TÜV RHEINLAND IMMISSIONSSCHUTZ UND ENERGIESYSTEME GMBH

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DAP-PL-3856.99

Report on suitability testing of the ambient air quality measurement system SWAM 5a Dual Channel Monitor with PM_{10} and $PM_{2.5}$ pre-separators of the company FAI Instruments s.r.l. for the components suspended particulate matter PM_{10} and $PM_{2.5}$

TÜV Report No.: 936/21207522/A

Koeln, March 23rd 2009

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TÜV Rheinland Immissionsschutz und Energiesysteme GmbH
are accredited for the following work areas:

- Determination of emissions and immissions of air pollution and odor substances;
- Inspection of correct installation, function and calibration of continuously running emission measuring devices including systems for data evaluation and remote monitoring of emissions;
- Suitability testing of measuring systems for continuous monitoring of emissions and immissions, and of electronic systems for data evaluation and remote monitoring of emissions

according to EN ISO/IEC 17025.

The accreditation is valid up to 31-01-2013. DAR-register number: DAP-PL-3856.99.

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Report on suitability testing of the ambient air quality measurement system SWAM 5a Dual Channel Monitor with PM10 and PM2.5 pre-separators of the company FAI Instruments s.r.l. for the components suspended particulate matter PM10 and PM2.5

Device tested:	SWAM 5a Dual Channel Monitor with PM10 and PM2.5 pre-separators
Manufacturer:	FAI Instruments s.r.l. Via Aurora, 25 00013 Fonte Nuova (Roma) Italy
Test period:	Start: July 2007 End: December 2008
Date of report:	March 23rd 2009
Report number:	936/21207522/A
Editor:	Dipl.-Ing. Karsten Pletscher T.: +49 221 806-2592 karsten.pletscher@de.tuv.com

Scope of report:

Report		202	Pages
Annex	Page	203	ff.
Manual	Page	305	ff.
Manual	of	226	Pages
Total		531	Pages

Content

1 Summary and proposal for declaration of suitability

1.1 Summary

According to Directive 2008/50/EG of 21 May 2008 on "Air quality and cleaner air for Europe" (replaces Council Directive of 27 September 1996 on ambient air quality assessment and management including its daughter directives 1999/30/EC, 2000/69/EC, 2002/3/EC and the Council Decision 97/101/EC), the methods described in Standard EN12341 „Air quality - Determination of the PM_{10} fraction of suspended particulate matter. Reference method and field test procedure to demonstrate reference equivalence of measurement methods" and Standard EN14907 „Ambient air quality - Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of suspended particulate matter" serve as reference methods for suspended particle measurement of the respective mass fraction. Anyhow, EC member states are free to use any other method in the case of particulate matter for which the Member State concerned can demonstrate displays a consistent relationship to the reference method. In that event the results achieved by that method must be corrected to produce results equivalent to those that would have been achieved by using the reference method." (2008/50/EC, Annex VI, B1).

The Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods" which was worked out by an ad hoc EC task group in November 2005
(Source: http://ec.europa.eu/environment/air/pdf/equivalence_report3.pdf)
describes an equivalence check method for non-standard measurement methods. Although this is not a normative Guide, it is tentatively recommended for application by so-called CAFE - committee.

The following limits were applied during suitability testing:

	$PM_{2.5}$	PM_{10}
Daily limit DL (24 h)	Not defined	50 µg/m³
Annual limit AL (1 a)	25 µg/m³ *	40 µg/m³
Annual limit AL (1 a)	20 µg/m³ **	

* Stage 1 starting 01 January 2015
** Stage 2 starting 01 January 2020

Standard VDI 4202, sheet 1 of June 2002 describes all „Minimum requirements for suitability tests of automatic ambient air measuring systems". General parameters for the related tests are given in Standard VDI 4203, sheet 1 „Testing of automatic measuring systems - General concepts" of October 2001 and furthermore specified in VDI 4203, sheet 3 „Testing of automatic measuring systems - Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants" of August 2004.

Since all reference values given in these standards are adapted for PM_{10} we recommend applying the following reference values for $PM_{2.5}$ measurement:

	$PM_{2.5}$	PM_{10}
B_0	2 µg/m³	2 µg/m³
B_1	25 µg/m³	40 µg/m³
B_2	200 µg/m³	200 µg/m³

Only for B_1 an adaption has been done on the level of the limit value for the annual mean.

FAI Instruments s.r.l. has commissioned TÜV Rheinland Immissionsschutz und Energiesysteme GmbH with the performance of a suitability testing of SWAM 5a Dual Channel Monitor measuring system for the components suspended particulate matter PM10 and PM2.5.

The suitability testing of the measuring system was carried out applying the German, British and European Standards regarding minimum requirements for testing and approving ambient air measurement systems. This includes in particular:

- Standard VDI 4202 sheet 1, „Minimum requirements for suitability tests of automatic ambient air measuring systems – Point-related measurement methods of gaseous and particulate pollutants", June 2002
- Standard VDI 4203 sheet 3, „Testing of automatic measuring systems - Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants", August 2004

- Standard EN 12341, „Air quality - Determination of the PM_{10} fraction of suspended particulate matter; Reference method and field test procedure to demonstrate reference equivalence of measurement methods“, German version EN 12341: 1998
- Standard EN 14907, „Ambient air quality - Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of suspended particulate matter“, German version EN 14907: 2005
- Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English version of November 2005

The present suitability testing is similar to all previous suitability tests in strategy, design and performance. All minimum requirements for both PM_{10} or $PM_{2.5}$ were met by the measuring system with this approach.

