap, fit the hose and place the water trap on the sampling tube holder.
    d. Hang the plumb bob through the centre of the roof flange.
    e. Carefully adjust the alignment of the rack so that the plumb bob comes out in the middle of the sampling tube slot.
    f. Remove the plumb bob.
    g. Remove the protective cap from the sampling tube.

4. **To install the sampling tube:**
    a. Run the sampling tube through the roof flange from above until it comes out approx. 10 cm above the sampling tube holder.
    b. Slide the water trap onto the sampling tube.
    c. Turn the red dot on the sampling tube towards the front of the sampling tube holder.
    d. Thread the cable out of the sampling tube through the sampling tube holder.

> **Attention**
> When lowering the sampling tube, be careful not to squeeze the cables.

    e. Lower the sampling tube into the sampling tube holder and fix it into place.

Attention
The notch mark must be flush in the sampling tube holder and disappear from view.

If the notch mark does not disappear:

1 Turn the tube a few degrees, the red dot must face exactly to the front.
2 Unscrew the fixing screw a little further.
3 Check the angle between the tube and the holder, it should be a right angle.

Is there a cable in the way? Does a cable have to go through a different opening?

f. Screw in the fixing screw with an Allen key on the sampling tube holder.

5. To mount the weather sensor and head:

a. Mount the weather sensor holder on the sampling tube.
b. Plug the cable into the weather sensor.
c. Mount the weather sensor on the holder.

Align the WS600 weather sensor with the arrow on the bottom pointing north.
Tighten the screws on the weather sensor into place with a size 13 open-end spanner.

d. Mount the sampling head.

6. To seal the roof bushing:

a. Slide the rain deflector completely over the roof flange, screw the grub screws into the rain deflector.
b. Tighten the screws in the water trap into place and connect the hose.
c. Run the hose into the rain drain or collection container.

7. To prepare the measuring module:

a. Turn the lift cover on the measuring module to the side and onto the holding magnet.
b. Remove the protective cap from the inlet nozzle.
c. Unscrew the transport lock for the lift. Screw the knurled screw into the back of the device to store it.

8. Insert the measuring module into the rack and screw it into place.

9. Use an 8 mm hex key to turn the lift lock from position  to .

a. The lift is held in place in the end positions by a magnet, causing a slight jolt.
b. You should be able to apply the force needed with two fingers.

If not:
- Has the transport lock been removed from the lift?
- Is there still a protective cap on the inlet nozzle or tube?
- Are the sampling assembly and tube aligned perpendicular to the measuring module?
- Is there a cable in the way?

c. Check to ensure that the lift is fully closed on the back.
The lift contacts must be closed over their entire width, see figure below.

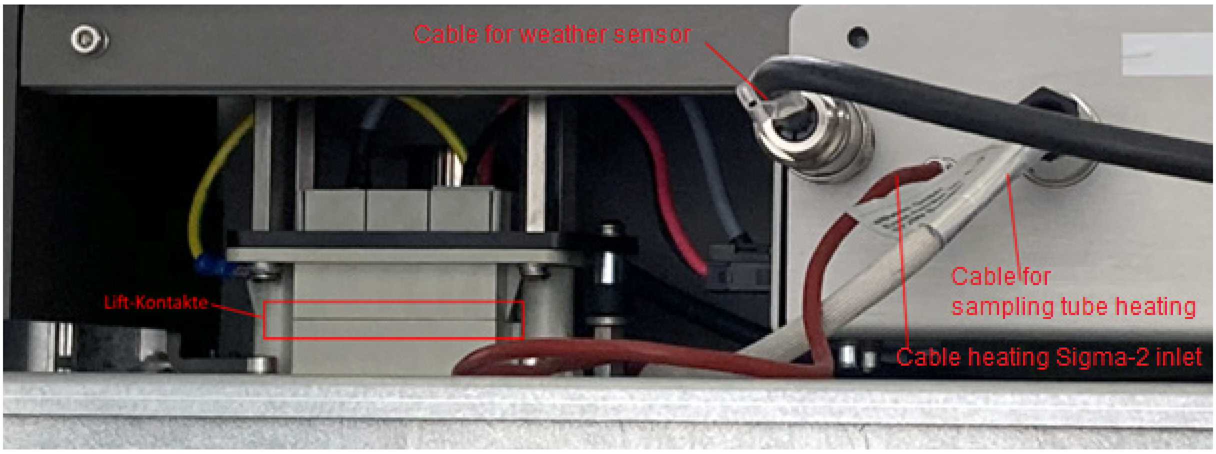


Figure 5-2: Back of sampling tube holder with lift contact and connected cables

10. Connect the cables for the weather sensor, sampling tube heater and sampling head heater to the sampling tube holder, fix into place with cable ties if necessary.

11. Fit the hose onto the condensate outlet.

a. Run the hose into the rain drain or collection container.

12. Plug in the optional RS-232 cable or network cable.

13. Plug in the IEC device cable and supply it with voltage.

⚠	**Attention** Never open or close the lift when it is switched on (i.e. when the LED ring on the on/off switch is blue). Always switch it off first.

Installation of the EDM 280 is now complete.

5.2 Starting operation

The following steps describe how to start operation of the EDM 280 after completing its installation.

1. **Press the on/off switch and switch on the EDM 280.**
   a. The switch lights up blue.
2. **Optional: Adjust the configuration,** see Figure 5-8: Enter settings.
3. **Optional: Insert the USB flash drive for data logging.**
4. **To start measuring operation:**
   a. Select the 'Measuring operation control' menu on the touch display.
5. **Check outputs:**
   a. Is the self test showing error messages?
   b. Is measuring operation starting?
   c. Are measured values coming in from the weather sensor (meteorological sensor)?
   d. Is a plausible temperature value for the sampling tube temperature being output? (Between indoor and outdoor temperature)
6. **To check the USB flash drive:**
   a. Remove the USB flash drive.
   b. Check on the PC that the data has been logged.
   c. Plug the USB flash drive back in.
7. **Optional: Check data logging using GESYTEC or data logger.**

Attention
Never open or close the lift when it is switched on (i.e. when the LED ring on the on/off switch is blue). Always switch it off first.

Tip:

- After a power failure, measuring operation continues automatically.
- The USB cable can be simply removed from the service interface.
- The USB flash drive can be inserted and removed during operation.

Before starting a regular measurement, the method to be used to log and process the measurement data must be defined. The following options are available:

- Save the data to a USB flash drive without online data acquisition.
- Online data acquisition using one of three communication protocols (GRIMM protocol, Modbus TCP or GESYTEC / Bayern-Hessen protocol) with or without simultaneous storage on a USB flash drive.

5.3 Data log on the USB flash drive

Note: The measurement data can be very easily logged for later evaluation on the USB flash drives included in delivery. The data is written to text files in the GRIMM protocol GP-280. Each time measuring operation is started, a new file is created and named with a serial number and continuous index.

1. Insert a supplied USB flash drive into the data log interface on the front.
2. If the EDM 280 is already in measuring operation, the data will now be saved on the USB flash drive at the set measurement interval.
3. If the measurement interval is set to
    a. 1 minute, the USB flash drive should be cleared after two years.
    b. 6 seconds, the USB flash drive should be cleared after two months.
4. To read out the data, simply remove the flash drive and plug it into a PC.

5.4 Operation via the service interface with a terminal programme

1. Connect the USB cable to the PC at the service interface on the front
2. Start the terminal program, our recommendations are:
    a. tinyTerm, TeraTerm or PuTTY
    b. Support for RS-232, USB-COM and TCP socket
    c. Support for ANSI control characters ("VT100 mode")
3. Select the COM port for the USB service interface
4. Configuration with 115200-8N1, 115200 bit/s and 8 data bits, no parity bit, one stop bit.
5. Each command ends with \r\n. This is done by pressing the Enter key.
6. Pressing ? and Enter provides an overview of all commands.
7. Some commands can only be activated in standby mode.
8. The command ! outputs the model name and firmware version.
9. The command @ outputs the serial number.
10. The command R starts measuring operation. A self test starts automatically beforehand.
11. The command S stops measuring operation and switches to standby.
12. The system starts in service mode 1, so the following settings are enabled:
    a. T Adjust time and date
    b. I Adjust measurement interval
    c. A Adjust time and cycle for the automatic self test
    d. \ Adjust IP address
    e. : Adjust GESYTEC / Bayern-Hessen protocol
13. More extensive settings only become active when a service dongle is plugged in.
14. If they are activated unintentionally, you can exit the menus by pressing the Escape key.

Note: Some settings only take effect after a restart, so press the on/off switch after exiting a menu.

5.5 Operation via the RS-232 interface with GESYTEC protocol:

	Note: The GESYTEC / Bayern-Hessen protocol is only output on the RS-232 interface. The settings can be changed via the service interface.

1. Connect the RS-232 interface on the back of the measuring module with the RS-232 null modem cable.
2. Adjust the interface configuration on the measuring location computer
   The EDM 280 systems are preconfigured as follows:
   i. Serial interface 115200 bit/s, 8N1
   ii. By default, the measuring device identifier is set to the last three digits of the serial number and the base identifier to 200.
3. Start the measurement with an ST telegram and control byte 01
   Example: <STX> ST12301 <ETX>
4. Query the measurement data with a DA telegram
   Example: <STX> DA <ETX>
5. End the measurement and switch to standby with an ST telegram and control byte 00, example: <STX> ST12300 <ETX>

5.6 Display of measured values on the touch display

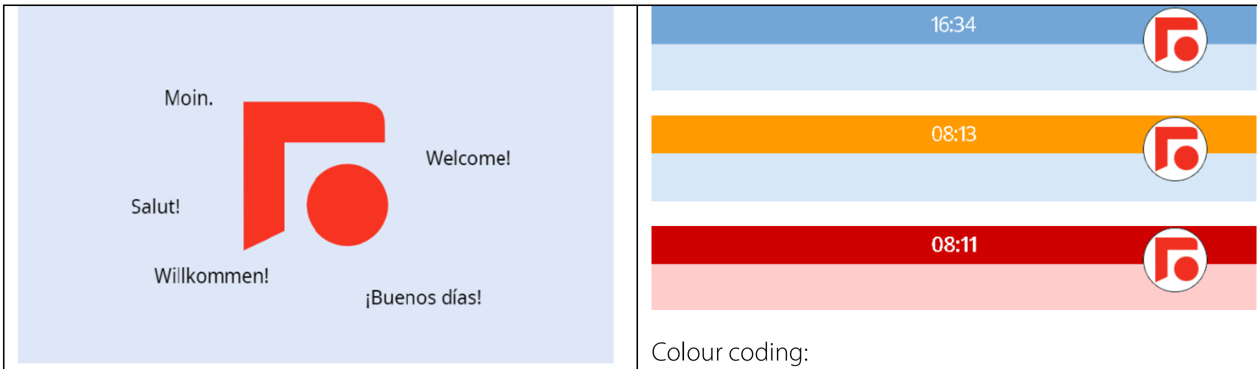
The touch display is multilingual and uses text, numbers, graphics, symbols and colours. At the top of the programme line, symbols, the time and the GRIMM logo for opening the menu are displayed.

