TÜV RHEINLAND ENERGY GMBH

Deutsche Akkreditierungsstelle
D-PL-11120-02-00

Report on the performance test of the MP101M ambient air quality measuring system for suspended particulate matter $PM_{2.5}$ manufactured by ENVEA

TÜV Report: 936/21240384/D
Cologne, 15 August 2019

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- Determination of emissions and ambient air quality affected by air pollutants and odorous substances,
- Inspection of correct installation, function and calibration of continuously operating emission measuring instruments, including data evaluation and remote emission monitoring systems;
- Measurements in combustion chambers;
- Performance testing of measuring systems for continuous monitoring of emissions and ambient air, and of electronic data evaluation and remote emission monitoring systems;
- Determination of the stack height and air quality forecasts for hazardous and odorous substances;
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according to EN ISO/IEC 17025.

The accreditation will expire on 10-12-2022 and
covers the scope specified in the annex to certificate D-PL-11120-02-00.

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Summary Overview

ENVEA located in Poissy, France, commissioned TÜV Rheinland Energy GmbH to carry out performance testing of the MP101M measuring system for suspended particulate matter $PM_{2.5}$ in accordance with the following standards:

- Standard EN 16450 “Ambient air – Automated measuring systems for the measurement of the concentration of particulate matter (PM10; PM2.5, German version dated July 2017)
- 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

The MP101M measuring system determines dust concentrations using beta attenuation as its measuring principle. A pump sucks in ambient air via a $PM_{2,5}$ pre-separator. The air is then transported to the measuring system via a sampling tube. The sampling tube contains a heater to avoid condensation effects. Inside the instrument, particles are separated onto a filter tape. A radiometric measurement determines the filter load once an hour.

The tests were performed in the laboratory and in a seventeen-months long field test.

The several-months long field test was performed at the sites listed in Table 1.

Table 1: Description of the measurement sites

	Cologne (parking lot) Winter	Bonn-Belderberg (summer)	(Cologne) Bulk handling, Summer	(Cologne) Bulk handling, Winter
Period	12/2017 – 03/2018	04/2018 – 06/2018	07/2018 – 11/2018	12/2018 – 02/2019
Number of measurement pairs: Test specimens	57	40	66	45
Description	Urban background	Affected by traffic	Industrial back-ground	Industrial back-ground
Classification of am-bient air pollution	low to high	average	average to high	average to high

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

Table 2: Equivalence test results (raw data)

Comparison campaigns		Slope	Axis inter-cept	All Data sets W_{CM}<25 % Raw data	Calibration yes/no	All Data sets W_{CM}<25% cal. Data
4	Cyc.	1.020	-1.097	yes	yes	yes
	Per.	1.018	-1.153	yes	yes	yes

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Report on the performance test of the MP101M ambient air quality measuring system for suspended particulate matter $PM_{2.5}$ manufactured by ENVEA ,

AMS designation:	MP101M
Manufacturer:	ENVEA 111, Bd Robespierre 78304 Poissy Cedex 4 France
Test period:	07.2017 to 04.2019
Date of report:	15 August 2019
Report Number:	936/21240384/D
Editor:	Fritz Hausberg
Technical supervisor:	Guido Baum

Scope of the report:	Report:	100	pages
	Appendix	101	
	Manual	127	
	Manual	192	pages
	Total	325	pages

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Table of contents

List of tables

List of figures

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:

MP101M for suspended particulate matter $PM_{2.5}$

Manufacturer:

ENVEA, Poissy, France

Field of application:

For continuous and stationary air quality control of suspended particulate matter, $PM_{2,5}$ fraction

Measurement ranges during performance testing:

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

Software version:

MP101M 4.0.h

Restrictions:

None

Notes:

1. The maintenance interval is one month.
2. This report on the performance test is available online at www.qal1.de.

Test Report:

TÜV Rheinland Energy GmbH, Cologne
Report no.936/21240384/D dated 15 August 2019

1.2 Summary report on test results

Summary of test results in accordance with standard EN 16450

Performance criterion	Requirement	Test result	satis-fied	Page
1 Measuring ranges	0 µg/m³ to 1000 µg/m³ as a 24-hour average value 0 µg/m³ to 10,000 µg/m³ as a 1-hour average value, if applicable	The upper limit of the measuring range is at 10,000 µg/m³.	yes	31
2 negative signals	Shall not be suppressed	The AMS is able to display negative readings directly and via the various measured signal outputs.	yes	32
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 were determined at 1.35 µg/m³ for S/N 6160 and 1.59 µg/m³ for S/N 6160.	yes	33
4 Flow rate accuracy (7.4.4)	≤ 2.0%	The relative difference determined for the mean of the measuring results at flow rates at 5°C and at 40°C did not exceed -1.25%.	yes	35
Constancy of sample flow rate (7.4.5)	≤ 2.0% sampling flow (averaged flow) ≤ 5% rated flow (instantaneous flow)	The 24h-averages deviate from their rated values by less then -1.10%, all instantaneous values deviate by less than 3.18%.	yes	37
6 Leak tightness of the sampling system (7.4.6)	≤ 2.0% of sample flow rate	The criterion for passing the leak test as specified by the AMS manufacturer – maximum flow rate of 5 l/min as well as P1 and P2 below 250 mbar when the inlet is blocked – proved to be adequate during performance testing as a criterion for monitoring the instrument's leak tightness. The maximum leak rate is 4.85 l/min, all pressures determined were below 250 l/min.	yes	40
7 Dependence of measured value on surrounding temperature (7.4.7)	≤ 2.0 µg/m³	The tested temperature range was 5 °C to 40 °C. The maximum deviation from the mean reading at $TS_{,n}$ was at 1.1 µg/m³.	yes	42
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 mean reading at 20 °C was at 2.2 %.	yes	44

Performance criterion	Requirement	Test result	satis-fied	Page
9 Dependence of span on supply voltage (7.4.8)	≤ 5% from the value at the nominal test voltage	Voltage variations did not cause deviations exceeding 0.6% of the average at 230V at the extreme values.	yes	46
10 Effect of failure of mains voltage	Instrument parameters shall be secured against loss. On return of main voltage the instrument shall automatically resume functioning.	All instrument parameters are secured against loss. On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring.	yes	48
11 Dependence of reading on water vapour concentration (7.4.9)	≤ 2.0 µg/m³ in zero air	Differences between readings determined at relative humidities of 40% and 90% did not exceed -2.04 µg/m³.	yes	49
12 Zero checks (7.5.3)	Absolute value ≤ 3.0 µg/m³	The absolute measured value determined at the zero point did not exceed 0.1 µg/m³.	yes	51
13 Recording of operational parameters (7.5.4)	Measuring systems shall be able to provide data of operational states for telemetric transmission of – at minimum – the following parameters: Flow rate pressure drop over sample filter (if relevant) Sampling time Sampling volume (if relevant); Mass concentration of relevant PM fraction(s) Ambient temperature Exterior air pressure Air temperature in measuring section temperature of sampling inlet if heated inlet is used	The measuring system allows for comprehensive monitoring and control via various connectors (Ethernet, RS232). The instrument provides operating statuses and all relevant parameters.	yes	53
14 Daily averages (7.5.5)	The AMS shall allow for the formation of daily averages or values.	It is possible to form valid daily averages.	yes	55
15 Availability (7.5.6)	At least 90%.	Availability was at 100% for both instruments.	yes	56
16 Between-AMS uncertainty (7.5.8.4)	≤ 2.5 µg/m³	At no more than 0.95 µg/m³ the uncertainty between the test specimen ubs remains well below the permissible maximum of 2.5 µg/m³.	yes	59

Performance criterion	Requirement	Test result	satis-fied	Page
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 (after calibration where necessary, see 7.5.8.5)	Without the need for any correction factors, the expanded uncertainties WAMS were below the expanded, relative uncertainty Wdqo defined for fine dust at 25% for all data sets observed. As the axis intercept determined for system 1 is significantly different from 0, section 6.1 17 Use of correction factors/terms required the use of a correction factor.	yes	66
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 air quality monitors for all data sets. The requirements had been met even before a correction factor was applied.	yes	88
18 Maintenance interval (7.5.7)	At least 14 d	The maintenance interval is 1 month.	yes	95
6.1 19 Automatic diagnostic check (7.5.4)	Shall be possible for the AMS	The instrument provides all features described in the operation manual. The current operating status is continuously monitored and any issues will be flagged via a series of different warning messages. Data recording includes all monitored parameters.	yes	96
20 Checks of temperature sensors, pressure and/or humidity sensors	Shall be checked for the AMS to be within the following criteria ± 2°C ± 1kPa ± 5 % RH	It is possible to check and adjust the sensors for determining ambient temperature, ambient pressure and relative humidity on-site. The sensors' deviations remained within the required ranges.	yes	97

2. Task Definition

2.1 Nature of the test

ENVEA commissioned TÜV Rheinland Energy GmbH to submit the MP101M air quality monitor for suspended particulate matter $PM_{2.5}$ to performance testing.

2.2 Objectives

The air quality monitor is designed to determine suspended particulate matter $PM_{2.5}$ in ambient air in the concentration range between 0 and 10,000 µg/m³.

The measuring system uses beta attenuation to determine the concentration of suspended particulate matter.

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 (PM10; PM2.5, 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

3. Description of the AMS tested

3.1 Measuring principle

The MP101M measuring system is designed to measure suspended particulate matter in ambient air. The determination of the mass concentration relies on the principle of beta ray attenuation. The sample is first sucked through a $PM_{2,5}$ pre-separator and then through a glass fibre filter tape in the instrument. Suspended particulate matter is deposited on the filter tape. Every hour, a beta source (^{14}C element) is swivelled in to determine the mass deposited on the filter tape. A Geiger Müller counter measuring beta radiation is situation below the filter tape. The ^{14}C radioelement emits beta rays as it decays. Particles deposited on the filter tape partially absorb the beta radiation. The filter spot is measured before and after loading. The difference in radiation intensity measured by the Geiger Müller counter serves as measure for the deposited amount of particulate matter.

3.2 Functioning of the measuring system

The particulate sample passes the sampling head (USEPA) at a flow rate of 16.67 l/min and enters the sampling tube, which connects the sampling head to the actual measuring instrument. The sampling head separates all particles larger than $PM_{2.5}$. The sampling tube can be heated in order to avoid possible condensation effects, especially in situations with high outdoor air humidity. After entering the measuring instrument, the air stream contained in the sample is separated on the filter tape. After leaving the measuring system, the air flow reaches the pump and then exits into the environment via a particle filter.

Figure 1: View of the MP101M

Every hour (1 period), the sample volumetric flow is stopped and a beta radiation source is swivelled over the filter band. The Geiger Müller counter situated below the filter tape measures the intensity of radiation. Every filter tape is measured before and after filter loading. The absorbed radiation is proportional to the separated particle mass and thus the absorption difference is the measured quantity. One measurement takes 200 seconds. The measured values of 24 periods are the averaged 24 hour value (1 cycle). After 24 hours, the filter tape is transported forward and a new blank spot is sampled.

The volumetric flow is kept constant at 1m³/h in the separator head. Since the velocity in the sampling head determines the separation characteristics, the volume flow is controlled by the weather sensors so that the volume flow in the sampling head is constant.

The sampling tube can be heated to avoid condensation effects. Since excessive temperatures in the sampling tube can lead to reduced results due to volatilization, the sampling tube is only heated as much as absolutely necessary. A sensor measuring relative moisture is situated near the Geiger Müller counter. If this sensor detects relative moisture above 50%, the heater will be activated.

(1) reference gauge, (3) source holder, (4) retractable tip on sample inlet, (5) capstan, (6) pinch roller, (7) take-up reel, (8) Geiger-Müller detector tube, (9) plate assembly, (10) pay-out reel.

Figure 2: Front view of the MP101M (open)

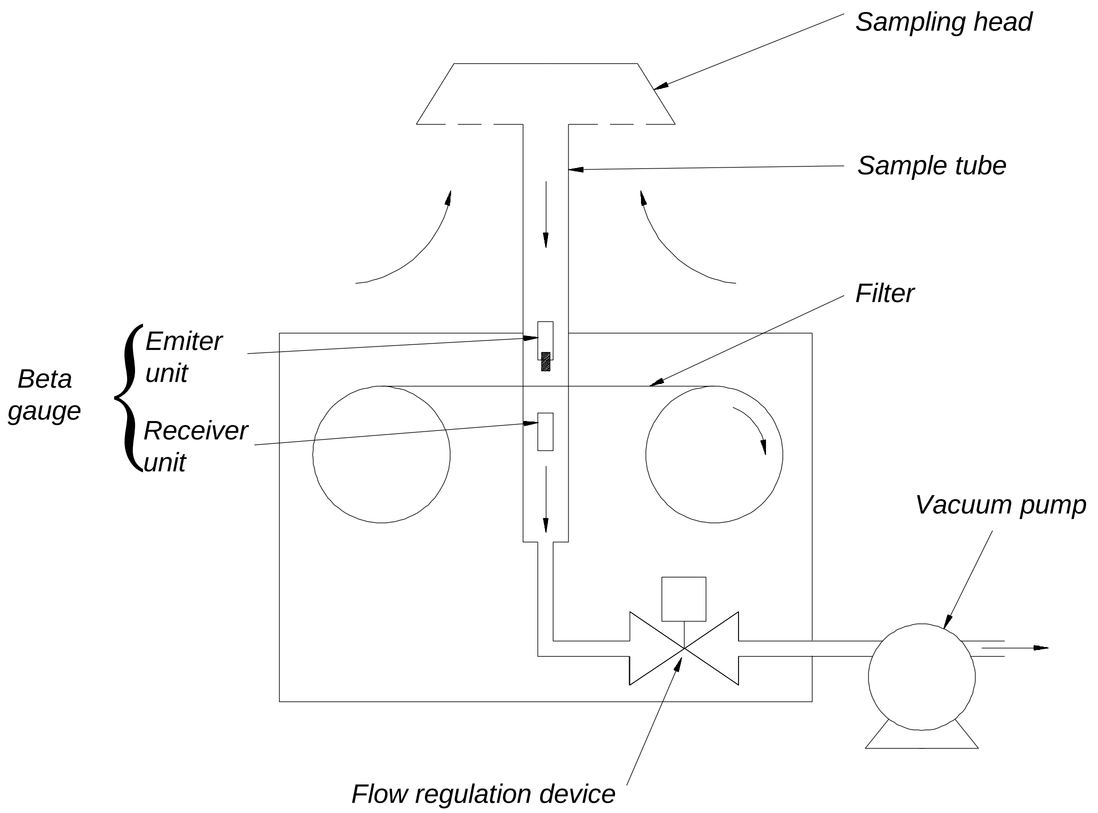

Figure 3: Functional diagramme MP101M

The MP101M measuring system saves data in a text format. Results are already converted to particle mass concentrations.

The measuring system generally provides results simultaneously via the display and the data records. Measured values are updated hourly after each measurement (periodically, “Per.”) and every 24 hours (cyclically, “Cyc.”). Where feasible, all tests were evaluated separately for the two options of data output. Results are indicated for both output options. Tests referring to the flow rate or using the reference foil were not evaluated separately.

3.3 AMS scope and set-up

The measuring system is designed to be installed at temperature controlled sites (e.g. air conditioned measuring station).

The tested AMS consists of

- the $PM_{2.5}$ USEPA sampling head,
- the sampling tube with heater, protective tube made of stainless steel and isolation (2m long),
- the weather sensor (mounted at the sampling tube below the sample inlet) comprising a temperature sensor and a sensor which determines the relative moisture.
- the analyser,
- the pump unit,
- the required connecting tubes and cables,
- the operation manuals in German.

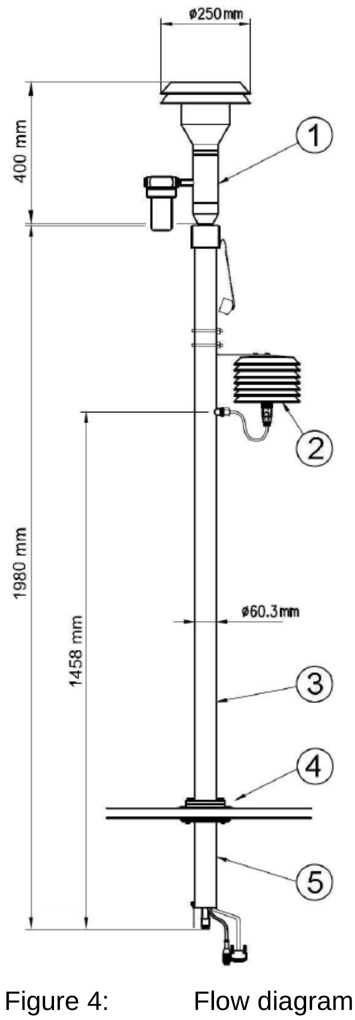

Figure 4: Flow diagramme for sampling (1) $PM_{2.5}$ sampling head (2) weather sensor, (3) sample line, (4) roof bushing, (5) sample line inside

Figure 5: MP101M measuring systems on the measuring station (bulk handling)

The measuring system may be operated either directly via the touch screen at the front of the instrument or remotely via an internet connection or a wireless modem. The user may retrieve measurement data and system information, change parameters and perform functionality tests of the measuring system.

A zero filter is mounted to the instrument inlet for the purpose of external zero checks. The use of this filter allows the provision of PM-free air. A special foil is used for span checks which is manually placed between the beta ray source and the Geiger Müller counter.

4. Test programme

4.1. General

The performance test was carried out using two identical instruments with the following serial numbers:

System 1 6160

System 2 6161

Software version MP101M 4.0.h was implemented during the performance test.

The measuring system generally provides results simultaneously via the display and the data records. Measured values are updated hourly after each measurement (periodically, “Per.”) and every 24 hours (cyclically, “Cyc.”). Where feasible, all tests were evaluated separately for the two options of data output. Results are indicated for both output options. Tests referring to the flow rate or using the reference foil were not evaluated separately.

4.2 Laboratory test

The laboratory test was carried out with two identical instruments, type MP101M, with serial numbers S/N: 6160 and SN: 6161. Standard [9] specifies the following test programme for the laboratory test:

- Readings
- Negative signals
- Zero level and detection limit
- Flow rate accuracy
- Water 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
- Reference foils

The measured values were recorded internally. The set of raw data was downloaded and evaluated in Excel.

Chapter 6 summarizes the results of the laboratory tests.

4.3 Field test

The field test was carried out with two identical instruments, type MP101M, with serial numbers S/N: 6160 and SN: 6161. Standard [4] specifies 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
- Weather station (WS 888 manufactured by ELV Elektronik AG) for collecting meteorological data such as temperature, air pressure, humidity, wind speed, wind direction and precipitation.
- 2 reference measuring systems, LVS3 for $PM_{2.5}$ in accordance with item 5
- 1 mass flow meter Model 4043 (manufacturer: TSI)
- Zero filter for external zero checks
- Calibration foil

During the field test, two MP101M measuring systems and two reference systems each for $PM_{2,5}$ were operated simultaneously over a period of 24h. The reference system is a discontinuous system: the filter has to be replaced manually after sampling.

Impaction plates of the $PM_{2.5}$ sampling inlets were cleaned approximately every two weeks during the test period and greased with silicone grease in order to ensure reliable separation of particles. The sampling inlets of the candidate systems were cleaned roughly every three months in line with the manufacturer's instructions. The sampling head generally has to be cleaned following the manufacturer's instruction taking into account local concentrations of suspended particulate matter.

The flow rates of the tested and the reference instruments were checked before and after each re-location using a dry gas meter or a mass flow controller in each case connected to the instrument's air inlet via a hose line.

Sites of measurement and instrument installation

Measuring systems in the field test were installed in such a way that only the sampling inlets were outside the measuring container on its roof. The central units of the tested instruments were positioned inside the air-conditioned measurement cabinet. The reference system (LVS3) was installed outdoors on the roof of the measurement container.

The field test was performed at the following measurement sites:

Table 3: Field test sites

No.	Measurement site	Period	Description
1	Cologne, Winter	12/2017 – 03/2018	Urban background
2	Bonn-Belderberg	04/2018 – 06/2018	Urban background Affected by traffic
3	Bulk handling, Summer	07/2018 – 11/2018	Industrial background
4	Bulk handling, Winter	12/2018 – 02/2019	Industrial background

Figure 6 to Figure 9 show the PM concentrations measured with the reference systems at the field test sites.

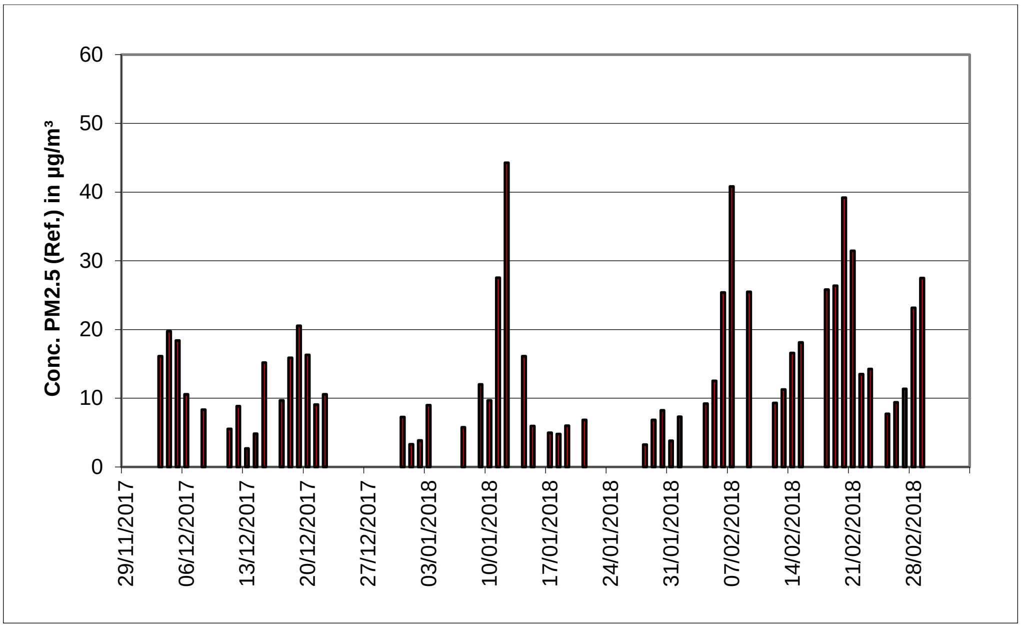

Figure 6: Distribution of $PM_{2,5}$ concentrations (reference) at the site in Cologne

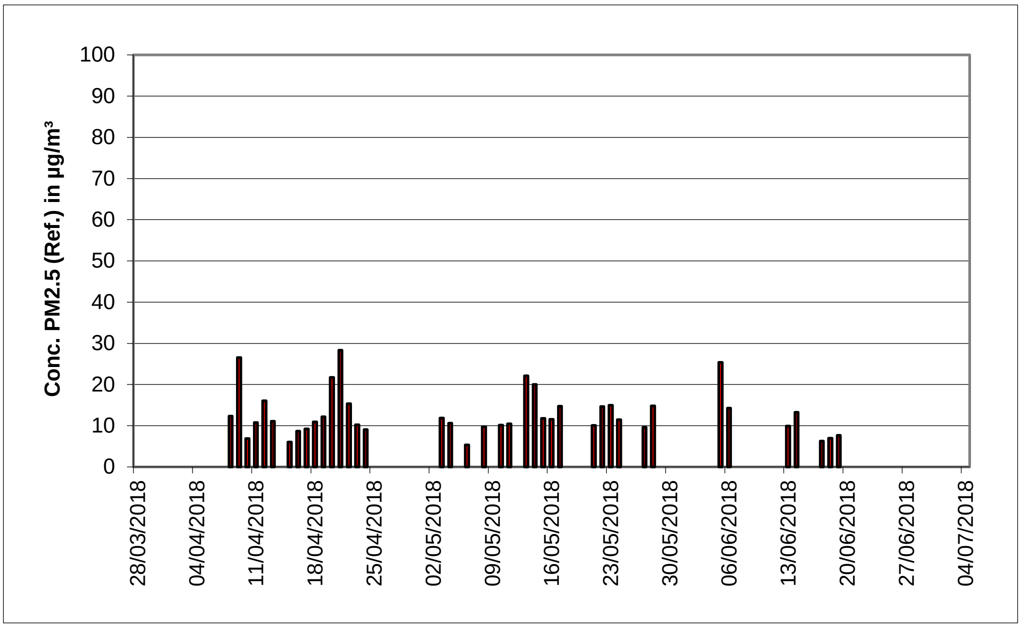

Figure 7: Distribution of $PM_{2,5}$ concentrations (reference) at the site “Bonn-Belderberg”

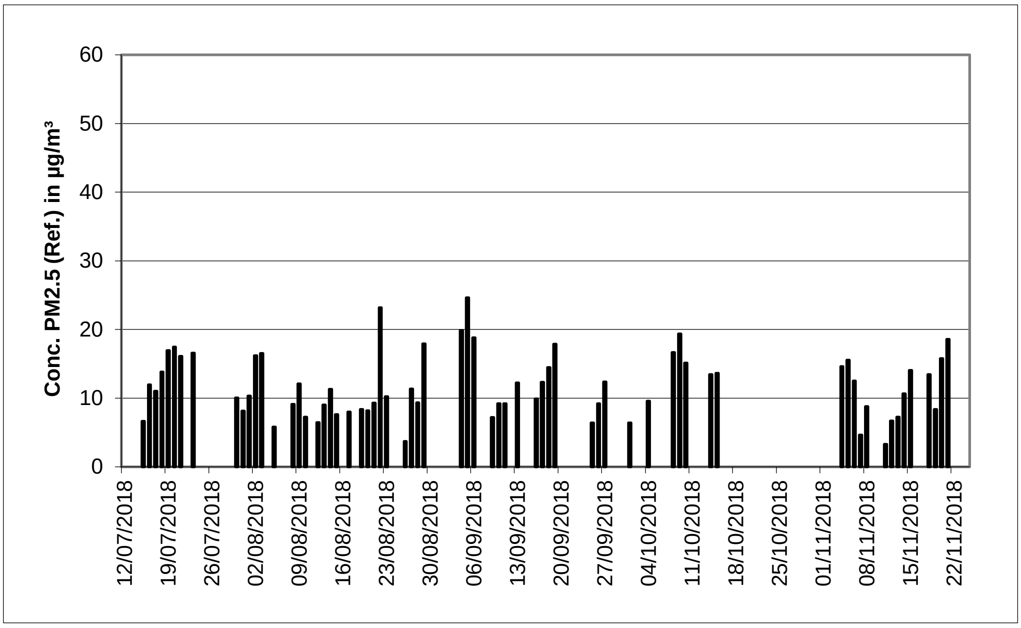

Figure 8: Distribution of $PM_{2,5}$ concentrations (reference) at the site “Bulk handling, summer”

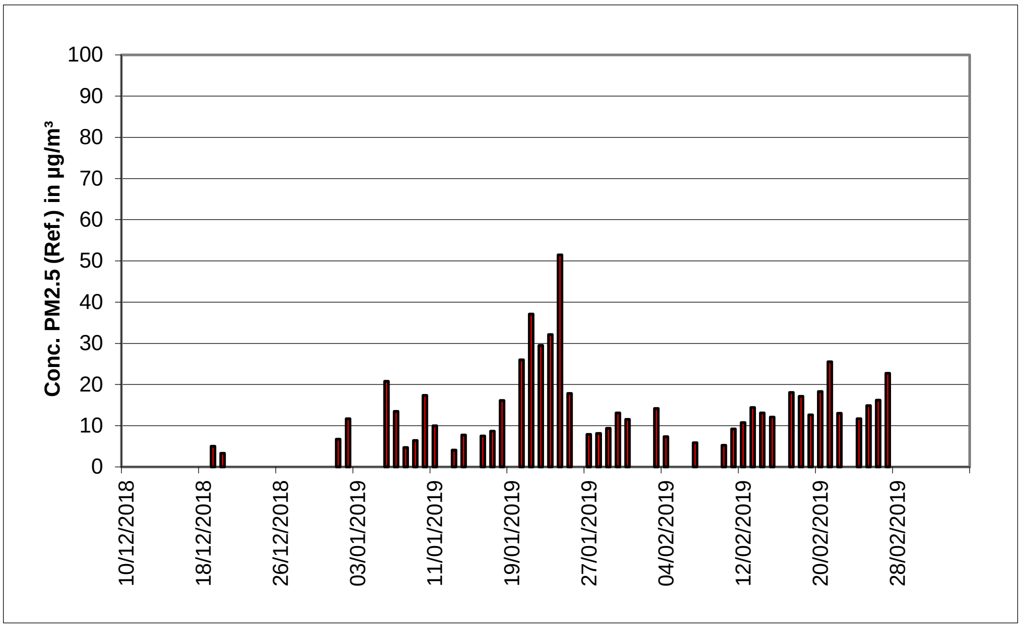

Figure 9: Distribution of $PM_{2,5}$ concentrations (reference) at the site “Bulk handling, winter”

The photos below show the measurement container at the field test sites in Cologne (parking lot and bulk handling) and in Bonn.

Figure 10: Field test site, Cologne, winter

Figure 11: Field test site in Bonn-Belderberg

Figure 12: Field test site in Cologne, bulk handling, summer + winter

In addition to the air quality measuring systems for monitoring suspended particulate matter, a data logger for meteorological data was installed at the container/measurement site. Data on air temperature, pressure, humidity, wind speed, wind direction and precipitation were continually measured. 10-minute mean values were recorded.

The following dimensions describe the design of the measurement cabinet as well as the position of the sampling probes.

Germany

- Height of cabinet roof. 2.50m
- Height of the sampling system for test/ 3.70m/1.20m above cabinet roof
- Reference system 3.47m above ground/0.97 m above container roof
- Height of the wind vane: 4.5 m above ground level

In addition to an overview of the meteorological conditions determined during measurements at the 4 field test sites, the following Table 4 therefore provides information on the concentrations of suspended particulate matter.

Table 4: Ambient condition at the field test sites (Germany), as daily averages

	Cologne Winter	Bonn-Belderberg	Bulk handling, Summer	Bulk handling, Winter
number of measurements Reference $PM_{2,5}$	56	40	66	45
Ratio of $PM_{2.5}$ to PM_{10} [%]				
Range	40.8 - 92.3	34.8 / 72.3	30.9 - 80.8	35.4 / 98.5
Average	70.1	53.1	51.4	61.0
Air temperature [°C]				
Range	-5.2 - 12.0	6.8 / 29.4	2.4 / 28.5	-2.8 - 12.8
Average	4.7	18.7	15.5	5.7
Air pressure [hPa]				
Range	973 – 1026	991 – 1019	981 – 1026	981 – 1029
Average	1005	1006	1006	1010
Rel. Humidity [%]				
Range	43.2 / 92.7	35.7 / 87.8	37.1 / 94.8	46.1 / 87.7
Average	76.6	61.9	70.5	74.5
Wind speed [m/s]				
Range	0.1 / 5.3	0.9 / 3.7	0.5 / 15.3	0.0 / 29.2
Average	1.5	1.8	5.3	8.0
Precipitation rate [mm/d]				
Range	0.0 / 19.4	0.0 / 31.6	0.0 / 19.6	0.0 / 22.3
Average	1.5	3.1	1.1	2.7

Sampling duration

Standard EN 12341 [3] fixes the sampling time at 24 h ± 1 h.