Nevertheless the deviations for PM_{10} were strikingly large during suitability testing, especially at days with high levels of dust concentration. For this reason, the expanded uncertainties for PM_{10} dusts are significantly higher than those determined for $PM_{2.5}$.

The instrument performance cannot be the reason for the significantly worse results for PM_{10} in comparison with $PM_{2.5}$ since the separated particle mass for either PM_{10} or $PM_{2.5}$ are determined by one and the same module of the SWAM5a Dual Channel Monitor. The requirements for all relevant parameters (e.g. design of the sampling inlet, flow rates, tightness) were met by both devices.

On further inspection of the reference equipment we found, that the PM_{10} nozzles used with the PM_{10} sampling inlets are not exactly in compliance with the requirements of Standard DIN EN 12341. Instead of an inner diameter of constantly 6.5 mm the nozzles manufactured by LECKEL GmbH comprise an inner diameter of 10 mm which narrows to a diameter of 6.5 mm at the end of the nozzle. The sampling inlet design of the FAI instruments however complies exactly with the requirements of DIN EN 12341.

This difference in the construction of the sampling inlets has caused the significantly different separation behaviour of the reference devices in comparison with the candidates especially for particles of approx. 10µm. Analysis, evaluation and results of the deviations are presented in detail in annex 2 of this report.

Mind that the tests for component $PM_{2.5}$ were not affected in any way and that all minimum requirements were fulfilled for PM_{10} in spite of this problem.

SWAM 5a Dual Channel Monitor measuring system is an automatic and sequential device for dust measurement on membrane filters. The system is operated with two entirely separate sampling lines. One sampling line was operated with a PM_{10} sampling inlet and the other with a $PM_{2.5}$ sampling inlet during the suitability test. Different configurations are possible. Ambient air was sucked *via* the PM_{10} and $PM_{2.5}$ sampling inlet with the aid of two pumps. The dust-laden air is then separated by one filter each (1 x PM_{10}, 1 x $PM_{2.5}$). The dust separated by the filters is determined after sampling according to the radiometric measuring principle of beta absorption. A gravimetric weighing of the dusts is possible, and the filters can be used for additional analytic procedures such as the detection of heavy metals.

The tests took place in the laboratory and for several months in the field. The following sites were chosen for the field test:

Table 1: Description of the test sites

	Koeln, Parking lot	Bonn, Belderberg	Teddington, UK*	Bruehl
Time period	10/2007 to 02/2008	02/2008 to 04/2008	07/2008 to 11/2008	09/2008 to 12/2008
No. of paired values: Instruments PM_{10}	100	64	83	55
No. of paired values: Instruments $PM_{2.5}$	100	64	83	55
Characteristics	Urban background	Traffic	Urban background	Gravel pit
Classification of ambient air load	Average / high	Average / high	Low / average	Average

*The test in Teddington was done parallel to the test in Germany, which has been done with an identical set of instruments. Both tests were performed within the scope of the test program „Combined MCERTS and TÜV PM Equivalence Testing Programme“ which was developed by British and German test institutes (NPL, Bureau Veritas, TÜV Rheinland) in the context of European harmonization. It comprises laboratory and field tests (performed in different German and British sites) for the latest series of suspended particle measurement systems by different manufacturers.

The minimum requirements were fulfilled during suitability testing.

TÜV Rheinland Immissionsschutz und Energiesysteme GmbH therefore suggests publication of SWAM 5a Dual Channel Monitor as a suitability-tested measuring system for continuous monitoring of suspended particulate matter PM_{10} and $PM_{2.5}$ in ambient air.

1.2 Notification proposal:

On the basis of the positive results that have been achieved, the following recommendation is made for the notification as a suitability-tested measuring system:

1.2.1	**Task**	:	Continuous monitoring of suspended particulate matter PM_{10} and $PM_{2.5}$ in ambient air.
1.2.2	**Device designation**	:	SWAM 5a Dual Channel Monitor with PM10 and PM2.5 pre-separators
1.2.3	**Components**	:	suspended particulate matter PM10 and PM2.5
1.2.4	**Manufacturer**	:	FAI Instruments s.r.l. Via Aurora, 25 – 00013 Fonte Nuova (Roma), Italy
1.2.5	**Application**	:	For permanent monitoring of suspended particulate matter PM_{10} and $PM_{2.5}$ in ambient air(stationary operation).
1.2.6	**Measuring ranges**	:	PM_{10}: 0 to 200 µg/m³ $PM_{2.5}$: 0 to 200 µg/m³
1.2.7	**Software version**	:	Version Rel 04-08.01.65-30.02.00
1.2.8	**Restrictions**	:	None
1.2.9	**Notices**	:	1. The requirements according to guide “Demonstration of Equivalence of Ambient Air Monitoring Methods” are fulfilled. 2. Filter cartridges with a β-equivalent spot area of 5.20 cm² have been used for the testwork. 3. The AMS is to be calibrated on site in regular intervals by application of the gravimetric PM_{10} reference method according to DIN EN 12341. 4. The AMS is to be calibrated on site in regular intervals by application of the gravimetric $PM_{2.5}$ reference method according to DIN EN 14907.
1.2.10	**Test institute**	:	TÜV Rheinland Immissionsschutz und Energiesysteme GmbH, Koeln TÜV Rheinland Group Responsible person: Dipl.-Ing. Karsten Pletscher
1.2.11	**Test report**	:	936/21207522/A of March 23rd 2009