The touch display has a colour-coded, intuitive input logic. It uses the following colour coding for the title line:

Table 5-1: Meaning of the colours on the touch display

Colour	Definition	Meaning
Blue	Normal	All functions okay
Orange	Warning	Continued operation with possible impairment of the measured values. Maintenance may be required
Red	Error	Measurement was aborted for protection, maintenance or repair required

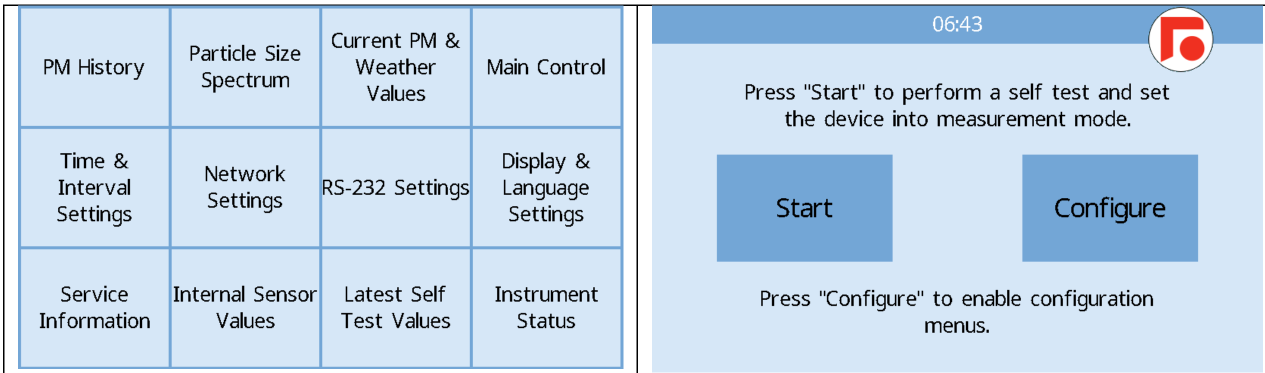
When an error occurs, the background also changes from light blue to pink, so that it is apparent even from some distance away that an error has occurred and action is required.



Start screen
Colour coding:
Normal (blue), warning (orange), error (red)

Figure 5-3: Touch display start screen and colour coding

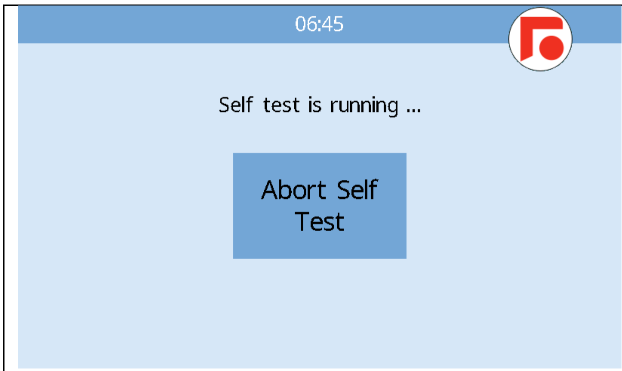
The touch display is divided into twelve menus. Selecting the GRIMM logo displays the menu overview. The "Main Control" menu can be used to start measuring operation and monitor warnings or error messages. The configuration entries can only be enabled in standby. This protects settings against unintentional adjustment.



Menu overview with twelve menus
Main Control menu

Figure 5-4: Menu overview and measuring operation or standby

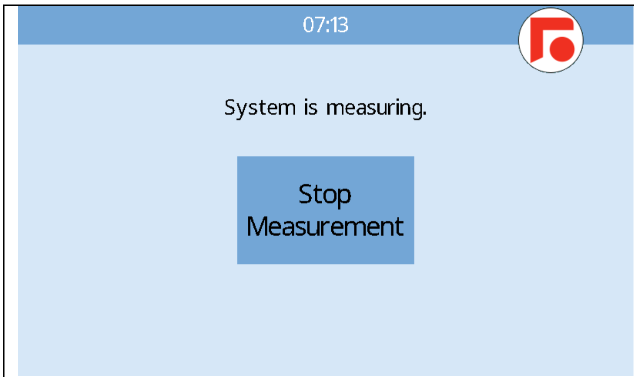
If measuring operation is started with a self test, a message indicating that the self test is running is displayed. If initialisation with the self test does not proceed normally, a warning or error message is displayed.



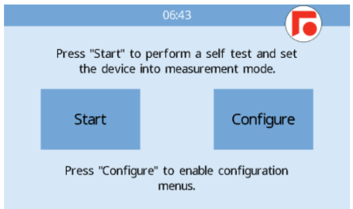
Self test running normally

Error message during the self test

Figure 5-5: Normal self test and self test with error message



Main Control menu: Standby: Start measuring operation with a self test or configure the settings.

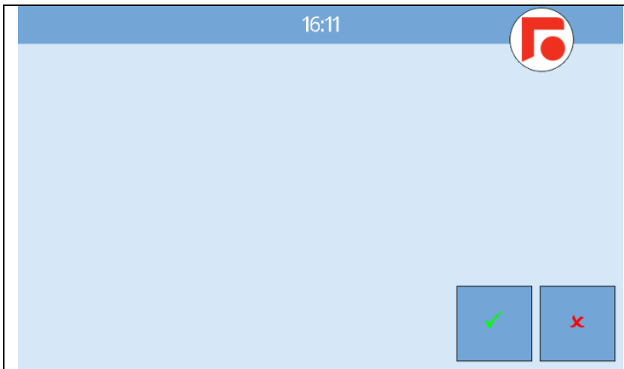


Measuring operation: Stop a running measurement.

Figure 5-6: Stop measurements or configure settings

Making settings

The Yes/No buttons or the digits 0 to 9 are used for selection and entry.



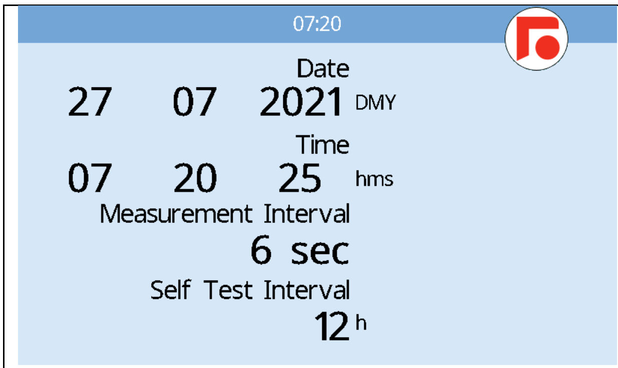
Yes/No input screen

0 to 9 numeric keypad input screen

Figure 5-7: Yes/No and numeric keypad input screens

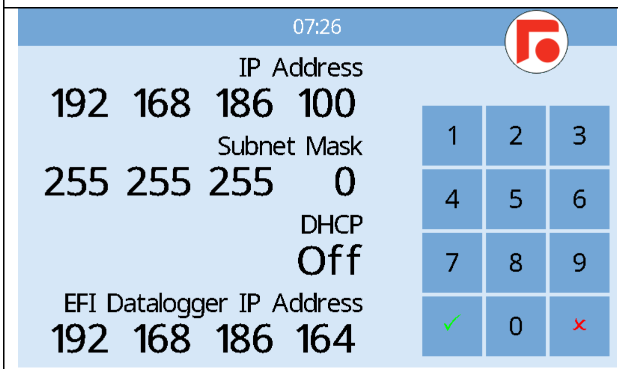
Configuring settings

The configuration menus are secured against unintentional adjustment. To unlock, you will need to select 'Configure' in the Main Control menu in standby, see Figure 5-6. When measuring operation is started, the configuration menus are again locked against adjustment. Various settings can be configured in the middle row of the main menu.



Time & Interval Settings menu

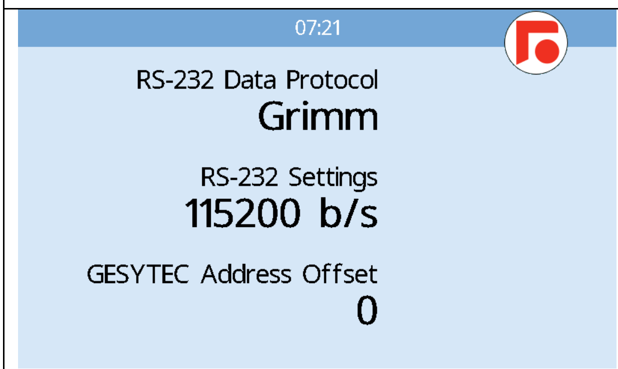
Enter the date, time, measurement interval and self test interval



Network Settings menu

Enter the network interface

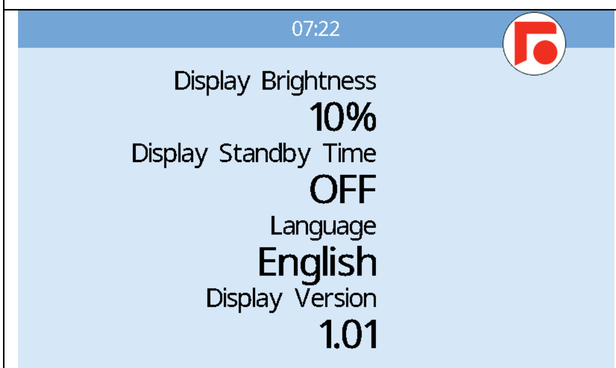
Communication with µEFI Datalogger (optional accessory)



RS-232 Settings menu

Enter the RS-232 interface (GESYTEC)

Communication protocol for the RS-232 interface on the back of the measuring module
Switch between GRIMM and Gesytec/Bayern-Hessen protocol



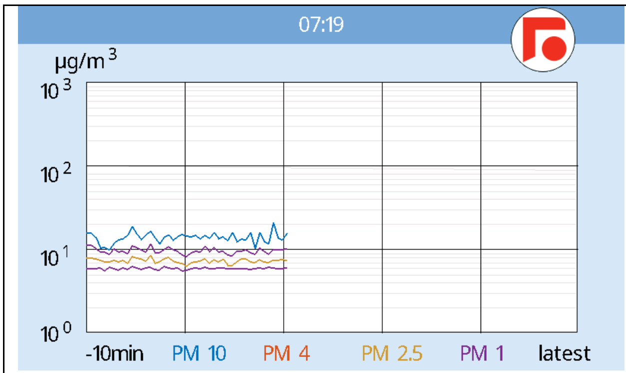
Display & Language Settings menu

Enter display settings and language selection

Figure 5-8: Enter settings.

Displaying measured values and sensor values

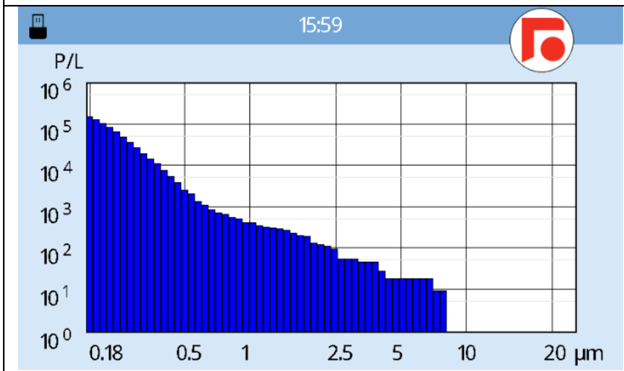
In measuring operation, the main menu can be used to select displays of the measured values and sensor values and control measuring operation (top row in the main menu from left to right):



PM History menu

History of PM values in the last ten minutes.