During the entire field test, all instruments were set to a sampling time of 24 h (from 10:00 to 10:00 o'clock).

Data handling

Prior to their assessment for each field test site, measured value pairs determined from reference values during the field test were submitted to a statistical Grubb's test for outliers (99%) in order to prevent distortions of the measured results from data, which evidently is implausible. Measured values pairs detected as significant outliers may be expunged from the pool of values as long as the test statistic remains above the critical value. In accordance with standard EN 16450, it is permitted to remove up to 2.5% of data pairs that qualify as outliers of reference results as long as the number of valid data pairs per comparison is at least 40. One outlier was identified for $PM_{2,5}$.

The following value pair has been expunged:

Table 5: Expunged value pair in line with Gubbs, reference $PM_{2,5}$

Location	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]
Cologne, parking lot, winter	16.01.2018	3.5	5.7

In principle, no measured value pairs are expunged for the tested AMS, unless there are justifiable technical reasons for implausible values. During the entire test, no implausible measured values were expunged for the tested AMS.

Filter handling – Mass measurement

The following filters were used during performance testing:

Table 6: Filter materials used

Measuring device	**Filter material, type**	**Manufacturer**
Reference devices LVS3	Emfab™, ∅ 47 mm	Pall

Filter handling was performed in compliance with EN 12341.

The methods used for processing and weighing filters and for weighing are described in detail in appendix 2 to this report.

5. Reference Measurement Method

The following instruments were used for the field test.

1. as $PM_{2.5}$ reference system: Low Volume Sampler LVS3
   Manufacturer: Sven Leckel Ingenieurbüro GmbH, Berlin
   Date of manufacture: 2007 + 2010
   $PM_{2,5}$ sample inlet

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

For the LVS3 low volume sampler, the rotary vane vacuum pump takes in sample air via the sampling inlet. The volumetric flow is measured between the filter and the vacuum pump with the help of a measuring orifice. The air taken in flows from the pump via a separator for the abrasion of the rotary vane to the air outlet.

After sampling has been completed, the electronics display the sample air volume in standard or operating m³.

The $PM_{2.5}$ concentrations were determined by dividing the quantity of suspended particulate matter on each filter determined in the laboratory with a gravimetric method by the corresponding throughput of sample air flow as operating m³.

As the performance test of the ENVEA MP101M measuring system for was carried out for PM_{10} in parallel, reference systems for PM_{10} were operated simultaneously. It was thus possible to calculate the $PM_{2,5}/PM_{10}$ ratio. Appendix 1, part 6 shows the results of the PM_{10} determination.

6. Test results

6.1 1 Measuring ranges

The measuring ranges should meet the following requirements:
0 µg/m³ to 1000 µg/m³ as a 24-hour average value
0 µg/m³ to 10,000 µg/m³ as a 1-hour average value, if applicable

6.2 Equipment

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

6.3 Testing

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

6.4 Evaluation

The instrument allows to set the measuring range to a maximum of 0–10,000 µg/m³.

6.5 Assessment

The upper limit of the measuring range is at 10,000 µg/m³.
Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion

6.1 2 negative signals

Negative signals shall not be suppressed.

6.2 Equipment

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

6.3 Testing

The possibility of displaying negative signals was tested both in the laboratory and in the field test.

6.4 Evaluation

The measuring system is able to output negative signals both via its display and its data outputs.

6.5 Assessment

The AMS is able to display negative readings directly and via the various measured signal outputs.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion

6.1 Zero level and detection limit (7.4.3)

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

6.2 Equipment

Zero filter for zero checks

6.3 Testing

The zero level and detection limit of the AMS shall be determined by measurement of 15 24-hour average readings obtained by sampling from zero air (no rolling or overlapped averages are permitted). The mean of these 15 24-h averages is used as the zero level. The detection limit is calculated as 3.3 times the standard deviation of the 15 24h-averages.

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

6.4 Evaluation

The detection limit X is calculated from the standard deviation s_{x0} of the measured values sucking air free from suspended particulate matter through both test specimen. It is equal to the standard deviation of the average x_0 of the measured values x_{0i} multiplied by 3.3 for each test specimen.

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

6.5 Assessment

The zero level and the detection limit were determined at 1.35 µg/m³ for S/N 6160 and 1.59 µg/m³ for S/N 6160.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 7: Zero level and detection limit $PM_{2,5}$ (cyc.)

		Device SN 6160	Device SN 6161
Number of values n		15	15
Average of the zero values (Zero level) $\bar{x}_0$	µg/m³	0.08	-0.03
Standard deviation of the values s_{x0}	µg/m³	0.41	0.48
Detection limit x	µg/m³	**1.35**	**1.59**

Table 8: Zero level and detection limit $PM_{2,5}$ (per.)

		Device SN 6160	Device SN 6161
Number of values n		15	15
Average of the zero values (Zero level) $\bar{x}_0$	µg/m³	0.05	0.03
Standard deviation of the values s_{x0}	µg/m³	0.39	0.47
Detection limit x	µg/m³	**1.27**	**1.55**

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

6.1 4 Flow rate accuracy (7.4.4)

The relative difference between the two values determined for the flow rate shall be ≤ 2.0%.
The relative difference between the two values determined for the flow rate shall fulfil the following performance requirements:

≤ 2.0%

- *at 5°C and 40°C for installations in an air-conditioned environment by default*
- *at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures.*

6.2 Equipment

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

6.3 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 MP101M measuring system operates at a flow rate of 1 m³/h (16.67 l/min).

With the help of a reference flow meter, the volume flow was measured at 5 °C and 40 °C by means of 10 measurements over 1 hour at the operational volume flow specified by the manufacturer. The measurements were performed at equal intervals throughout the measurement period.

6.4 Evaluation

Averages were calculated from the 10 measured values determined at each temperature and deviations from the operating flow rate determined.

6.5 Assessment

The relative difference determined for the mean of the measuring results at flow rates at 5°C and at 40°C did not exceed -1.25%.

Criterion satisfied? yes

6.6 Detailed presentation of test results

The results of the flow measurements at the permissible ambient temperature are presented below:

Table 9: Flow rate accuracy at +5 °C and +40 °C

		Device SN 6160	Device SN 6161
Nominal value flow rate	l/min	16.67	16.67
Mean value at 5°C	l/min	16.46	16.51
Dev. from nominal value	%	-1.25	-0.98
Mean value at 40°C	l/min	16.86	16.84
Dev. from nominal value	%	1.12	1.01

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

6.1 Constancy of sample flow rate (7.4.5)

The instantaneous flow rate and the flow rate averaged over the sampling period shall fulfil the performance requirements below.
≤ 2.0% sample flow (instantaneous flow)
≤ 5% rated flow (instantaneous flow)

6.2 Equipment

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

6.3 Testing

The MP101M measuring system operates at a flow rate of 1 m³/h (16.67 l/min).

The sample flow rate was calibrated before and after each first field test and then checked with the help of a mass flow controller at every new field test site and re-adjusted when necessary.

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

6.4 Evaluation

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

6.5 Assessment

No deviations exceeding -1.2% were found in the flow rate controls in the field (short-term value).

The charts illustrating the constancy of the sample flow rate (24h average) demonstrate that all measured values determined during sampling deviate from their respective rated values by less than 3.18%. The deviation of the daily averages for the overall flow rate of 16.67 l/min did not exceed -1.10% of the rated value.

The 24h-averages deviate from their rated values by less then -1.10%, all instantaneous values deviate by less than 3.18%.

Criterion satisfied? yes

6.6 Detailed presentation of test results for the rated flow

Table 10 presents the results of the flow rate checks performed at every field test site.

Table 10: Results of flow rate checks at the end of the field test (instantaneous values)

Flow rate check before:	SN 6160		SN 6161	
Field test site:	[l/min]	Dev. from target [%]	[l/min]	Dev. from target [%]
Cologne, Winter	16.47	-1.2	16.75	0.5
Bonn-Belderberg	16.84	1.0	16.73	0.4
Bulk handling, summer	16.80	0.8	16.74	0.4
Bulk handling, winter	16.81	0.8	16.72	0.3

Table Table 11 lists the characteristics determined for the flow rate. Figure 1313 to Figure 1413 provide a chart of the flow rate measurement for both instruments.

Table 11: Performance characteristics for the overall flow rate measurement (daily average)

		Device SN 6160	Device SN 6161
Mean value	l/min	16.49	16.72
Dev. from nominal value	%	-1.10	0.28
Standard deviation	l/min	0.09	0.12
Minimum value	l/min	16.16	16.40
Maximum value	l/min	16.96	17.12

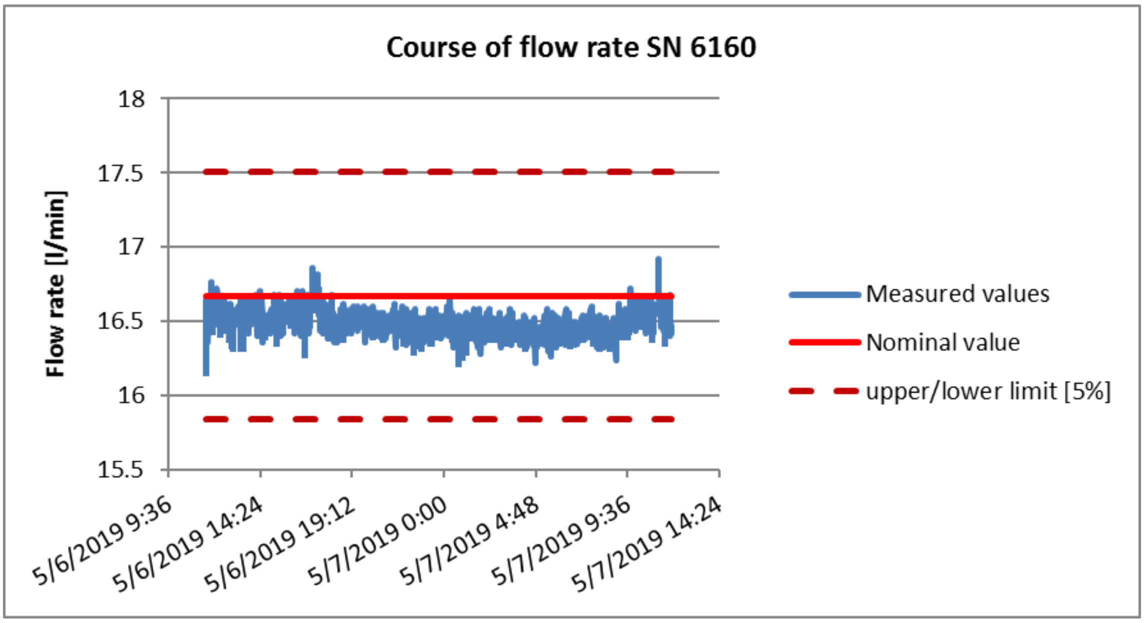

Figure 1313: Flow rate of tested instrument SN 6160

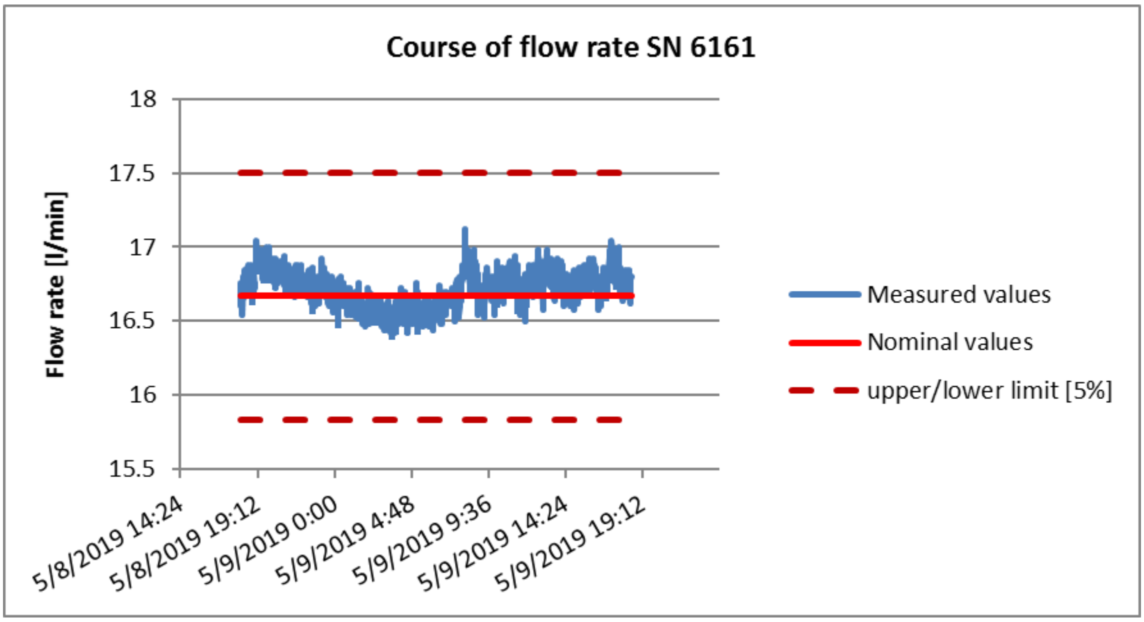

Figure 1413: Flow rate of tested instrument SN 6161

6.1 6 Leak tightness of the sampling system (7.4.6)

Leakage shall not exceed 2.0% of the sample flow rate or else meet the AMS manufacturer's specifications in complying with the required data quality objectives (DQO).

6.2 Equipment

Means to block the sample inlet

6.3 Testing

The leak tightness (leak rate) of the complete air flow path of the AMS (sample inlet, sampling line, measuring system) shall be tested according to the manufacturer's specification. 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. Since it was not possible to properly block the sample inlet, the inlet was not included in the test.

There is a defined procedure to verify the leak tightness of the MP101M measuring system. For this purpose, the leak tightness test mode was activated in accordance with chapter 3.4.2.12 of the operation manual and the instrument blocked. To this effect, the sample inlet is removed and a ball valve recommended by the manufacturer is fitted. In accordance with the manufacturer's specifications, the flow rate measured by the instrument with the pump running and the ball valve closed should the drop to 5 l/min and the pressures P1 and P2 of the internal differential pressure measurement should be below 250 mbar. As soon as the pressures dropped below 250 mbar, the pump is automatically switched off to avoid damage to the instrument.

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

6.4 Evaluation

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

The criterion for passing the leak test as specified by the AMS manufacturer – maximum flow rate of 5 l/min as well as P1 and P2 below 250 mbar when the inlet is blocked – proved to be adequate during performance testing as a criterion for monitoring the instrument's leak tightness. Compared to the standard sample volumetric flow, a maximum flow of 5 l/min appears rather high. This is explained by the very small pressure difference of less than 1 mbar at this volume flow and absolute pressure. If the system pressure is below 250 mbar when the pump is running and the ball valve closed, it can safely be assumed that the measuring system is leak-tight.

The maximum leak rate is 4.85 l/min, all pressures determined were below 250 l/min.

6.5 Assessment

The criterion for passing the leak test as specified by the AMS manufacturer – maximum flow rate of 5 l/min as well as P1 and P2 below 250 mbar when the inlet is blocked – proved to be adequate during performance testing as a criterion for monitoring the instrument's leak tightness. The maximum leak rate is 4.85 l/min, all pressures determined were below 250 l/min.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 12 lists the result from the leak test.

Table 12: Results of the leak tests obtained during the field tests at the beginning of each campaign

Location	SN 6160	SN 6161	max. permissible leak rate in l/min
	Leak rate in l/min	Leak rate in l/min	
Cologne, Winter	3.23	0.00	5
Bonn-Belderberg	2.36	0.00	5
Bulk handling, summer	2.38	0.00	5
Bulk handling, winter	4.85	0.00	5

6.1 7 Dependence of measured value on surrounding temperature (7.4.7)

The differences found shall comply with the performance criteria given below.
Zero point ≤ 2.0 µg/m³

- *between 5°C and 40°C by default, for installations in an air-conditioned environment.*
- *at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures.*

6.2 Equipment

Climatic chamber for the temperature range between 5 and +40 °C; zero filter for the zero point check

6.3 Testing

The dependence of the zero reading and span value, measured by applying a calibration artefact on the surrounding temperature, shall 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. Sample air, free of suspended particles, was supplied to the two candidate systems after fitting two zero filters at the AMS inlet in order to perform zero point checks.

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

The criteria for the running-in or stabilisation time listed in Section 7.4.2.1 have to be met at each temperature setting.

The tests were performed in the temperature sequence $T_{S,n}$ — $T_{S,1}$ — $T_{S,n}$ — $T_{S,2}$ — $T_{S,n}$.

Readings were recorded at zero point after an equilibration period of at least 6h for every temperature step (3 readings each).

6.4 Evaluation

Measured values for the concentrations of the individual readings were read and evaluated.

In order to exclude any possible drift due to factors other than temperature, the measurements at $T_{S,n}$ were averaged.

The differences between readings at both extreme temperatures and $T_{S,lab}$ were determined.

6.5 Assessment

The tested temperature range was 5 °C to 40 °C. The maximum deviation from the mean reading at $T_{S,n}$ was at 1.1 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 13: Dependence of the zero point on the surrounding temperature, deviation in µg/m³, average of measurements, cyc.

Temperature	SN 6160		SN 6161	
	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	-0.9	0.1	1.0	0.9
5	-0.4	0.6	-0.2	-0.4
20	-1.5	-0.5	0.6	0.5
40	0.0	1.1	0.2	0.1
20	-0.6	0.4	-1.3	-1.4
Mean value at 20°C	-1.0	-	0.1	-

Table 14: Dependence of the zero point on the surrounding temperature, deviation in µg/m³, average of measurements, per.

Temperature	SN 6160		SN 6161	
	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	-0.9	0.1	1.0	0.8
5	-0.4	0.6	-0.2	-0.4
20	-1.5	-0.5	0.6	0.5
40	0.1	1.1	0.2	0.1
20	-0.6	0.4	-1.1	-1.3
Mean value at 20°C	-1.0	-	0.2	-

Schedule 3 in the annex contains the individual measuring results.

6.1 8 Dependence of measured value (span) on surrounding temperature (7.4.7)

The differences found shall comply with the performance criteria given below.
Sensitivity of the measuring system (span):
≤ 5% from the value at the nominal test temperature

- *between 5°C and 40°C by default, for installations in an air-conditioned environment.*
- *at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures.*

6.2 Equipment

Climatic chamber for the temperature range between 5 and +40 °C; internal reference foil for span checks

6.3 Testing

The dependence of the zero reading and span value, measured by applying a calibration artefact on the surrounding temperature, shall 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 span checks, the reference foil was mounted on the tested instruments to check the stability of the sensitivity.

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

The criteria for the running-in or stabilisation time listed in Section 7.4.2.1 have to be met at each temperature setting.

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 each).

6.4 Evaluation

Measured values for the concentrations of the individual readings were read and evaluated.

In order to exclude any possible drift due to factors other than temperature, the measurements at $T_{S,n}$ were averaged.

The differences between readings at both extreme temperatures and $T_{S,lab}$ were determined.

6.5 Assessment

The tested temperature range was 5 °C to 40 °C. The maximum deviation from the mean reading at 20 °C was at 2.2 %.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 15: Dependence of measured value on surrounding temperature, deviation in %, average from three measurements

Temperature	SN 6160		SN 6161	
	Measured value	Deviation to mean value at 20°C	Measured value	Deviation to mean value at 20°C
°C	[µg/cm²]	%	[µg/cm²]	%
20	810.2	-0.9	837.6	0.5
5	835.5	2.2	834.6	0.1
20	818.2	0.1	834.8	0.1
40	806.6	-1.3	828.6	-0.6
20	823.3	0.7	828.9	-0.6
Mean value at 20°C	817.2	-	833.7	-

Schedule 3 in the annex contains the results from 3 individual measurements.

6.1 9 Dependence of span on supply voltage (7.4.8)

The differences found shall comply with the performance criteria given below.
Sensitivity of the measuring system (span):
≤ 5% from the value at the nominal test voltage

6.2 Equipment

Isolating transformer, internal reference foil

6.3 Testing

The dependence of the measured value corrected by a calibration factor on the supply voltage must be determined at the following voltages (cf. EN 50160 [10] taking into consideration 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.

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

The criteria for the running-in or stabilisation time listed in Section 7.4.2.1 have to be met at each voltage setting.

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

For the span checks, the reference foil was mounted on the tested instruments to check the stability of the sensitivity.

6.4 Evaluation

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.

6.5 Assessment

Voltage variations did not cause deviations exceeding 0.6% of the average at 230V at the extreme values.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 16: Influence of mains voltage on measured value, deviation in %

Supply voltage	SN 6160		SN 6161	
	Measured value	Deviation to start value at 230 V	Measured value	Deviation to start value at 230 V
V	[µg/cm²]	%	[µg/cm²]	%
230	800.9	0.5	822.4	1.2
195	795.7	-0.1	817.6	0.6
230	794.1	-0.3	809.2	-0.5
253	799.1	0.3	807.8	-0.6
230	795.3	-0.2	807.3	-0.7
Mean value at 230 V	796.8	-	813.0	-

Schedule 4 in the annex contains the individual results.

6.1 10 Effect of failure of mains voltage

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

6.2 Equipment

Not required for this performance criterion

6.3 Testing

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

6.4 Evaluation

The measuring system resumes operation after a power failure and the start of the operating system. It is operational after a couple of minutes. All instrument parameters are preserved.

6.5 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

6.6 Detailed presentation of test results

Not applicable.

6.1 11 Dependence of reading on water vapour concentration (7.4.9)

The largest difference in readings between 40% and 90% relative humidity shall fulfil the performance criterion stated below:
≤ 2.0 µg/m³ in zero air when cycling relative humidity from 40% to 90% and back.

6.2 Equipment

Climatic chamber c/w humidity control for the range between 40% and 90% relative humidity, zero filter for zero checks

6.3 Testing

The dependence of reading on water vapour concentration in the sample air was determined by feeding humidified zero air in the range between 40% and 90% relative humidity. To this effect, the measuring system was operated in the climatic chamber and the relative humidity of the entire surrounding atmosphere was controlled. Sample air, free of suspended particles was supplied to the instruments after fitting two zero filters at either AMS inlet in order to perform zero point checks.

After stabilisation of relative humidity and the concentration values, a reading over an 24h-averaging period at 40% relative humidity was recorded. Within 24h, the relative humidity evenly to 90%. The time to reaching the equilibrium (ramp) and the average concentration reading were recorded. The moisture content was then reduced to 40% gradually over a period of 24 h. Again, the time to reaching the equilibrium (ramp) and the average concentration reading were recorded.

6.4 Evaluation

The measured value for the zero level of 24-hour individual measurements at stable humidity levels were obtained and assessed. The characteristic concerned is the largest difference in µg/m³ between values in the range of 40% to 90% relative humidity.

6.5 Assessment

Differences between readings determined at relative humidities of 40% and 90% did not exceed -2.04 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 17: Dependence of reading on water vapour concentration, deviations in µg/m³, cyc.

rel. Humidity	SN 6160		SN 6161	
	Measured value	Deviation to previous value	Measured value	Deviation to previous value
%	µg/m³	µg/m³	µg/m³	µg/m³
40	0.39	-	1.41	-
90	0.65	0.25	1.32	-0.09
40	-1.39	-2.04	-0.16	-1.48
Maximum deviation	-2.04		-1.48	

Table 18: Dependence of reading on water vapour concentration, deviations in µg/m³, per.

rel. Humidity	SN 6160		SN 6161	
	Measured value	Deviation to previous value	Measured value	Deviation to previous value
%	µg/m³	µg/m³	µg/m³	µg/m³
40	0.39	-	1.42	-
90	0.65	0.26	1.33	-0.09
40	-1.35	-2.00	-0.16	-1.50
Maximum deviation	-2.00		-1.50	

6.1 12 Zero checks (7.5.3)

During the tests, the absolute measured value of the AMS shall not exceed the following criterion:
Absolute value ≤ 3.0 µg/m³

6.2 Equipment

Zero filter for zero checks

6.3 Testing

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 to generate zero air is the sampling of ambient air through a zero filter (HEPA) installed at the inlet of the AMS instead of the regular sampling inlet. The zero check shall be performed for at least 24 h.

The checks shall be performed at least at the beginning and at the end of each of the 4 comparisons.

6.4 Evaluation

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

6.5 Assessment

The absolute measured value determined at the zero point did not exceed 0.1 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 19: Zero checks, Cyc.

Date	SN 6160		Date	SN 6161	
	Measured Value µg/m³	Measured value (absolute) < 3.0 µg/m³		Measured Value µg/m³	Measured value (absolute) < 3.0 µg/m³
11/30/2017	-0.3	ok	11/30/2017	0.6	ok
3/5/2018	-2.6	ok	3/5/2018	1.1	ok
3/30/2018	0.2	ok	3/30/2018	0.7	ok
7/3/2018	-0.2	ok	7/3/2018	1.1	ok
7/12/2018	2.3	ok	7/12/2018	2.5	ok
11/29/2018	2.1	ok	11/29/2018	1.8	ok
12/13/2018	1.2	ok	12/13/2018	2.0	ok
4/4/2019	2.2	ok	4/4/2019	1.8	ok

Table 20: Zero checks, Per.

Date	SN 6160		Date	SN 6161	
	Measured Value µg/m³	Measured value (absolute) < 3.0 µg/m³		Measured Value µg/m³	Measured value (absolute) < 3.0 µg/m³
11/30/2017	-0.3	ok	11/30/2017	0.6	ok
3/5/2018	-2.6	ok	3/5/2018	1.1	ok
3/30/2018	0.2	ok	3/30/2018	0.7	ok
7/3/2018	-0.2	ok	7/3/2018	1.1	ok
7/12/2018	2.3	ok	7/12/2018	2.5	ok
11/29/2018	2.1	ok	11/29/2018	1.8	ok
12/13/2018	1.2	ok	12/13/2018	2.0	ok
4/4/2019	2.2	ok	4/4/2019	1.8	ok

6.1 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:
Flow rate;

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

When available, results of automatic diagnostic/functional checks shall be recorded.

6.2 Equipment

Computer for data acquisition

6.3 Testing

The measuring system allows for comprehensive monitoring and control via various connectors (Ethernet, RS232) and, according to information provided by the manufacturer, is able to output measured values and status information via various protocols (e.g. Bayern-Hessen protocol or serial ASCII)

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

- Flow rate
- Mass concentrations,
- Ambient temperature, pressure, humidity
- Temperature of the sampling inlet,
- Temperature inside the instrument,
- Various pressures inside the instrument,

All values are saved at 1-minute intervals.

Remote monitoring and control is easily possible via routers or modems. To test this criterion, a network was established and the instrument controlled via a PC.

6.4 Evaluation

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

6.5 Assessment

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 14 Daily averages (7.5.5)

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

6.2 Equipment

For this test, a clock was additionally provided.

6.3 Testing

We verified whether the measuring system allows for the formation of daily averages.

6.4 Evaluation

The measuring system determines the sampled mass on the filter at hourly intervals. Both the dust concentration for each hour (1 period) and the dust concentration after 24 h (1 cycle = 24 periods) are output and recorded. The filter tape is transported forwards after one cycle to sample a blank filter spot.

6.5 Assessment

It is possible to form valid daily averages.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 15 Availability (7.5.6)

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

6.2 Equipment

Not required for this performance criterion

6.3 Testing

The start and end times at each of the four field test sites marked the start and end time for the availability test. Proper operation of the measuring system was verified during every on-site visit (usually every working day). This daily check consisted of plausibility checks on the measured values, status signals and other relevant parameters (see 7.5.4). Time, duration and nature of any error in functioning are recorded.

The total time during the field test in which valid measurement data of ambient air concentrations were obtained was used for calculating availability. Time needed for scheduled calibrations and maintenance (cleaning; change of consumables) should not be included.

Availability is calculated as

$$A = \frac{t_{valid} + t_{cal,maint}}{t_{field}}$$

Where:

t_{valid} is the time during which valid data have been collected;

$t_{cal,maint}$ is the time spent for scheduled calibrations and maintenance;

t_{field} is the total duration of the field test.

6.4 Evaluation

Operation times, maintenance and outage times are summarized in Table 21. During the field test, the measuring systems were operated for a total of 419 measuring days. This period covers 18 days with zero filter operation and a seven-day loss caused by switching from the inlet to the zero filter (see annex 5). Maintenance work was performed on instrument 1 on 17 January 2018 and 18 January 2018. The reference foil was used, leak tightness and the flow rate were checked.

Outages caused by external events not ascribed to the measuring system amounted to 5 days (power outage). The externally-caused outages reduce the total time of operation to 414 measuring days.

No instrument malfunctions were observed.

Regular maintenance of the sampling inlets and regular flow and leak tests resulted in outage times of 0.5 to 1h . Daily averages thus affected were not discarded.

6.5 Assessment

Availability was at 100% for both instruments.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 21: Determination of the availability

		System 1 (SN 6160)	System 2 (SN 6161)
Operation time (t_{field})	d	414	414
Outage time	d	0	0
Maintenance time incl. zero filter ($t_{cal,maint}$)	d	20	18
Actual operating time (t_{valid})	d	394	396
Availability	%	100	100

6.1 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 PM10, or to be greater than 17 µg/m3 for PM2,5 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 PM_{10} and 18 µg/m³ $PM_{2.5}$.
3. The uncertainty between reference systems shall not exceed 2.0 µg/m³.
4. The expanded uncertainty (W_{CM}) is calculated at 50 µg/m³ for PM_{10} and at 30 µg/m³ for $PM_{2.5}$ for every individual test specimen and checked against the average of the reference method. For each of the following cases, the expanded uncertainty shall not exceed 25%:
   - Full data set:
   - datasets representing PM concentrations greater than/equal to 30 µg/m³ for PM_{10}, or concentrations greater than/equal to 18 µg/m³ for $PM_{2.5}$, provided that the set contains 40 or more valid data pairs
   - Datasets for each individual site
5. Preconditions for acceptance of the full dataset are that the slope b is insignificantly different from $|b-1| \le 2 \cdot u(b)$ and the intercept a is insignificantly different from 0: $|a| \le 2 \cdot u(a)$. If these preconditions are not met, the candidate method may be calibrated using the values obtained for slope and/or intercept.

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

Chapter 6.1 16 Between-AMS uncertainty (7.5.8.4) addresses verification of criteria 1 and 2.

Verification of criteria 3, 4 and 5 is reported on in chapter

6.1 17 Expanded uncertainty (7.5.8.5 – 7.5.8.8)

Chapter 6.1 17 Use of correction factors/terms (7.5.8.5–7.5.8.8) contains an assessment for the case that criterion 5 is not complied with without applying correction factors.

6.1 16 Between-AMS uncertainty (7.5.8.4)

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

6.2 Equipment

Not required for this performance criterion

6.3 Testing

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

In the full dataset, at least 20% of the results obtained using the reference method should be greater than 17 µg/m³ for $PM_{2.5}$. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.

For each comparison campaign, at least 40 valid value pairs were determined. In the full dataset a total of 21.0% value pairs (corresponds to 43 > 32 value pairs) exceed 17 µg/m³ for $PM_{2,5}$. The concentrations measured were related to the ambient conditions.