1.3 Summary of test results

Minimum requirement		Specification	Test result	Fulfilled	Page
4	Requirements on instrument design				
4.1	General requirements				
4.1.1	Display for measured values	Shall be available.	The measuring device comprises a display for measured values.	yes	71
4.1.2	Maintainability	Maintenance works should be feasible from outside without taking much time and effort.	External maintenance is possible. All works can be carried out with customary tools taking reasonable time and effort.	yes	72
4.1.3	Function test	Particular instruments for function tests shall be considered as part of the device and thus shall be evaluated in the corresponding sub-tests. Test gas units shall indicate readiness by status signals and shall allow direct or remote access to control functions via the measuring system. The measurement uncertainty of the test gas unit shall not exceed 1% of B_2 within three months.	All system functions listed in the manual are available, activatable and functioning. The current system status is continuously monitored and displayed by a set of different status messages (operation, warning and error messages).	yes	75
4.1.4	Setup- and warm-up times	Shall be specified in the manual.	The setup- and warm-up times were determined.	yes	77
4.1.5	Instrument design	Shall be specified in the manual.	The instrument design specifications listed in the operating manual are complete and correct..	yes	78
4.1.6	Security	Shall contain a protection mechanism against unauthorized adjustment.	The AMS is protected against unauthorized and unintended adjustment. In addition, the AMS shall be locked in a measuring container or an outdoor measuring cabinet.	yes	79
4.1.7	Data output	Analogue and / or digital outputs shall be available.	Measured signals are offered via analogue (0 to 5 V) and digital (via RS232) ports.	yes	80
4.2	Requirements for mobile measuring systems	Permanent availability shall be ensured. The requirements of stationary operation shall also be fulfilled during mobile operation.	The AMS was operated in different site during the field test but cannot be operated in moving vehicles..	no	82

Minimum requirement		Specification	Test result	Fulfilled	Page
5.	Performance requirements				
5.1	General	The manufacturer's specifications given in the manual shall not contradict the results of the suitability test.	Differences between the instrument design and the descriptions given in the manual could not be detected.	yes	83
5.2	General requirements				
5.2.1	Measuring range	The upper limit of the measuring range shall exceed B_2.	A measuring range of 0 to 200 µg/m³ is set by default.	yes	84
5.2.2	Negative output signals	Shall not be suppressed (living zero point).	Negative output signals are displayed correctly by the measuring device and presented correctly by the respective measuring signal outputs.	yes	85
5.2.3	Analytical function	The relation between output signals and measured quantity shall be determined by regression calculation and represented by the analysis function.	A statistically reliable correlation could be determined between the reference measuring procedure and the device display.	yes	86
5.2.4	Linearity	The deviation of the group averages of the measured values for calibration function shall not exceed 5% of B_1 within the range of zero to B_1. Within the range of zero to B_2 the deviation shall not exceed 1% of B_2.	The test should be carried out according to minimum requirement 5.3.1 „Equivalency of the sampling system" for dust measuring devices for PM10 measurement. For dust measuring devices for PM2.5 measurements, the test should be carried out according to point 7.1 Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6].	yes	89
5.2.5	Detection limit	B_0 or less.	A detection limit of 0.69 µg/m³ (sampling line A) and 0.77 µg/m³ (sampling line B) was determined for device 1 (SN 127), and a detection limit of 0.64 µg/m³ (sampling line A) and 0.69 µg/m³ (sampling line B) was determined for device 2 (SN 131) during the test.	yes	89
5.2.6	Response time	Not more than 5% of the averaging time (equal to 180 s).	Not applicable.	-	92
5.2.7	Ambient temperature dependency of zero point	The measured value at zero point shall not exceed B_0 at ΔT_u by more than 15 K between +5°C and +20°C. Between +20°C and +40°C it shall not exceed B_0 at ΔT_u by more than 20 K.	In consideration of the obtained results, the influence of ambient temperature on zero point did not exceed 0.6 µg/m³.	yes	93

Minimum requirement	Specification	Test result	Fulfilled	Page
5.2.8 Ambient temperature dependency of the measured value	The measured value in the range of B_1 shall not exceed 5% at ΔT_u by more than 15 K between +5°C and +20°C. Between +20°C and +40°C it shall not exceed 5% at ΔT_u by more than 20 K.	No deviations higher than > -1.3 % were determined for device 1 (SN 127). For device 2 (SN 131) deviations did not exceed -2.8 % of the initial value at 20 °C.	yes	95
5.2.9 Zero drift	Shall not exceed B_0 within 24h or during the maintenance interval.	The detected values are within the allowed limits during the maintenance interval.	yes	97
5.2.10 Drift of the measured value	Shall not exceed 5% of B_1 within 24h or during the maintenance interval.	The drift of the measured value did not exceed -1.1% (SN 127) resp. -1.3% (SN 131) during the maintenance interval.	yes	101
5.2.11 Cross sensitivity	Shall not exceed B_0 in the range of zero point and 3% of B_2 within the range of B_2.	Not applicable.	-	105
5.2.12 Reproducibility RD R_D	$R_D \geq 10$ related to B_1.	Reproducibility RD in the field was at minimum 23 for PM10 and at minimum 19 for PM2.5.	yes	106
5.2.13 Hourly mean values	Formation shall be possible.	Formation of hourly mean values is not required for the components particulate matter PM10 and PM2.5 for monitoring the respective limits.	-	109
5.2.14 Mains voltage and frequency	Change of the measured value in the voltage interval (230 + 15/-20 V) does not exceed B_0 at B_1. For mobile use, the change of the measured value does not exceed B_0 for the frequency interval (50 ± 2) Hz.	No significant deviations caused by frequency changes could be detected at the tested span points.	yes	110
5.2.15 Power outage	Uncontrolled emission of operating gas or reference gas for calibration shall be prevented. Device parameters shall be buffered against loss. Operating mode shall be secured on return of the mains voltage and the measurement shall be resumed.	All instrument parameters are protected against loss by buffering. The measuring system is undamaged and ready for operation as soon as the mains voltage returns and independently continues measuring.	yes	113