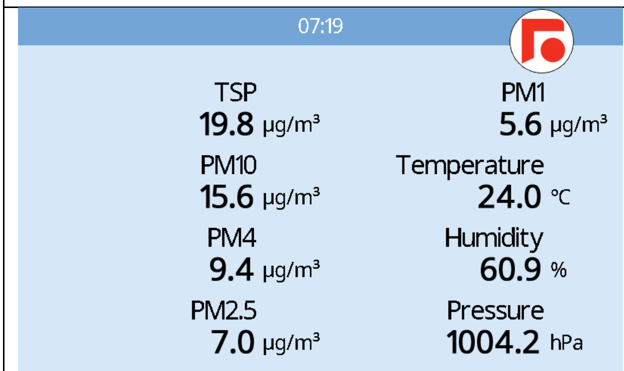
The USB symbol in the upper left corner indicates that the USB flash drive has been recognised and the EDM 280 is logging data.



Particle Size Spectrum menu

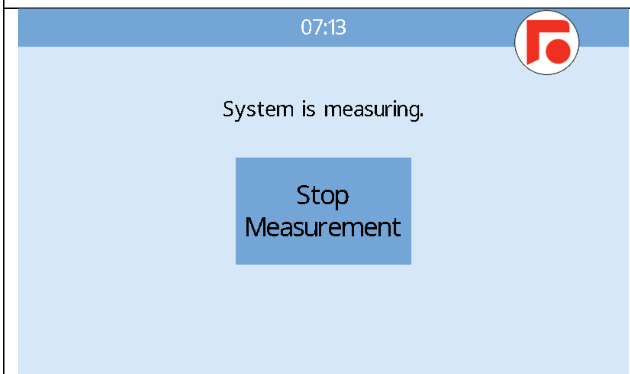
Display of the cumulative particle number size distribution

The USB symbol in the upper left corner indicates that the USB flash drive has been recognised and the EDM 280 is logging data.



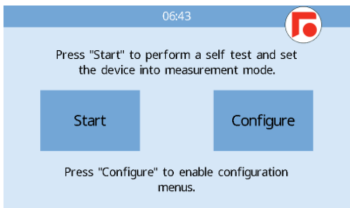
Current PM & Weather Values menu

Displays the measured values. You can tap to freely assign the available measuring variables to the displays.



Main Control menu:

Standby: Start measuring operation with a self test or configure the settings.



Measuring operation: Stop a running measurement.

Figure 5-9: Display of measured values and sensor values and control of measuring operation

Displaying settings

In measuring mode, the main menu can be used to display the selected settings (middle row in the main menu from left to right)

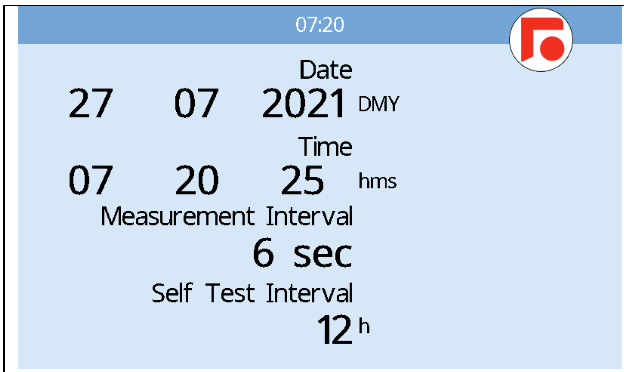
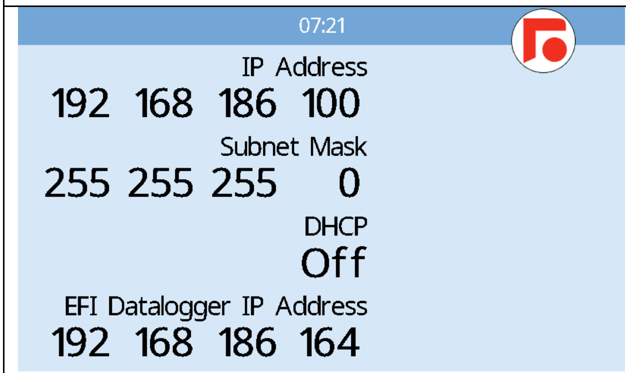
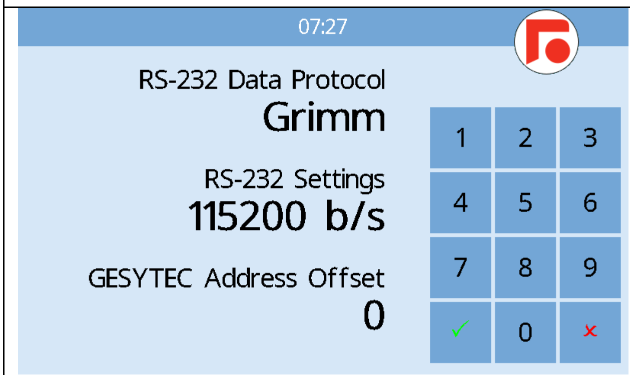
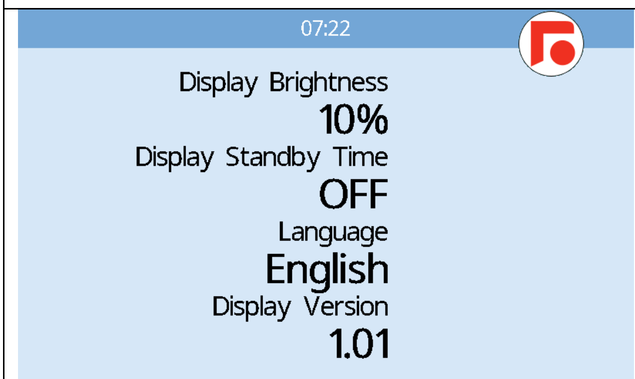
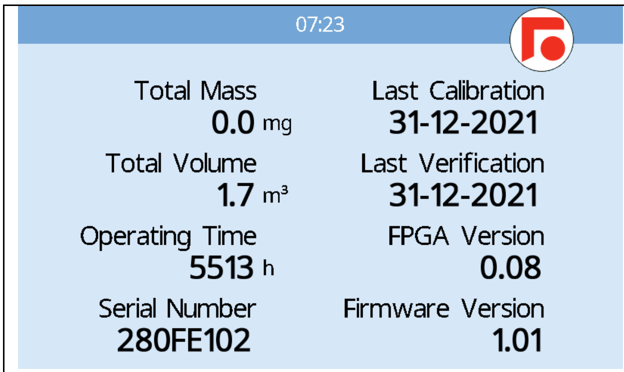
	Time & Interval Settings menu Displays the date, time, measurement interval and self test interval
	Network Settings menu Displays the network interface
	RS-232 Settings menu Displays the RS-232 interface (GESYTEC)
	Display & Language Settings menu Displays the display and language settings

Figure 5-10: Display of settings.

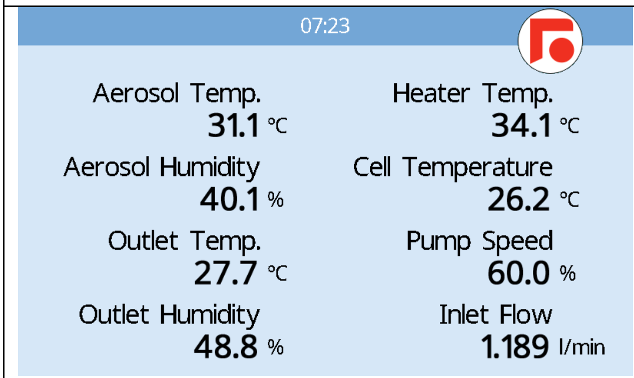
Retrieving service information

The bottom row of the menu overview contains further menus for error diagnosis and maintenance work, as well as internal sensor values (explanation from left to right):



Service Information menu

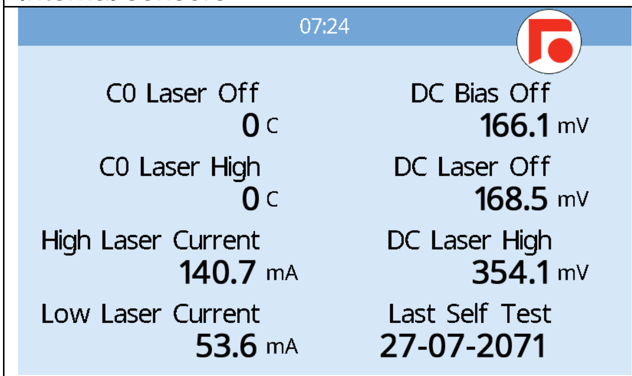
Displays the serial number, version numbers and running times.



Internal sensors

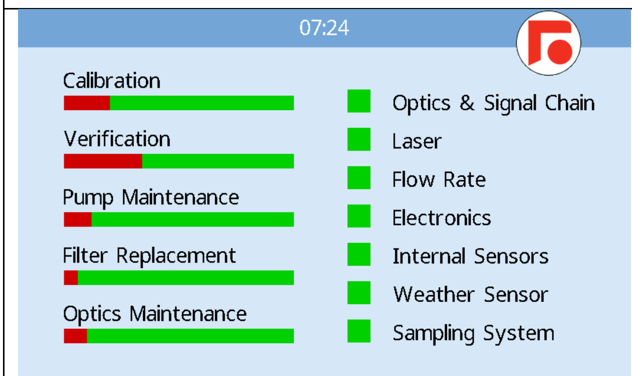
Internal Sensor Values menu

Displays the aerosol temperature, aerosol humidity, outlet temperature, outlet humidity, heater temperature, measuring cell temperature, pump speed and inlet volume flow



Latest Self Test Values menu

Numerical diagnostic values from the last self test.



Instrument Status menu

Graphic colour display of relevant optical, pneumatic and electronic components and functions

Left: Wear indicators for upcoming maintenance work.
Right: Display of errors (red) and warnings (yellow) in subsystems.