6.4 Evaluation

Chapter 7.5.8.4 of standard EN 16450 specifies that:

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

Uncertainty is determined for:

- All results combined (complete dataset)
- 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

6.5 Assessment

At no more than 0.95 µg/m³ the uncertainty between the test specimen u_{bs} remains well below the permissible maximum of 2.5 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 22: Between-AMS uncertainty $u_{bs,AMS}$.

Location	Number of meas-ure-ments	Uncertainty $u_{bs,AMS}$ µg/m³	
		Cyc.	Per.
All locations	**205**	**1.27**	**1.29**
Classing over reference values			
Values ≥ 18 µg/m³	**37**	**1.50**	**1.52**

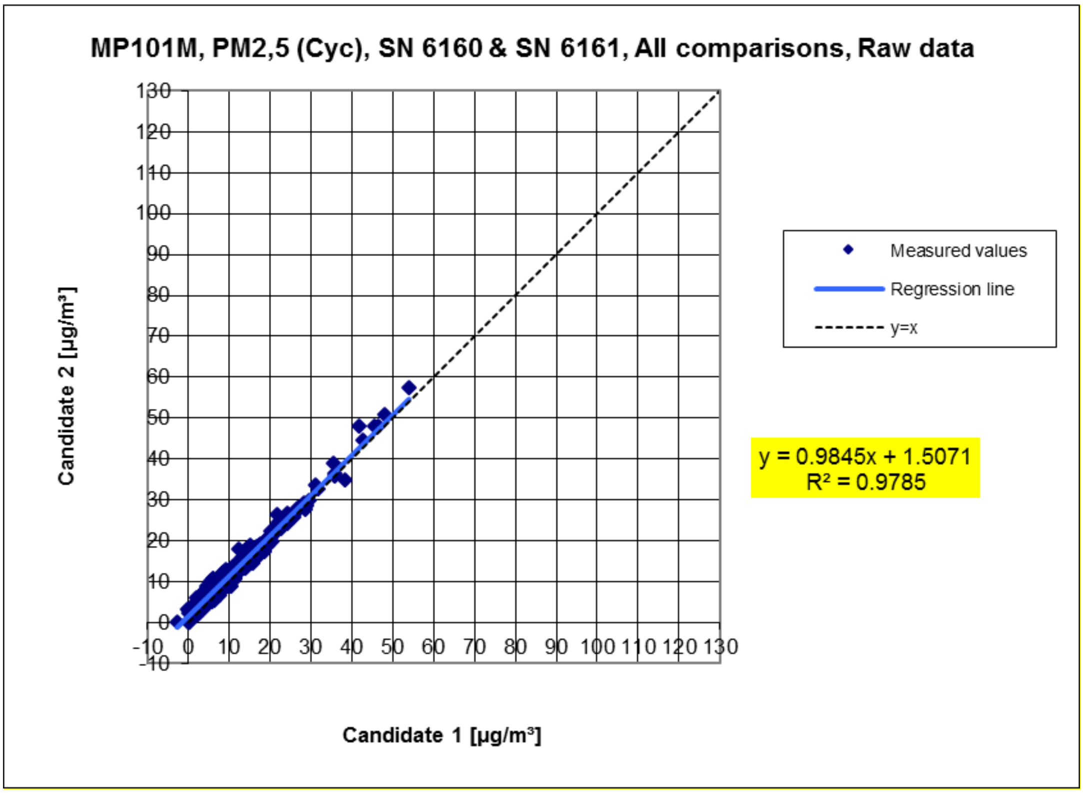

Figure 15: Results of the parallel measurements, all sites, Cyc.

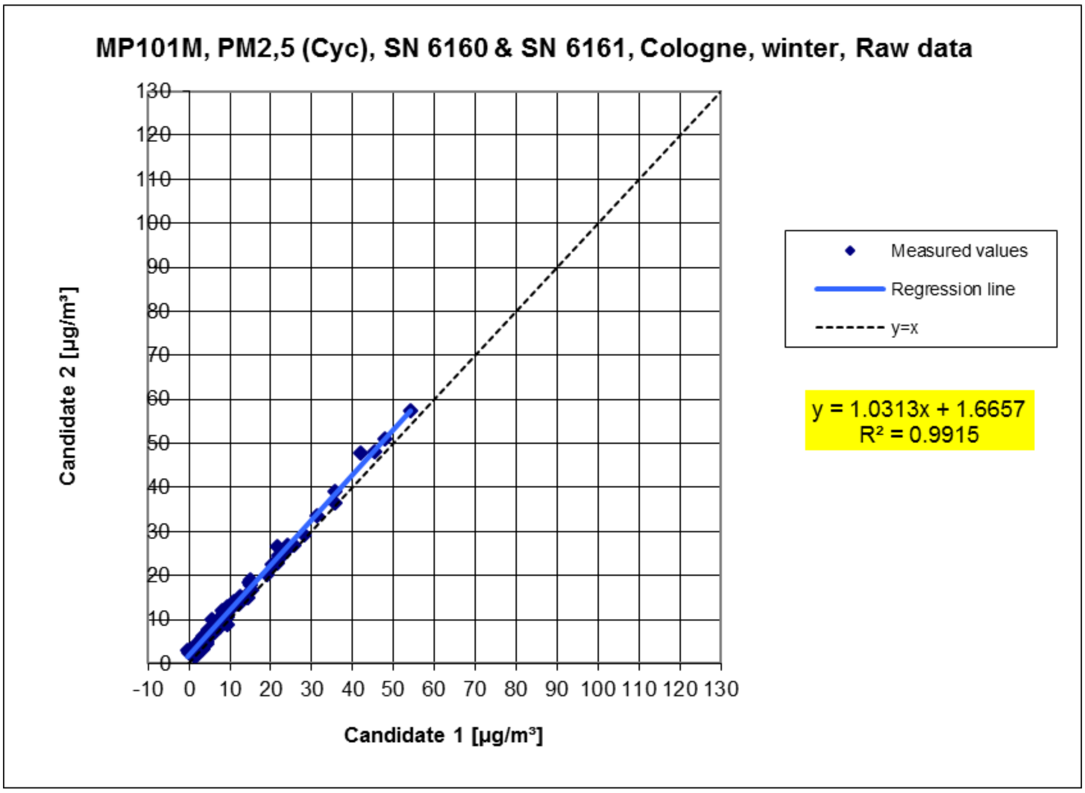

Figure 16: Results of the parallel measurements, Cologne, winter, Cyc.

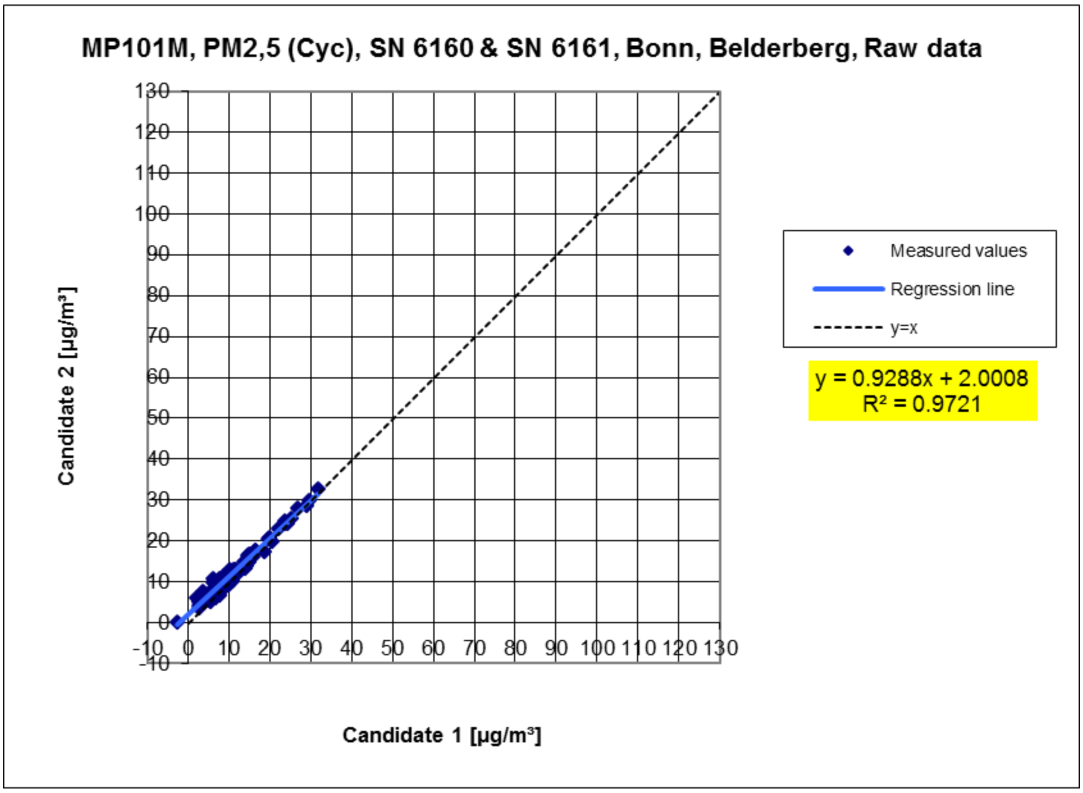

Figure 17: Results of the parallel measurements, Bonn-Belderberg, Cyc.

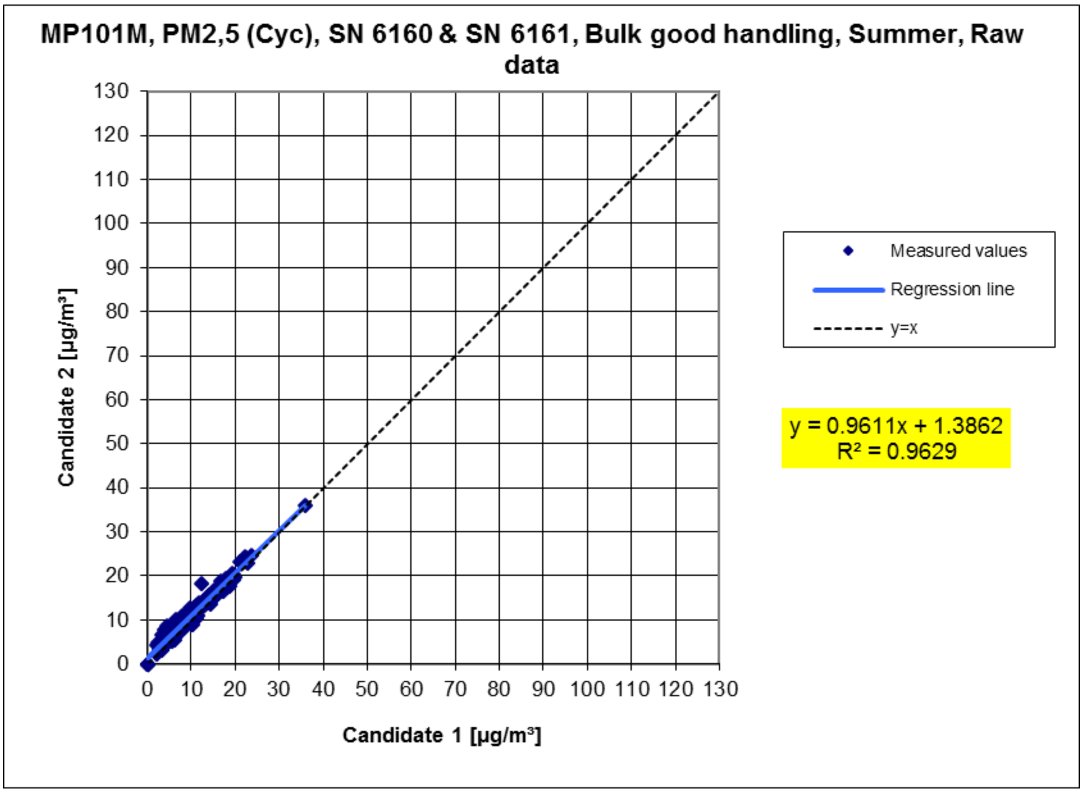

Figure 18: Results of the parallel measurements, bulk handling, summer, Cyc.

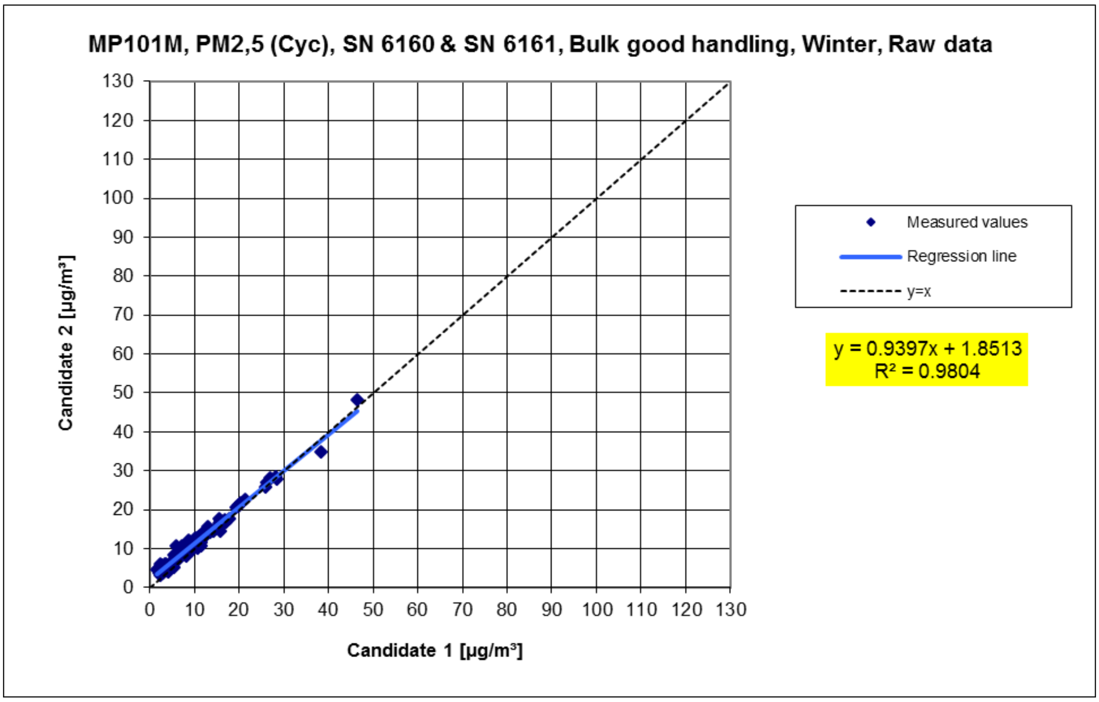

Figure 19: Results of the parallel measurements, bulk handling, winter, Cyc.

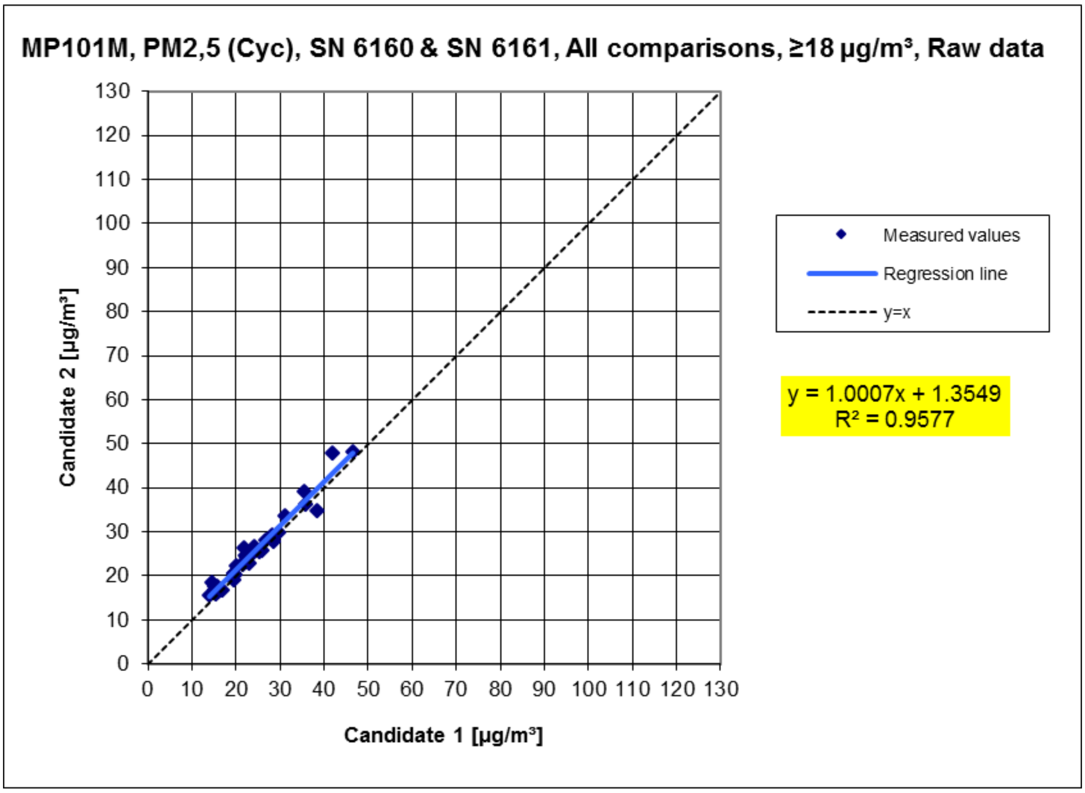

Figure 20: Results of the parallel measurements, all sites, values ≥ 18 µg/m³, Cyc.

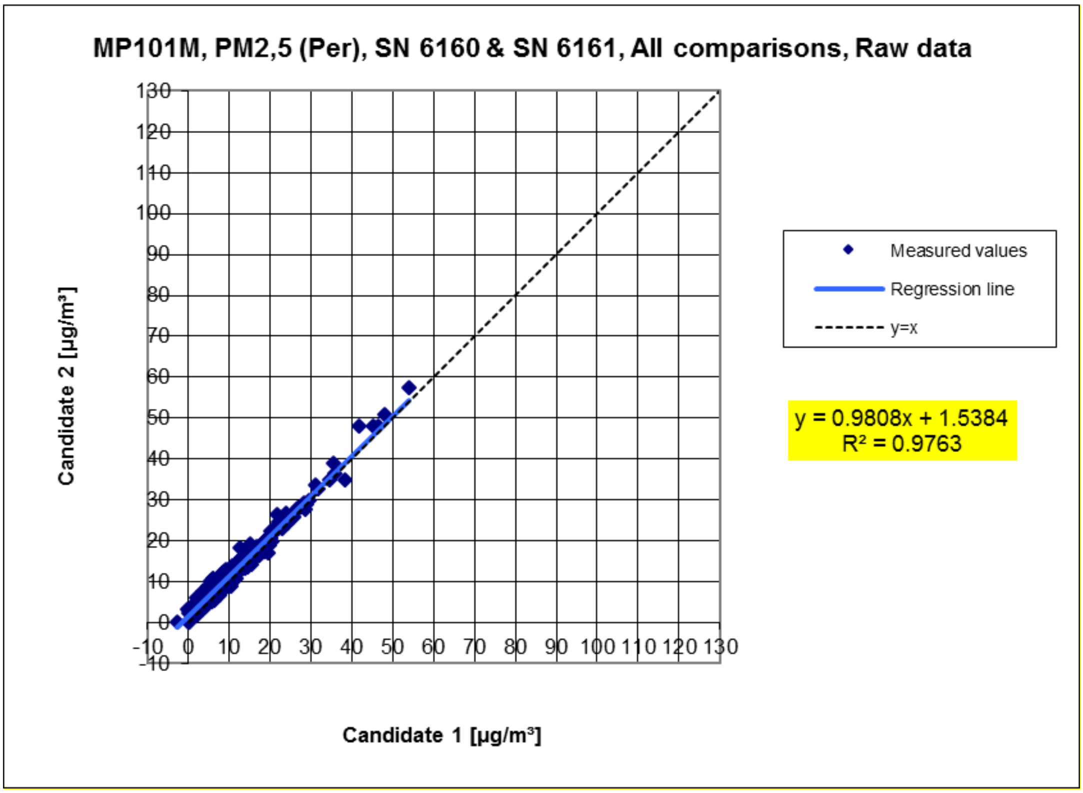

Figure 21: Results of the parallel measurements, all sites, per.

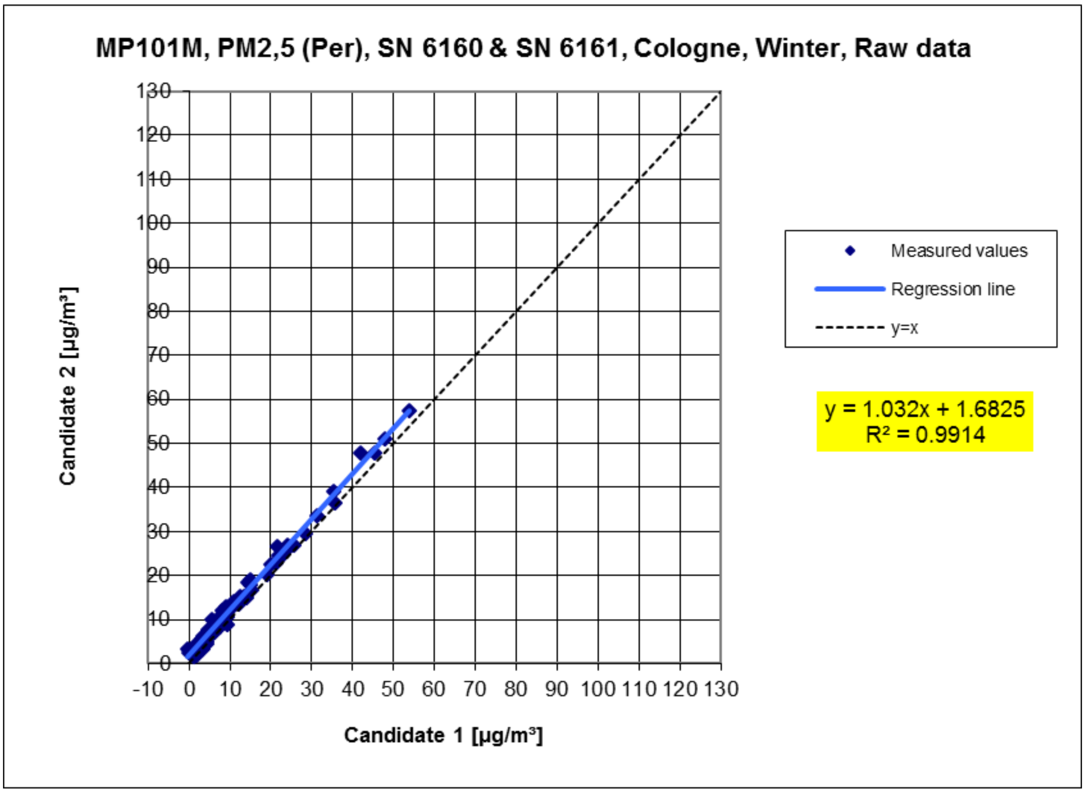

Figure 22: Results of the parallel measurements, Cologne, winter, per.

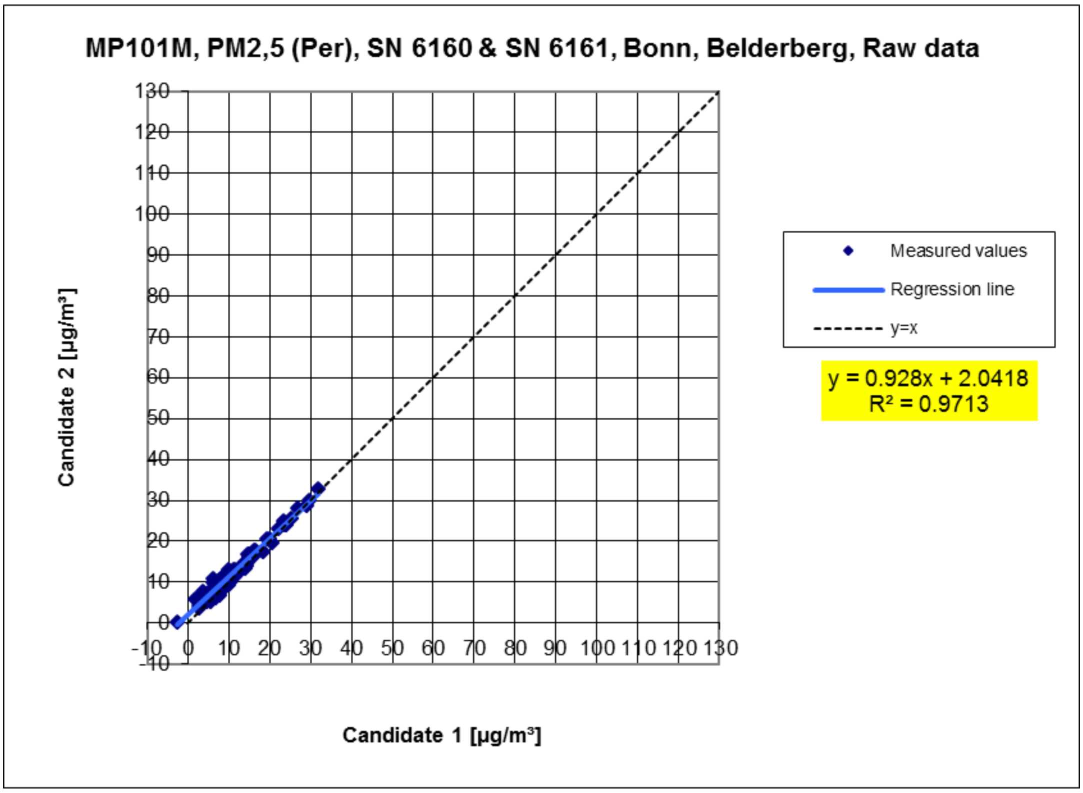

Figure 23: Results of the parallel measurements, Bonn-Belderberg, per.

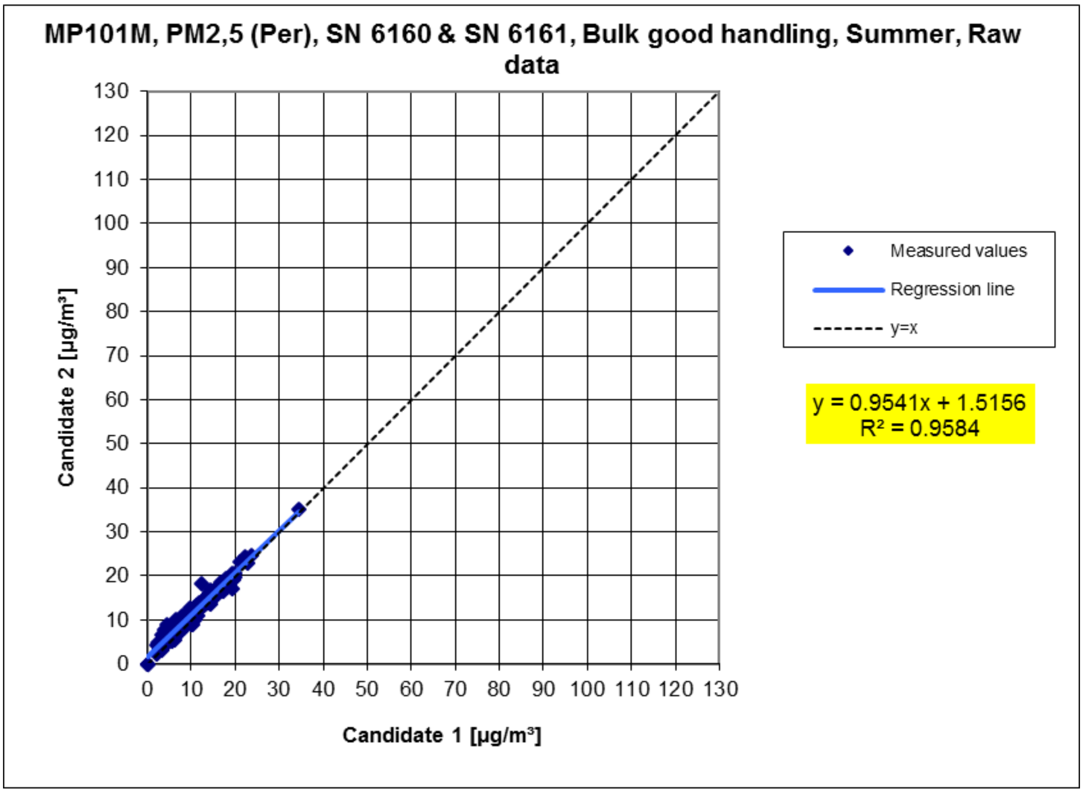

Figure 24: Results of the parallel measurements, bulk handling, summer, per.

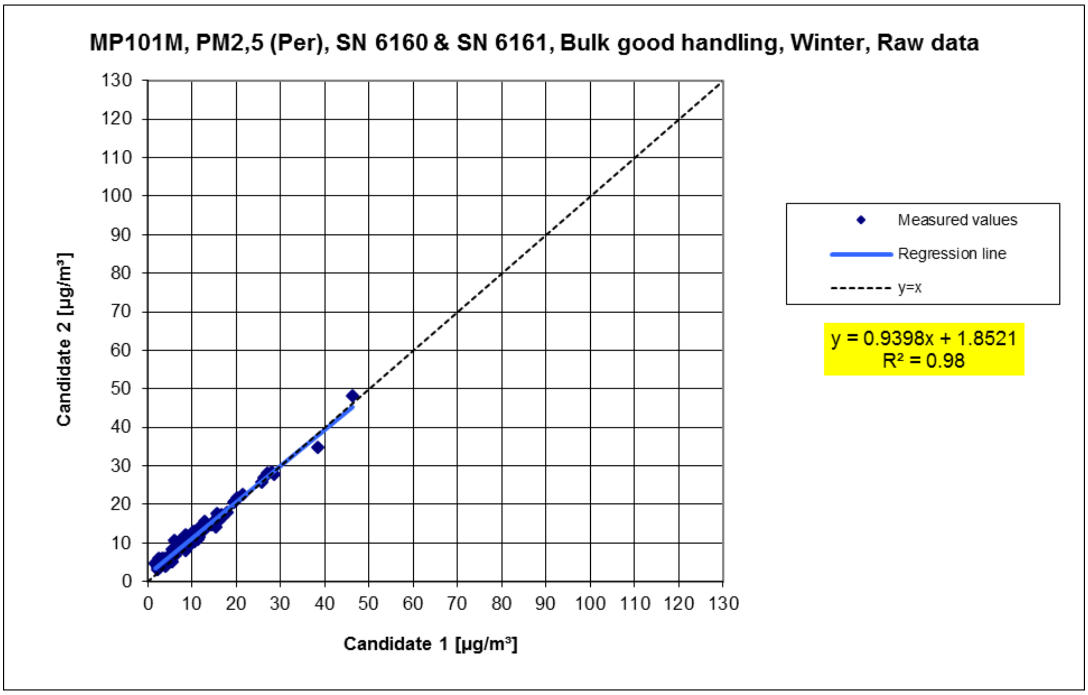

Figure 25: Results of the parallel measurements, bulk handling, winter, per.