Minimum requirement	Specification	Test result	Fulfilled	Page
5.2.16 Operating states	The AMS shall allow monitoring of system functions by telemetrically transmitted status signals.	The measuring devices allow an extensive control via external PC and modem which is comparable to direct operation.	yes	114
5.2.17 Switchover	The AMS shall allow manual and telemetric activation of measurement, function test and/or calibration.	Basically all activities for function control and calibration may be performed either by direct access or by telemetric remote control via external PC and modem.	yes	115
5.2.18 Availability	At least 90%.	At the field test sites in Koeln, Bonn and Bruehl, availability amounts 98.9% for device SN 127 and 97.6% for device SN 131 without test-related outage times. Those included availability amounts 95.8% for device SN 127 and 94.5% for device SN 131. At the field test site in Teddington, availability amounts to 96.3% for device SN 145 and 99.6% for device SN 149 without test-related outage times. Those included availability amounts 93.0% for device SN 145 and 96.3% for device SN 149.	yes	117
5.2.19 Converter efficiency	At least 95%.	Not applicable.	-	119
5.2.20 Maintenance interval	Preferably 28 days, at least 14 days.	The maintenance interval is defined by necessary maintenance works (filter exchange / cleaning of the sampling inlets) and should be done every 2nd week.	yes	120
5.2.21 Total uncertainty	Compliance with the requirements on data quality [G10 to G12].	For PM10, the determined total uncertainties were 6.83 % (6.57 %) for U(c) and 7.22 % (7.16 %) for U($\bar{c}$). For PM2.5, the determined total uncertainties were 7.44 % (9.40 %) for U(c) and 6.77 % (7.75 %) for U($\bar{c}$) .	yes	121
5.3 Requirements on measuring systems for particulate air pollution				
5.3.1 Equivalency of the sampling system	Shall be confirmed in comparison with the reference method according to EN 12341 [T2].	The reference-equivalence-functions are within the limits of the respective acceptance range. Furthermore, the variation coefficient R² of the calculated reference-equivalence-functions for the respective concentration range is equal to 0.95 or higher.	yes	127

Minimum requirement		Specification	Test result	Fulfilled	Page
5.3.2	Reproducibility of the sampling system	Shall be confirmed in the field for two identical sampling systems according to DIN EN 12 341 [T2].	The two-sided confidence interval CI95 is 1.64 µg/m³ which is below the specified value of 5 µg/m³.	yes	135
5.3.3	Calibration	Comparative measurement with the reference method under field conditions according to DIN EN 12 341 [T2]; Relation between the gravimetrically determined reference concentration and the measured signal shall be determined as a continuous function.	See Module 5.2.3..	-	139
5.3.4	Cross sensitivity	Not more than 10% of B_1.	No interferences caused by humidity, contained in the measured medium, which led to deviations of more than 1.7 µg/m³ between nominal value and measured signal, could be detected. Negative influences on the measured value caused by varying relative air humidity were not detected.	yes	141
5.3.5	Daily averages	24 h mean values shall be possible; time needed for filter changes shall not exceed 1% of the averaging time.	Calculation of daily averages is possible. The time needed for filter exchanges (including device-internal filter transport and all QS measures carried out for each cycle, such as an internal tightness or flow rate check) is not more than 0.8% of the averaging time.	yes	144
5.3.6	Constancy of sample volumetric flow	At least 3% of the nominal value during sampling and at least 5% for instantaneous values.	All determined daily averages deviate less than ± 3%, all individual values less than ± 5% from the nominal value.	yes	147
5.3.7	Tightness of the sampling system	Leakage shall not exceed 1% of the sampling volume.	The maximum leak rates were not more than 0.24% for device 1 (SN 127), not more than 0.30% for device 2 (SN 131) at a residual pressure p0 within the system; and not more than 0.08% for device 1 (SN 127) or 0.06 % for device 2 (SN 131) at an atmospheric pressure of 102.8 kPa each.	yes	150
5.4	Requirements for multiple-component measuring systems	Shall be fulfilled for each individual component during simultaneous operation of all measuring channels; generation of hourly mean values shall be ensured during sequential operation.	The results of both components were simultaneously available for assessing the minimum requirements.	yes	151

Minimum requirement	Specification	Test result	Fulfilled	Page
Additional test criteria according to Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods“				
Determination of the in-between-instrument uncertainty ubs [9.5.2.1]	Shall be determined in the field for two identical systems according to point 9.5.2.1 of guide „Demonstration of Equivalence of Ambient Air Monitoring Methods“.	The in-between-instrument uncertainty between the candidates ubs does not exceed 0.98 µg/m³ for PM10 and 0.69 µg/m³ for PM2.5. This is significantly below the required value of 3 µg/m³.	yes	152
Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6]	Determination of the expanded uncertainty of the devices under test according to point 9.5.2.2ff of Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods“.	The determined uncertainties WCM are below the specified expanded relative uncertainty Wdqo of 25% (particulate matter) for all data sets without usage of corrective factors.	yes	166
Application of correction factors or terms [9.7]	Correction factors may be applied if the highest expanded uncertainty which has been calculated exceeds the relative expanded uncertainty specified in the requirements on the data quality of ambient air quality measurements according to EU Guideline [7]. The corrected values must comply with the requirements according to point 9.5.2.2ff. of Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods“.	The candidate systems fulfil the requirements on the data quality of ambient air quality measurements during the test without application of correction factors.	yes	193