Figure 5-11: Display of service information and wear indicators for maintenance

Examples of colour-coded function display (normal, warning, error)

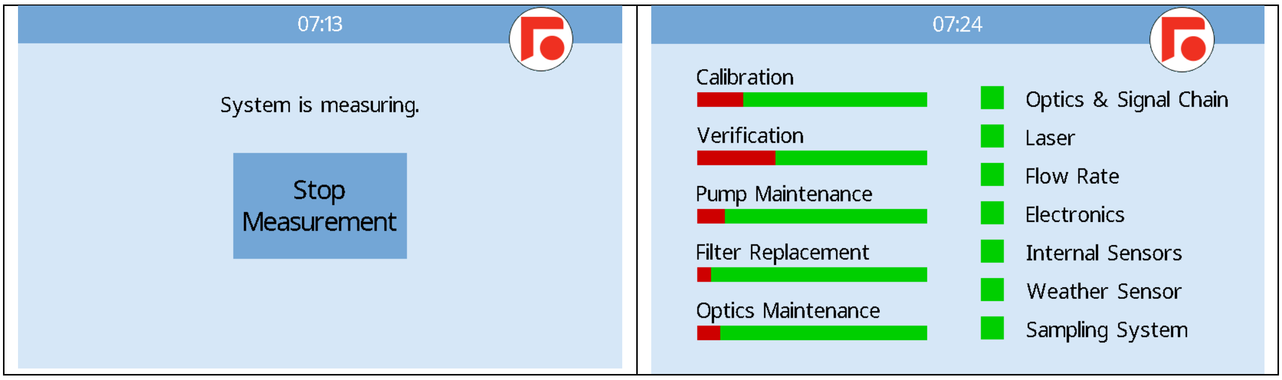


Figure 5-12: Touch display example, normal colour code

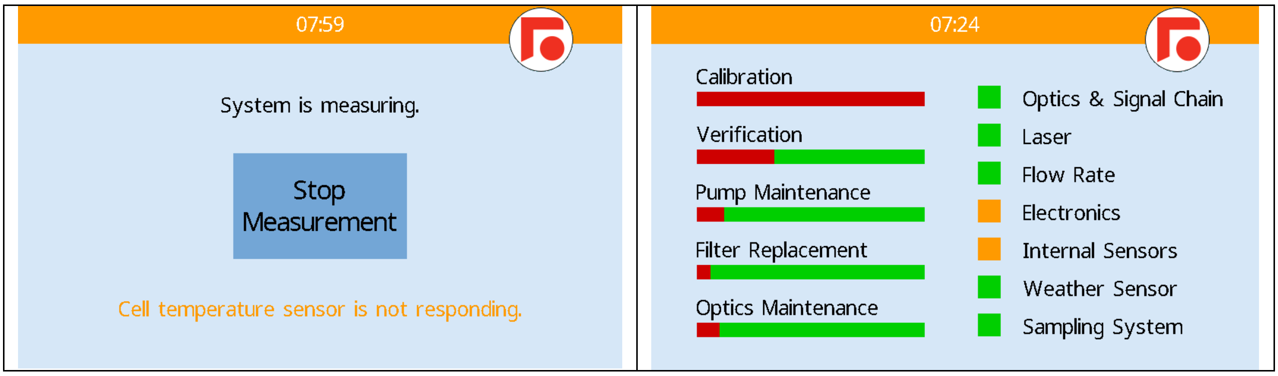


Figure 5-13: Touch display example, warning colour code

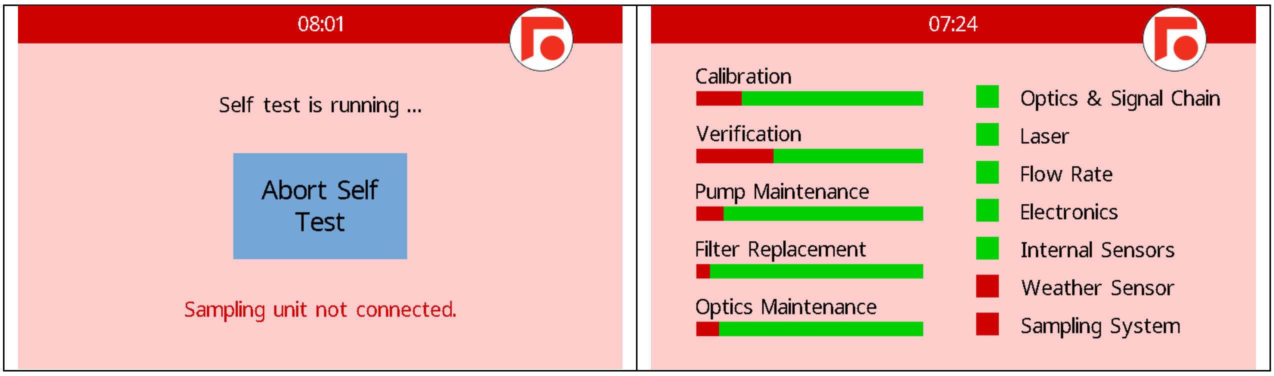


Figure 5-14: Touch display example, error colour code

Explanation of the wear indicators:

Calibration: Time from last calibration to maximum value 100% = 12 months after last calibration.

Validation: Time from last validation to maximum value 100% = 3 months after last validation.

Pump Maintenance: Pumped volume PVolume of the pump up to maximum value 100% = 720 m^3.

Filter Replacement: Total dust conveyed PWeight up to maximum value 100% = 100 mg.

Optics Maintenance: DC component of the scattered light signal from the measuring cell up to maximum value 100% = 500 mV.

6 | Data protocols

There are three data protocols available to the user:

- GRIMM protocol (GP280 V1.1)
- Modbus TCP
- GESYTEC / Bayern-Hessen protocol

The protocols are described below.

6.1 GRIMM protocol

The GRIMM protocol (GP280 V1.1) consists of ASCII telegrams. Each data telegram begins with ?$? followed by a character that identifies the telegram type. The telegram concludes with a checksum and CR + LF. Data is delimited with semicolons. For placeholders or data that is not available, the relevant fields are left empty, which means there can be several semicolons one after the other. The decimal point is used as the decimal separator.

The checksum is formed as a bit by bit XOR operation of all characters starting from $ up to and including the last character before the checksum (without the semicolon before the checksum).

6.1.1 Self test data

Among the things checked during the self test is whether the internal sensors and the weather sensor are responding. Dust-free purge air is pumped into the measuring cell and the DC level of the scattered light signal (7-9), the zero counts (10-11) and the laser current (12-13) are recorded.

Table 6-1: GRIMM protocol self test data

Position in string	Data	Unit	Format
1	$S	-	2
2	Protocol version	-	.1
3	Timestamp date	-	DD.MM.YYYY
4	Timestamp time	-	hh:mm:ss
5	Diagnostics code	-	.0
6	Extended diagnostics code	-	1
7	DC without bias, without laser	mV	.0
8	DC with bias, without laser	mV	.1
9	DC with bias, high laser power	mV	.1
10	Zero counts at high laser power	-	.0
11	Zero counts without laser	-	1
12	Laser current at low laser power	mA	.0
13	Laser current at high laser power	mA	.1
14	Checksum	-	.0
15	CR + LF	-	2

Explanation of the format:

1	One character
2	Two characters
.0	Number without decimal places
.1	Number with one decimal place
.2	Number with two decimal places

6.1.2 Formatting of the diagnostics code

The diagnostics code in the self test is produced by binary OR operation on the following bits: Bits 6, 7, 8 and 9 are broken down in greater detail in the extended diagnostics code.

Table 6-2: GRIMM protocol formatting of the diagnostics code

Bit	Description	Impact
0	Signal chain error	Error
1	Laser error	Error
2	High baseline light level	Warning
3	High zero counts	Error
4	Reserved: Purge air error	Error
5	Main filter clogged	Warning
6	Internal I^2C bus error	See below
7	Internal SPI error	See below
8	Supply voltage error	See below
9	Unexpected restart	Warning
10	Sampling not connected	Warning
11	Weather sensor error	Error
12	Sampling unit error	Error
13	Sampling heater error	Error
14	Sampling heater temperature sensor error	Error
15	Sampling head heater error	Warning

6.1.3 Formatting of the extended diagnostics code

The extended diagnostics code breaks down the internal components of the measuring module in detail.

Table 6-3: GRIMM protocol formatting of the diagnostics code

Bit	Description	Diagnostics code
0	Restart after power interruption	Bit 9
1	Restart after watchdog reset	Bit 9
2	+3.3V supply voltage error	Bit 8
3	+5.0V supply voltage error	Bit 8
4	+10.0V supply voltage error	Bit 8
5	+12V supply voltage error	Bit 8
6	Cell temperature sensor error	Bit 6
7	Outlet temperature sensor error	Bit 6
8	Spectrometer pressure/temperature sensor error	Bit 6
9	Differential pressure sensor error	Bit 6
10	Reserved: Gauge pressure sensor error	Bit 6
11	Spectrometer port expander error	Bit 6
12	Measurement unit port expander error	Bit 6
13	EEPROM error	Bit 6
14	FPGA error	Bit 7
15	RTC error	Bit 7
16	ADC error	Bit 7
17	FRAM error	Bit 7
18	Flash memory error	Bit 7
19	Display error	Bit 7

6.1.4 GRIMM protocol measurement data

The measurement data in the GRIMM protocol is shown below in Table 6-4.

Table 6-4: GRIMM protocol measurement data

Position in string	Data	Unit	Format	Header symbol
1	$M	-	2	$m
2	Protocol version	-	.1	PrV
3	Timestamp date	-	DD.MM.YYYY	DD.MM.YYYY
4	Timestamp time	-	hh:mm:ss	hh:mm:ss
5	Measurement interval	-	1	I
6	Status code	-	.0	Sta
7	Warning code	-	.0	War
8	Error code	-	.0	Err
9	Sample volume over interval	L	.3	Volume
10	Valid measurement time in interval	s	.0	MTime
11	Location number	-	.0	Loc
12	Measurement number	-	.0	Run
13	Reserved (gravimetric factor)	-	-	GF
14	Relative humidity (measuring cell)	%	.1	MrH
15	Temperature (measuring cell)	°C	.1	MTemp
16	Relative humidity (outlet aperture)	%	.1	VrH
17	Temperature (outlet aperture)	°C	.1	VTemp
18	Sampling flow rate	l/min	.3	Flow
19	Control value for pump	%	.0	Pump
20	Set value for heater (heated sampling tube)	°C	.1	HtSet
21	Actual value for heater (heated sampling tube)	°C	.1	HtAct
22	Relative humidity (weather sensor)	%	.1	rHum
23	Temperature (weather sensor)	°C	.1	Temp
24	Air pressure	hPa	.1	Pres
25	Wind speed (weather sensor)	m/s	.1	Wind
26	Wind direction (weather sensor)	°	.1	WDir
27	Precipitation intensity (weather sensor)	mm/h	.1	Rain
28	Reserved (GPS position latitude)	°	-	Lat
29	Reserved (GPS position longitude)	°	-	Lng
30	Reserved (GPS position height)	m	-	Hgt
31	Reserved (filter capacity)	-	-	-
32	Reserved (battery capacity)	-	-	-
33	Total dust quantity PWeight	mg	.1	PWeight
34	Total air volume PVolume	m^3	.1	PVolume
35	TSP	$\mu g/m^3$	.1	TSP
36	PM10	$\mu g/m^3$	.1	PM10
37	PM4	$\mu g/m^3$	.1	PM4
38	PM2.5	$\mu g/m^3$	.1	PM2.5
39	PM1	$\mu g/m^3$	.1	PM1
40	PMcoarse	$\mu g/m^3$	.1	PMc
41	Total counts	P/L	.0	TC
42	Reserved (inhalable)	-	-	-
43	Reserved (thoracic)	-	-	-
44	Reserved (respirable)	-	-	-
45 – 116	72 channels counts accumulative	P/L	.0	(PSL diameter)
117 – 199	83 raw classifications accumulative (service 1 only)	P/L	.0	-
204	DC at high laser power (service 1 only)	mV	.1	DCh
205	DC at low laser power (service 1 only)	mV	.1	DCl
206	Checksum	-	.0	CS
207	CR + LF	-	2	

6.1.5 GRIMM protocol formatting of measurement intervals

The measurement interval in the GRIMM protocol is formatted as specified in Table 6-5.