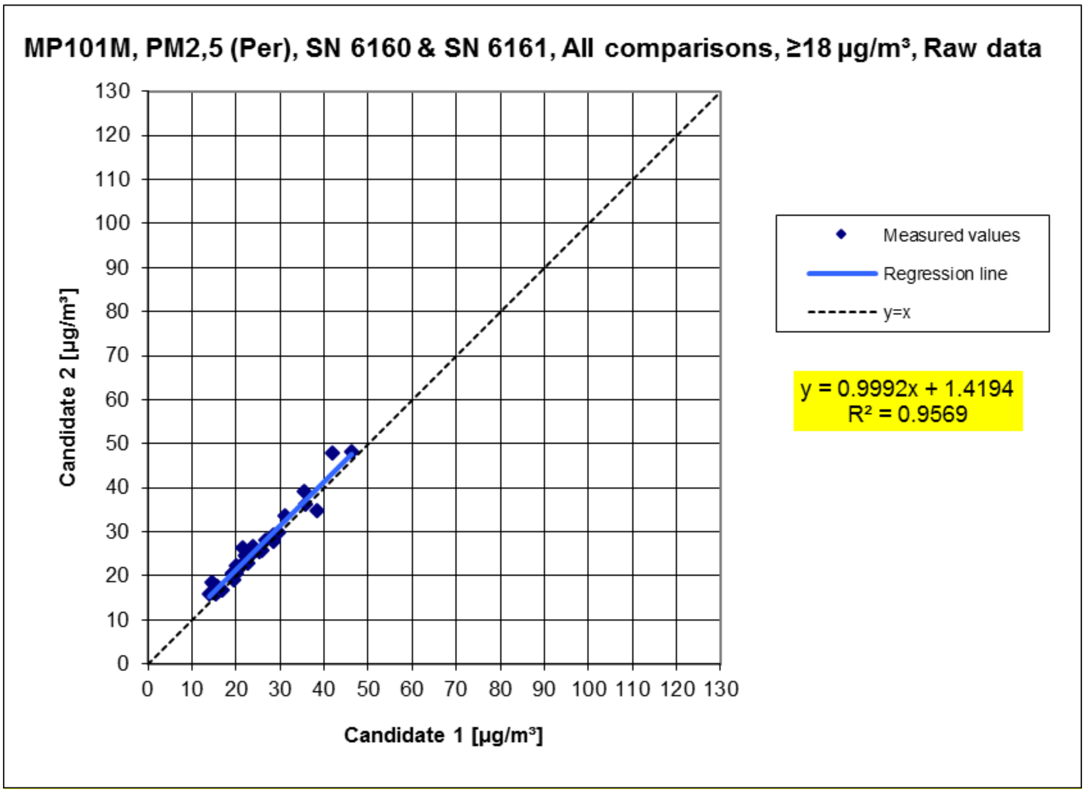

Figure 26: Results of the parallel measurements, all sites, values ≥ 18 µg/m³, Cyc.

6.1 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.

6.2 Equipment

Additional reference measurement system as described in chapter 5 of this report was used for this test.

6.3 Testing

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

In the full dataset, at least 20% of the results obtained using the reference method should be greater than 17 µg/m³ for $PM_{2.5}$. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.

For each comparison campaign, at least 40 valid value pairs were determined. In the full dataset a total of 21.0% value pairs (corresponds to 43 > 32 value pairs) exceed 17 µg/m³ for $PM_{2,5}$. The concentrations measured were related to the ambient conditions.

6.4 Evaluation

[EN 16450, 7.5.8.3]

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

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

Results of the evaluation are summarised in section 6.6.

[EN 16450, 7.5.8.5 & 7.5.8.6]

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

The regression is calculated for:

- all sites or comparisons respectively together
- Every location or comparison separately
- For a reduced data set only taking into account concentrations greater than or equal to 18 µg/m³ for $PM_{2.5}$, provided that the subset contains 40 or more valid data pairs.

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

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

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

u_{RM} =random uncertainty of 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 = 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 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_{CR} is calculated for:

- all sites or comparisons respectively together
- Every location or comparison separately
- For a reduced data set only taking into account concentrations greater than or equal to 18 µg/m³ for $PM_{2.5}$, provided that the subset contains 40 or more valid data pairs.

The Guideline states the following prerequisite for accepting the full data set:

- The slope be is insignificantly different from 1: $|b-1| \leq 2 \cdot u(b)$

and

- The axis intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$, where u(a) and u(b) describe the standard uncertainty of the slope and the axis intercept calculated as the square root of the variance. If the prerequisites are not met, it is possible to calibrate the measuring systems in accordance with section 4 of the Guideline7.5.8.6 [4] (also see 6.1 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 $PM_{2.5}$ as well as L = 50 µg/m³ for PM_{10}.

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

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

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

7.5 Assessment

Without the need for any correction factors, the expanded uncertainties W_{AMS} were below the expanded, relative uncertainty W_{dqo} defined for fine dust at 25% for all data sets observed. As the axis intercept determined for system 1 is significantly different from 0, section 6.1 17 Use of correction factors/terms required the use of a correction factor.

Criterion satisfied? yes

Table 23 and Table 24 below summarise all results for the equivalence tests. This page presents the combined results for the two instruments obtained at all 4 sites for all values ≥ 18 µg/m³. The following page summarises the results separately for each instrument and site for all values ≥ 18 µg/m³ and fro all 4 sites.

Where a criterion was not satisfied, the corresponding line is marked in red.

Table 23: Overview of equivalence testing, cyc.

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	MP101M, PM2,5 (Cyc)		SN	SN 6160 & SN 6161	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.41**	**µg/m³**			
Uncertainty between Candidates	**1.27**	**µg/m³**			
	SN 6160 & SN 6161				
Number of data pairs	**205**				
Slope b	**1.020**	**not significant**			
Uncertainty of b	**0.019**				
Ordinate intercept a	**-1.153**	**significant**			
Uncertainty of a	**0.286**				
Expanded meas. uncertainty W_{CM}	**14.07**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.33**	**µg/m³**			
Uncertainty between Candidates	**1.50**	**µg/m³**			
	SN 6160 & SN 6161				
Number of data pairs	**37**				
Slope b	**0.998**				
Uncertainty of b	**0.047**				
Ordinate intercept a	**-1.258**				
Uncertainty of a	**1.291**				
Expanded meas. uncertainty W_{CM}	**17.32**	**%**			

Comparison candidate with reference according to Standard EN 16450:2017				
Candidate	MP101M, PM2,5 (Cyc)	SN	SN 6160 & SN 6161	
		Limit value	30	µg/m³
Status of measured values	Raw data	Allowed uncertainty	25	%
Cologne, Winter				
Uncertainty between Reference	**0.42**	**µg/m³**		
Uncertainty between Candidates	**1.62**	**µg/m³**		
	SN 6160		**SN 6161**	
Number of data pairs	**54**		**56**	
Slope b	**1.022**		**1.063**	
Uncertainty of b	**0.030**		**0.027**	
Ordinate intercept a	**-3.208**		**-1.736**	
Uncertainty of a	**0.518**		**0.466**	
Expanded meas. uncertainty W_{CM}	**22.18**	**%**	**13.18**	**%**
Bonn, Belderberg				
Uncertainty between Reference	**0.53**	**µg/m³**		
Uncertainty between Candidates	**1.17**	**µg/m³**		
	SN 6160		**SN 6161**	
Number of data pairs	**40**		**40**	
Slope b	**1.146**		**1.100**	
Uncertainty of b	**0.044**		**0.042**	
Ordinate intercept a	**-2.598**		**-0.756**	
Uncertainty of a	**0.612**		**0.580**	
Expanded meas. uncertainty W_{CM}	**15.40**	**%**	**17.67**	**%**
Bulk good handling, Summer				
Uncertainty between Reference	**0.35**	**µg/m³**		
Uncertainty between Candidates	**1.06**	**µg/m³**		
	SN 6160		**SN 6161**	
Number of data pairs	**66**		**66**	
Slope b	**1.113**		**1.066**	
Uncertainty of b	**0.052**		**0.045**	
Ordinate intercept a	**-1.561**		**-0.144**	
Uncertainty of a	**0.655**		**0.577**	
Expanded meas. uncertainty W_{CM}	**17.87**	**%**	**16.74**	**%**
Bulk good handling, Winter				
Uncertainty between Reference	**0.33**	**µg/m³**		
Uncertainty between Candidates	**1.20**	**µg/m³**		
	SN 6160		**SN 6161**	
Number of data pairs	**45**		**45**	
Slope b	**1.011**		**0.943**	
Uncertainty of b	**0.034**		**0.031**	
Ordinate intercept a	**-2.736**		**-0.418**	
Uncertainty of a	**0.587**		**0.534**	
Expanded meas. uncertainty W_{CM}	**21.49**	**%**	**19.15**	**%**
All comparisons, ≥18 µg/m³				
Uncertainty between Reference	**0.33**	**µg/m³**		
Uncertainty between Candidates	**1.50**	**µg/m³**		
	SN 6160		**SN 6161**	
Number of data pairs	**37**		**37**	
Slope b	**0.992**		**1.016**	
Uncertainty of b	**0.052**		**0.049**	
Ordinate intercept a	**-1.784**		**-1.023**	
Uncertainty of a	**1.417**		**1.33**	
Expanded meas. uncertainty W_{CM}	**21.28**	**%**	**15.91**	**%**
All comparisons				
Uncertainty between Reference	**0.41**	**µg/m³**		
Uncertainty between Candidates	**1.27**	**µg/m³**		
	SN 6160		**SN 6161**	
Number of data pairs	**205**		**207**	
Slope b	**1.029**	**not significant**	**1.020**	**not significant**
Uncertainty of b	**0.021**		**0.018**	
Ordinate intercept a	**-1.968**	**significant**	**-0.452**	**not significant**
Uncertainty of a	**0.317**		**0.277**	
Expanded meas. uncertainty W_{CM}	**16.77**	**%**	**13.31**	**%**

Table 24: Overview of equivalence testing, per.

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	MP101M, PM2,5 (Per)		SN	SN 6160 & SN 6161	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.41**	**µg/m³**			
Uncertainty between Candidates	**1.29**	**µg/m³**			
	SN 6160 & SN 6161				
Number of data pairs	**205**				
Slope b	**1.020**	**not significant**			
Uncertainty of b	**0.019**				
Ordinate intercept a	**-1.136**	**significant**			
Uncertainty of a	**0.290**				
Expanded meas. uncertainty W_{CM}	**14.21**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.33**	**µg/m³**			
Uncertainty between Candidates	**1.52**	**µg/m³**			
	SN 6160 & SN 6161				
Number of data pairs	**37**				
Slope b	**0.998**				
Uncertainty of b	**0.048**				
Ordinate intercept a	**-1.254**				
Uncertainty of a	**1.304**				
Expanded meas. uncertainty W_{CM}	**17.49**	**%**			

Comparison candidate with reference according to Standard EN 16450:2017				
Candidate	MP101M, PM2,5 (Per)	SN	SN 6160 & SN 6161	
		Limit value	30	µg/m³
Status of measured values	Raw data	Allowed uncertainty	25	%
Cologne, Winter				
Uncertainty between Reference	**0.42**	**µg/m³**		
Uncertainty between Candidates	**1.64**	**µg/m³**		
	SN 6160		**SN 6161**	
Number of data pairs	**54**		**56**	
Slope b	**1.021**		**1.062**	
Uncertainty of b	**0.030**		**0.027**	
Ordinate intercept a	**-3.218**		**-1.726**	
Uncertainty of a	**0.521**		**0.468**	
Expanded meas. uncertainty W_{CM}	**22.43**	**%**	**13.24**	**%**
Bonn, Belderberg				
Uncertainty between Reference	**0.53**	**µg/m³**		
Uncertainty between Candidates	**1.20**	**µg/m³**		
	SN 6160		**SN 6161**	
Number of data pairs	**40**		**40**	
Slope b	**1.146**		**1.101**	
Uncertainty of b	**0.044**		**0.042**	
Ordinate intercept a	**-2.621**		**-0.758**	
Uncertainty of a	**0.620**		**0.587**	
Expanded meas. uncertainty W_{CM}	**15.43**	**%**	**17.79**	**%**
Bulk good handling, Summer				
Uncertainty between Reference	**0.35**	**µg/m³**		
Uncertainty between Candidates	**1.10**	**µg/m³**		
	SN 6160		**SN 6161**	
Number of data pairs	**66**		**66**	
Slope b	**1.113**		**1.068**	
Uncertainty of b	**0.052**		**0.046**	
Ordinate intercept a	**-1.557**		**-0.145**	
Uncertainty of a	**0.658**		**0.583**	
Expanded meas. uncertainty W_{CM}	**17.92**	**%**	**17.08**	**%**
Bulk good handling, Winter				
Uncertainty between Reference	**0.33**	**µg/m³**		
Uncertainty between Candidates	**1.21**	**µg/m³**		
	SN 6160		**SN 6161**	
Number of data pairs	**45**		**45**	
Slope b	**1.010**		**0.942**	
Uncertainty of b	**0.034**		**0.031**	
Ordinate intercept a	**-2.722**		**-0.395**	
Uncertainty of a	**0.591**		**0.540**	
Expanded meas. uncertainty W_{CM}	**21.64**	**%**	**19.31**	**%**
All comparisons, ≥18 µg/m³				
Uncertainty between Reference	**0.33**	**µg/m³**		
Uncertainty between Candidates	**1.52**	**µg/m³**		
	SN 6160		**SN 6161**	
Number of data pairs	**37**		**37**	
Slope b	**0.992**		**1.015**	
Uncertainty of b	**0.053**		**0.050**	
Ordinate intercept a	**-1.812**		**-0.993**	
Uncertainty of a	**1.430**		**1.35**	
Expanded meas. uncertainty W_{CM}	**21.50**	**%**	**16.06**	**%**
All comparisons				
Uncertainty between Reference	**0.41**	**µg/m³**		
Uncertainty between Candidates	**1.29**	**µg/m³**		
	SN 6160		**SN 6161**	
Number of data pairs	**205**		**207**	
Slope b	**1.030**	**not significant**	**1.019**	**not significant**
Uncertainty of b	**0.021**		**0.018**	
Ordinate intercept a	**-1.951**	**significant**	**-0.440**	**not significant**
Uncertainty of a	**0.322**		**0.279**	
Expanded meas. uncertainty W_{CM}	**16.92**	**%**	**13.42**	**%**

Results for testing the five criteria from chapter 6.1 Method used for equivalence testing were as follows:

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

Criterion 2: Between-AMS uncertainty of the AMS tested did not exceed 2.5 µg/m³.

Criterion 3: Uncertainty between reference instruments did not exceed 2.0 µg/m³.

Criterion 4: All expanded uncertainties remained below 25%.

Criterion 5: When evaluating the full data set, the slope determined for one instrument is significantly higher than allowed.

Additional: The slope determined for the full data set regarding both test specimens combined was at 1.020 (cyc.) and 1.020 (per.), the axis intercept was at -1.153 (cyc.) and -1.136 (per) at a total expanded uncertainty of 14.07% (cyc.) and 14.21% (per.).

At -1.968 (cyc.) and -1.951 (per.) for instrument 1, the axis intercept is significantly different from 0. This is why chapter 6.1 17 Use of correction factors/terms contains an additional assessment for which the corresponding calibration factor was applied to the data sets.

It should be noted here that the uncertainty W_{CM} determined without applying correction factors for all observed data sets is below the determined expanded relative uncertainty W_{dqo} of 25% for $PM_{2.5}$.

6.6 Detailed presentation of test results

Table 25 provides an overview of the between-RM uncertainties $u_{bs,RM}$ determined during the field tests.

Table 25: Between RM uncertainty $u_{bs,RM}$

Reference instruments	Location	Number of measurements	Uncertainty $u_{bs,RM}$
No.			µg/m³
1 / 2	Cologne, Winter	54	0.42
1 / 2	Bonn, Belderberg	40	0.53
1 / 2	Bulk handling, summer	66	0.35
1 / 2	Bulk handling, summer	45	0.33
1 / 2	All locations	205	0.41

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

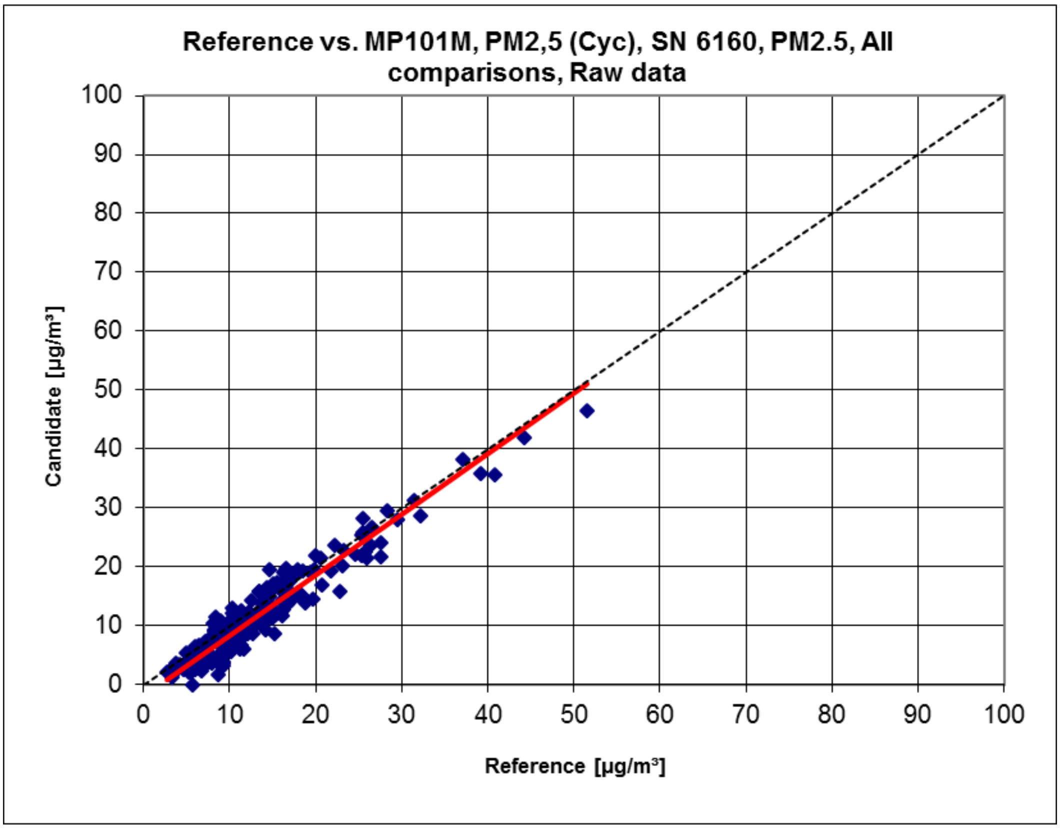

Figure 27: Reference vs. Tested instrument, S/N 6160, all sites, cyc.

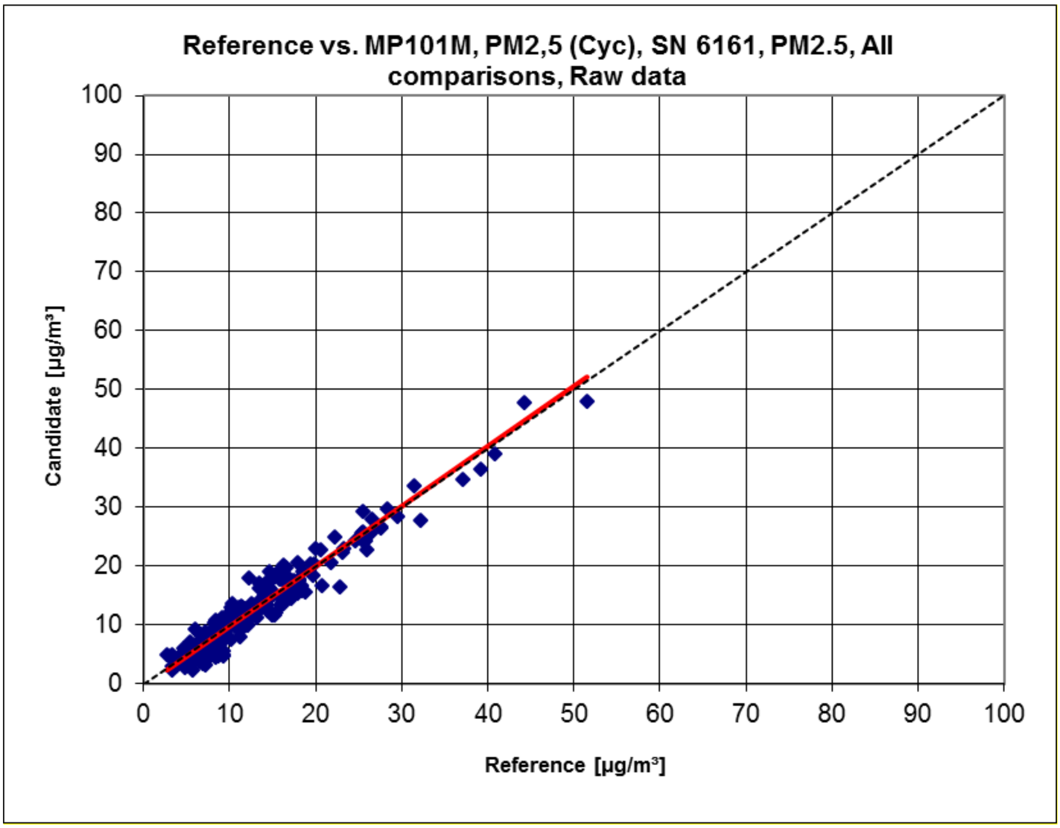

Figure 28: Reference vs. Tested instrument, S/N 6161, all sites, cyc.

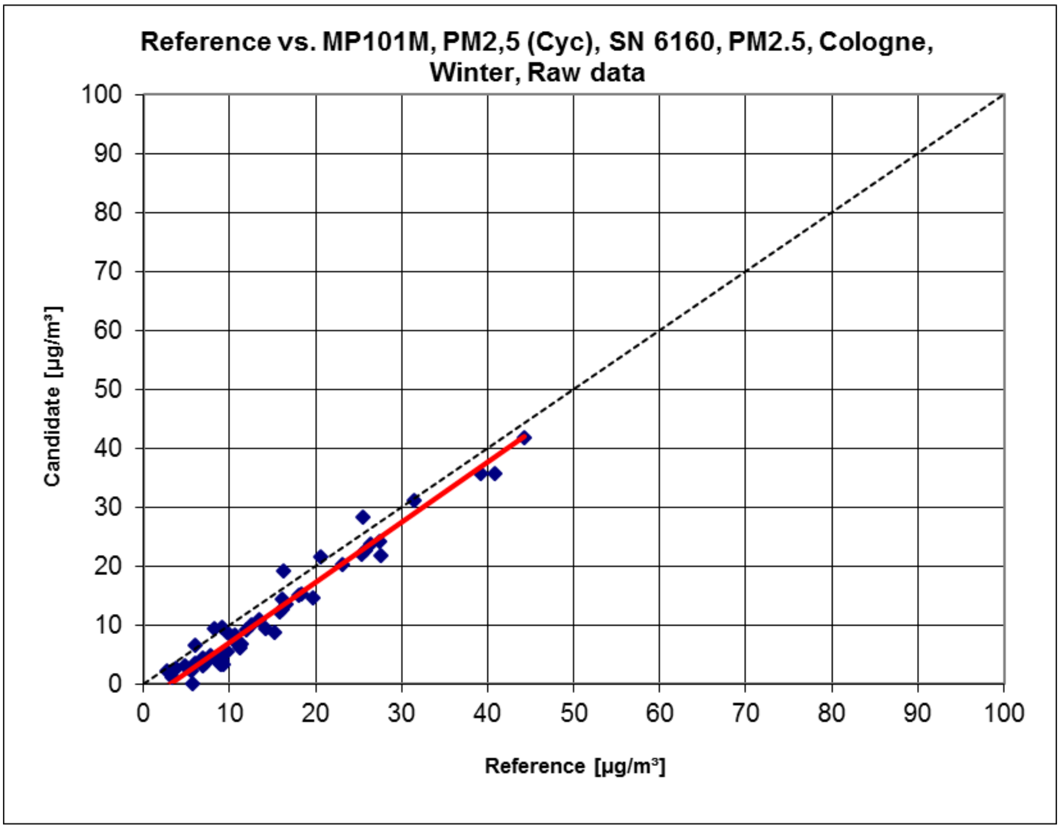

Figure 29: Reference vs. Tested instrument, S/N 6160, Cologne, winter, cyc.

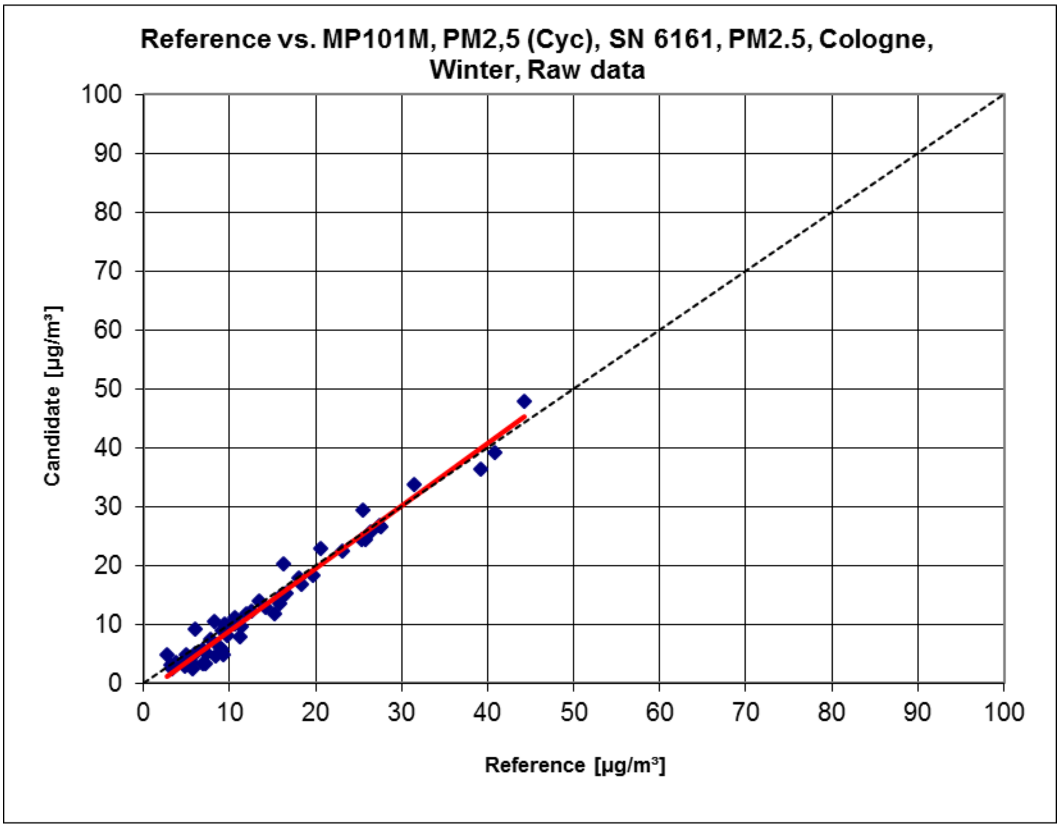

Figure 30: Reference vs. Tested instrument, S/N 6161, Cologne, winter, cyc.

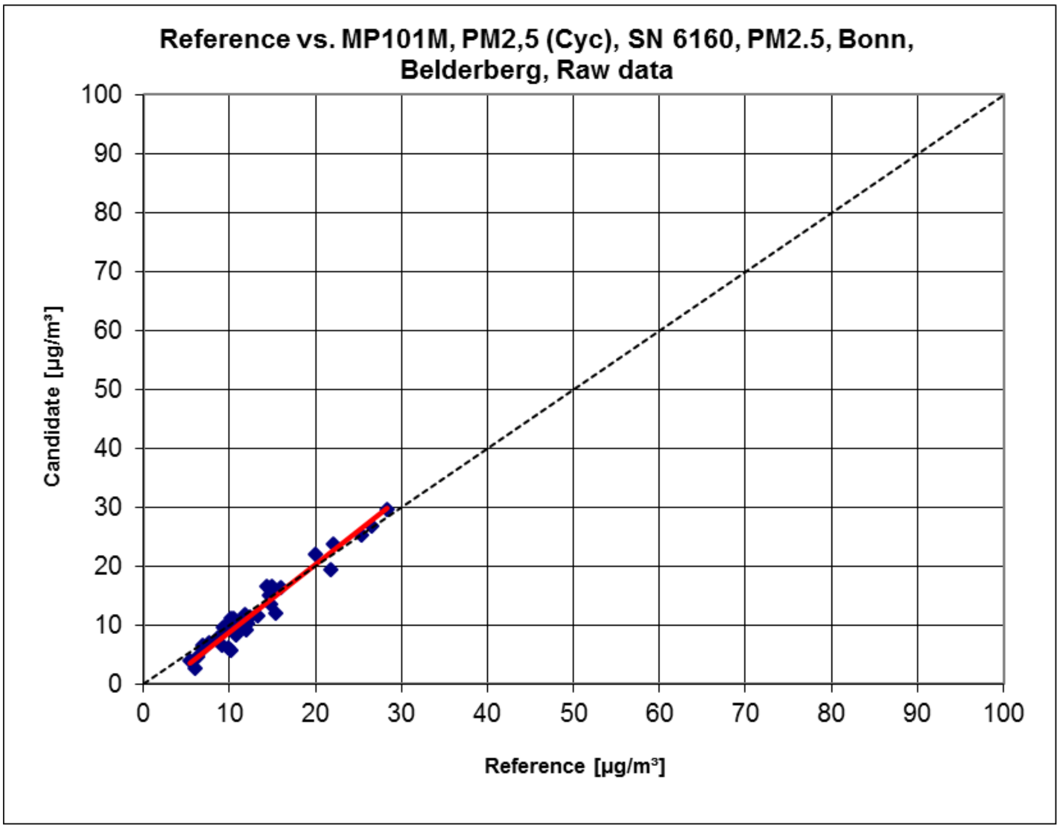

Figure 31: Reference vs. Tested instrument, S/N 6160, Bonn-Belderberg, cyc.