2 Task definition

2.1 Type of test

FAI Instruments s.r.l. has commissioned TÜV Rheinland Immissionsschutz und Energiesysteme GmbH with the performance of a suitability test of SWAM 5a Dual Channel Monitor with PM10 and PM2.5 pre-separators. The test was conducted as a complete suitability testing.

2.2 Objective

The AMS shall simultaneously determine the content of PM_{10} and $PM_{2.5}$ suspended particulate matter in ambient air within the concentration range of 0 to 200 µg/m^3.
The suitability test was carried out based on the current standards for suitability tests while taking into account the latest developments.

The test was performed in consideration of the following standards:

- Standard VDI 4202 sheet 1, „Minimum requirements for suitability tests of automatic ambient air measuring systems – Point-related measurement methods of gaseous and particulate pollutants“, June 2002
- Standard VDI 4203 sheet 3, „Testing of automatic measuring systems - Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants“, August 2004
- Standard EN 12341, „Air quality - Determination of the PM_{10} fraction of suspended particulate matter; Reference method and field test procedure to demonstrate reference equivalence of measurement methods“, German version EN 12341: 1998
- Standard EN 14907, „Ambient air quality - Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of suspended particulate matter“, German version EN 14907: 2005
- Guide "Demonstration of Equivalence of Ambient Air Monitoring Methods",
  English version of November 2005

3 Description of the tested measuring system

3.1 Measuring principle

SWAM 5a Dual Channel Monitor measuring system determines the mass of separated particles based on the principle of beta attenuation. The relation between the attenuation of beta radiation after passing a layer of thin material and the mass thickness of the material can be described with the help of an equation.

The estimation of the mass thickness x_p of a particulate matter film accumulated on a filter medium with x_f mass thickness using the beta attenuation method is based on the correct quantification of the relative variation sustained by a flux of beta electrons achieving an appropriate detector, this film being present or absent.

Highly simplified, the following relation is given: $m_p = S * x_p$ with $x_p = k(z) \cdot \ln \frac{Flux_{blank}}{Flux_{collect}}$

With: m_p mass of the dust particles

m_p	mass of the dust particles
S	loaded surface
X_p	mass thickness of the dust particles
k(z)	mass absorption coefficient function
$Flux_{blank}$	beta radiation flux before sampling
$Flux_{collect}$	beta radiation flux after sampling

The measured beta radiation fluxes may include systematic fluctuations which cannot be attributed to the particulate mass on the filter. Those contributions to uncertainty primarily result from:

- Mass thickness changes of the filter medium (e.g. humidity effects)
- Air density fluctuations
- Detector sensitivity variations

In order to quantify and consider these influences for calculation the system is equipped with so-called spy-filters, which consist of the same material as the operative filters and which constantly remain in the system. The spy filters are measured in turns with the operative filters. Hence, possible influences as mentioned above can be considered on the basis of the beta fluxes obtained during spy filter measurement.

This results in the equation

$$m_P = S \cdot x_p = S \cdot \overline{k}(z) \cdot Z_{r1}^{*} \cong S \cdot k_{sh} \cdot \left[\overline{k}(z) \cdot \ln\left(\frac{\overline{\Phi}^{i}(x_{Fr})}{\overline{\Phi}^{j}(x_{Fr}+x_p)} \frac{\overline{\Phi}^{j}(x_{Fs})}{\overline{\Phi}^{i}(x_{Fs})} \right) + offset \right],$$

where the value of constant k_{sh} is defined as „1“.

p = particles, F_r = operative filters, F_s = spy filters

and x_{Fr} = blank

and $x_{Fr}+X_p$ = collect

Function k(z) is determined by the manufacturer with the help of six reference aluminium foils and programmed to the system. This calibration can be verified after each system restart (or else triggered manually) with the help of two reference aluminium foils of known mass thickness which are integrated in the system. The obtained results are compared with the respective default values and indicated as deviations in %. The result of the latest “beta span test” can be accessed at any time.

3.2 Functionality of the measuring system

The SWAM 5a Dual Channel Monitor measuring system is an automatic and sequential measuring device for dust measurement on filter membranes. The system operates with two independent sampling lines. One of the sampling lines was operated with a PM_{10} sampling inlet and the second line was operated with a $PM_{2.5}$ sampling inlet during the suitability test. Different configurations are possible.

Ambient air was aspirated *via* both sampling inlets with the help of two separate pumps. The dust-laden sampling air was then separated by the respective filter (1 x PM_{10}, 1 x $PM_{2.5}$), followed by determining the mass of the separated dust based on the radiometric principle of beta absorption. The mass of dust collected on the filters of both sampling lines was determined by a single radiometric mass determination module.

A detailed description of the summary on internal processes of the SWAM 5a Dual Channel Monitor measuring system as given below can be found in the chapters 2, 3 and 4 and the appendixes of the manual, which is included in the annex of this report.

a) Operating modes of the measuring system

The AMS can be operated in two different modes: monitoring mode and reference mode.