Table 6-5: GRIMM protocol measurement intervals

Value	Interval
1	1 minute
2	5 minutes
3	10 minutes
4	15 minutes
5	30 minutes
6	60 minutes
7	1 minute
8	6 seconds
9	Daily average values
M	Indicates in the measurement data that the telegram is a manual average (command 'M' or 'Z')

6.1.6 GRIMM protocol formatting of status codes, warning codes and error codes

Table 6-6 to Table 6-8 show the formatting of the status, warning and error codes in the GRIMM protocol. For status events that can change during the measurement interval (e.g. status of sample conditioning), the single occurrence of this event is sufficient to generate a status code to that effect at the end of the measurement interval for the average value output. The status code in measuring operation is produced by binary OR operation on the following bits:

Table 6-6: GRIMM protocol status codes

Bit	Status
0-2	000: Standby 001: Self test 111: Measuring operation 010: Error status 100: Service mode
3	Validity of the daily average value; Valid = 1, Invalid = 0
4	Logging to local memory; Log active = 1, No log = 0
5	Status of the fog indicator; Normal = 1, Indication of fog = 0
6	Status of particle classification; N= 1, Unnatural aerosol spectrum = 0
7	Status of sample conditioning; O= 1, Off = 0

The single occurrence of a warning event is sufficient to generate a warning code to that effect at the end of the measurement interval for the average value output. The warning code in measuring operation is produced by binary OR operation on the following bits:

Table 6-7: GRIMM protocol warning codes

Bit	Status
0	High baseline light warning
1	Laser current >90% (Laser current warning)
2	Pump output at >90% (Pump warning)
3	Dust filter at >90% (Filter warning)
4	Internal bus warning
5	Internal temperature warning
6	Weather sensor warning
7	Sampling unit warning

In the event of an error, the error code is output, the device aborts the measurement and switches to an error status. The error code in measuring operation is produced by binary OR operation on of the following bits:

Table 6-8: GRIMM protocol error codes

Bit	Status
0	Signal chain error
1	Laser error
2	Flow control error
3	Sampling not connected
4	Internal bus error
5	Reserved
6	Weather sensor error
7	Sampling unit error

6.2 Modbus TCP

The Modbus TCP implementation in the EDM 280 has the following properties:

- Access only via the RJ-45 socket on the back of the measuring module (Ethernet)
- IP address corresponds to the IP address set on the device. It can be set globally on the device
- The port used is 502 ("well-known port" for Modbus TCP)

Two data types are available for the registers:

- Float: 32-bit floating-point number as per IEEE 754, 1-bit sign, 8-bit exponent, 23-bit mantissa
- Unsigned: 32-bit unsigned integer

A value is therefore always assigned to 2 Modbus registers. The upper 16 bits of a value are stored in the respective start register for the measured value (see Table 6-9: Modbus overview of supported function codes). The lower 16 bits are stored in the following register.

<table>
<tr><td>31</td><td colspan="2" align="right">16</td><td>15   0</td></tr>
<tr><td>VZ</td><td>Exponent</td><td>Mantissa</td><td>Mantissa</td></tr>
<tr><td colspan="3">Register n</td><td>Register n + 1</td></tr>
</table>

Register assignment for float

<table>
<tr><td>31   16</td><td>15   0</td></tr>
<tr><td>High word</td><td>Low word</td></tr>
<tr><td>Register n</td><td>Register n + 1</td></tr>
</table>

Register assignment for unsigned

Supported function codes

The EDM 280 provides the following function codes, with no functionality implemented for the function codes 0x01 (Read Coils) and 0x0f (Write Coils). The corresponding coils are reserved for possible later extensions:

Table 6-9: Modbus overview of supported function codes

Name	Code
Read Coils	0x01
Read Holding Registers	0x03
Write Coils	0x0f
Write Holding Registers	0x10
Read Device ID	0x2b

Table 6-10 below contains the assignment of the holding registers when the interface is output via Modbus. Column 1 contains the name of the measured values, column 2 the unit in each case, column 3 the start register, column 4 the file type floating-point number with sign (F = float) or unsigned integer (U = unsigned) and column 5 read access (R = read) or read and write access (R/W = read and write).

The dust mass fractions and particle number concentrations are stored in the start registers 0 to 174. The lower channel threshold of the 72 size channels follows in start registers 204 to 346. Start registers 350 to 386 contain measured values from the internal and external sensors.

Start registers 400 to 412 contain information on the status of the measuring cell. Start registers 420 to 504 provide information on the device status. The meaning of the error codes is identical to the GRIMM protocol covered in the previous section. Start register 998 contains the timestamp for the last update of the measured values as a Unix timestamp.

Table 6-10: Modbus assignment of the holding registers

Measured value	Unit	Start register	Data type	Access
TSP	µg/m³	0	F	R
PM_{10}	µg/m³	2	F	R
PM_4	µg/m³	4	F	R
$PM_{2.5}$	µg/m³	6	F	R
PM_1	µg/m³	8	F	R
PM_{coarse}	µg/m³	12	F	R
Total counts	P/L	14	U	R
Reserved (inhalable)	µg/m³	16	F	R
Reserved (thoracic)	µg/m³	18	F	R
Reserved (respirable)	µg/m³	20	F	R
Reserved (pm_{10})	µg/m³	22	F	R
Reserved ($pm_{2.5}$)	µg/m³	24	F	R
Reserved (pm_1)	µg/m³	26	F	R
Particle number concentration channel 1	P/L	30	U	R
...	...			
Particle number concentration channel 71	P/L	174	U	R
Channel threshold channel 1	µm	204	F	R
...	...		F	R
Channel threshold channel 71	µm	346	F	R
Temperature (weather sensor)	°C	350	F	R
Humidity (weather sensor)	%	352	F	R
Wind speed (weather sensor)	m/s	354	F	R
Air pressure	hPa	356	F	R
Wind direction (weather sensor)	°	358	F	R
Precipitation intensity (weather sensor)	mm/h	360		
Latitude	° (decimal degrees)	370	F	R
Longitude	° (decimal degrees)	372	F	R
Height	m	374	F	R
Temperature (outlet aperture)	°C	380	F	R
Humidity (outlet aperture)	%	382	F	R
Temperature (measuring cell)	°C	384	F	R
Humidity (measuring cell)	%	386	F	R
Volume flow (outdoor conditions)	l/min	388	F	R
DC without bias, without laser	mV	400	F	R
DC with bias, without laser	mV	402	F	R
DC with bias, high laser power	mV	404	F	R
Zero counts with bias, without laser	P	406	U	R
Zero counts with bias, high laser power	P	408	U	R
Laser current at low laser power	mA	410	F	R
Laser current at high laser power	mA	412	F	R
P weight	µg	420	F	R
P volume	m³	422	F	R
Pump speed	%	424	F	R
Reserved (battery charge)	%	426	U	R
Error code self test	-	498	U	R
Status code measuring operation	-	500	U	R
Warning code self test	-	502	U	R
Error code measuring operation	-	504	U	R
Timestamp self test (UNIX timestamp)	s	996	U	R
Timestamp measuring operation (UNIX timestamp)	s	998	U	R
Interval	-	1000	U	R/W
Operating status	-	1002	U	R/W
Reserved (C factor)	-	1004		

The coding for interval (start register 1000) and operating status (start register 1002) can be found in the following tables.

Table 6-11: Modbus coding of the interval

Value	0	1	2	3	4	5	6	7
Interval	1 min	5 min	10 min	15 min	30 min	60 min	6 sec	Daily average values

Changing the measurement interval while a measurement is running causes the measurement to restart. It is averaged over the interval. The measured value is updated at the end of the interval.

Table 6-12: Modbus coding of the operating status

Content	Status
0	Standby
1	Self test
2	Measuring operation (the user cannot actively switch to this status)
3	Error status (the user cannot actively switch to this status)

The device IDs (function code 0x2B) can be used to query assorted manufacturer or device-specific information. All information is output as strings with a maximum length of 32 characters.

Table 6-13: Modbus assignment of device IDs

Device ID (hex)	Content	Conformity level
0x00	Manufacturer	Basic
0x01	Product code	
0x02	Version	
0x03	Manufacturer website	Regular
0x04	Product name	
0x80	Serial number	Extended
0x81	Weather sensor	

6.3 GESYTEC / Bayern-Hessen protocol

The GESYTEC / Bayern-Hessen protocol, referred to below simply as the GESYTEC protocol, transfers the data via the serial interface at a baud rate of 115200 bit/s.

6.3.1 Measuring device identifiers

The GESYTEC protocol has a variable base identifier. The base identifier can be freely selected by the customer in the range from 0 to 988.

Table 6-14: GESYTEC protocol addressable measured values

Measured value	Device identifier	Unit
PM10	Base identifier + 0	µg/m^3
PM4	Base identifier + 1	µg/m^3
PM2.5	Base identifier + 2	µg/m^3
PM1	Base identifier + 3	µg/m^3
PMcoarse	Base identifier + 4	µg/m^3
Total counts	Base identifier + 5	P/L
Temperature (weather sensor)	Base identifier + 6	°C
Relative humidity (weather sensor)	Base identifier + 7	%
Air pressure	Base identifier + 8	hPa
Temperature (outlet aperture)	Base identifier + 9	°C
Relative humidity (outlet aperture)	Base identifier + 10	%
Temperature (measuring cell)	Base identifier + 11	°C
Relative humidity (measuring cell)	Base identifier + 12	%

6.3.2 Status values

The operating status is global, as is the error status of the measuring location. This means that each measuring device at a measuring location returns the same operating status or the same error status. Operating status and error status correspond to the status code in the GRIMM data protocol GP280.

The freely usable mearing location field is global, which means that each measuring device at a measuring location sends the same coding from the respective freely usable field. 3 bytes can be encoded as ASCII hex in each field. The following coding is implemented.

Table 6-15: GESYTEC protocol coding of operating status, error status and measurement interval

Byte	Meaning	Comments
0	Warning code	Corresponds to the warning code in GP280
1	Device status	Corresponds to the status code in GP280
2	Measurement interval	Corresponds to the coding of the measurement interval in GP280

6.3.3 Control commands

The following control commands (control byte ST telegram) are supported.

Table 6-16: GESYTEC protocol coding of control commands

Control byte (hex)	Meaning
00	Device switches to standby.
01	Device switches to self test and then to measuring operation

7 | Maintenance and cleaning

The components of the EDM 280 are designed to enable low-maintenance operation. The calibration, testing and maintenance work required at fixed intervals is compulsory and must be carried out by the operator. Part of the process of regular calibration is to check the wear indicators and carry out preventive maintenance in order to make downtimes predictable and keep them to a minimum. The sample air pump, filters and ventilator are wear parts that are replaced at the end of their life time (MTBF), while the mirror optics and measuring cell are cleaned as part of preventive maintenance.