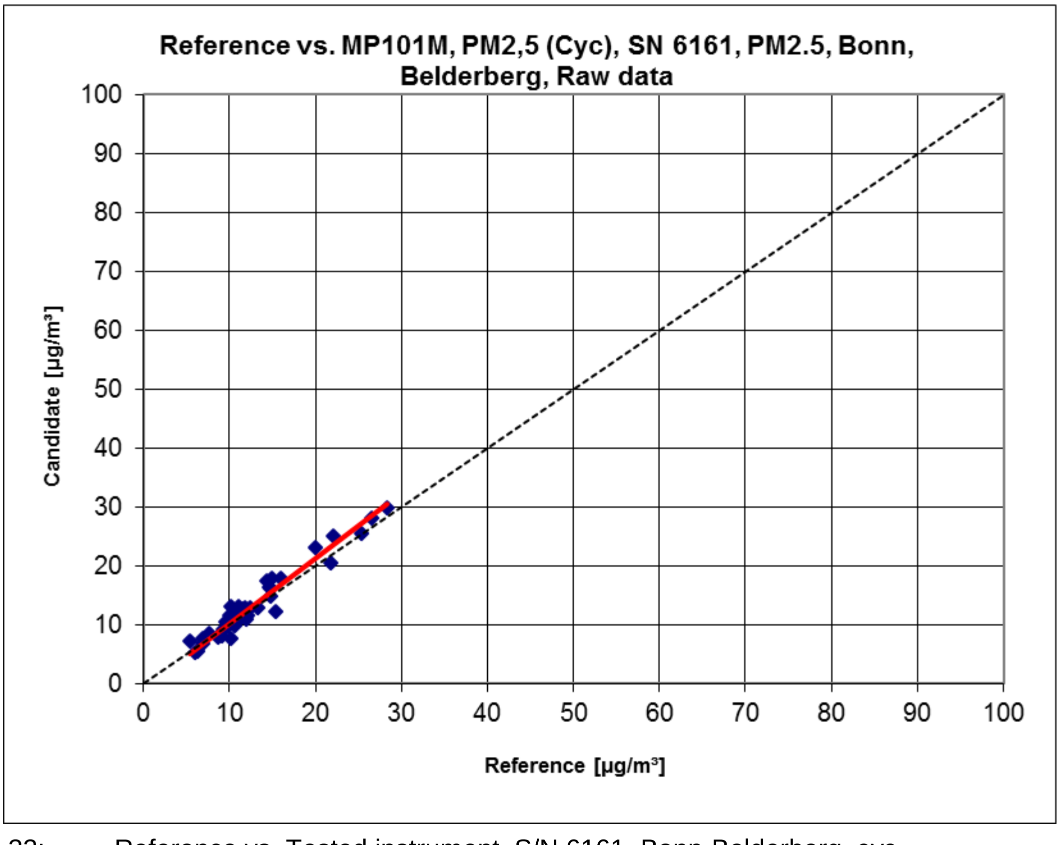

Figure 32: Reference vs. Tested instrument, S/N 6161, Bonn-Belderberg, cyc.

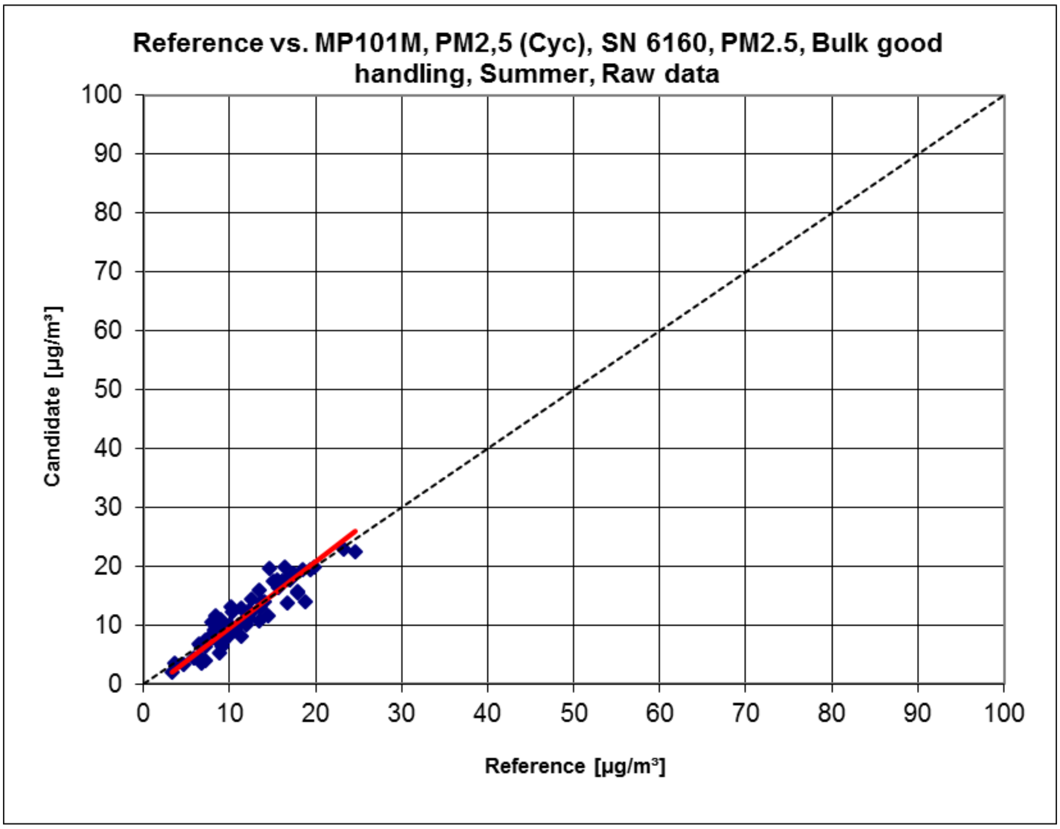

Figure 33: Reference vs. Tested instrument, S/N 6160, bulk handling, summer, cyc.

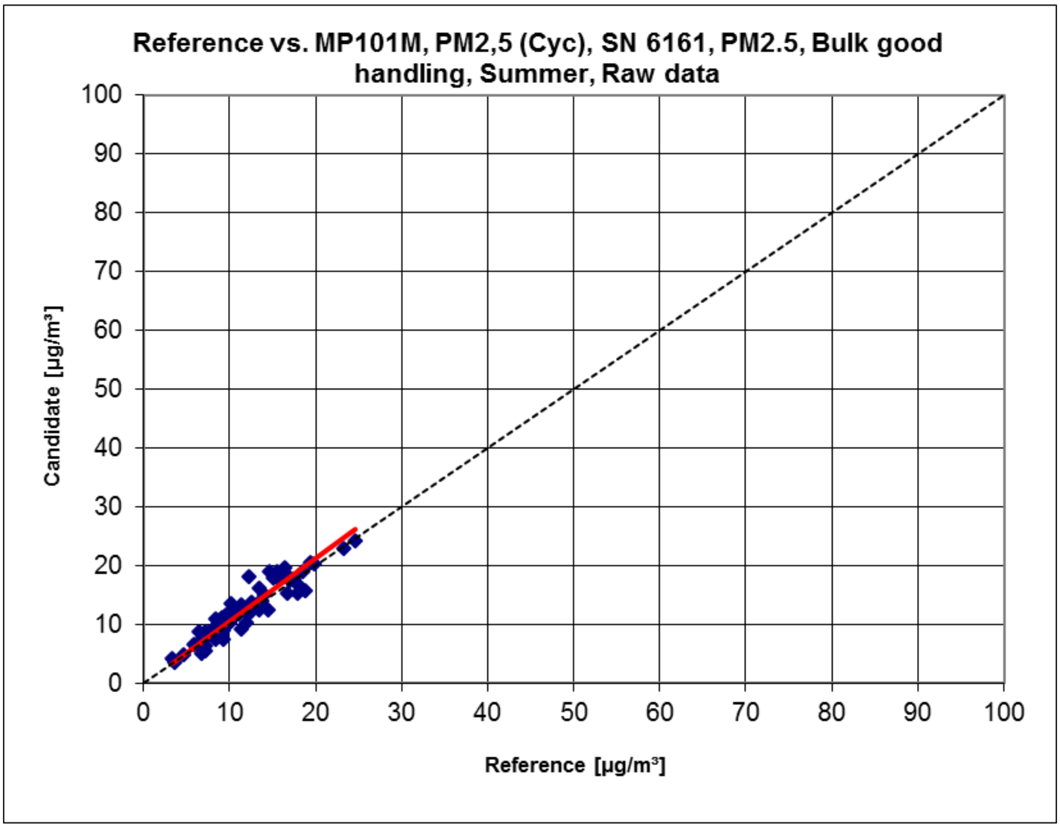

Figure 34: Reference vs. Tested instrument, S/N 6161, bulk handling, summer, cyc.

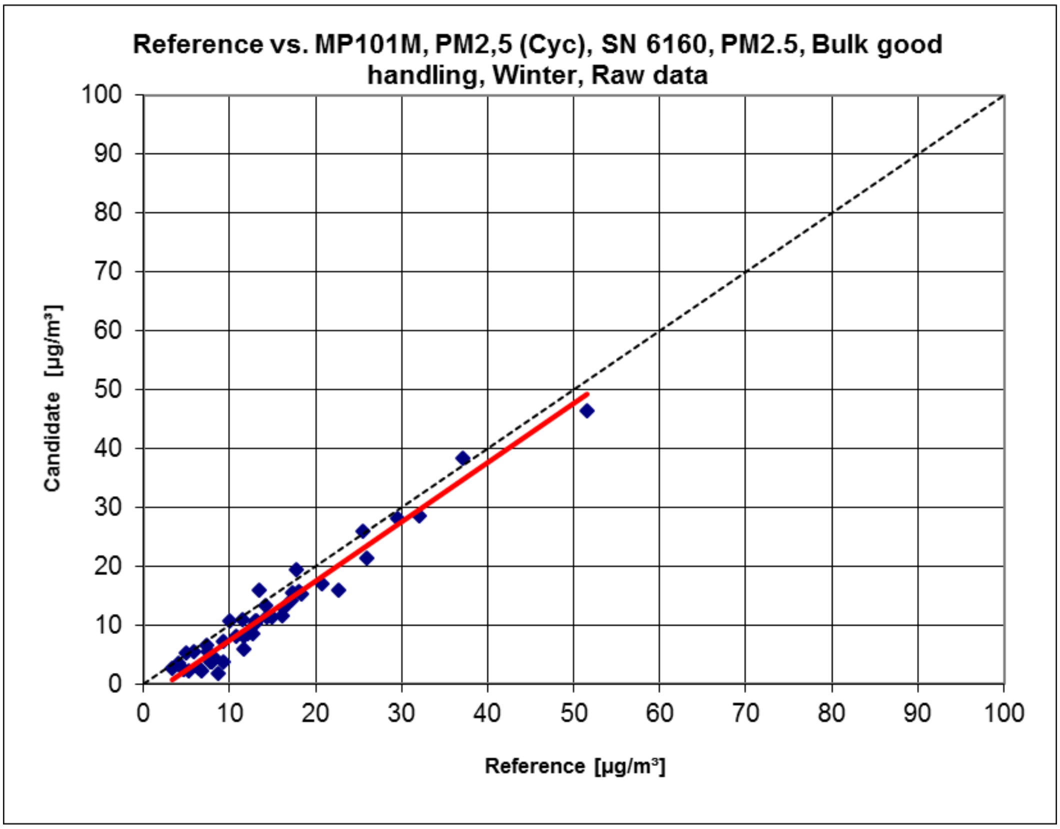

Figure 35: Reference vs. Tested instrument, S/N 6160, bulk handling, winter, cyc.

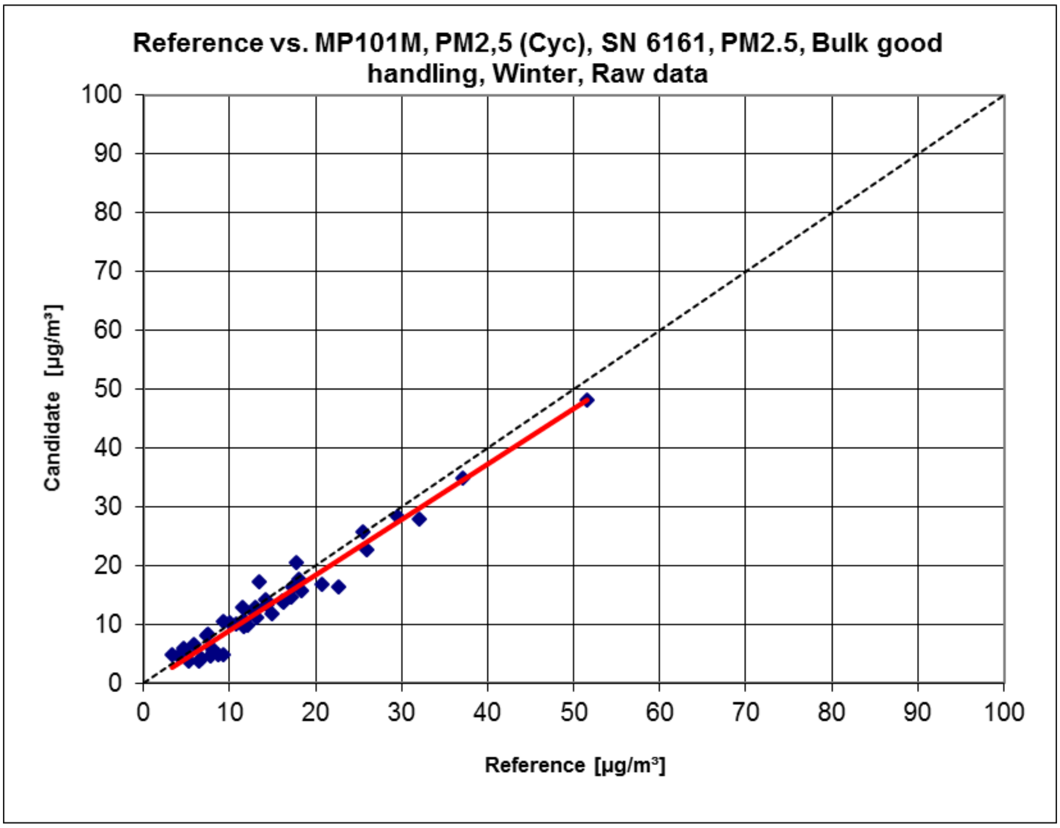

Figure 36: Reference vs. Tested instrument, S/N 6161, bulk handling, winter, cyc.

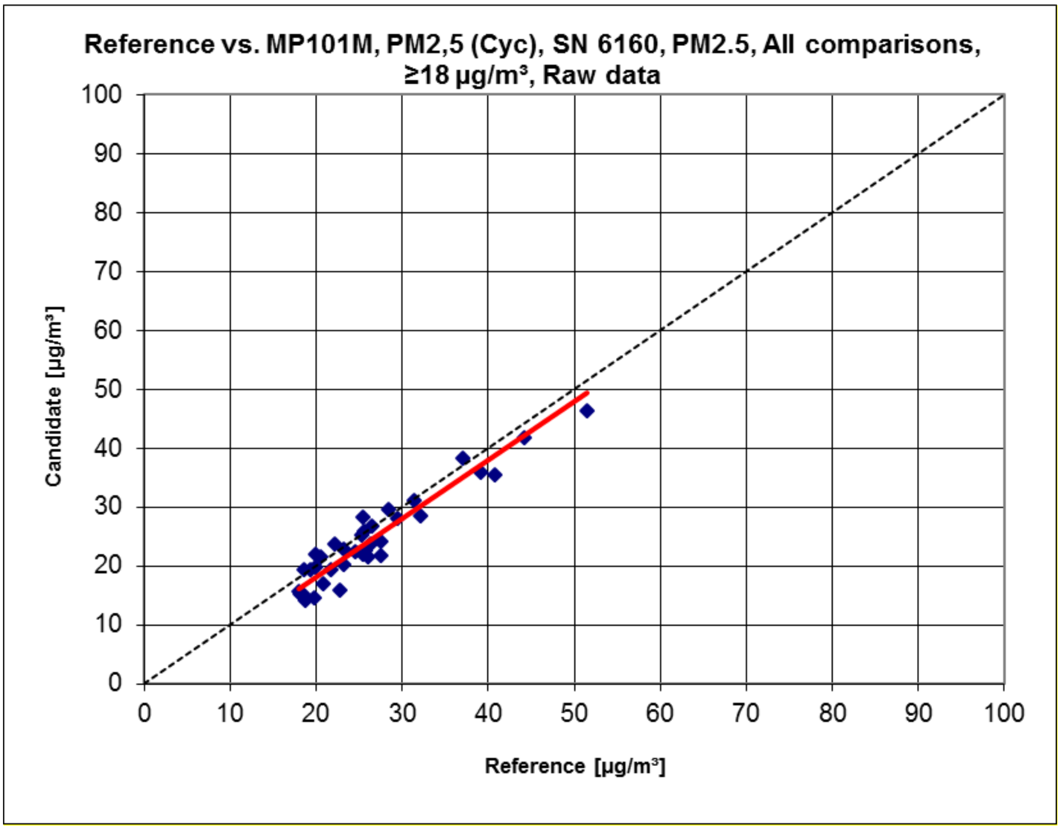

Figure 37: Reference vs. Tested instrument, S/N 6160, values ≥ 18 µg/m³, cyc.

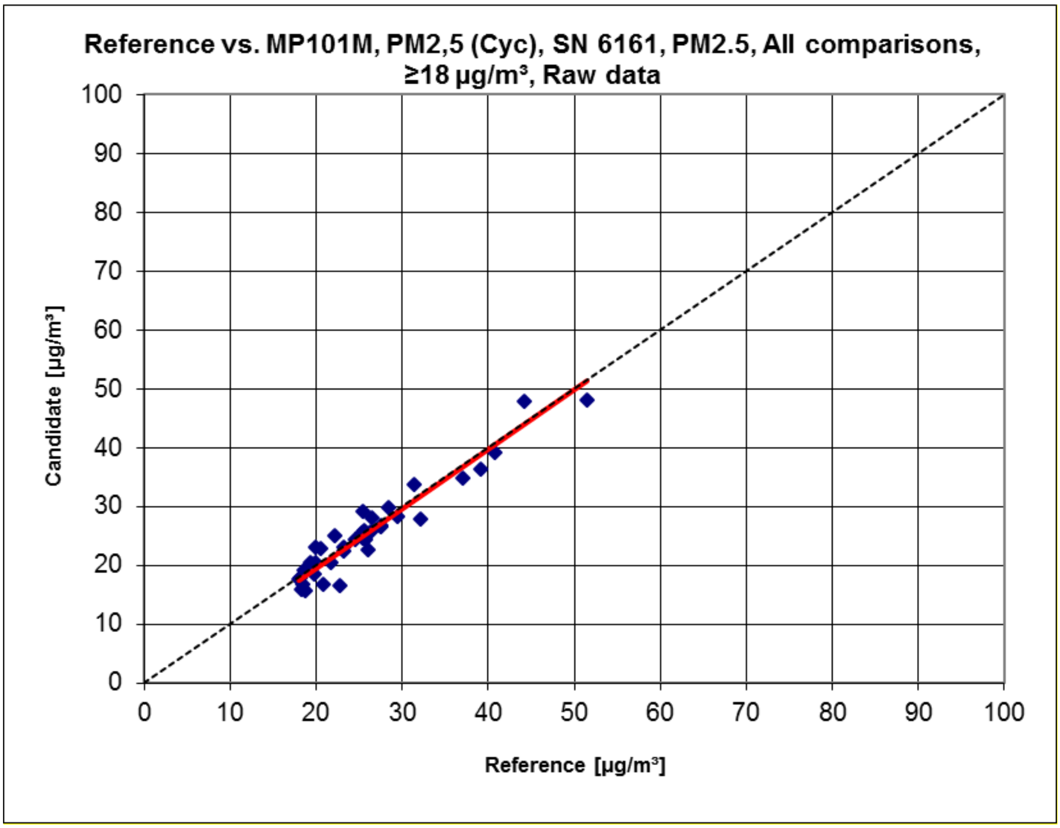

Figure 38: Reference vs. Tested instrument, S/N 6161, values ≥ 18 µg/m³, cyc.

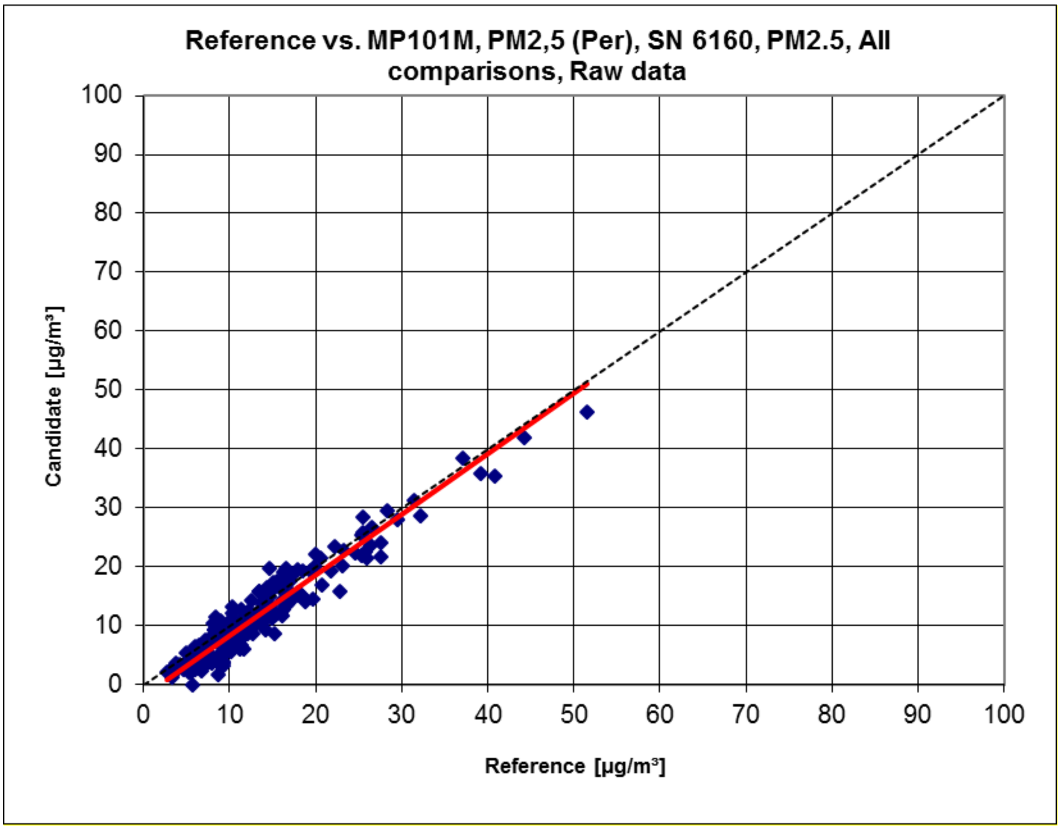

Figure 39: Reference vs. Tested instrument, S/N 6160, all sites, per.

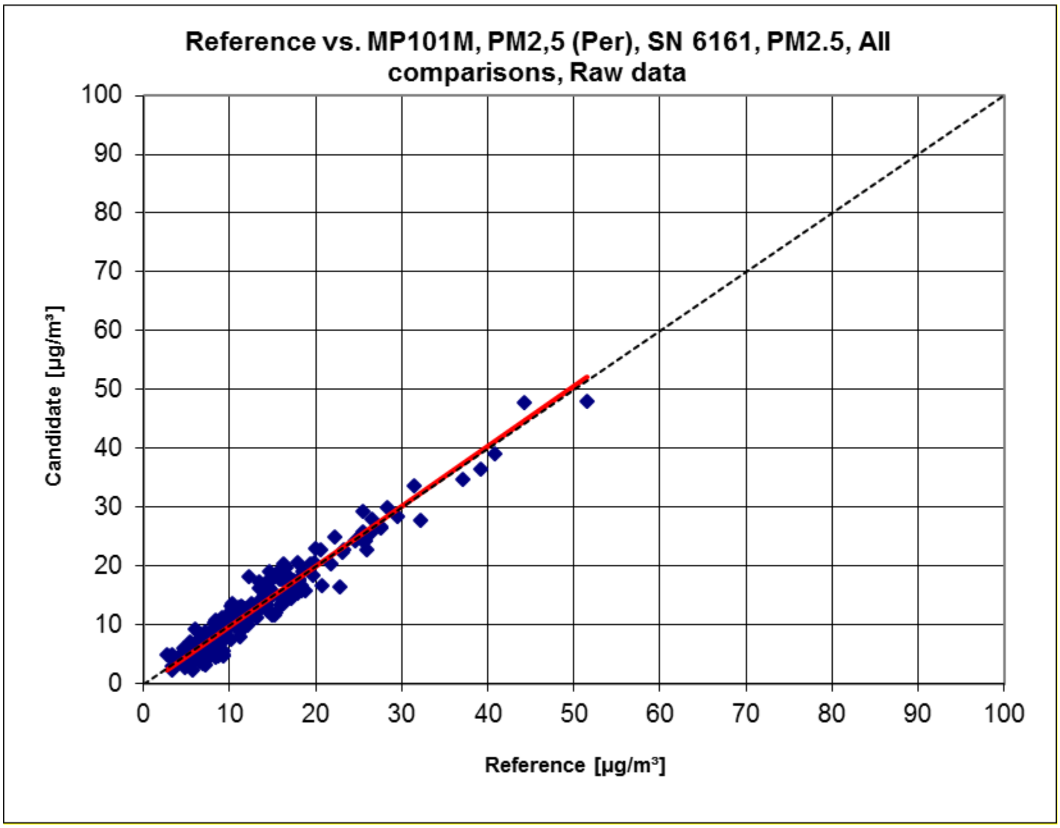

Figure 40: Reference vs. Tested instrument, S/N 6161, all sites, per.

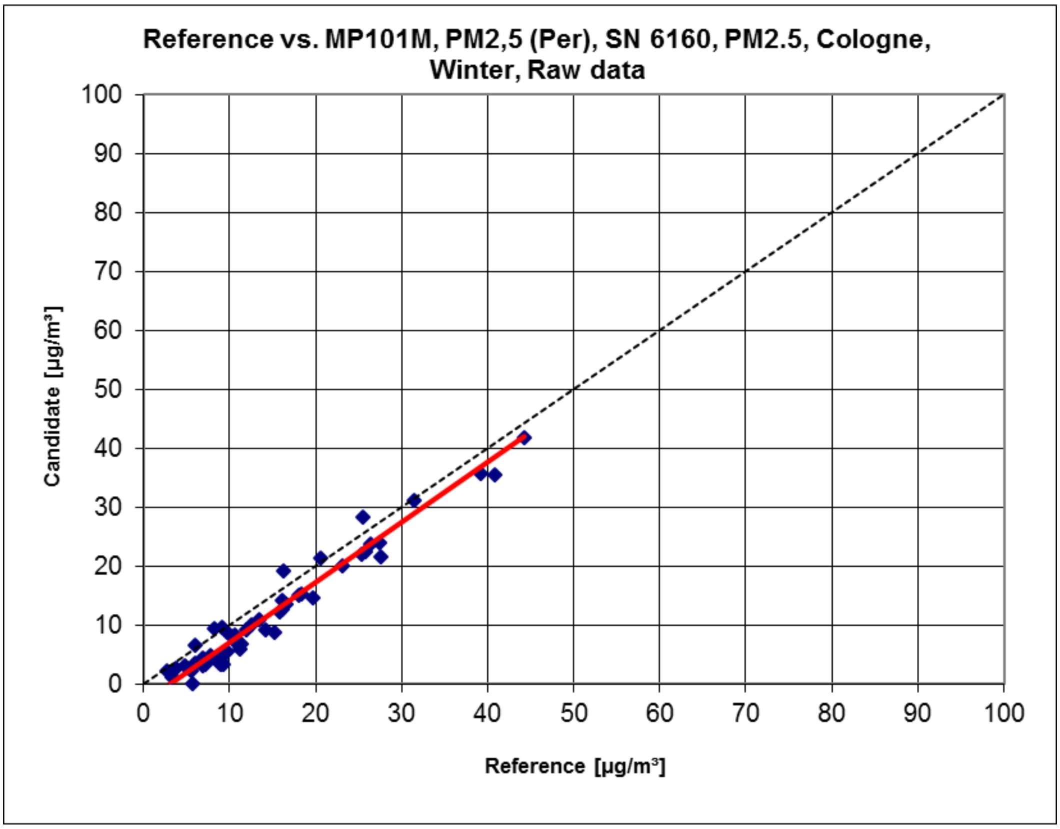

Figure 41: Reference vs. Tested instrument, S/N 6160, Cologne, winter, per.

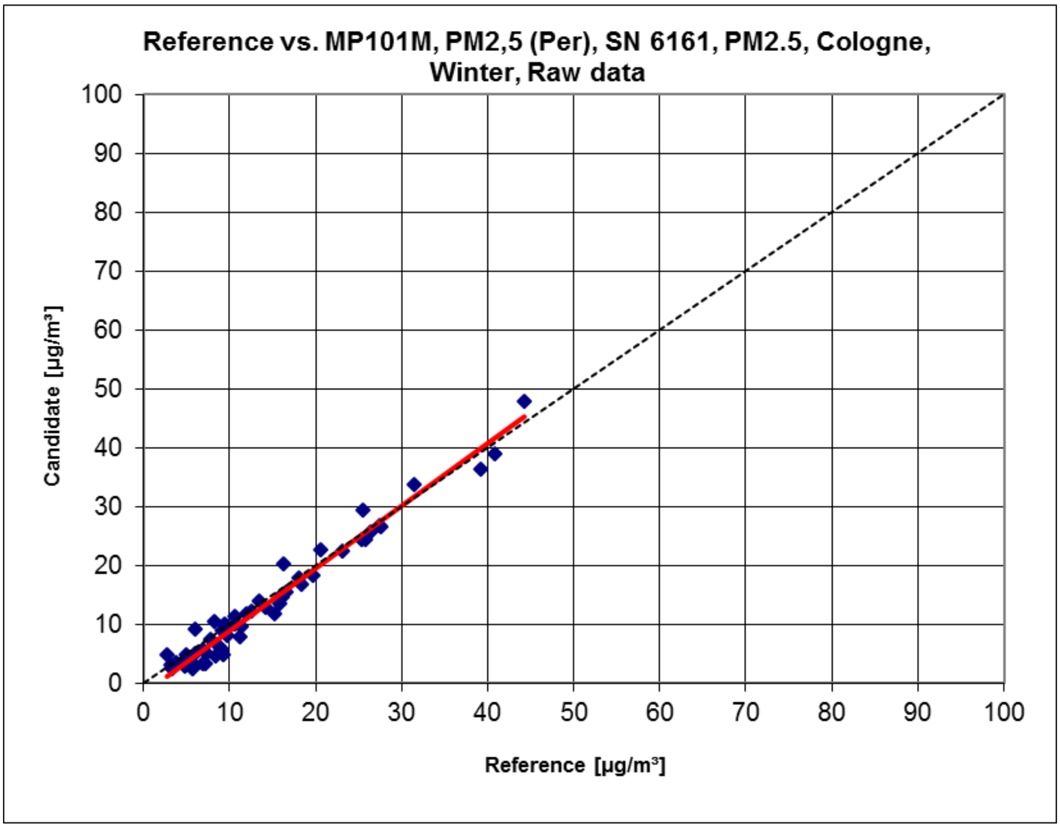

Figure 42: Reference vs. Tested instrument, S/N 6161, Cologne, winter, per.