Monitoring mode (Monitor Modus):

The monitoring mode allows sampling and mass determination of particulate matter on two independent sampling lines. Therefore, this configuration allows simultaneous measurement of two PM-fractions (e.g. PM_{10} and $PM_{2.5}$). Moreover, this configuration allows performing meteorological evaluations such as

- Determination of the proportion of volatile dust components with the help of one heated (or cooled) and one unheated (or uncooled) sampling line
- Performance test / determination of the reproducibility of different sampling inlets

The SWAM 5a Dual Channel Monitor measuring system was operated with a PM_{10} and a $PM_{2.5}$ line during monitoring mode within the frame of the suitability testing.

Reference mode:

The AMS is used as high quality standard reference single-channel measuring system while operating in reference mode. In this mode one line is used for the PM_x sample accumulation while the other line is equipped with an absolute filter for particulate matter in order to have a membrane that will serve as “field blank”. A field blank value is available for each measured value in this mode.

b) Mass determination

The module for radiometric mass operation is installed to a mechanical rotating plate in order to connect source and detector so both can be collocated to different positions (see Figure 1).

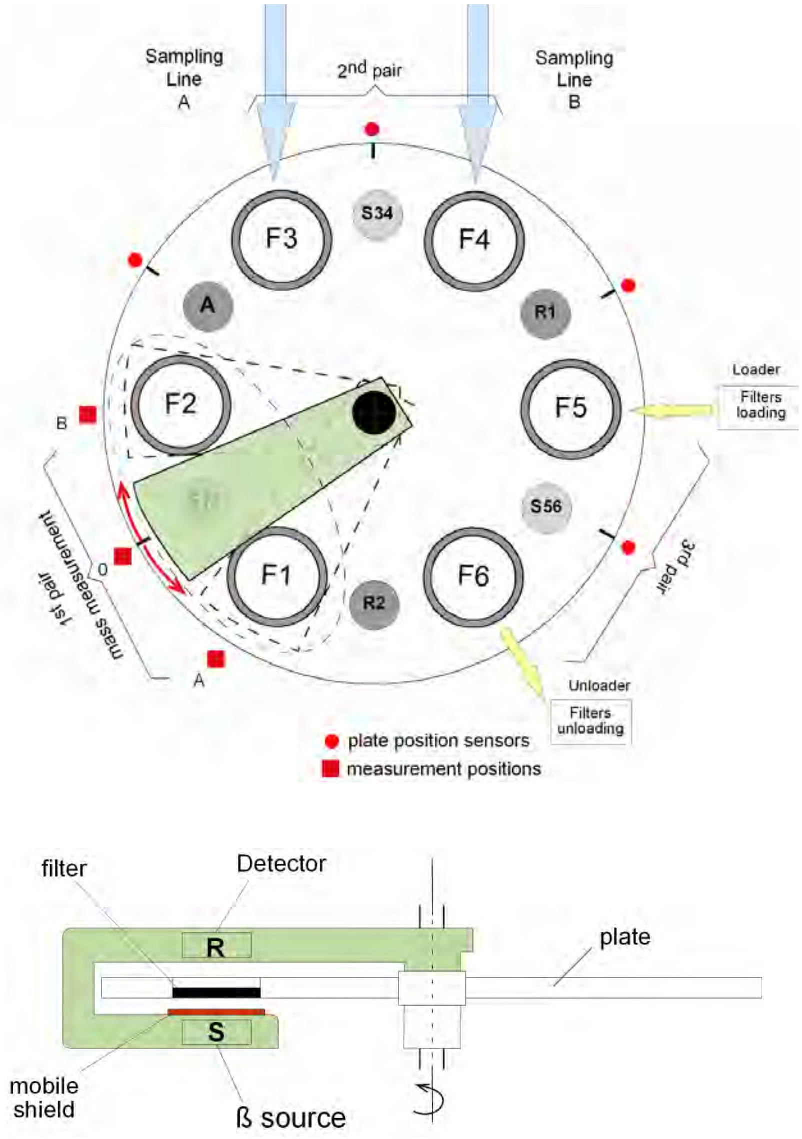


Figure 1: Mass determination in the SWAM5a Dual Channel Monitor

Appendix 11 of the manual provides a detailed description of the necessary measuring processes.

Each measuring process, whether blank or collect, consists of a sequence of n beta radiation flux measuring cycles. The two operative filters F_{r1} and F_{r2} are measured as well as the spy filter F_s during each cycle. The matrix which describes the measuring sequence in all n measuring cycles is:

$$\begin{bmatrix} F_s^{11} & F_{r1}^{1} & F_s^{12} & F_{r2}^{1} & F_s^{13} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ F_s^{n1} & F_{r1}^{n} & F_s^{n2} & F_{r2}^{n} & F_s^{n3} \end{bmatrix} \quad \text{with } 4 \le n \le 6$$

The time spans of the radiometric measurements are:

- 10 min for the operative filters F_r
- 5 min for the spy filters

The number of measuring cycles n depends on the time span of the sampling cycle:

n = 4 for 8 hours long sampling cycles

n = 6 for 12 or more hours long sampling cycles

Therefore, each measuring filter is measured six times and the spy filter is measured 18 times for each measuring process during a normal cycle of 24 h (n = 6).

Furthermore the measuring cycles are integrated with background noise measurements, where beta radiation source and detector are shielded (= dark), as well as beta flux measurements without a filter between source and detector (= beta flux in air) for quality control purposes. The former allows quantifying the background noise while the latter allows evaluating the stability of the Geiger-Müller detector.