If a cost-optimised approach is preferred, where pump, filters and ventilator are used until they actually fail, spare parts kits are available for on-site repairs. The operator is responsible for electrical safety after on-site repairs. Service training is required for these work steps.

Menu navigation on the touch display is designed to provide the user with all relevant information for necessary service and maintenance work. For more information, see also section Display of measured values on the touch display.

Table 7-1: Maintenance intervals

Measure	Interval	Measure	Typical time and effort
Calibration	Every 12 months When the "Calibration" wear indicator is completely red.	Section 7.2.1	15 minutes 1 person
Verification	Every 3 months When the "Verification" wear indicator is completely red.	Section 7.2.2	30 minutes 1 person
Cleaning of the Sigma-2 sampling head	Every 3 months Depending on the dirt and contamination	Section 7.2.9	10 minutes 1 person
Cleaning of the inlet nozzle	Every 3 months	Section 7.2.10	5 minutes 1 person
Cleaning of the sampling tube	Every 12 months Depending on the dirt and contamination	Section 7.2.11	15 minutes 1 person
Replacement of filters in sample air stream	Preventive, when the "Filter Replacement" wear indicator is completely red.	Section 7.2.12	Only with service training
Replacement of sample air pump	Preventive, when the "Pump Maintenance" wear indicator is completely red.	Section 7.2.12	Only with service training

7.1 Replaceability of spare parts

The following components/assemblies can be replaced by a service technician on site

- Aerosol pump
- Filter kit
- Condensate trap
- Condensate valve
- Housing ventilator
- Gaskets/seals
- Touch display
- Power adapter

The following components/assemblies can only be replaced after the measuring module has been sent in for servicing

- Laser
- Touch display
- Measuring cell
- Power adapter
- Circuit boards

7.2 Maintenance procedures

7.2.1 Calibration

Calibration requires an air-conditioned laboratory, special equipment and trained personnel. Please send the measuring module to GRIMM Service or a GRIMM service partner for calibration. Proceed as follows:

1. End measuring operation and switch to standby.
2. Remove the measuring module.
3. Put the protective dust cap on the inlet nozzle and close the protective dust cover.
4. Screw in the transport lock on the right-hand side.
5. Pack the measuring module in its original cardboard box.
6. If the weather sensor deviates, send it in as well.

7.2.2 Verification

The purpose of verification is to regularly check relevant measured variables for gross deviations from reference measured values. It is therefore carried out on site and requires reference measuring devices with the accuracy specified in brackets for temperature (± 1.5 °C), humidity (± 3% RH), pressure (± 5 hPa) and volume flow (± 2% at 1.2 l/min).

A field test kit and a computer with a connection to one of the interfaces are also required. We recommend using the USB service interface on the front.

It is a good idea to also take care of the cleaning steps while doing this work, assuming that the dirt and contamination situation requires it. The cleaning kit is required for this purpose.

⚠	**Attention** The sampling head is disassembled for the following work. Be careful not to let anything fall into the inlet tube and do not let it rain into it. Always fit the inlet adapter immediately.

7.2.3 Visual inspection

1) Stop measuring operation, switch off the switch
2) Release the lift, remove the measuring module
3) Remove the inlet nozzle and check for dirt, contamination and blockage, see section 7.2.10
   - ✘ If there are visible deposits, remove them with the cleaning kit
   - ✘ If the seal is damaged, replace it
   - ✓ Screw the inlet nozzle back into place

4) Remove the sampling head and check for dirt and contamination, see section 7.2.9
   - ✗ If the sampling head plate or sampling head are clearly dirty, clean them
   - ✗ In this case, also clean the sampling tube, see section 7.2.11
   - ✓ Set the sampling head and screws aside
5) Fit the inlet adapter onto the inlet tube
6) Screw the sealing screw from the field test kit into the sample air outlet
7) Install the measuring module back into place and close the lift
8) Insert the service dongle S2 into the measuring module. This will log data from all subsequent tests and enable the configuration menus.

7.2.4 Leak test

💡	Leakage can lead to air from the measuring container flowing unchecked into the sample air path in the measuring system. This can adulterate the dust concentrations. If the otherwise particle-free purge air becomes impure, further damage from contamination is possible. The leak tightness of the pneumatics therefore needs to be checked.

Figure 7-1: Leak test and inlet adapter set (centre, front)

9) Fit the pressure gauge into place and build up 100 Torr overpressure. To do this:
   1. Close the valve knob in the clockwise direction
   2. Pump with the rubber ball until you reach approx. 150 Torr overpressure
   3. Gently open the valve knob until the pressure has dropped to 100 Torr
10) Watch the pressure drop over 60 seconds
   - ✓ The pressure should drop by a maximum of 5 Torr
   - ✗ If the pressure falls faster, check the seals on the sealing screw, the inlet nozzle and the inlet adapter for damage. Disconnect the hose from the pressure gauge and check the gauge itself for leaks.
11) Remove the pressure gauge

7.2.5 Zero point test

12) Fit the zero filter for the zero point test so that the flow (arrow) is pointing in the direction of the sample inlet
13) Remove the sealing screw from the sample air outlet
14) Switch on the switch, start measuring operation with a 6-second measurement interval
15) Watch the TSP and TC values, after two minutes both values should have fallen

✓ TSP is continuously displayed or output with 0.0 µg/m^3

✓ TC is continuously below 2000 p/l

End the zero point test after 5 minutes

✗ If the concentration does not fall below the limit values:

1. Perform a self test. If it does not produce a warning, the zero filter from the field test kit is probably defective. Replace it.
2. Log the self test and zero point check on a USB flash drive. Contact GRIMM Service or a service partner with this data.

7.2.6 Volume flow test

The following section describes three methods for testing the volume flow:

- 20 a) is the simplest if a volumetric reference measuring device is in use
- 20 b) tests the volume flow at the measuring orifice under device-internal conditions
- 20 c) tests the volume flow under different reference conditions, for example when a mass-related reference measuring device is in use

20 a) and 20 c) assume that the weather sensor is measuring correctly, this is not checked until later in the procedure.

16) Remove the zero filter again, connect the reference volume flow measuring device to the inlet adapter
17) Wait until the measured values have stabilised
18) Log volume flow Q_{ref} and where applicable also the reference conditions (temperature T_{ref}, pressure p_{ref})
19) Open the Current PM & Weather Values menu and make a note of temperature T and air pressure p
20) Open the Internal Sensor Values menu and make a note of volume flow Q

20 a) Reference measured value to ambient conditions:

✓ The volume flow Q must not deviate by more than 5% from the reference measured value Q_{ref}.

✗ If there are differences in temperatures and pressures, convert the volume flow as follows.

20 b) Reference measured value to other reference conditions:

Convert the volume flow with $Q'_{ref} = (T + 273.15) / (T_{ref} + 273.15) \cdot (p_{ref} / p) \cdot Q_{ref}$

The temperatures are given here in degrees Celsius (°C), the pressures in hectopascals (hPa)

✓ The volume flow Q must not deviate by more than 5% from the converted reference measured value Q_{ref}.

✗ In the event of major deviations:

✗ Check for leaks or kinks between the reference measuring device and the sample inlet

✗ Check the measuring range for the reference measuring device, if possible choose a smaller measuring range (target value 1.2 l/min) and a longer averaging interval

✗ Open the Instrument Status menu. Check for warnings and errors

✘ If the deviation cannot be remedied, the cause will need to be found and the volume flow measurement recalibrated. To do this, the measuring module must be removed and set up in a thermally stable environment with a suitable volume flow reference measuring device. Please contact GRIMM Service or a GRIMM service partner.

21) Remove the inlet adapter, fit the sample head back into place and screw in the screws

7.2.7 Weather sensor test

💡	Direct sunlight can have a negative impact on the reference measuring device's temperature and humidity measurement. It is therefore better to carry out the test when it is cloudy or in the morning or evening.

The measured values from the weather sensor are required for correct conversion of the dust concentrations to the ambient conditions and for controlling sample conditioning. Strong deviations will also result in a deviation in the dust concentrations and classified particle diameters.

22) Open the Current PM & Weather Values menu
    a) If they are not visible, select the displays for pressure, temperature and humidity

23) Compare with the reference measured values. The following deviations are tolerable:
    - ✓ Temperature: ± 2.0°C
    - ✓ Humidity: ± 5% RH
    - ✓ Ambient pressure: ± 10 hPa
    - ✘ If deviations outside the tolerances occur, disassemble the weather sensor and send it in for calibration.

7.2.8 Reset the verification display

24) Connect to the computer via the service interface or in the GRIMM protocol

25) Use the S command to end measuring operation, switch to standby

26) Calculate the current Unix timestamp UTS:
    UTS = 31556926 * (Y – 1970) + 604800 * W
    where Y is the current year and W is the current calendar week

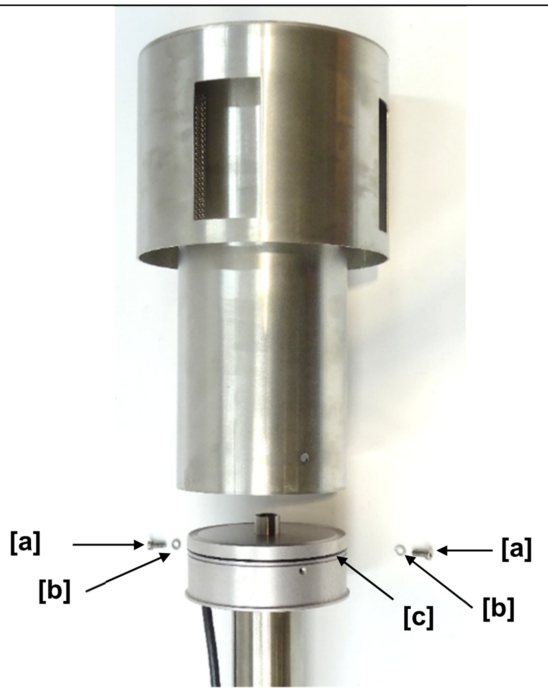
27) Use the command [Ctrl] + S to call up the settings for the service registers and set the following values:
    1. SRVI_VERDATE: UTS
    2. SRVW_VERDATE: UTS + 7889229
    3. Save the settings with [Enter] and exit the menu

28) Switch the measuring module off and on again
    ✓ Open the Instrument Status menu. The verification bar is now completely green again and will remind you of the next verification.

7.2.9 Cleaning of the Sigma-2 sampling head

The steps for cleaning the Sigma-2 sampling head are shown in Table 7-2. The tools required for this job are underlined, wear or spare parts are indicated with their respective seven-digit item number.