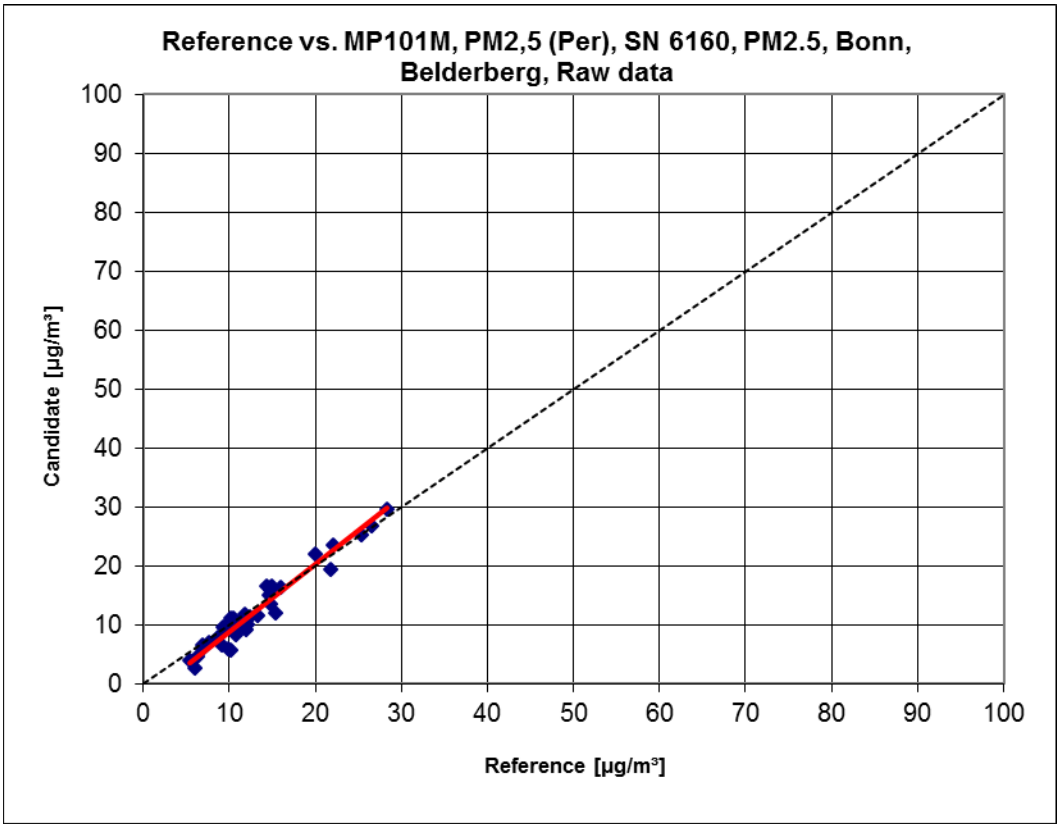

Figure 43: Reference vs. Tested instrument, S/N 6160, Bonn-Belderberg, per.

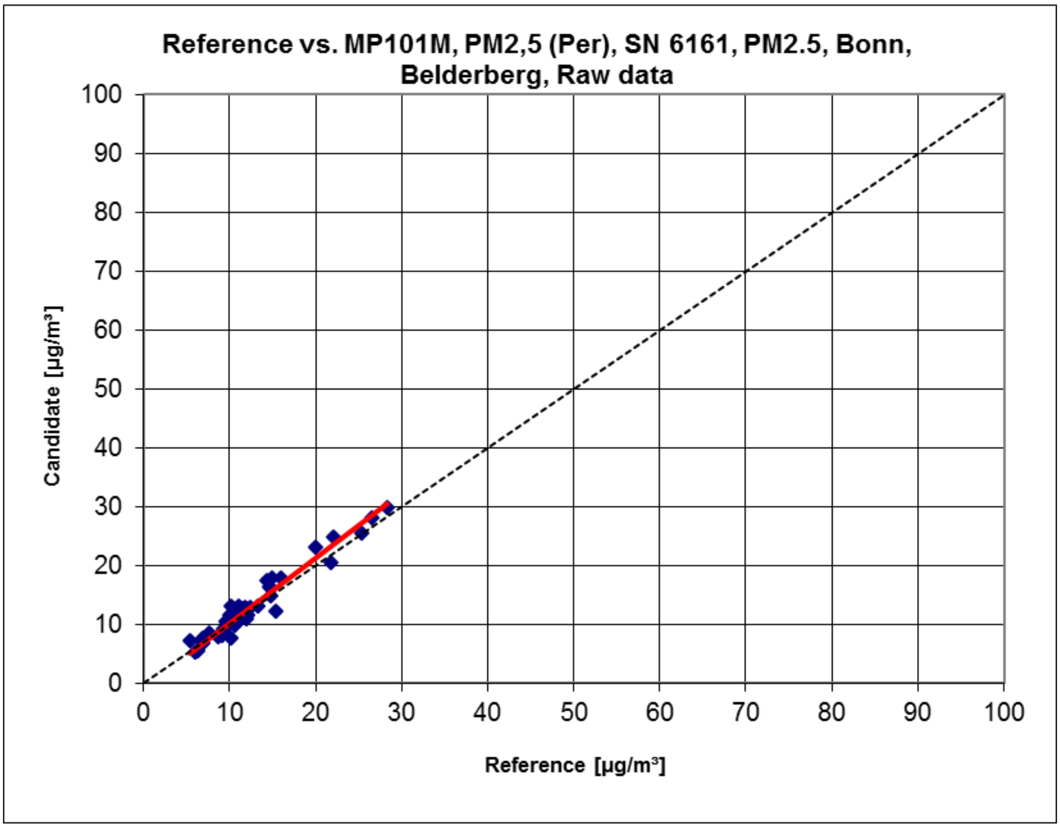

Figure 44: Reference vs. Tested instrument, S/N 6161, Bonn-Belderberg, per.

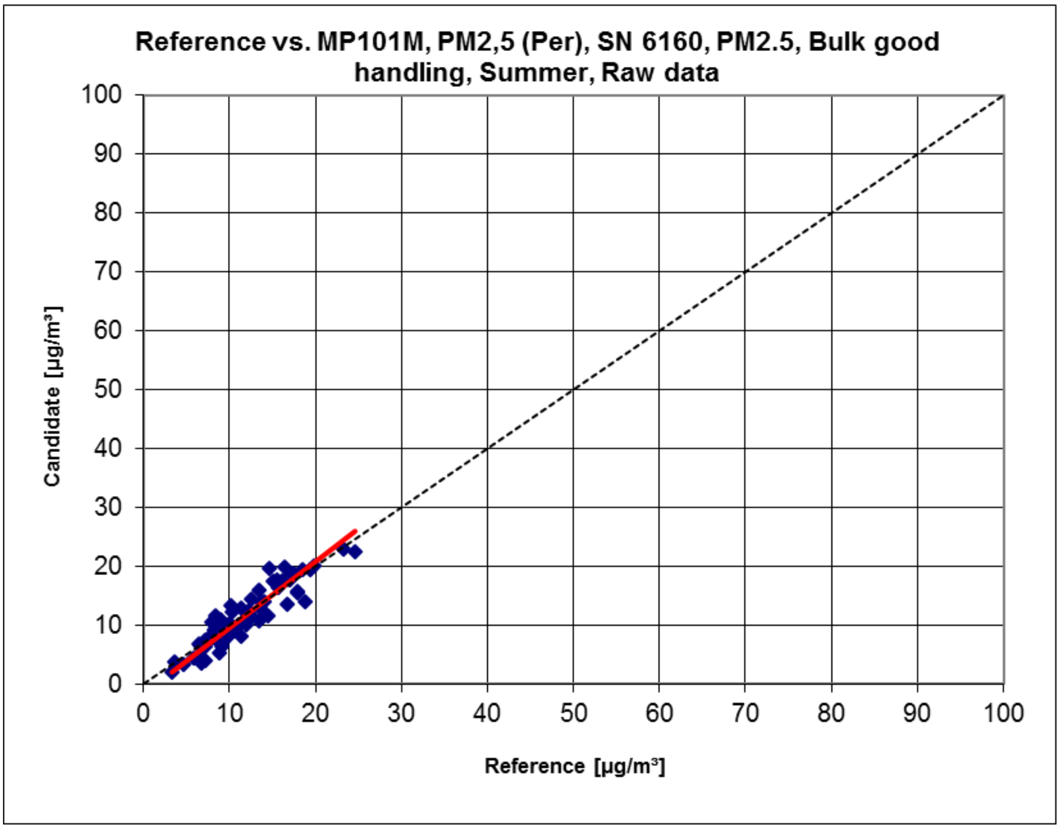

Figure 45: Reference vs. Tested instrument, S/N 6160, bulk handling, summer, per.

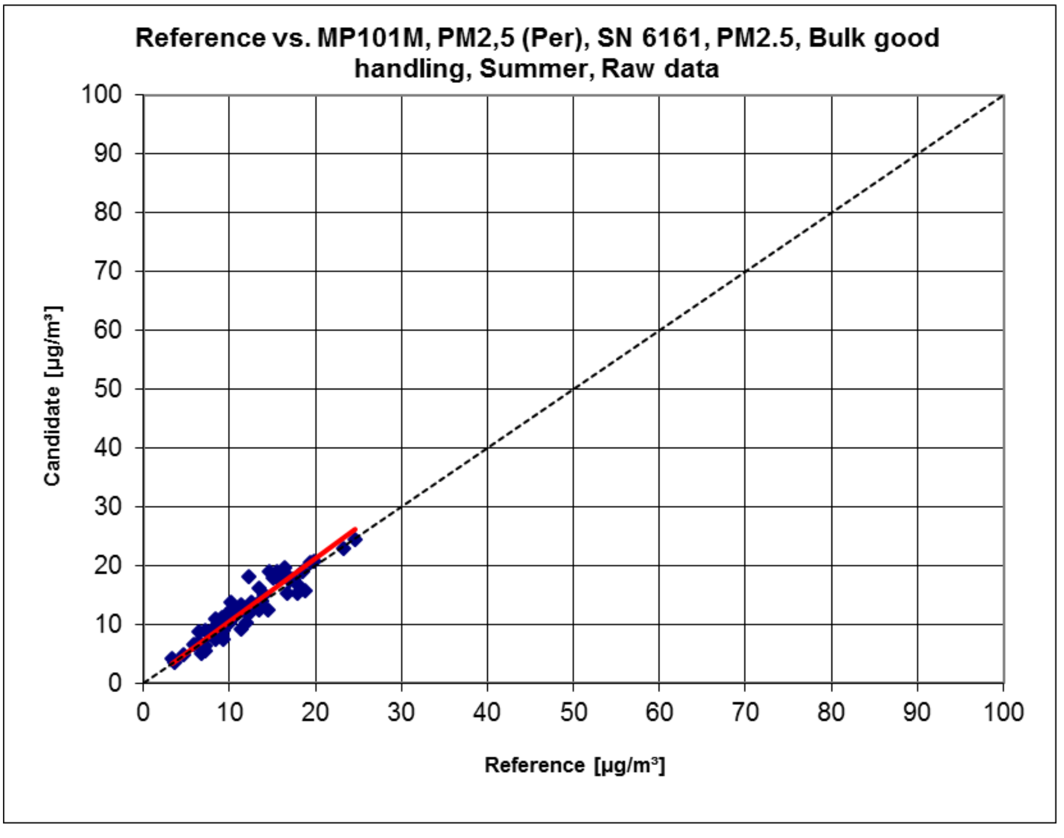

Figure 46: Reference vs. Tested instrument, S/N 6161, bulk handling, summer, per.

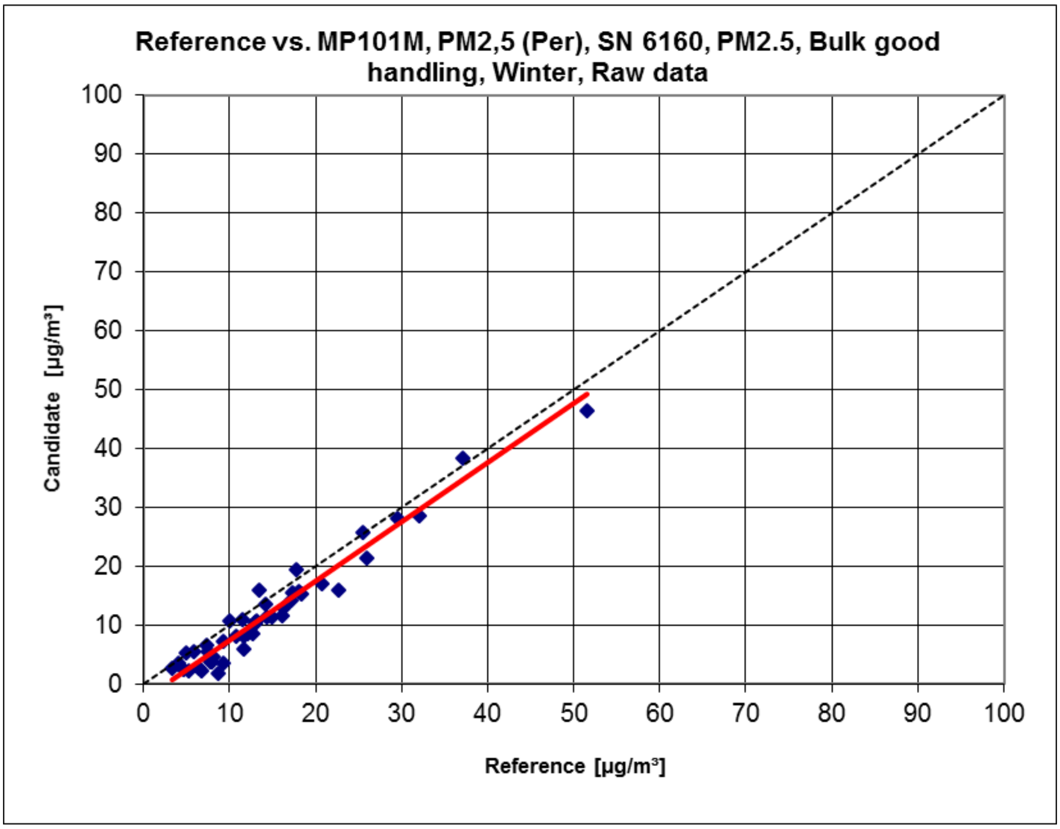

Figure 47: Reference vs. Tested instrument, S/N 6160, bulk handling, winter, per.

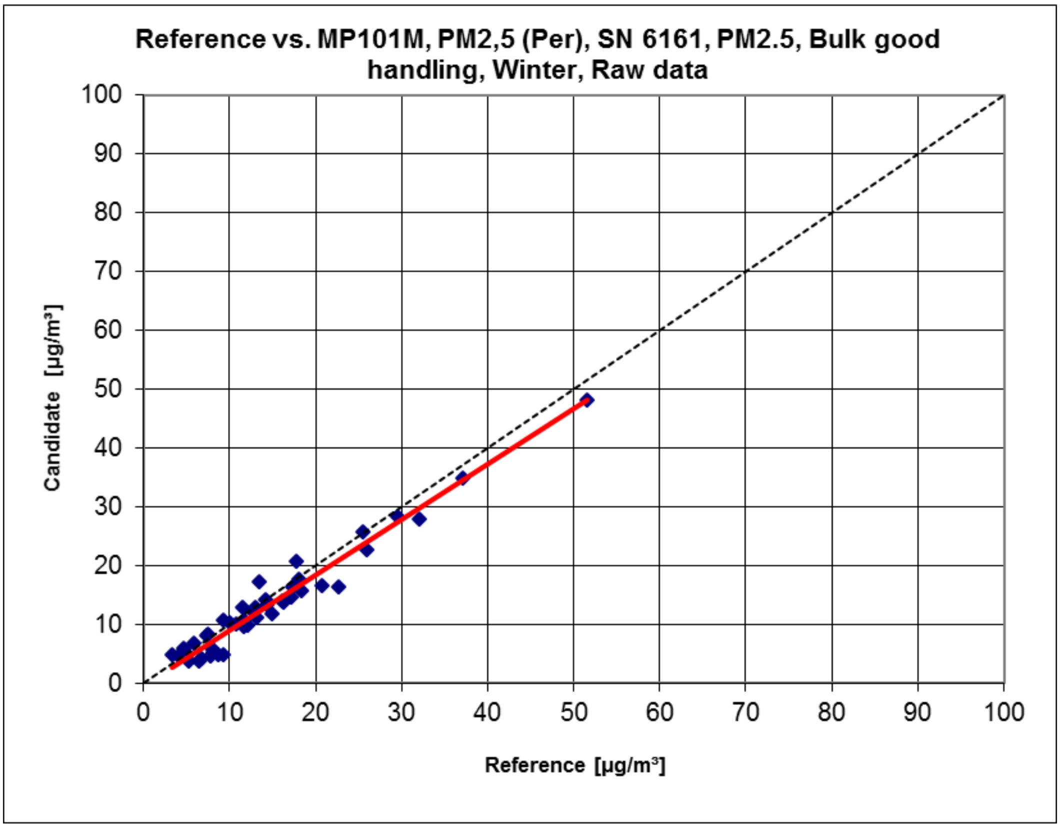

Figure 48: Reference vs. Tested instrument, S/N 6161, bulk handling, winter, per.

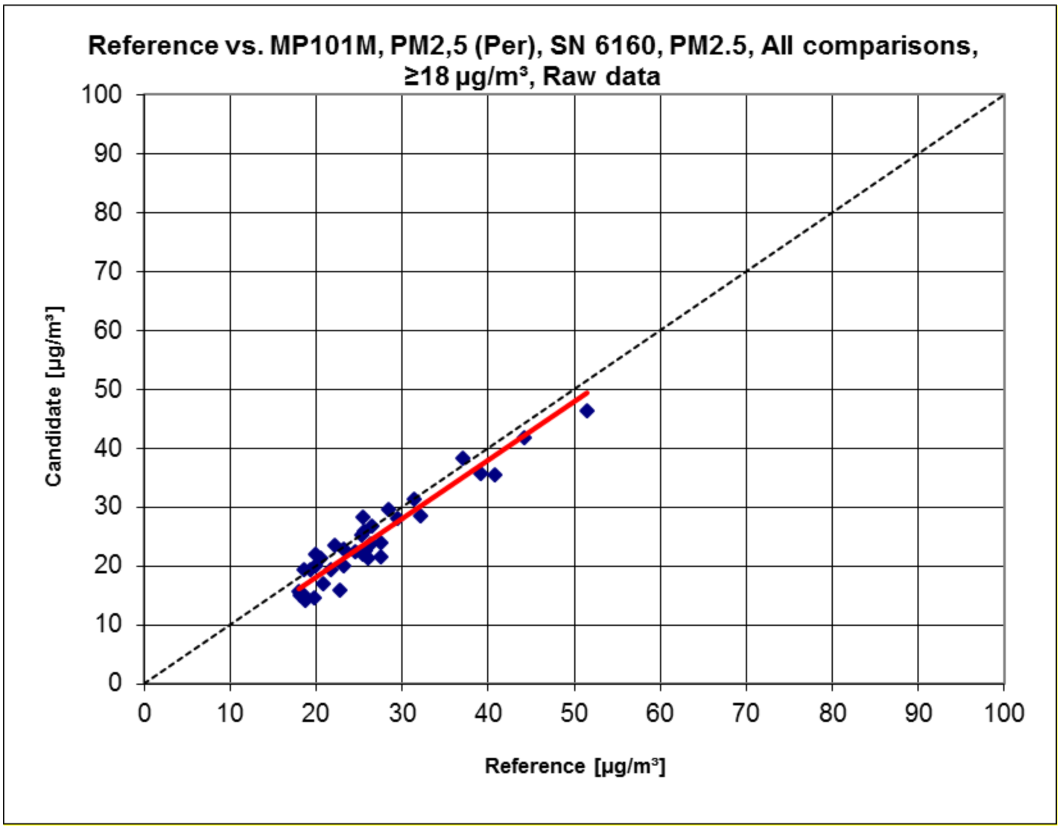

Figure 49: Reference vs. Tested instrument, S/N 6160, values ≥ 18 µg/m³, per.

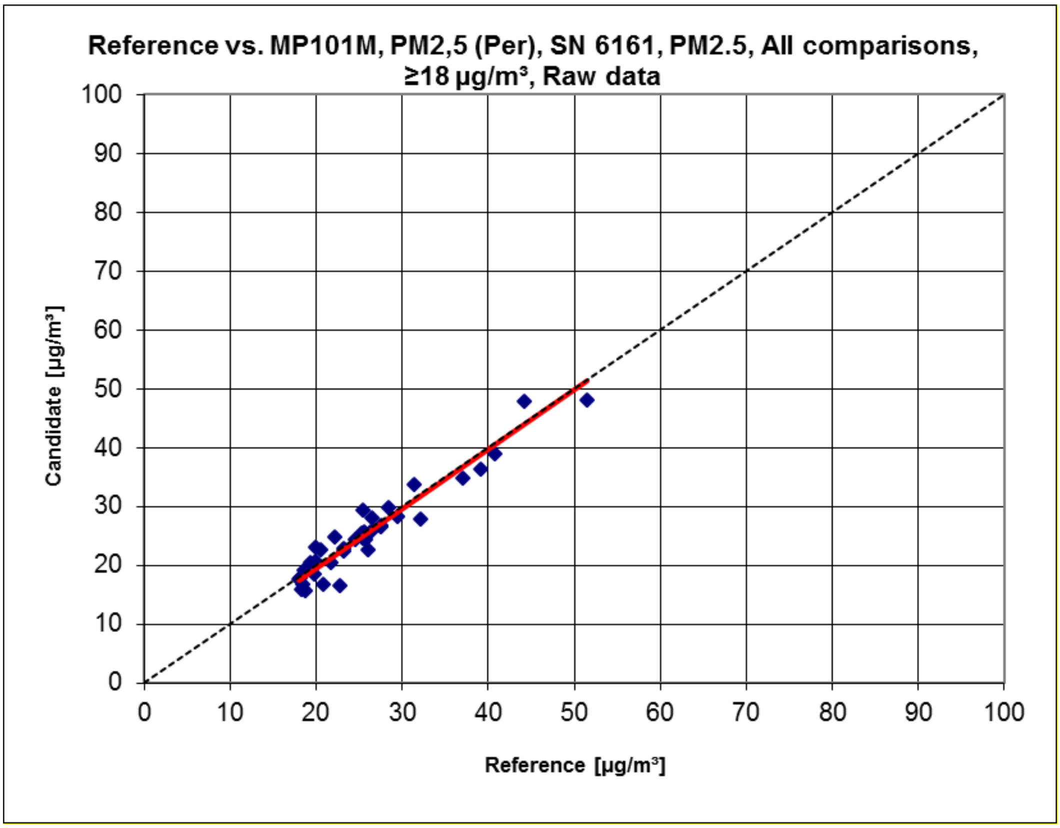

Figure 50: Reference vs. Tested instrument, S/N 6161, values ≥ 18 µg/m³, per.

6.1 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.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

See section 6.1 17 Expanded uncertainty (7.5.8.5 – 7.5.8.8)

6.4 Evaluation

If it emerges from the evaluation of raw data in accordance with 6.1 17 Expanded uncertainty (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: $|a| \leq 2u(a)$

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

concerning a)

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

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

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

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

and

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

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

The algorithms for calculating axis intercepts and slopes as well as their variance by means of orthogonal regression are described in detail in the annex to [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 [9].

concerning c)

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

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

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

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

and

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

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 [8]. Two situations are conceivable:

1. $W_{AMS,corr} \leq W_{dqo}$ → The tested instrument is deemed equivalent to the reference method.

2. $W_{AMS,corr} > W_{dqo}$ → The tested instrument is not deemed equivalent to the reference method.

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

6.5 Assessment

After the use of correction factors, the candidate systems met the requirements for data quality of air quality monitors for all data sets. The requirements had been met even before a correction factor was applied.

Criterion satisfied? yes

In evaluating the full dataset, it emerged that the axis intercept determined for instrument 1 is significantly different from 0.

At -1.968 (cyc.) and -1.951 (per.) for instrument 1, the axis intercept is significantly different from 0. At -1.153 (cyc.) and -1.136, the axis intercept determined for the full dataset also differs significantly from 0.

The full data set was corrected in terms of the intercept. All data sets were re-evaluated using the corrected values.

Dependence of the reading on the ambient temperature

When a measuring system is operated in the context of a measurement grid, the January 2010 version of the Guideline and standard EN 16450 require that the instruments are tested annually at a number of sites which in turn depends on the highest's expanded uncertainty determined during equivalence testing. The criterion used for specifying the number of sites for annual testing is grouped into 5% steps (Guideline [9], Chapter 9.9.2, Table 6 and/or EN 16450 [4], Chapter 8.6.2, Table 5). It should be noted that the highest expanded uncertainty determined after applying the correction was in the range 20% to 25%.

The operator of the measurement grid or the competent authority of a member state is responsible for compliant implementation of the requirements for regular tests as described above. TÜV Rheinland recommend, however, to consider the expanded uncertainty of the full dataset, in this instance 14.07% (cyc.) and 14.21% (per.) (uncorrected) as well as 14.34% (cyc.) and 14.50% (Per.) (dataset after correction of the axis intercept), which would imply annual verification at three measurement sites.

6.6 Detailed presentation of test results

Table 26 and Table 27 show the evaluation results of the equivalence test after applying the correction factor to the full data set.

Table 26: Summary of equivalence test results after intercept correction (cyc)

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	MP101M, PM2,5 (Cyc)		SN	SN 6160 & SN 6161	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.41**	**µg/m³**			
Uncertainty between Candidates	**1.27**	**µg/m³**			
	SN 6160 & SN 6161				
Number of data pairs	**205**				
Slope b	**1.020**	**not significant**			
Uncertainty of b	**0.019**				
Ordinate intercept a	**0.000**	**not significant**			
Uncertainty of a	**0.286**				
Expanded meas. uncertainty W_{CM}	**14.34**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.33**	**µg/m³**			
Uncertainty between Candidates	**1.51**	**µg/m³**			
	SN 6160 & SN 6161				
Number of data pairs	**37**				
Slope b	**1.000**				
Uncertainty of b	**0.048**				
Ordinate intercept a	**-0.155**				
Uncertainty of a	**1.292**				
Expanded meas. uncertainty W_{CM}	**15.14**	**%**			

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	MP101M, PM2,5 (Cyc)		SN	SN 6160 & SN 6161	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
Cologne, Winter					
Uncertainty between Reference	**0.42**	**µg/m³**			
Uncertainty between Candidates	**1.62**	**µg/m³**			
	SN 6160			**SN 6161**	
Number of data pairs	**54**			**56**	
Slope b	**1.022**			**1.063**	
Uncertainty of b	**0.030**			**0.027**	
Ordinate intercept a	**-2.056**			**-0.584**	
Uncertainty of a	**0.518**			**0.466**	
Expanded meas. uncertainty W_{CM}	**17.10**	**%**		**15.84**	**%**
Bonn, Belderberg					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**1.17**	**µg/m³**			
	SN 6160			**SN 6161**	
Number of data pairs	**40**			**40**	
Slope b	**1.146**			**1.100**	
Uncertainty of b	**0.044**			**0.042**	
Ordinate intercept a	**-1.446**			**0.397**	
Uncertainty of a	**0.612**			**0.580**	
Expanded meas. uncertainty W_{CM}	**21.93**	**%**		**24.60**	**%**
Bulk good handling, Summer					
Uncertainty between Reference	**0.35**	**µg/m³**			
Uncertainty between Candidates	**1.10**	**µg/m³**			
	SN 6160			**SN 6161**	
Number of data pairs	**66**			**66**	
Slope b	**1.102**			**1.065**	
Uncertainty of b	**0.051**			**0.045**	
Ordinate intercept a	**-0.382**			**1.018**	
Uncertainty of a	**0.649**			**0.577**	
Expanded meas. uncertainty W_{CM}	**22.12**	**%**		**23.01**	**%**
Bulk good handling, Winter					
Uncertainty between Reference	**0.33**	**µg/m³**			
Uncertainty between Candidates	**1.21**	**µg/m³**			
	SN 6160			**SN 6161**	
Number of data pairs	**45**			**45**	
Slope b	**1.011**			**0.943**	
Uncertainty of b	**0.034**			**0.031**	
Ordinate intercept a	**-1.583**			**0.734**	
Uncertainty of a	**0.587**			**0.534**	
Expanded meas. uncertainty W_{CM}	**16.66**	**%**		**14.59**	**%**
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.33**	**µg/m³**			
Uncertainty between Candidates	**1.51**	**µg/m³**			
	SN 6160			**SN 6161**	
Number of data pairs	**37**			**37**	
Slope b	**0.995**			**1.016**	
Uncertainty of b	**0.052**			**0.049**	
Ordinate intercept a	**-0.731**			**0.135**	
Uncertainty of a	**1.413**			**1.34**	
Expanded meas. uncertainty W_{CM}	**17.56**	**%**		**16.16**	**%**
All comparisons					
Uncertainty between Reference	**0.41**	**µg/m³**			
Uncertainty between Candidates	**1.27**	**µg/m³**			
	SN 6160			**SN 6161**	
Number of data pairs	**205**			**207**	
Slope b	**1.029**	**not significant**		**1.020**	**not significant**
Uncertainty of b	**0.021**			**0.018**	
Ordinate intercept a	**-0.815**	significant		**0.700**	significant
Uncertainty of a	**0.317**			**0.277**	
Expanded meas. uncertainty W_{CM}	**15.26**	**%**		**15.93**	**%**

Table 27: Summary of equivalence test results after intercept correction (per)

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	MP101M, PM2,5 (Per)		SN	SN 6160 & SN 6161	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.41**	**µg/m³**			
Uncertainty between Candidates	**1.29**	**µg/m³**			
	SN 6160 & SN 6161				
Number of data pairs	**205**				
Slope b	**1.020**	**not significant**			
Uncertainty of b	**0.019**				
Ordinate intercept a	**0.000**	**not significant**			
Uncertainty of a	**0.290**				
Expanded meas. uncertainty W_{CM}	**14.50**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.33**	**µg/m³**			
Uncertainty between Candidates	**1.52**	**µg/m³**			
	SN 6160 & SN 6161				
Number of data pairs	**37**				
Slope b	**0.998**				
Uncertainty of b	**0.048**				
Ordinate intercept a	**-0.124**				
Uncertainty of a	**1.303**				
Expanded meas. uncertainty W_{CM}	**15.30**	**%**			

Comparison candidate with reference according to Standard EN 16450:2017					
Candidate	MP101M, PM2,5 (Per)		SN	SN 6160 & SN 6161	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
Cologne, Winter					
Uncertainty between Reference	**0.42**	**µg/m³**			
Uncertainty between Candidates	**1.64**	**µg/m³**			
	SN 6160			**SN 6161**	
Number of data pairs	**54**			**56**	
Slope b	**1.021**			**1.062**	
Uncertainty of b	**0.030**			**0.027**	
Ordinate intercept a	**-2.083**			**-0.590**	
Uncertainty of a	**0.521**			**0.468**	
Expanded meas. uncertainty W_{CM}	**17.38**	**%**		**15.83**	**%**
Bonn, Belderberg					
Uncertainty between Reference	**0.53**	**µg/m³**			
Uncertainty between Candidates	**1.20**	**µg/m³**			
	SN 6160			**SN 6161**	
Number of data pairs	**40**			**40**	
Slope b	**1.146**			**1.101**	
Uncertainty of b	**0.044**			**0.042**	
Ordinate intercept a	**-1.485**			**0.377**	
Uncertainty of a	**0.620**			**0.587**	
Expanded meas. uncertainty W_{CM}	**21.83**	**%**		**24.60**	**%**
Bulk good handling, Summer					
Uncertainty between Reference	**0.35**	**µg/m³**			
Uncertainty between Candidates	**1.10**	**µg/m³**			
	SN 6160			**SN 6161**	
Number of data pairs	**66**			**66**	
Slope b	**1.113**			**1.068**	
Uncertainty of b	**0.052**			**0.046**	
Ordinate intercept a	**-0.421**			**0.991**	
Uncertainty of a	**0.658**			**0.583**	
Expanded meas. uncertainty W_{CM}	**23.80**	**%**		**23.30**	**%**
Bulk good handling, Winter					
Uncertainty between Reference	**0.33**	**µg/m³**			
Uncertainty between Candidates	**1.21**	**µg/m³**			
	SN 6160			**SN 6161**	
Number of data pairs	**45**			**45**	
Slope b	**1.010**			**0.942**	
Uncertainty of b	**0.034**			**0.031**	
Ordinate intercept a	**-1.586**			**0.741**	
Uncertainty of a	**0.591**			**0.540**	
Expanded meas. uncertainty W_{CM}	**16.86**	**%**		**14.80**	**%**
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.33**	**µg/m³**			
Uncertainty between Candidates	**1.52**	**µg/m³**			
	SN 6160			**SN 6161**	
Number of data pairs	**37**			**37**	
Slope b	**0.993**			**1.015**	
Uncertainty of b	**0.053**			**0.050**	
Ordinate intercept a	**-0.685**			**0.142**	
Uncertainty of a	**1.430**			**1.35**	
Expanded meas. uncertainty W_{CM}	**17.80**	**%**		**16.22**	**%**
All comparisons					
Uncertainty between Reference	**0.41**	**µg/m³**			
Uncertainty between Candidates	**1.29**	**µg/m³**			
	SN 6160			**SN 6161**	
Number of data pairs	**205**			**207**	
Slope b	**1.030**	**not significant**		**1.019**	**not significant**
Uncertainty of b	**0.021**			**0.018**	
Ordinate intercept a	**-0.815**	significant		**0.695**	significant
Uncertainty of a	**0.322**			**0.279**	
Expanded meas. uncertainty W_{CM}	**15.53**	**%**		**15.98**	**%**

6.1 18 Maintenance interval (7.5.7)

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

6.2 Equipment

Not required for this performance criterion

6.3 Testing

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

6.4 Evaluation

The manufacturer has prepared a maintenance plan for this measuring system. The shortest maintenance interval is at 1 month (cleaning of the sample inlet).