Appendix 11 of the manual provides a detailed description of the necessary measuring processes for blank and collect measurement.

c) Pneumatic Circuit

The sampling module uses two vacuum pumps which allow setting a sampling flow rate within the range of 0.5 to 2.5 m³. Continuous regulation of the flow rate is performed by a step motor moving the regulation valve.

Two solenoid valves placed on each sampling line allow switching the pneumatic circuit from sampling configuration to span test configuration (automatic check of the flow rate measurement system calibration) and to leak test configuration (automatic check of the pneumatic circuit seal).

Therefore, the three possible pneumatic configurations are (see Figure 2):

- Sampling: EV1 open, EV2 closed
- Leak test: EV1 closed, EV2 closed
- Span test: EV1 closed, EV2 open

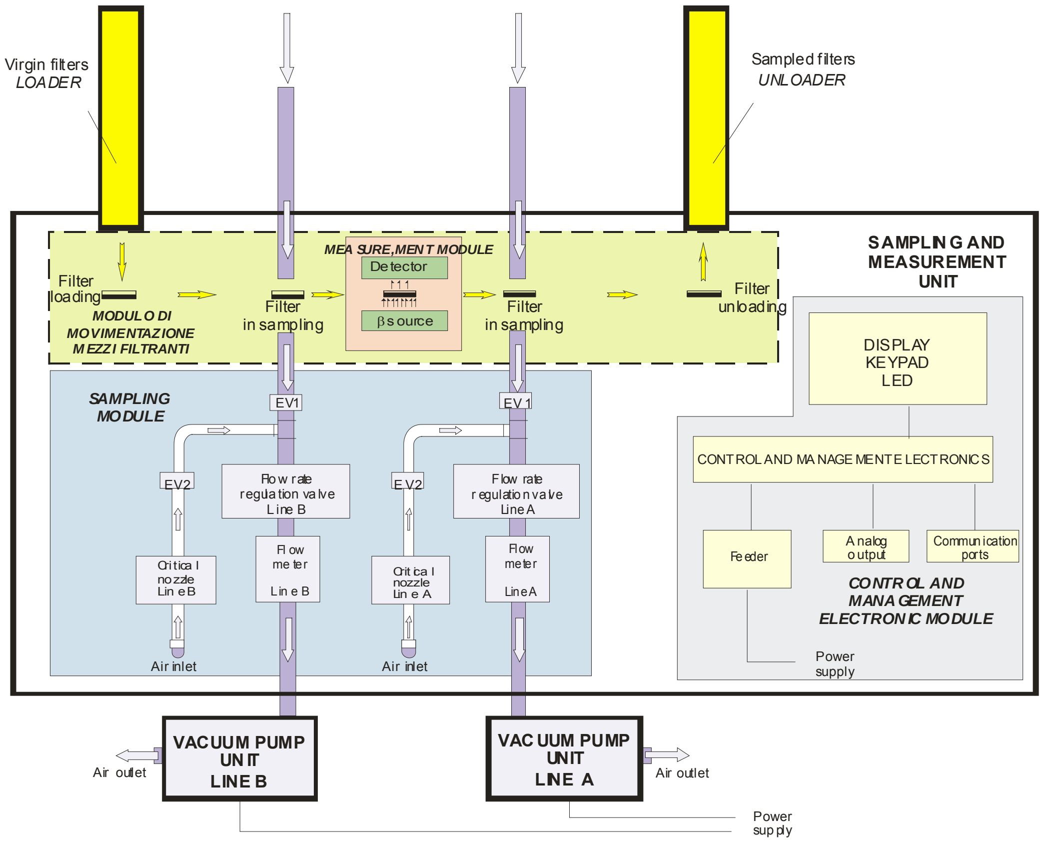


Figure 2: Configuration of the sampling system

The sampling flow rate measurement is based on the physical laws controlling air mass transfers through a nozzle which is placed downstream the regulation valve in the SWAM 5a Dual Channel Monitor measuring system.

By measuring the pressure value P_p downstream the nozzle, the nozzle pressure drop ΔP and the air temperature T_m in the measurement area, it is possible to calculate the standard flow rate Q_s by using the relation:

$$Qs = f(z) \quad \text{with} \quad z = \sqrt{\frac{\Delta p \cdot (2P_p - \Delta p)}{T_m}}$$

In SWAM 5a Dual Channel Monitor the form of the function *f(z)* is approximated to a second-order polynomial in *z* whose coefficients are determined using a multipoint calibration procedure.

d) Filter management

SWAM 5a Dual Channel Monitor can automatically manage up to 72 filter membranes. The sampled filters are immediately moved to the unloading device at the end of every sampling and measurement cycle and thus can be removed by the operator.

The filter management system comprises:

- Rotating plate allowing placing the filter membranes „F", the spy filters „S" and the reference aluminium foils „R". The plate also comprises a hole „A" for air beta flux measurement.
- Loading device for virgin filters
- Virgin filters reserve (inside the instrument)
- Unloading device for sampled filters
- Pneumatic pistons for filter loading and unloading
- Pneumatic pistons to fixate the filters at the sampling position

Figure 3 provides an overview on the design of the filter management system.