Table 7-2: Cleaning of the Sigma-2 sampling head

<table>
<tr>
<td>




</td>
<td>
Cleaning of the Sigma-2 sampling head

1) Disassemble the Sigma 2 head (4018100) from the sampling tube
■ Loosen the two screws [a] with a <u>2.5 Allen screwdriver</u>
■ Carefully pull off the Sigma-2 head with a twisting motion

2) Clean the Sigma-2 head
■ Wipe off dirt on the outside with a <u>cloth</u>
■ Remove any dirt and contamination inside
■ Clean the inlet grille and blow it out with <u>compressed air</u> (oil-free) if necessary

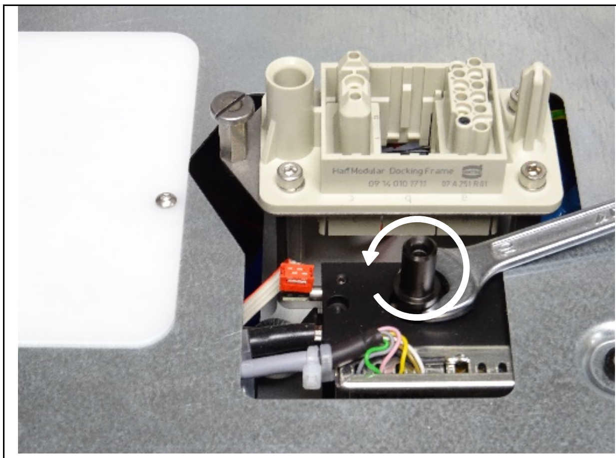
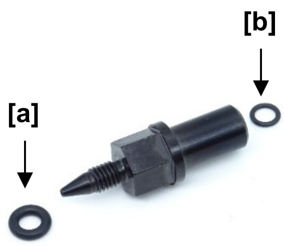
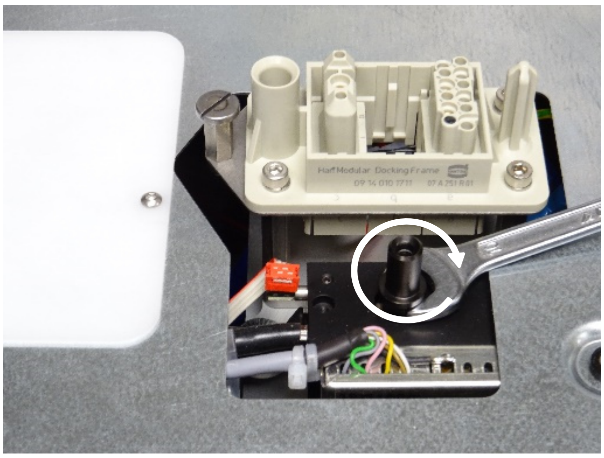
3) Check the 80 x 1.5 O-ring (1200570) [c], it must not show any damage ✓
■ Regrease with a little <u>silicone grease</u> if necessary

4) Carefully fit the Sigma-2 head back onto the sampling tube with a twisting motion
Do not damage the O-ring
■ Fix the Sigma-2 head to the sampling tube with
2 M4x10 A4 cylinder screws (4027263) [a] and
2 4 A4 lock washers (1203502) [b]
</td>
</tr>
</table>

7.2.10 Cleaning of the inlet nozzle

The steps for cleaning the inlet nozzle are shown in Table 7-3. The tools required for this job are underlined, wear or spare parts are indicated with their respective seven-digit item number.

Table 7-3: Cleaning of the inlet nozzle

	**Cleaning of the inlet nozzle** 1) Remove the inlet nozzle ■ Turn the lift lever in the EDM 280 upwards and unscrew the EDM 280 inlet nozzle (4026450) in the counterclockwise direction with a <u>size 10 open-end spanner</u> 2) Check the inlet nozzle ■ For mechanical damage ■ For foreign bodies in the nozzle
	3) Clean the inlet nozzle ■ Clean the nozzle with the cleaning set and blow it out with compressed air (oil-free) ■ Visual inspection – when clean and free, the nozzle hole must appear circular against a light background ✓
	4) Check the O-rings ■ O-ring 4x2.0 EPDM 70 (4029626) **[a]** and O-ring 4x1.0 EPDM 70 (1200552) **[b]** must not be damaged ✓ Replace if necessary ■ Apply a little <u>silicone grease</u> to the O-rings
	5) Install the inlet nozzle ■ Tighten the EDM 280 inlet nozzle (4026450) back into place in the clockwise direction by hand with the <u>size 10 open-end spanner</u> You should be able to apply the force needed with two fingers

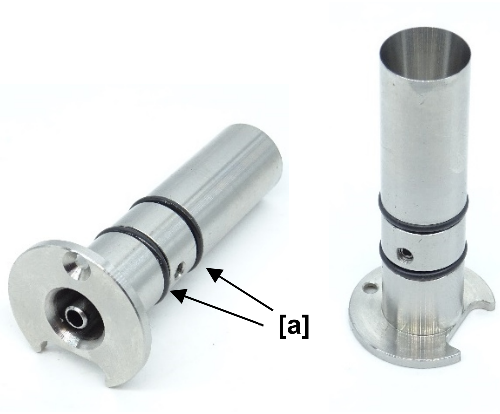
7.2.11 Cleaning of the sampling tube

The steps for cleaning the sampling tube are shown in Table 7-4. The tools required for this job are underlined, wear or spare parts are indicated with their respective seven-digit item number.

Table 7-4: Cleaning the sampling tube

Cleaning the sampling tube

1) Remove the coupling on the sampling tube outlet from the support tube
   - Remove the Phillips countersunk screw M2 x 5 A2 (4034773) with a PH0 screwdriver and
   - Pull the coupling carefully out, for example with a large screwdriver



2) Clean and check the coupling
   - Clean the coupling with a soft cloth and blow out with compressed air (oil-free)
   - Visual inspection:
     There should be no lint or other residues left in the coupling ✓

3) Check the O-rings
   - If necessary, apply a little silicone grease to both O-rings 11x1.5 (4025686) [a]

4) Clean the sampling tube
   - Clean the inside of the sampling tube with the cleaning set
   - Visual inspection:
     There should be no lint or other residues left in the sampling tube ✓

5) Install the coupling back into place
   - Insert the coupling into the support tube and fix it back into place with the Phillips screw

7.2.12 Replacing the filters in the sample air stream and replacing the sample air pump

The filters in the sample air stream and the sample air pump are wear parts that are replaced at the end of their life time (MTBF). This is usually done during servicing by the manufacturer.

If a cost-optimised approach is preferred, where pump and filters are used until they actually fail, spare parts kits are available for on-site repairs. The operator is responsible for electrical safety after on-site repairs. Service training is required for these steps, and also special, detailed work instructions.

7.3 Service modes and keys

The maintenance and servicing work for the EDM 280 is divided into four service levels (service mode) structured in a hierarchy. Functions at a lower service level are also available at the higher service levels.

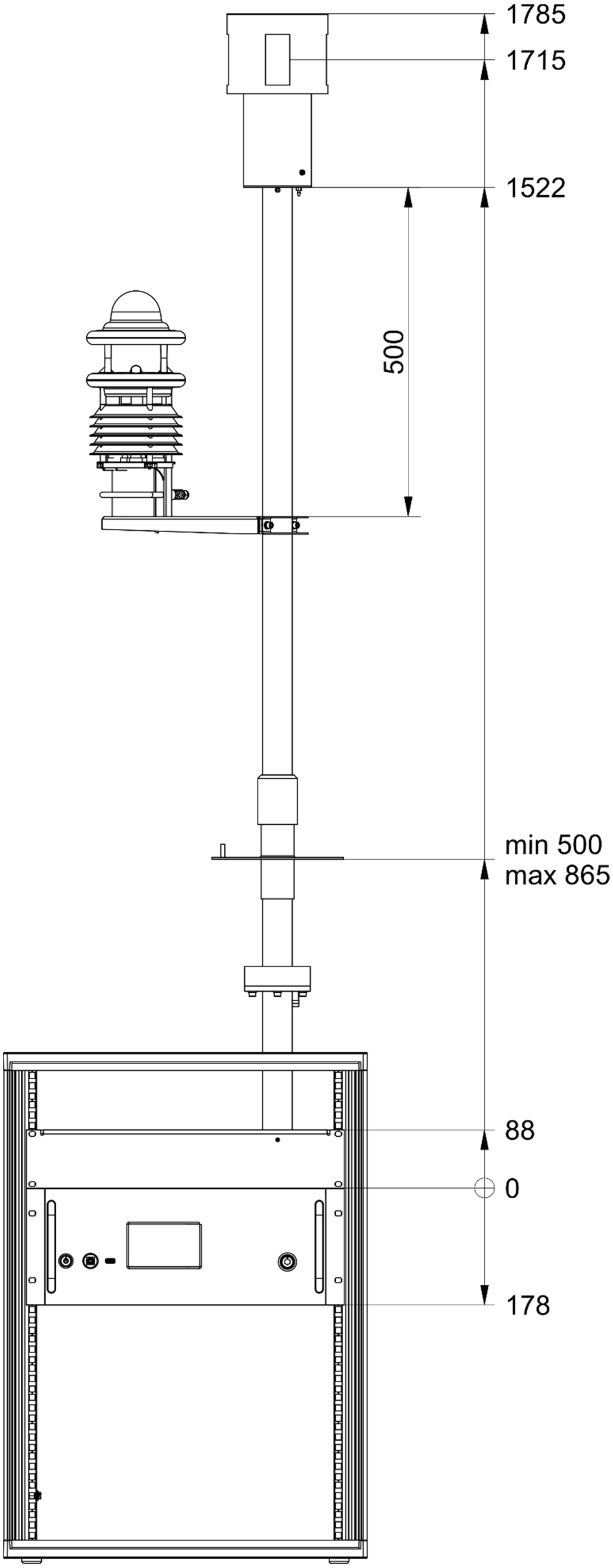
Service mode 1 is activated via command line or touch display. A USB dongle is required from service mode 1 to enable service mode. The dongle contains the signed XML file key.xml, which authenticates the dongle.