6.5 Assessment

The maintenance interval is 1 month.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Chapter 4.2 of the manual lists the necessary maintenance work.

6.1 19 Automatic diagnostic check (7.5.4)

Automatic checks must be possible.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

The current operating status of the measuring system is continuously monitored and any issues will be flagged via a series of different error messages. The current state of monitored parameters can be displayed on the instrument itself and is recorded as part of data logging. An error message is flagged if performance characteristics are outside the permissible range of tolerance.

6.4 Evaluation

The instrument provides all features described in the operation manual. The current operating status is continuously monitored and any issues will be flagged via a series of different warning messages. Data recording includes all monitored parameters.

6.5 Assessment

The instrument provides all features described in the operation manual. The current operating status is continuously monitored and any issues will be flagged via a series of different warning messages. Data recording includes all monitored parameters.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Chapter 5 of the operation manual describes all possible alarms and status codes.

6.1 20 Checks of temperature sensors, pressure and/or humidity sensors

The verifiability of temperature sensors, pressure and/or humidity sensors shall be checked for the AMS. Deviations determined shall be within the following criteria:
T ±2 °C
p ±1 kPa
rF ± 5 %

6.2 Equipment

Barometer, thermometer and hygrometer.

6.3 Testing

This minimum requirement serves to verify whether AMS sensors for temperature, pressure and humidity, which are necessary for correct AMS performance, are accessible and can be checked at the field test site location. In the event, checks cannot be performed on-site, this has to be documented. AMS sensors were checked at the beginning and at the end of each field test.

6.4 Evaluation

The measuring system uses a weather sensor (mounted at the sampling tube below the sample inlet) to record ambient temperature and relative moisture. Air pressure is measured inside the instrument.

Relying on transfer standards, it is easily possible to perform comparison measurements on-site at any time and to adjust the sensors. The sensors' deviations remained within the required ranges.

6.5 Assessment

It is possible to check and adjust the sensors for determining ambient temperature, ambient pressure and relative humidity on-site. The sensors' deviations remained within the required ranges.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion

7. Recommendations for use in practice

7.1 Work in the maintenance interval

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

Every month:

- Clean the sample inlet

Every quarter:

- Test the power supply
- Check sensors for temperature, pressure and moisture
- Check flow
- Automatic contamination test

Every year:

- Check the pump
- Check the voltage affecting the filter
- Calibrate sensors for temperature, pressure and moisture
- Calibrate the throughput
- Perform a leak test
- Calibrate the beta dust meter
- Check the beta dust meter (dust meter test, mass test)
- Check zero measurements

Consult the maintenance sheets in the manual for further details.

EN 16450 requires the status values of operational parameters to be checked daily (on working days).

7.2 Additional maintenance tasks

In addition to the regular tasks to be performed during the maintenance interval, the following tasks need to be performed.

- A single filter tape collects 1200 daily averages. Thus, the filter tape must be changed after a maximum period of 3 years..
- In the event an warning is signalled for the Geiger Müller counter, this component must be replaced.

Consult the manual for further details.

Environmental Protection/Air Pollution Control

Dipl.-Ing. Guido Baum

Dipl.-Ing. Fritz Hausberg

Cologne, 15 August 2019
936/21240384/D

8. 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 (PM10; PM2.5, German version dated July 2017)

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

[6] Operation manual MP101M, March 2019 version

[7] Operation manual LVS3 of 2000

[8] Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe

9. Appendix

Schedule 1 **Zero level and Detection limit** **Page 1 of 2**

Manufacturer	ENVEA		
Type	MP101M, Cyclic	Standards	ZP Measured values with zero filter
Serial-No.	SN 6160 / SN 6161		

No.	Date	Measured values [µg/m³] SN 6160	Date	Measured values [µg/m³] SN 6161
1	9/11/2017	0.8	9/11/2017	-0.2
2	9/12/2017	0.8	9/12/2017	-0.3
3	9/13/2017	0.2	9/13/2017	0.0
4	9/14/2017	-0.5	9/14/2017	0.5
5	9/15/2017	-0.5	9/15/2017	0.7
6	9/16/2017	0.1	9/16/2017	0.6
7	9/17/2017	-0.2	9/17/2017	0.7
8	9/18/2017	0.2	9/18/2017	0.3
9	9/19/2017	0.0	9/19/2017	-0.7
10	9/20/2017	0.0	9/20/2017	-0.7
11	9/21/2017	0.4	9/21/2017	-0.7
12	9/22/2017	0.4	9/22/2017	-0.3
13	9/23/2017	-0.3	9/23/2017	-0.3
14	9/24/2017	-0.3	9/24/2017	-0.2
15	9/25/2017	0.1	9/25/2017	-0.2
	No. of values	15	No. of values	15
	Mean (Zero level)	0.08	Mean (Zero level)	-0.03
	Standard deviation s_{x0}	0.41	Standard deviation s_{x0}	0.48
	Detection limit x	1.35	Detection limit x	1.59

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

Schedule 1 **Zero level and Detection limit** **Page 2 of 2**

Manufacturer	ENVEA		
Type	MP101M, Periodic	Standards	ZP Measured values with zero filter
Serial-No.	SN 6160 / SN 6161		

No.	Date	Measured values [µg/m³] SN 6160	Date	Measured values [µg/m³] SN 6161
1	9/11/2019	0.9	9/11/2019	-0.2
2	9/12/2019	0.4	9/12/2019	-0.3
3	9/13/2019	0.2	9/13/2019	0.1
4	9/14/2019	-0.5	9/14/2019	0.5
5	9/15/2019	-0.5	9/15/2019	0.7
6	9/16/2019	0.1	9/16/2019	0.6
7	9/17/2019	-0.2	9/17/2019	0.7
8	9/18/2019	0.2	9/18/2019	0.3
9	9/19/2019	0.0	9/19/2019	-0.7
10	9/20/2019	-0.4	9/20/2019	-0.5
11	9/21/2019	0.4	9/21/2019	-0.7
12	9/22/2019	0.4	9/22/2019	-0.3
13	9/23/2019	-0.3	9/23/2019	0.2
14	9/24/2019	0.1	9/24/2019	-0.2
15	9/25/2019	0.1	9/25/2019	0.2
	No. of values	15	No. of values	15
	Mean (Zero level)	0.05	Mean (Zero level)	0.03
	Standard deviation s_{x0}	0.39	Standard deviation s_{x0}	0.47
	Detection limit x	1.27	Detection limit x	1.55

$$s_{xo} = \sqrt{\left(\frac{1}{n-1}\right) \cdot \sum_{i=1,n} (x_{0i} - \overline{x}_0)^2}$$

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

Manufacturer ENVEA

Type MP101M

Serial-No. SN 6160 / SN 6161

Nominal flow rate [l/min] 16.67

		SN 6160			SN 6161		
Temperature 1	5°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
		1	11/7/2017 10:06	16.41	1	11/7/2017 10:46	16.48
		2	11/7/2017 10:10	16.42	2	11/7/2017 10:50	16.50
		3	11/7/2017 10:14	16.54	3	11/7/2017 10:54	16.49
		4	11/7/2017 10:18	16.50	4	11/7/2017 11:04	16.48
		5	11/7/2017 10:22	16.52	5	11/7/2017 11:08	16.56
		6	11/7/2017 10:26	16.42	6	11/7/2017 11:12	16.51
		7	11/7/2017 10:30	16.45	7	11/7/2017 11:16	16.52
		8	11/7/2017 10:34	16.47	8	11/7/2017 11:20	16.51
		9	11/7/2017 10:38	16.44	9	11/7/2017 11:24	16.51
		10	11/7/2017 10:42	16.44	10	11/7/2017 11:28	16.50
			Mean	**16.46**		**Mean**	**16.51**

		SN 6160			SN 6161		
Temperature 2	40°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
		1	11/8/2017 10:13	16.88	1	11/8/2017 10:55	16.84
		2	11/8/2017 10:17	16.89	2	11/8/2017 11:03	16.85
		3	11/8/2017 10:21	16.88	3	11/8/2017 11:07	16.84
		4	11/8/2017 10:25	16.90	4	11/8/2017 11:11	16.84
		5	11/8/2017 10:29	16.88	5	11/8/2017 11:15	16.83
		6	11/8/2017 10:33	16.76	6	11/8/2017 11:19	16.84
		7	11/8/2017 10:37	16.76	7	11/8/2017 11:23	16.85
		8	11/8/2017 10:41	16.88	8	11/8/2017 11:27	16.85
		9	11/8/2017 10:45	16.89	9	11/8/2017 11:31	16.83
		10	11/8/2017 10:49	16.86	10	11/8/2017 11:35	16.84
			Mean	**16.86**		**Mean**	**16.84**

Schedule 3 **Dependence of zero point on surrounding temperature** **Page 1 of 3**

Manufacturer ENVEA

Type MP101M, Cyclic

Serial-No. SN 6160 / SN 6161

SN 6160	No.	Temperature [°C]	Measurement 1 Measured value [µg/m³]	Measurement 2 Measured value [µg/m³]	Measurement 3 Measured value [µg/m³]	Mean value of 3 measurements [µg/m³]	Mean value at 20°C [µg/m³]
Zero	1	20	-0.5	-1.2	-1.0	-0.9	-1.0
	2	5	-0.9	-0.1	-0.2	-0.4	
	3	20	-2.2	-1.3	-1.1	-1.5	
	4	40	-1.0	0.7	0.4	0.0	
	5	20	-1.2	-0.7	0.0	-0.6	
SN 6161	**No.**	**Temperature [°C]**	**Measured value [µg/m³]**	**Measured value [µg/m³]**	**Measured value [µg/m³]**	**Mean value of 3 measurements [µg/m³]**	**Mean value at 20°C [µg/m³]**
Zero	1	20	1.8	0.7	0.4	1.0	0.1
	2	5	-0.5	-0.1	-0.1	-0.2	
	3	20	1.0	0.7	0.1	0.6	
	4	40	0.4	0.2	0.0	0.2	
	5	20	-1.8	-1.0	-1.0	-1.3	

Schedule 3 Dependence of zero point on surrounding temperature Page 2 of 3

Manufacturer ENVEA

Type MP101M, Periodic

Serial-No. SN 6160 / SN 6161

SN 6160	No.	Temperature [°C]	Measurement 1 Measured value [µg/m³]	Measurement 2 Measured value [µg/m³]	Measurement 3 Measured value [µg/m³]	Mean value of 3 measurements [µg/m³]	Mean value at 20°C [µg/m³]
Zero	1	20	-0.5	-1.2	-1.0	-0.9	-1.0
	2	5	-0.9	-0.1	-0.2	-0.4	
	3	20	-2.2	-1.3	-1.1	-1.5	
	4	40	-1.0	0.8	0.4	0.1	
	5	20	-1.2	-0.7	0.0	-0.6	

SN 6161	No.	Temperature [°C]	Measurement 1 Measured value [µg/m³]	Measurement 2 Measured value [µg/m³]	Measurement 3 Measured value [µg/m³]	Mean value of 3 measurements [µg/m³]	Mean value at 20°C [µg/m³]
Zero	1	20	1.8	0.7	0.4	1.0	0.2
	2	5	-0.5	0.0	-0.1	-0.2	
	3	20	1.0	0.7	0.1	0.6	
	4	40	0.4	0.3	0.0	0.2	
	5	20	-1.8	-1.0	-0.6	-1.1	

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

Manufacturer ENVEA

Used test standard internal reference foil

Type MP101M

Serial-No. SN 6160 / SN 6161

SN 6160	No.	Temperature [°C]	Measurement 1 Measured value [µg/cm²]	Measurement 2 Measured value [µg/cm²]	Meaurement 3 Measured value [µg/cm²]	Mean value of 3 measurements [µg/cm²]	Mean value at 20°C [µg/cm²]
Span	1	20	810.2	805.4	815.0	810.2	817.2
	2	5	839.3	838.5	828.7	835.5	
	3	20	811.3	819.8	823.6	818.2	
	4	40	805.8	811.3	802.8	806.6	
	5	20	814.2	825.1	830.6	823.3	
SN 6161	**No.**	**Temperature [°C]**	**Measured value [µg/cm²]**	**Measured value [µg/cm²]**	**Measured value [µg/cm²]**	**Mean value of 3 measurements [µg/cm²]**	**Mean value at 20°C [µg/cm²]**
Span	1	20	842.0	830.3	840.4	837.6	833.7
	2	5	837.0	828.9	838.0	834.6	
	3	20	833.6	840.2	830.6	834.8	
	4	40	836.5	827.2	822.1	828.6	
	5	20	830.9	827.8	828.0	828.9	

Schedule 4 — Dependence of span on supply voltage — Page 1 of 1

Manufacturer ENVEA

Type MP101M

Serial-No. SN 6160 / SN 6161

Used test standard internal reference foil

SN 6160	No.	Mains voltage [V]	Measurement 1 Measured value [µg/cm²]	Measurement 2 Measured value [µg/cm²]	Measurement 3 Measured value [µg/cm²]	Mean value of 3 measurements [µg/cm²]
Span	1	230	809.4	798.1	795.3	800.9
	2	195	798.5	790.1	798.4	795.7
	3	230	790.7	795.0	796.7	794.1
	4	253	800.4	798.6	798.3	799.1
	5	230	786.1	796.0	803.9	795.3

SN 6161	No.	Mains voltage [V]	Measured value [µg/cm²]	Measured value [µg/cm²]	Measured value [µg/cm²]	Mean value of 3 measurements [µg/cm²]
Span	1	230	822.3	820.2	824.8	822.4
	2	195	816.1	814.1	822.7	817.6
	3	230	807.8	810.7	809.1	809.2
	4	253	809.3	808.4	805.5	807.8
	5	230	806.7	805.9	809.4	807.3

Schedule 5 **Measured values from field test sites, related to actual conditions** **Page 1 of 14**

Manufacturer: ENVEA
Type of instrument: MP101M
Serial-No.: SN 6160 / SN 6161

PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
1	11/29/2017										Zero check	Cologne,Winter
2	11/30/2017										Zero check	
3	12/1/2017										Change to measurement	
4	12/2/2017						25.7	26.8	25.7	26.8		
5	12/3/2017	16.0	16.2	20.3	20.8	78.3	14.2	15.0	14.3	15.0		
6	12/4/2017	19.8	19.7	30.8	31.0	63.9	14.5	18.4	14.6	18.4		
7	12/5/2017	18.3	18.5	24.5	24.8	74.6	15.2	16.7	15.2	16.7		
8	12/6/2017	10.4	10.7	14.5	14.4	73.0	7.2	10.1	7.2	10.1		
9	12/7/2017						3.9	6.5	3.9	6.6		
10	12/8/2017	8.0	8.7	14.6	15.1	56.2	4.4	4.5	4.4	4.5		
11	12/9/2017						6.1	7.2	6.2	7.2		
12	12/10/2017						3.6	5.1	3.6	5.1		
13	12/11/2017	5.8	5.3	8.2	7.5	70.7	2.1	3.6	2.1	3.6		
14	12/12/2017	9.0	8.7	13.2	12.7	68.3	3.5	6.1	3.5	6.1		
15	12/13/2017	2.9	2.5	6.1	5.7	45.8	2.2	4.9	2.2	4.9		
16	12/14/2017	5.5	4.2	8.1	7.7	61.4	3.0	4.0	3.0	4.0		
17	12/15/2017	15.7	14.7	21.4	21.5	70.9	8.7	11.7	8.7	11.7		
18	12/16/2017						8.2	10.3	8.2	10.2		
19	12/17/2017	10.1	9.3	13.6	13.8	70.8	8.7	9.7	8.7	9.7		
20	12/18/2017	16.4	15.4	20.8	21.2	75.7	12.2	13.5	12.2	13.5		
21	12/19/2017	20.9	20.2	34.8	36.1	58.0	21.4	22.7	21.5	22.8		
22	12/20/2017	16.6	16.0	22.3	23.6	71.0	19.2	20.3	19.2	20.2		
23	12/21/2017	9.5	8.7	11.8	12.8	74.0	9.5	9.0	9.5	9.0		
24	12/22/2017	10.8	10.3	13.3	14.1	77.0	8.4	11.3	8.4	11.2		
25	12/23/2017						4.5	5.2	4.5	5.1		
26	12/24/2017						1.2	2.0	1.2	2.0		
27	12/25/2017						2.0	2.3	2.0	2.3		
28	12/26/2017						1.1	1.7	1.1	1.8		
29	12/27/2017						0.7	3.2	0.7	3.2		
30	12/28/2017						2.8	4.2	2.8	4.2		

Schedule 5 **Measured values from field test sites, related to actual conditions** **Page 2 of 14**

Manufacturer	ENVEA		
Type of instrument	MP101M	PM2.5	Measured values in µg/m³ (ACT)
Serial-No.	SN 6160 / SN 6161		

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
31	12/29/2017						4.1	5.1	4.1	5.1		Cologne,Winter
32	12/30/2017						6.7	8.2	6.7	8.2		
33	12/31/2017	7.3	7.2	10.0	10.7	70.0	3.4	3.3	3.5	3.3		
34	1/1/2018	3.4	3.2	4.8	6.0	61.1	1.2	2.4	1.2	2.4		
35	1/2/2018	4.5	3.2	8.1	8.0	47.8	2.6	3.6	2.6	3.6		
36	1/3/2018	9.0	9.0	21.7	22.4	40.8	3.4	5.2	3.4	5.2		
37	1/4/2018						4.6	7.6	4.6	7.6		
38	1/5/2018						2.5	4.9	2.5	4.9		
39	1/6/2018						7.5	9.4	7.5	9.4		
40	1/7/2018	5.9	5.6	6.1	6.7	89.8	0.0	2.4		2.4		
41	1/8/2018						8.2	12.0	8.2	12.0		
42	1/9/2018	11.9	12.1	15.5	15.3	77.9	9.2	11.8	9.2	11.8		
43	1/10/2018	9.4	10.0	14.0	13.9	69.5	5.5	8.1	5.5	8.1		
44	1/11/2018	27.3	27.8	35.6	35.7	77.3	21.6	26.5	21.7	26.5		
45	1/12/2018	44.4	44.1	51.4	52.3	85.3	41.9	47.9	41.9	47.9		
46	1/13/2018						8.2	9.4	8.2	9.4		
47	1/14/2018	15.7	16.5	17.5	17.4	92.3	12.6	14.5	12.6	14.5		
48	1/15/2018	5.3	6.6	7.3	7.8	78.8	6.5	9.2	6.5	9.2		
49	1/16/2018			8.1	7.8		0.6	3.0	0.6	3.0	Outlier ref. PM2.5	
50	1/17/2018	5.1	4.9	11.5	11.6	43.3		4.8		4.8	Maintenance 6160	
51	1/18/2018	4.3	5.3	9.7	9.9	49.0		2.8		2.8	Maintenance 6160	
52	1/19/2018	5.7	6.3	11.0	11.2	54.1	3.5	5.1	3.5	5.1		
53	1/20/2018						2.9	5.2	2.9	5.2		
54	1/21/2018	6.4	7.3	9.7	10.4	68.2	4.4	5.7	4.4	5.7		
55	1/22/2018						5.9	7.3	5.9	7.3		
56	1/23/2018						2.8	4.8	2.8	4.8		
57	1/24/2018						2.0	1.8	2.0	1.8		
58	1/25/2018						3.0	5.6	3.0	5.6		
59	1/26/2018						10.6	12.9	10.6	12.9		
60	1/27/2018						8.5	9.6	8.5	9.6		

Schedule 5 | **Measured values from field test sites, related to actual conditions** | **Page 3 of 14**

Manufacturer: ENVEA
Type of instrument: MP101M
Serial-No.: SN 6160 / SN 6161

PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
61	1/28/2018	2.8	3.7	4.8	3.7	65.7	1.9	3.0	1.9	3.0		Cologne,Winter
62	1/29/2018	6.3	7.4	13.1	13.3	51.9	3.0	3.4	3.0	3.4		
63	1/30/2018	8.1	8.4	13.7	13.6	60.4	9.4	10.5	9.4	10.5		
64	1/31/2018	3.5	4.1	7.1	6.6	55.5	-0.2	3.2	-0.2	3.1		
65	2/1/2018	6.8	7.8	11.7	12.6	60.1	3.9	5.1	3.9	5.1		
66	2/2/2018						5.2	8.0	5.3	8.0		
67	2/3/2018						7.5	8.4	7.5	8.4		
68	2/4/2018	9.1	9.3	11.8	11.9	77.6	3.8	5.7	3.9	5.7		
69	2/5/2018	12.5	12.6	16.1	15.4	79.7	10.0	12.3	10.0	12.3		
70	2/6/2018	25.1	25.7	30.7	30.4	83.1	22.0	24.5	22.0	24.5		
71	2/7/2018	40.4	41.2	50.9	51.5	79.7	35.5	39.0	35.6	39.1		
72	2/8/2018						53.9	57.4	54.1	57.5		
73	2/9/2018	25.3	25.7	29.1	29.5	87.0	28.4	29.4	28.3	29.3		
74	2/10/2018						9.0	11.1	9.0	11.1		
75	2/11/2018						1.4	3.1	1.4	3.1		
76	2/12/2018	9.1	9.5	14.6	14.9	63.1	3.2	4.9	3.2	4.9		
77	2/13/2018	11.3	11.2	15.7	16.0	71.0	6.0	7.9	6.1	7.9		
78	2/14/2018	16.4	16.8	21.1	21.4	78.1	13.5	15.4	13.6	15.3		
79	2/15/2018	18.0	18.2	25.0	25.4	71.8	15.1	17.8	15.1	17.8		
80	2/16/2018						12.6	15.4	12.6	15.3		
81	2/17/2018						15.0	19.1	15.0	19.0		
82	2/18/2018	25.9	25.7	34.2	34.0	75.7	22.5	24.3	22.6	24.3		
83	2/19/2018	26.5	26.2	34.1	34.5	76.8	23.7	25.6	23.7	25.6		
84	2/20/2018	39.0	39.4	47.5	48.2	81.9	35.8	36.4	35.8	36.4		
85	2/21/2018	31.4	31.5	38.1	38.5	82.1	31.2	33.7	31.2	33.7		
86	2/22/2018	13.5	13.5	18.4	18.6	73.0	10.8	14.0	10.9	14.0		
87	2/23/2018	14.4	14.1	17.9	18.1	79.2	9.2	12.9	9.3	12.9		
88	2/24/2018						6.8	9.9	6.8	9.8		
89	2/25/2018	7.7	7.8	9.8	10.7	75.6	4.8	7.4	4.8	7.4		
90	2/26/2018	9.3	9.5	12.3	13.6	72.6	5.5	10.1	5.5	10.1		

Schedule 5 **Measured values from field test sites, related to actual conditions** **Page 4 of 14**

Manufacturer ENVEA
Type of instrument MP101M
Serial-No. SN 6160 / SN 6161

PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
91	2/27/2018	11.4	11.3	15.9	16.5	70.1	6.8	9.5	6.8	9.5		Cologne,Winter
92	2/28/2018	23.2	23.1	28.8	28.6	80.7	20.1	22.4	20.2	22.4		
93	3/1/2018	27.3	27.7	34.8	34.3	79.6	24.0	26.8	24.1	26.8		
94	3/2/2018						45.3	47.9	45.4	48.0		
95	3/3/2018						48.0	51.0	48.0	51.0		
96	3/4/2018										Change to zero	
97	3/5/2018										Zero check	
98	3/6/2018										Zero check	
99	3/28/2018										Zero check	Bonn, Belderberg
100	3/29/2018										Zero check	
101	3/30/2018										Zero check	
102	3/31/2018										Change to measurement	
103	4/1/2018										Power outage (vandalism)	
104	4/2/2018										Power outage (vandalism)	
105	4/3/2018										Power outage (vandalism)	
106	4/4/2018										Power outage (vandalism)	
107	4/5/2018						5.6	5.2	5.6	5.2		
108	4/6/2018						6.8	6.1	6.8	6.1		
109	4/7/2018						10.4	12.1	10.5	12.1		
110	4/8/2018	12.5	12.2	24.6	25.4	49.4	11.4	12.9	11.4	12.9		
111	4/9/2018	26.4	26.7	42.8	44.9	60.5	26.7	28.1	26.7	28.1		
112	4/10/2018	7.0	6.8	12.3	12.5	55.6	5.9	7.6	5.9	7.6		
113	4/11/2018	11.0	10.5	16.2	16.7	65.3	8.4	10.9	8.4	10.9		
114	4/12/2018	16.4	15.7	25.5	27.4	60.7	16.3	17.8	16.3	17.8		
115	4/13/2018	11.5	10.7	19.5	20.8	55.1	10.0	13.0	10.1	13.0		
116	4/14/2018						19.9	20.7	19.9	20.7		
117	4/15/2018	6.5	5.6	11.4	12.5	50.6	2.6	5.2	2.6	5.2		
118	4/16/2018	9.1	8.3	20.1	21.7	41.6	7.9	7.8	7.9	7.8		
119	4/17/2018	9.4	9.1	18.5	20.0	48.1	9.6	9.2	9.6	9.2		
120	4/18/2018	11.0	10.9	20.7	22.5	50.7	10.2	10.7	10.2	10.7		

Schedule 5 **Measured values from field test sites, related to actual conditions** **Page 5 of 14**

Manufacturer ENVEA

Type of instrument MP101M

Serial-No. SN 6160 / SN 6161

PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
121	4/19/2018	11.8	12.5	21.4	23.7	53.9	10.1	11.5	10.2	11.5		Bonn, Belderberg
122	4/20/2018	22.0	21.5	39.6	41.2	53.8	19.3	20.5	19.4	20.6		
123	4/21/2018	28.4	28.3	41.3	41.5	68.5	29.6	29.9	29.6	29.8		
124	4/22/2018	15.0	15.7	25.9	26.4	58.7	12.0	12.2	12.0	12.2		
125	4/23/2018	9.8	10.6	19.5	19.2	52.7	5.6	7.6	5.7	7.6		
126	4/24/2018	9.1	9.1	19.0	17.6	49.7	6.5	8.1	6.5	8.2		
127	4/25/2018						2.7	3.7	2.7	3.7		
128	4/26/2018						1.9	6.0	2.0	6.0		
129	4/27/2018						5.0	7.4	5.0	7.4		
130	4/28/2018						3.7	4.9	3.7	4.9		
131	4/29/2018						8.0	10.1	8.1	10.1		
132	4/30/2018						-2.7	0.1	-2.7	0.1		
133	5/1/2018						2.6	5.2	2.6	5.3		
134	5/2/2018						3.5	7.7	3.7	7.7		
135	5/3/2018	11.2	12.6	31.3	30.0	38.8	9.1	10.9	9.1	10.9		
136	5/4/2018	10.3	11.0	24.5	24.1	43.8	8.9	9.8	8.9	9.8		
137	5/5/2018						7.6	10.7	7.6	10.7		
138	5/6/2018	5.6	5.1	11.0	10.9	48.9	4.0	7.2	4.0	7.2		
139	5/7/2018						6.0	10.8	6.0	10.7		
140	5/8/2018	9.9	9.6	20.5	20.4	47.7	10.0	10.3	10.0	10.3		
141	5/9/2018						14.9	16.7	15.0	16.7		
142	5/10/2018	10.6	9.7	23.9	22.9	43.4	11.1	13.2	11.1	13.1		
143	5/11/2018	10.0	11.0	19.1	18.1	56.5	11.1	12.0	11.1	12.0		
144	5/12/2018						11.4	12.5	11.4	12.4		
145	5/13/2018	21.6	22.7	33.1	32.4	67.6	23.5	24.9	23.7	25.0		
146	5/14/2018	19.7	20.3	34.9	35.5	56.8	22.1	23.1	22.0	23.0		
147	5/15/2018	11.1	12.5	20.8	21.2	56.2	11.7	12.8	11.7	12.8		
148	5/16/2018	11.0	12.1	23.3	23.6	49.3	10.8	12.6	10.8	12.6		
149	5/17/2018	15.3	14.2	34.7	37.3	41.0	13.5	14.8	13.5	14.8		
150	5/18/2018						14.7	15.0	14.8	15.0		

Schedule 5 **Measured values from field test sites, related to actual conditions** **Page 6 of 14**

Manufacturer ENVEA
Type of instrument MP101M
Serial-No. SN 6160 / SN 6161

PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
151	5/19/2018						24.1	24.1	24.2	24.2		Bonn, Belderberg
152	5/20/2018						13.9	13.3	13.9	13.3		
153	5/21/2018	10.0	10.1	15.2	15.4	65.7	10.0	11.5	10.1	11.5		
154	5/22/2018	14.9	14.4	22.4	23.1	64.4	15.0	16.3	15.0	16.3		
155	5/23/2018	15.5	14.4	24.2	25.0	60.8	16.6	17.9	16.5	17.8		
156	5/24/2018	12.2	10.8	15.7	16.1	72.3	11.0	11.4	11.1	11.4		
157	5/25/2018						11.6	11.6	11.6	11.6		
158	5/26/2018						10.7	11.8	10.7	11.8		
159	5/27/2018	10.1	9.1	15.0	16.6	60.8	9.6	10.5	9.6	10.5		
160	5/28/2018	14.8	14.8	23.4	25.7	60.3	15.9	16.1	15.9	16.1		
161	5/29/2018						14.5	16.7	14.5	16.6		
162	5/30/2018						8.7	11.4	8.7	11.3		
163	5/31/2018						10.3	11.6	10.4	11.6		
164	6/1/2018						8.0	9.0	8.0	9.0		
165	6/2/2018						4.7	5.7	4.7	5.7		
166	6/3/2018						15.6	16.3	15.6	16.3		
167	6/4/2018						15.0	16.9	15.1	16.9		
168	6/5/2018	25.7	25.0	40.0	41.1	62.5	25.3	25.5	25.3	25.6		
169	6/6/2018	14.0	14.6	31.7	34.2	43.4	16.5	17.4	16.5	17.4		
170	6/7/2018						18.5	17.4	18.6	17.4		
171	6/8/2018						31.8	32.7	31.8	32.7		
172	6/9/2018						28.9	28.8	28.8	28.6		
173	6/10/2018						23.7	24.2	23.7	24.3		
174	6/11/2018						14.2	13.9	14.1	13.8		
175	6/12/2018						11.4	11.6	11.4	11.6		
176	6/13/2018	10.4	9.5	23.0	24.0	42.3	6.0	9.8	6.1	9.8		
177	6/14/2018	13.1	13.5	36.8	39.6	34.8	11.5	13.0	11.5	12.9		
178	6/15/2018						7.7	6.8	7.7	6.8		
179	6/16/2018						6.7	8.3	6.7	8.2		
180	6/17/2018	6.2	6.3	13.0	13.5	47.2	4.7	5.4	4.7	5.4		