Table 7-5: Service mode, overview of functions and areas of application

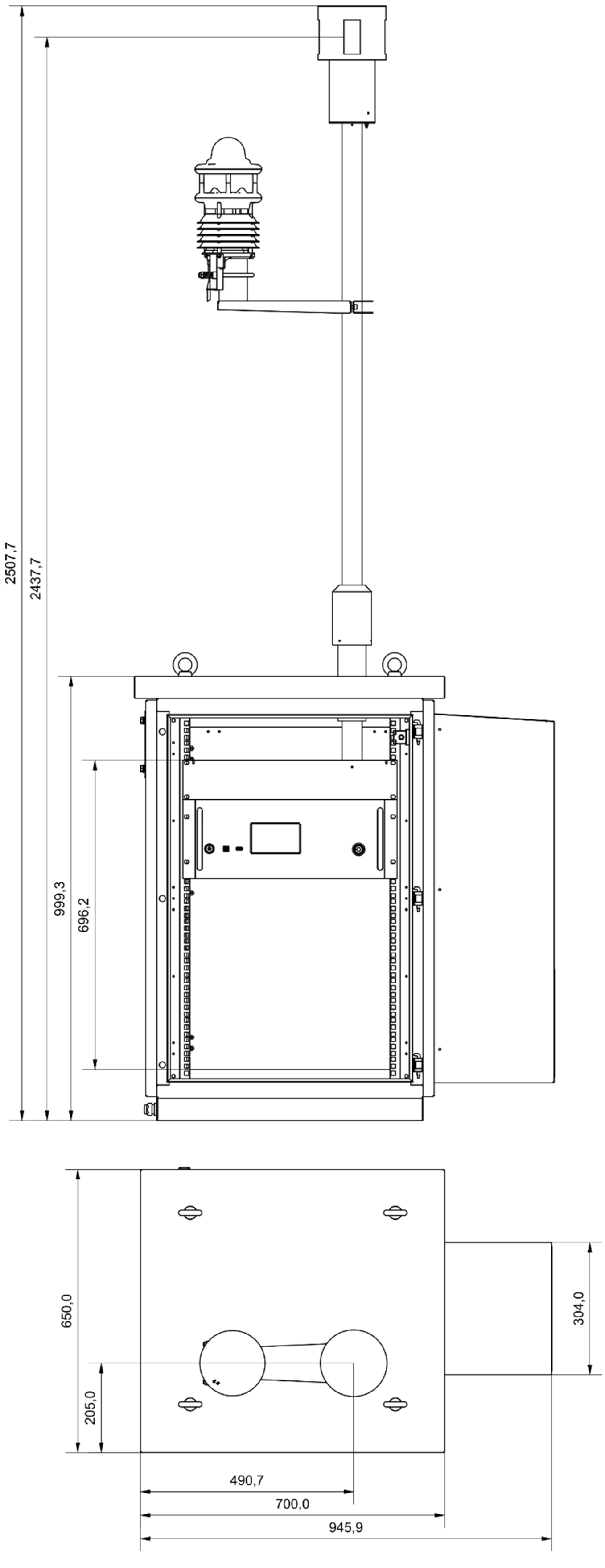
Service level	User / typical use case	Functions
Service mode 0	Normal measuring operation	Start/stop measurement Display operating time Display firmware and FPGA version Output averages Output serial number Output model name Output data header in GRIMM protocol
Service mode 1	Protected settings that can be changed by the customer	Adjust measurement interval Adjust time and date Output and reset averages Enable/disable measured value output Display thresholds Output data in internal memory IP address configuration GESYTEC configuration
Service mode 2	Field calibration	Calibrate volume flow Configure heating (humidity threshold, factor, offset) Display/configure service register Reference point measurement
Service mode 3	Calibration, service	Advanced settings
Service mode 4	Production	Advanced settings

8 | Appendix

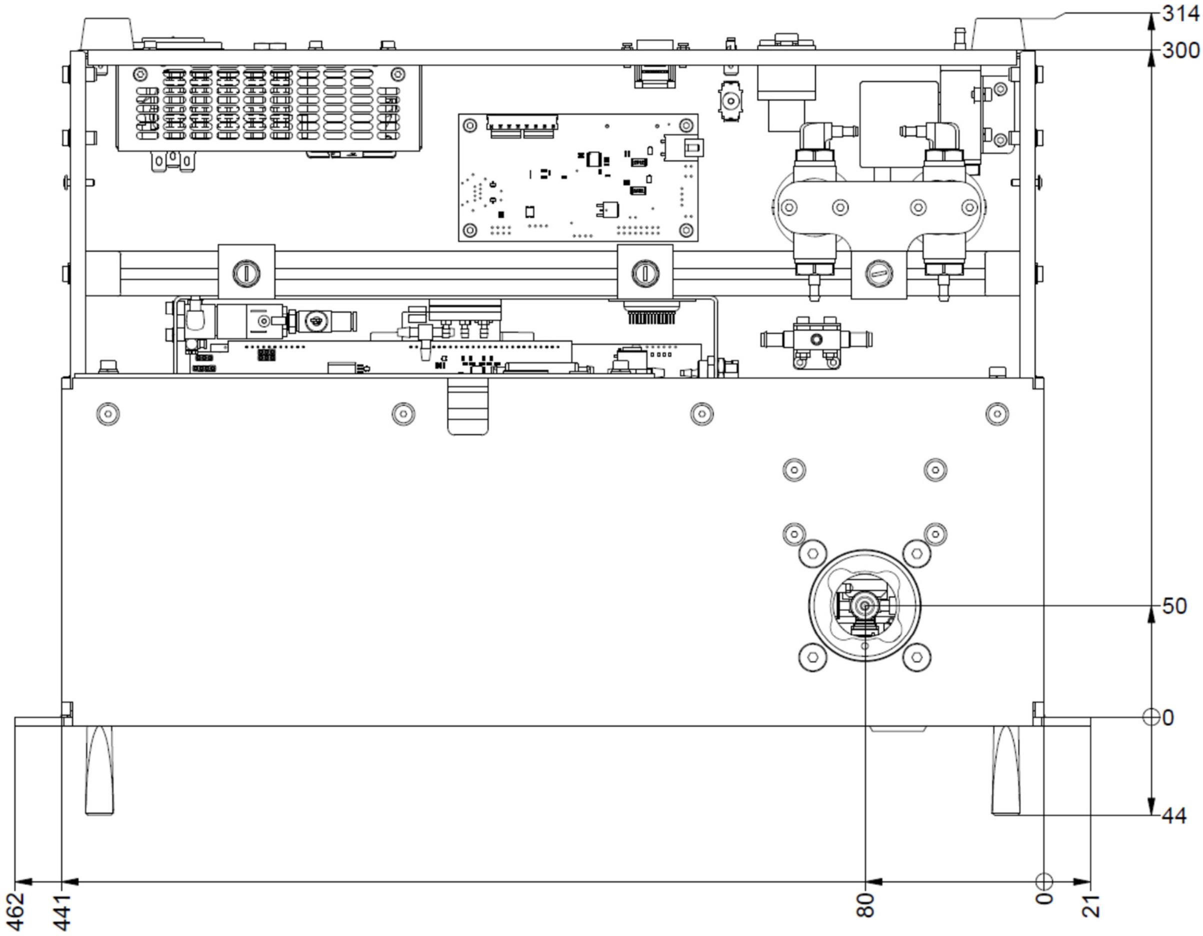
Complete system in 19" rack, with scale



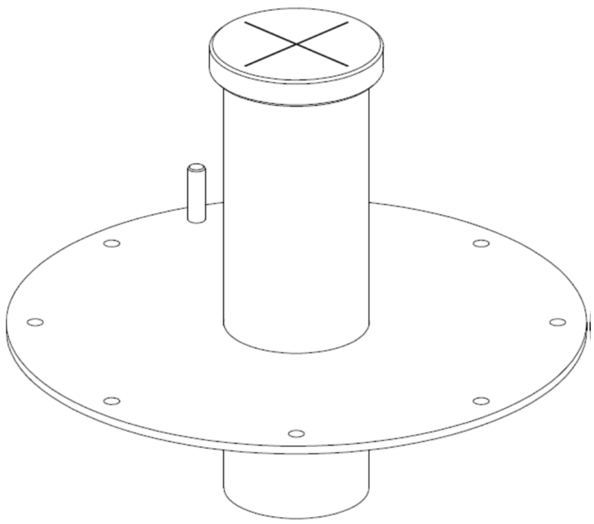
Complete system in fully air-conditioned, weatherproof housing for model 199 19″ device (item number 4025195), with scale



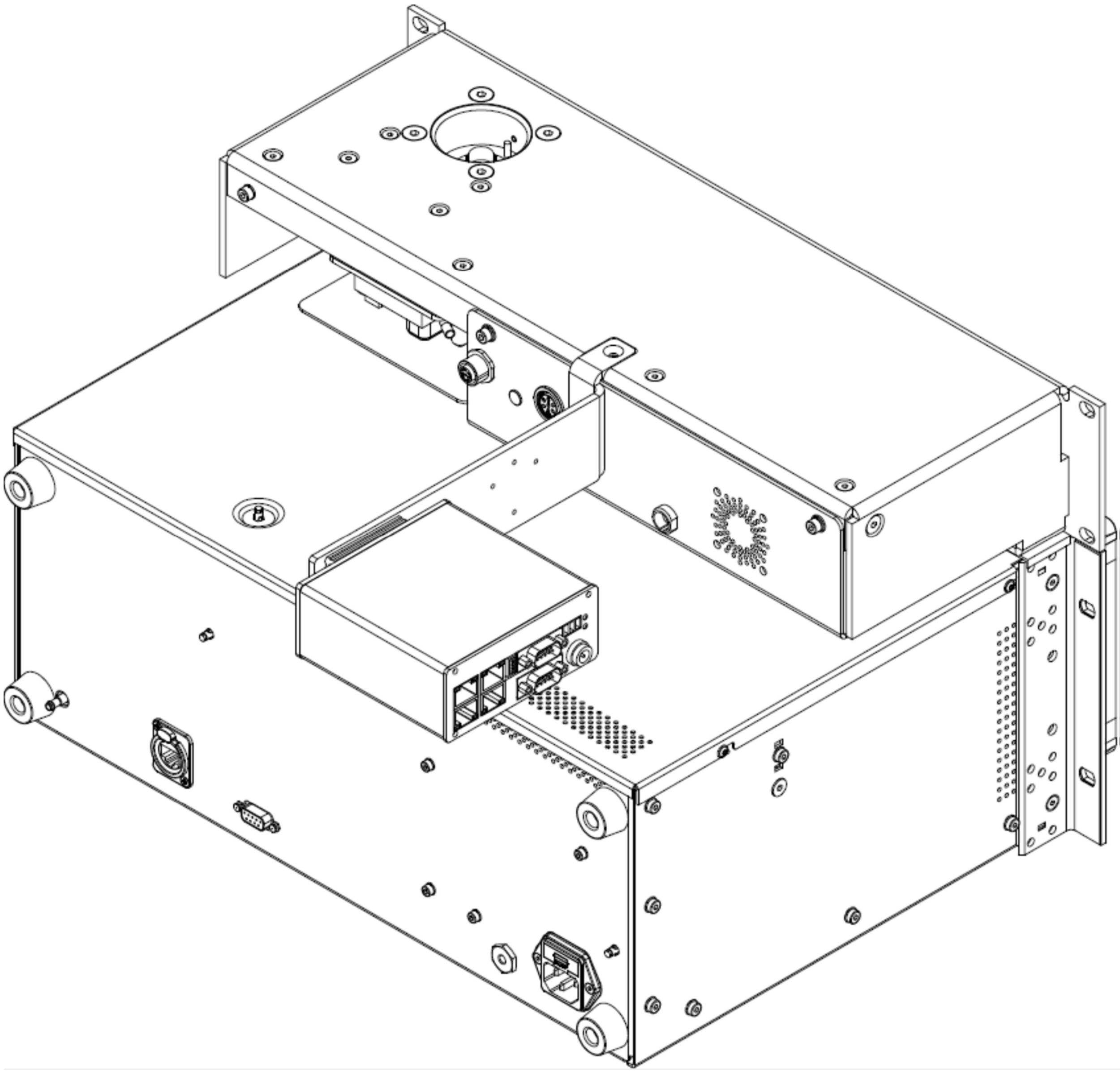
Position of the sample inlet in the 19″ module, with scale



EDM 280 roof flange with alignment aid



Measuring module and sampling tube holder with optional data logger



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