Schedule 5 **Measured values from field test sites, related to actual conditions** **Page 7 of 14**

Manufacturer ENVEA
Type of instrument MP101M
Serial-No. SN 6160 / SN 6161

PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
181	6/18/2018	6.6	7.3	16.1	16.1	41.2	6.6	6.7	6.6	6.7		Bonn, Belderberg
182	6/19/2018	7.3	8.0	17.8	17.8	44.1	6.9	8.6	6.9	8.6		
183	6/20/2018						9.8	9.2	9.8	9.1		
184	6/21/2018						8.8	10.5	8.9	10.5		
185	6/22/2018						7.3	8.0	7.3	8.0		
186	6/23/2018						10.6	10.3	10.7	10.3		
187	6/24/2018						8.0	8.9	8.0	8.9		
188	6/25/2018						10.1	11.3	10.1	11.3		
189	6/26/2018						20.6	19.8	20.6	19.8		
190	6/27/2018						7.9	9.4	7.7	9.0		
191	6/28/2018						8.4	9.9	8.5	9.9		
192	6/29/2018						9.6	11.4	9.6	11.4		
193	6/30/2018						4.2	6.9	4.2	6.8		
194	7/1/2018						2.7	4.3	2.7	4.3		
195	7/2/2018										Change to zero	
196	7/3/2018										Zero check	
197	7/4/2018										Zero check	
198	7/12/2018											Bulk handling, Summer
199	7/13/2018										Zero check	
200	7/14/2018						14.3	14.8	14.3	14.8		
201	7/15/2018	6.9	6.4	16.3	16.3	42.0	6.6	6.3	6.6	6.3		
202	7/16/2018	12.1	11.8	28.8	28.8	42.4	10.2	10.3	10.2	10.3		
203	7/17/2018	11.1	10.9	25.5	25.5	43.9	10.1	12.0	10.1	11.9		
204	7/18/2018	14.4	13.2	24.7	24.7	56.9	13.9	14.0	13.9	14.0		
205	7/19/2018	17.2	16.7	30.8	30.8	55.6	17.7	17.4	17.7	17.4		
206	7/20/2018	18.2	16.7	36.7	36.7	48.3	18.8	17.6	18.8	17.7		
207	7/21/2018	16.1	16.1	27.3	27.3	57.6	17.4	18.6	17.4	18.6		
208	7/22/2018						13.1	14.5	13.2	14.5		
209	7/23/2018	17.1	16.0	26.2	26.2	62.3	17.7	18.6	17.7	18.6		
210	7/24/2018										Power outage (construction)	

Schedule 5 **Measured values from field test sites, related to actual conditions** **Page 8 of 14**

Manufacturer: ENVEA
Type of instrument: MP101M
Serial-No.: SN 6160 / SN 6161

PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
211	7/25/2018										Power outage (construction)	Bulk handling, Summer
212	7/26/2018						14.2	16.1	14.2	15.7		
213	7/27/2018						13.3	13.9	13.3	13.9		
214	7/28/2018						9.6	9.9	9.6	9.9		
215	7/29/2018						8.4	8.1	8.4	8.2		
216	7/30/2018	10.0	10.1	25.7	25.9	39.0	10.2	10.2	10.2	10.2		
217	7/31/2018	8.5	7.8	20.3	21.9	38.6	8.0	9.0	8.0	9.0		
218	8/1/2018	10.8	9.8	23.5	23.2	44.1	12.2	12.6	12.1	12.6		
219	8/2/2018	16.1	16.3	31.9	30.8	51.7	17.5	18.4	17.5	18.3		
220	8/3/2018	16.1	16.9	30.2	29.4	55.4	19.8	19.7	19.8	19.7		
221	8/4/2018						10.4	11.2	10.4	11.1		
222	8/5/2018	5.5	6.1	11.6	11.6	50.0	4.5	6.6	4.5	6.6		
223	8/6/2018						9.5	9.4	9.6	9.5		
224	8/7/2018						17.2	16.4	17.3	16.5		
225	8/8/2018	9.1	9.1	18.8	17.6	50.0	10.2	11.2	10.2	11.1		
226	8/9/2018	12.0	12.2	36.1	34.5	34.3	11.3	11.9	11.3	11.8		
227	8/10/2018	7.0	7.5	21.6	20.5	34.4	7.5	8.9	7.5	8.8		
228	8/11/2018						6.0	7.2	6.0	7.2		
229	8/12/2018	6.4	6.5	10.8	9.5	63.5	6.7	8.7	6.7	8.7		
230	8/13/2018	8.7	9.3	27.1	25.9	34.0	10.9	10.1	10.9	10.1		
231	8/14/2018	11.2	11.4	29.2	28.5	39.2	12.8	13.3	12.8	13.3		
232	8/15/2018	7.2	8.0	18.8	18.2	41.1	7.8	8.4	7.8	8.4		
233	8/16/2018						12.6	14.3	12.6	14.3		
234	8/17/2018	7.9	8.1	16.3	16.2	49.2	10.5	9.0	10.4	9.0		
235	8/18/2018						9.6	10.8	9.6	10.8		
236	8/19/2018	8.4	8.3	19.6	19.9	42.3	11.6	10.9	11.6	10.9		
237	8/20/2018	8.4	8.0	16.9	17.8	47.3	9.3	9.5	9.3	9.4		
238	8/21/2018	9.5	9.1	16.2	17.2	55.7	9.9	9.0	10.0	9.0		
239	8/22/2018	23.2	23.2	35.7	37.2	63.6	22.8	22.9	22.9	23.0		
240	8/23/2018	10.5	10.0	24.8	26.0	40.4	13.2	13.7	13.1	13.5		

Schedule 5 **Measured values from field test sites, related to actual conditions** **Page 9 of 14**

Manufacturer ENVEA
Type of instrument MP101M
Serial-No. SN 6160 / SN 6161

PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
241	8/24/2018						5.0	6.7	5.0	6.7		Bulk handling, Summer
242	8/25/2018						3.3	3.2	3.3	3.2		
243	8/26/2018	3.7	3.7	5.7	6.5	60.7	3.6	3.6	3.6	3.6		
244	8/27/2018	11.1	11.6	34.2	35.3	32.7	8.2	9.2	8.2	9.2		
245	8/28/2018	8.9	9.8	21.3	22.3	42.9	9.9	11.0	9.9	10.9		
246	8/29/2018	18.1	17.7	29.5	30.3	59.9	15.4	16.7	15.4	16.7		
247	8/30/2018						4.6	8.9	4.5	8.8		
248	8/31/2018										Change to zero	
249	9/1/2018										Zero check	
250	9/2/2018										zero check	
251	9/3/2018						14.1	14.2	14.2	14.2		
252	9/4/2018	20.1	19.7	29.4	28.8	68.2	20.0	20.7	19.8	20.4		
253	9/5/2018	24.9	24.4	34.9	34.6	70.9	22.4	24.3	22.4	24.3		
254	9/6/2018	18.6	19.0	27.7	26.9	68.8	14.0	15.8	14.0	15.7		
255	9/7/2018						5.3	8.0	5.3	7.9		
256	9/8/2018						6.0	5.9	6.0	5.9		
257	9/9/2018	7.1	7.3	15.1	14.8	48.1	6.3	5.4	6.3	5.4		
258	9/10/2018	9.0	9.4	29.9	29.8	30.9	9.0	10.9	9.0	10.8		
259	9/11/2018	9.4	9.0	27.9	27.1	33.6	7.1	7.4	7.1	7.4		
260	9/12/2018						11.1	12.8	11.2	10.5		
261	9/13/2018	12.7	11.8	19.2	19.3	63.7	12.5	18.2	12.5	18.1		
262	9/14/2018						11.6	13.2	11.6	13.2		
263	9/15/2018						9.2	11.1	9.2	11.1		
264	9/16/2018	10.1	9.7	19.8	20.4	49.1	8.1	10.9	8.1	10.8		
265	9/17/2018	12.5	12.1	32.6	30.4	39.1	11.2	11.9	11.2	11.9		
266	9/18/2018	14.8	14.1	38.9	38.7	37.3	11.6	12.4	11.6	12.4		
267	9/19/2018	18.1	17.6	52.3	54.1	33.6	15.7	15.3	15.7	15.4		
268	9/20/2018						9.9	11.5	9.9	11.5		
269	9/21/2018						7.5	8.9	7.5	8.9		
270	9/22/2018						8.2	9.0	8.2	9.0		

Schedule 5 **Measured values from field test sites, related to actual conditions** **Page 10 of 14**

Manufacturer ENVEA
Type of instrument MP101M
Serial-No. SN 6160 / SN 6161

PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
271	9/23/2018						2.9	3.3	2.9	3.3		Bulk handling, Summer
272	9/24/2018						5.6	5.0	5.8	5.1		
273	9/25/2018	6.6	6.3	15.4	15.9	41.0	4.7	6.3	4.7	6.3		
274	9/26/2018	9.1	9.3	19.2	19.9	47.0	6.4	8.2	6.4	8.2		
275	9/27/2018	12.5	12.3	26.8	26.9	46.2	11.9	12.8	11.9	12.8		
276	9/28/2018						8.6	9.7	8.6	9.7		
277	9/29/2018						6.2	8.1	6.2	8.1		
278	9/30/2018						11.2	11.7	11.2	11.7		
279	10/1/2018	6.5	6.3	19.2	19.3	33.3	4.6	7.0	4.6	7.0		
280	10/2/2018						12.2	13.6	12.3	13.6		
281	10/3/2018						11.9	13.8	11.9	13.9		
282	10/4/2018	9.4	9.8	18.5	19.1	51.0	9.6	11.5	9.6	11.5		
283	10/5/2018						11.3	12.3	11.4	12.3		
284	10/6/2018						18.9	19.6	18.9	19.5		
285	10/7/2018						3.9	6.1	3.8	6.0		
286	10/8/2018	16.9	16.4	30.7	29.8	55.1	13.6	15.3	13.7	15.4		
287	10/9/2018	19.3	19.4	31.7	31.8	60.9	19.3	20.5	19.3	20.4		
288	10/10/2018	15.2	15.0	23.4	23.3	64.8	17.4	18.0	17.4	17.9		
289	10/11/2018						15.1	16.9	15.2	16.9		
290	10/12/2018						6.6	10.2	6.6	10.2		
291	10/13/2018						9.8	12.6	9.8	12.6		
292	10/14/2018	13.6	13.3	20.3	20.6	65.8	10.8	12.6	10.8	12.6		
293	10/15/2018	13.8	13.5	26.4	26.8	51.2	12.8	13.9	12.8	13.9		
294	10/16/2018						14.4	16.8				
295	10/17/2018						34.5	35.0	36.0	35.9		
296	10/18/2018						18.3	17.4	18.2	17.3		
297	10/19/2018						19.4	20.2	19.4	20.2		
298	10/20/2018						17.9	19.4	17.9	19.3		
299	10/21/2018						13.6	14.0	13.6	14.0		
300	10/22/2018						8.2	8.9	8.2	8.9		

Schedule 5 **Measured values from field test sites, related to actual conditions** **Page 11 of 14**

Manufacturer: ENVEA
Type of instrument: MP101M
Serial-No.: SN 6160 / SN 6161

PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
301	10/23/2018						13.8	14.7	13.9	14.7		Bulk handling, Summer
302	10/24/2018						4.0	7.7	4.0	7.7		
303	10/25/2018						19.4	19.8	19.4	19.8		
304	10/26/2018						11.0	12.5	10.9	12.4		
305	10/27/2018						11.1	13.2	11.1	13.2		
306	10/28/2018						3.3	6.7	3.3	6.7		
307	10/29/2018						4.8	6.0	4.8	6.0		
308	10/30/2018						2.1	2.3	2.1	2.2		
309	10/31/2018						4.5	5.6	4.5	5.6		
310	11/1/2018						7.5	7.7	7.5	7.7		
311	11/2/2018						6.0	9.0	6.0	9.0		
312	11/3/2018						16.8	18.7	16.8	18.7		
313	11/4/2018	14.8	14.5	18.1	19.0	78.9	19.7	19.0	19.7	19.0		
314	11/5/2018	15.6	15.5	23.3	23.5	66.5	17.6	18.9	17.6	18.9		
315	11/6/2018	12.3	12.7	19.5	20.3	63.0	14.4	13.7	14.4	13.7		
316	11/7/2018	4.7	4.6	11.8	11.8	39.4	3.4	4.9	3.4	4.8		
317	11/8/2018	9.0	8.6	16.9	17.2	51.6	5.2	8.2	5.2	8.3		
318	11/9/2018						11.9	13.3	11.9	13.3		
319	11/10/2018						2.5	4.9	2.5	4.9		
320	11/11/2018	3.2	3.4	6.4	5.8	54.4	2.0	4.2	2.0	4.2		
321	11/12/2018	6.8	6.6	11.5	11.3	58.5	3.6	5.0	3.6	5.0		
322	11/13/2018	7.3	7.3	20.7	19.7	35.9	3.9	6.4	3.9	6.4		
323	11/14/2018	10.5	10.8	17.0	16.8	63.0	9.2	11.3	9.2	11.3		
324	11/15/2018	14.0	14.1	19.8	19.4	71.7	14.0	15.0	14.0	15.0		
325	11/16/2018						17.5	18.0	17.5	18.0		
326	11/17/2018						11.2	13.0	11.2	13.0		
327	11/18/2018	13.6	13.3	16.8	16.4	80.8	15.9	16.2	15.9	16.2		
328	11/19/2018	8.6	8.2	16.4	16.6	50.8	7.6	7.4	7.6	7.4		
329	11/20/2018	15.7	15.8	24.0	24.6	64.8	16.4	17.7	16.5	17.7		
330	11/21/2018	18.5	18.6	25.2	24.4	74.9	19.4	19.0	19.4	19.1		

Schedule 5 **Measured values from field test sites, related to actual conditions** **Page 12 of 14**

Manufacturer ENVEA

Type of instrument MP101M

Serial-No. SN 6160 / SN 6161

PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
331	11/22/2018						21.2	23.1	21.2	23.1		Bulk handling, Summer
332	11/23/2018						23.7	24.7	23.7	24.7		
333	11/24/2018						12.9	14.0	12.9	14.0		
334	11/25/2018						20.2	19.7	20.2	19.7		
335	11/26/2018						15.9	18.4	15.9	18.4		
336	11/27/2018										Change to zero	
337	11/28/2018										Zero check	
338	11/29/2018										Zero check	
339	12/12/2018										Zero check	Bulk handling, Winter
340	12/13/2018										Zero check	
341	12/14/2018										Change to measurement	
342	12/15/2018											
343	12/16/2018			7.8	8.1							
344	12/17/2018			5.5	6.2							
345	12/18/2018						8.5	8.0	8.2	8.0		
346	12/19/2018	4.6	5.4			63.0	5.4	5.1	5.4	5.1		
347	12/20/2018	3.3	3.4			57.3	2.7	4.9	2.7	4.9		
348	12/21/2018						4.1	5.7	4.1	5.7		
349	12/22/2018						3.3	6.1	3.3	6.1		
350	12/23/2018						4.7	5.1	4.7	5.1		
351	12/24/2018						2.7	5.6	2.7	5.6		
352	12/25/2018						13.0	15.6	13.0	15.7		
353	12/26/2018						15.5	15.6	15.5	15.6		
354	12/27/2018						15.9	16.9	15.9	16.9		
355	12/28/2018						26.2	27.1	26.3	27.1		
356	12/29/2018			15.3	15.6		11.4	10.9	11.4	10.8		
357	12/30/2018			26.0	26.2		6.2	7.0	6.2	7.0		
358	12/31/2018						20.3	21.7	20.4	21.7		
359	1/1/2019	6.6	6.9			43.7	2.3	4.3	2.2	4.2		
360	1/2/2019	11.7	11.7			44.7	6.0	10.7	6.0	10.7		

Schedule 5 **Measured values from field test sites, related to actual conditions** **Page 13 of 14**

Manufacturer	ENVEA
Type of instrument	MP101M
Serial-No.	SN 6160 / SN 6161

PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
361	1/3/2019						11.0	12.9	11.0	12.9		Bulk handling, Winter
362	1/4/2019						19.8	20.8	19.8	20.8		
363	1/5/2019						4.6	6.3	4.6	6.3		
364	1/6/2019	20.4	21.1	27.8	28.4	73.9	16.9	16.7	17.0	16.7		
365	1/7/2019	13.4	13.5	27.2	28.1	48.6	15.9	17.3	15.8	17.2		
366	1/8/2019	4.3	5.0	11.7	12.3	39.1	2.5	6.0	2.5	6.0		
367	1/9/2019	6.4	6.4	15.3	14.7	42.6	2.8	3.8	2.8	3.8		
368	1/10/2019	17.1	17.7	28.9	28.9	60.1	15.4	16.3	15.5	16.4		
369	1/11/2019	9.9	10.1	13.8	14.3	70.9	10.7	10.3	10.7	10.3		
370	1/12/2019						9.5	9.4	9.5	9.5		
371	1/13/2019	3.7	4.6	7.9	7.9	52.4	3.5	4.7	3.5	4.7		
372	1/14/2019	7.8	7.7	18.0	18.3	42.8	3.8	4.7	3.8	4.7		
373	1/15/2019			45.3	45.6		16.1	15.9	16.1	15.9	Device error ref. PM2.5	
374	1/16/2019	7.5	7.5	12.0	13.1	59.7	5.5	8.4	5.5	8.4		
375	1/17/2019	9.1	8.2	11.5	12.3	72.6	1.8	4.8	1.8	4.8		
376	1/18/2019	16.2	16.0	20.2	21.2	77.9	11.6	13.9	11.7	13.9		
377	1/19/2019						9.0	11.1	9.0	11.1		
378	1/20/2019	25.9	26.1	29.9	30.4	86.1	21.4	22.7	21.5	22.7		
379	1/21/2019	37.1	37.0				38.3	34.8	38.3	34.8	Device error ref. PM10	
380	1/22/2019	29.4	29.6	32.9	33.3	89.2	28.1	28.4	28.1	28.4		
381	1/23/2019	32.1	32.2	36.2	36.9	87.9	28.6	27.8	28.6	27.8		
382	1/24/2019	51.6	51.5	59.7	59.8	86.2	46.3	48.1	46.4	48.1		
383	1/25/2019	17.9	17.8	23.4	23.7	75.8	19.5	20.7	19.5	20.5		
384	1/26/2019						4.4	6.0	4.4	6.0		
385	1/27/2019	7.8	8.0	21.9	21.6	36.4	3.7	6.0	3.8	6.0		
386	1/28/2019	7.8	8.5	18.7	18.6	43.7	4.6	5.3	4.6	5.3		
387	1/29/2019	9.4	9.3	14.6	13.7	66.1	7.3	10.6	7.3	10.6		
388	1/30/2019	13.0	13.2	17.4	17.7	74.5	10.6	12.7	10.6	12.6		
389	1/31/2019	11.4	11.6	10.9	12.5	98.5	10.9	13.0	10.9	12.9		
390	2/1/2019						11.6	11.6	11.6	11.6		

Schedule 5 **Measured values from field test sites, related to actual conditions** **Page 14 of 14**

Manufacturer ENVEA

Type of instrument MP101M

Serial-No. SN 6160 / SN 6161

PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 6160 PM2,5 (Per) [µg/m³]	SN 6161 PM2,5 (Per) [µg/m³]	SN 6160 PM2,5 (Cyc) [µg/m³]	SN 6161 PM2,5 (Cyc) [µg/m³]	Remark	Test site
391	2/2/2019						27.0	28.1	27.0	28.1		Bulk handling, Winter
392	2/3/2019	14.3	14.1	18.3	19.5	75.1	13.5	14.3	13.4	14.2		
393	2/4/2019	7.6	7.1	8.5	9.6	80.9	6.5	8.2	6.5	8.2		
394	2/5/2019						7.4	9.9	7.6	10.0		
395	2/6/2019						15.3	14.2	15.7	14.4		
396	2/7/2019	5.8	6.0	13.6	14.1	42.7	5.5	6.8	5.5	6.7		
397	2/8/2019						4.0	4.0	4.0	4.0		
398	2/9/2019						4.6	5.5	4.6	5.5		
399	2/10/2019	5.0	5.4	14.1	15.4	35.4	2.2	3.8	2.2	3.8		
400	2/11/2019	8.8	9.6	23.1	23.7	39.5	3.6	4.8	3.7	4.8		
401	2/12/2019	10.6	10.9	21.4	22.5	49.0	8.0	10.2	8.0	10.2		
402	2/13/2019	14.4	14.4	22.2	22.6	64.2	11.4	13.4	11.4	13.4		
403	2/14/2019	13.1	13.1	23.4	23.0	56.5	10.7	11.2	10.7	11.2		
404	2/15/2019	12.3	12.0	20.7	21.1	58.0	8.7	9.9	8.6	9.9		
405	2/16/2019						19.8	21.2	19.9	21.3		
406	2/17/2019	17.8	18.3	23.2	22.2	79.6	15.6	17.6	15.6	17.6		
407	2/18/2019	17.1	17.2	32.0	32.2	53.4	14.3	14.6	14.3	14.6		
408	2/19/2019	13.1	12.1	30.7	31.7	40.4	8.6	12.3	8.6	12.2		
409	2/20/2019	18.8	17.8	30.9	31.8	58.4	15.3	15.8	15.3	15.8		
410	2/21/2019	25.9	25.2	36.7	37.5	68.8	25.8	25.7	25.9	25.8		
411	2/22/2019	13.0	13.0	14.7	15.6	86.2	10.2	12.9	10.2	12.9		
412	2/23/2019						10.9	11.1	10.9	11.1		
413	2/24/2019	11.6	11.8	19.2	19.7	60.2	8.2	9.7	8.2	9.7		
414	2/25/2019	15.3	14.5	29.8	30.0	49.9	11.3	11.8	11.3	11.8		
415	2/26/2019	16.3	16.2	38.0	39.1	42.1	12.8	13.7	12.8	13.7		
416	2/27/2019	23.1	22.4	44.6	44.9	50.8	15.9	16.4	15.9	16.5		
417	2/28/2019						16.8	17.3	16.7	17.3		
418												
419	4/4/2019										Zero check	
420	4/5/2019										Zero check	

Annex 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 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 = initial weighing	After sampling = back 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 packaging	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 separately kept in polystyrene boxes for transports to and from the measurement site and for storage. The box is not opened until the filter is inserted in the filter cartridge. Virgin filters 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 the month. They are then weighed within a month.

Appendix 3 CE certificate and Certificate of Accreditation

envea™
KNOWLEDGE IN ACTION

EC DECLARATION OF CONFORMITY
In accordance with EN ISO 17050-2:2004

ORIGINAL MANUFACTURER
ENVEA - FRANCE

PRODUCT DESCRIPTION
MP101M-C – Color Beta Gauge ambient suspended particulate monitor

The above described product is declared conformed to the following dispositions:

- The Directive 2017/2102/UE of the European Parliament and of the Council on machinery, dated November 15th 2017 on the restriction of the use of certain hazardous substances in electrical and electronic equipment
- The Directive 2006/42/CE of the European Parliament and of the Council on machinery, dated May 17th, 2006 (replacing the Directive 1998/37/EC from December 30th, 2009)
- The Directive 2014/30/UE of the European Union Council, dated February 26th 2014 (replacing the Directive 2004/108/CEE) relating to electromagnetic compatibility.
- The Directive 2014/35/UE of the European Union Council, dated February 26th 2014 (replacing the Directive 2006/95/CEE) relating to the making available on the market of electrical equipment designed for use within certain voltage limits

This conformity is presumed in reference to the following specifications:

EN 61326-1: 2013	Electrical equipment for measurement, control and laboratory use-EMC requirement	
	EN 55011:2009 + A1:2010	"Class A" verified
	EN 61000-3-2: 2006 + A1/A2: 2009	
	EN 61000-3-3: 2013	
	EN 61000-4-2: 2008	
	EN 61000-4-3: 2006 + A2: 2010	with few frequencies susceptibilities
	EN 61000-4-4: 2012	
	EN 61000-4-5: 2006	
	EN 61000-4-6: 2008	
	EN 61000-4-11: 2004	"A Criteria" verified
EN 61010-1	Safety requirements for electrical equipment for measurement, control and laboratory use	

Poissy, June 27th 2019

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R&D - Innovation Director

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Limited Company - Capital 9 585 900 € - R.C.S Versailles B 313 997 223 - Siret 313 997 223 000 18 - APE 2651B - VAT FR 43 313 997 223

ENVEA, the new corporate name of Environnement S.A

Figure 51: CE certificate

DAkkS
Deutsche
Akkreditierungsstelle

Deutsche Akkreditierungsstelle GmbH

Beliehene gemäß § 8 Absatz 1 AkkStelleG i.V.m. § 1 Absatz 1 AkkStelleGBV
Unterzeichnerin der Multilateralen Abkommen
von EA, ILAC und IAF zur gegenseitigen Anerkennung

Akkreditierung

Die Deutsche Akkreditierungsstelle GmbH bestätigt hiermit, dass das Prüflaboratorium

TÜV Rheinland Energy GmbH

mit seinen in der Urkundenanlage aufgeführten Messstellen

die Kompetenz nach DIN EN ISO/IEC 17025:2005 besitzt, Prüfungen in folgenden Bereichen durchzuführen:

Bestimmung (Probenahme und Analytik) von anorganischen und organischen gas- oder partikel-förmigen Luftinhaltsstoffen im Rahmen von Emissions- und Immissionsmessungen; Probenahme von luftgetragenen polyhalogenierten Dibenzo-p-Dioxinen und Dibenzofuranen bei Emissionen und Immissionen; Probenahme von faserförmigen Partikeln bei Emissionen und Immissionen; Ermittlung von gas- oder partikelförmigen Luftinhaltsstoffen mit kontinuierlich arbeitenden Messgeräten; Bestimmung von Geruchsstoffen in Luft; Kalibrierungen und Funktionsprüfungen kontinuierlich arbeitender Messgeräte für Luftinhaltsstoffe einschließlich Systemen zur Datenauswertung und Emissionsfernüberwachung; Feuerraummessungen; Eignungsprüfungen von automatisch arbeitenden Emissions- und Immissionsmesseinrichtungen einschließlich Systemen zur Datenauswertung und Emissionsfernüberwachung; Ermittlung der Emissionen und Immissionen von Geräuschen; Ermittlung von Geräuschen und Vibrationen am Arbeitsplatz; akustische und schwingungstechnische Messungen im Eisenbahnwesen; Bestimmung von Schallleistungspegeln von zur Verwendung im Freien vorgesehenen Geräten und Maschinen nach Richtlinie 2000/14/EG und Konformitätsbewertungsverfahren; Schornsteinhöhenberechnung und Immissionsprognose auf der Grundlage der Technischen Anleitung zur Reinhaltung der Luft und der Geruchsimmissions-Richtlinie und der VDI 3783 Blatt 13; Windenergieanlagen: Bestimmung von Windpotential, Energieerträgen, Standorterträgen und Standortgüte nach EEG, standortbezogenen Turbulenz-charakteristika und Extremwinde; Schallimmissionsprognosen, Schattenwurfimmissionsberechnung und Sichtbarkeits-bestimmung; Probenahme und mikrobiologische Untersuchungen von Nutzwasser gemäß §3 Absatz 8 42. BImSchV; physikalische, physikalisch-chemische und mikrobiologische Untersuchungen von Wasser (Abwasser, Wasser aus Rückkühlwerken sowie raumlufttechnischen Anlagen); Probenahme von Abwasser; mikrobiologische und ausgewählte chemische Untersuchungen gemäß Trinkwasserverordnung; Probenahme von Roh- und Trinkwasser; ausgewählte mikrobiologische Untersuchungen von Bedarfsgegenständen und kosmetischen Mitteln; Probenahme anorganischer faserförmiger Partikel sowie von partikel- und gasförmigen luftverunreinigenden Stoffen in der Innenraumluft; ausgewählte mikrobiologische Untersuchungen in Innenräumen; Ermittlung von Aerosolen und Faserstäuben, anorganischen und organischen Gasen und Dämpfen sowie ausgewählten Parametern und/oder in ausgewählten Gebieten bei Arbeitsplatzmessungen gemäß Gefahrstoffverordnung §7, Abs. 10; Modul Immissionsschutz

Die Akkreditierungsurkunde gilt nur in Verbindung mit dem Bescheid vom 02.08.2018 mit der Akkreditierungsnummer D-PL-11120-02-00 und ist gültig bis 10.12.2022. Sie besteht aus diesem Deckblatt, der Rückseite des Deckblatts und der folgenden Anlage mit insgesamt 55 Seiten.

Registrierungsnummer der Urkunde: **D-PL-11120-02-00**

Berlin, 02.08.2018

Im Auftrag Dipl.-Ing. Andrea Valbuena
Abteilungsleiterin

Siehe Hinweise auf der Rückseite

Figure 52: Certificate of accreditation according to EN ISO/IEC 17025:2005

Deutsche Akkreditierungsstelle GmbH

Standort Berlin	Standort Frankfurt am Main	Standort Braunschweig
Spittelmarkt 10	Europa-Allee 52	Bundesallee 100
10117 Berlin	60327 Frankfurt am Main	38116 Braunschweig

Die auszugsweise Veröffentlichung der Akkreditierungsurkunde bedarf der vorherigen schriftlichen Zustimmung der Deutsche Akkreditierungsstelle GmbH (DAkkS). Ausgenommen davon ist die separate Weiterverbreitung des Deckblattes durch die umseitig genannte Konformitätsbewertungsstelle in unveränderter Form.

Es darf nicht der Anschein erweckt werden, dass sich die Akkreditierung auch auf Bereiche erstreckt, die über den durch die DAkkS bestätigten Akkreditierungsbereich hinausgehen.

Die Akkreditierung erfolgte gemäß des Gesetzes über die Akkreditierungsstelle (AkkStelleG) vom 31. Juli 2009 (BGBl. I S. 2625) sowie der Verordnung (EG) Nr. 765/2008 des Europäischen Parlaments und des Rates vom 9. Juli 2008 über die Vorschriften für die Akkreditierung und Marktüberwachung im Zusammenhang mit der Vermarktung von Produkten (Abl. L 218 vom 9. Juli 2008, S. 30).
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). Die Unterzeichner dieser Abkommen erkennen ihre Akkreditierungen gegenseitig an.

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

Figure 53: Certificate of accreditation according to EN ISO/IEC 17025:2005 - page 2

Appendix 4: Operation manual