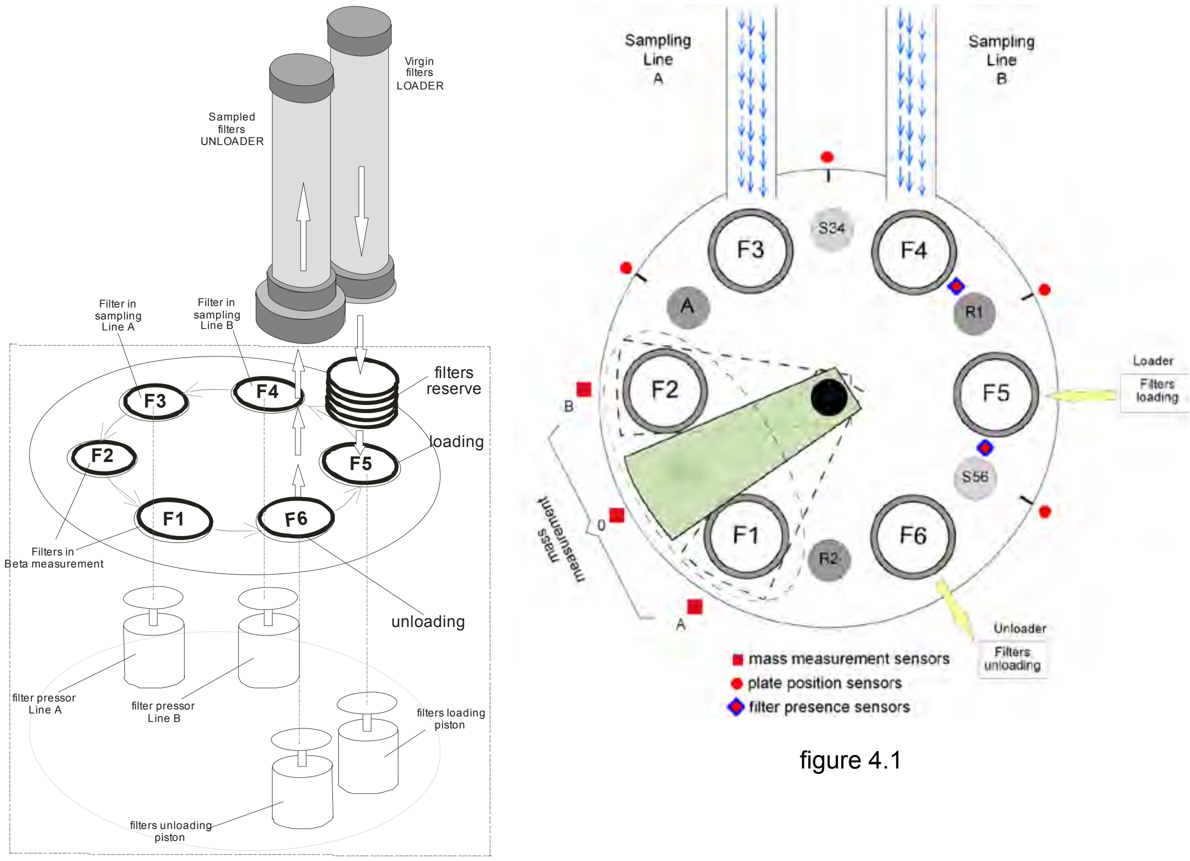


Figure 3: *Filter management system*

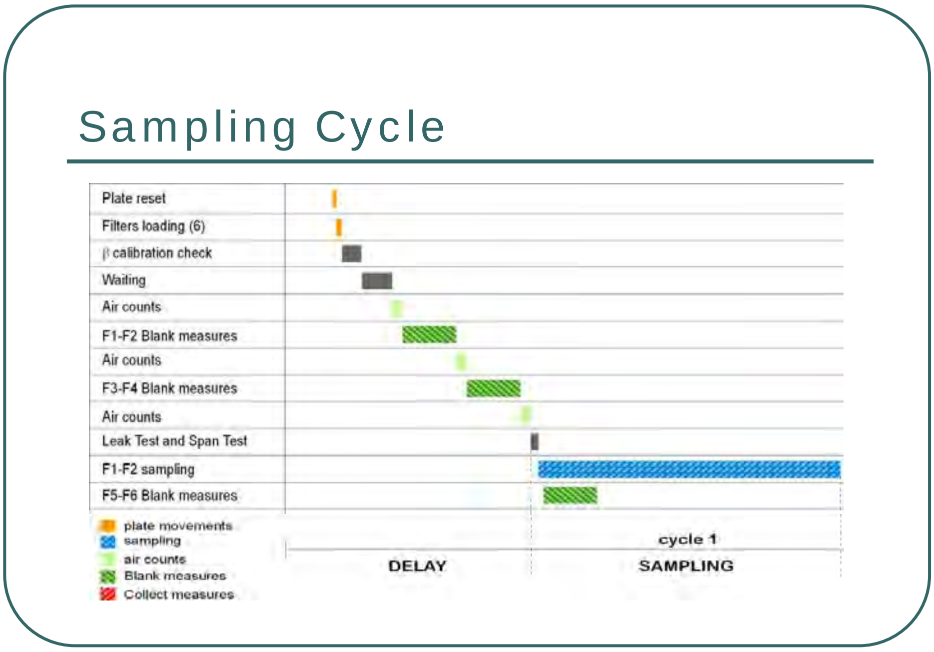
The measuring filters (∅ 47 mm) are inserted to special filter holders, which can be chosen in different sampling surface sizes between 2.54 cm^2 (for small amounts) to 11.95 cm^2 (for large amounts) depending on the expected amount of dust on the filters. The chosen sampling surface size must be taken into account during the parameterisation of the instrument.

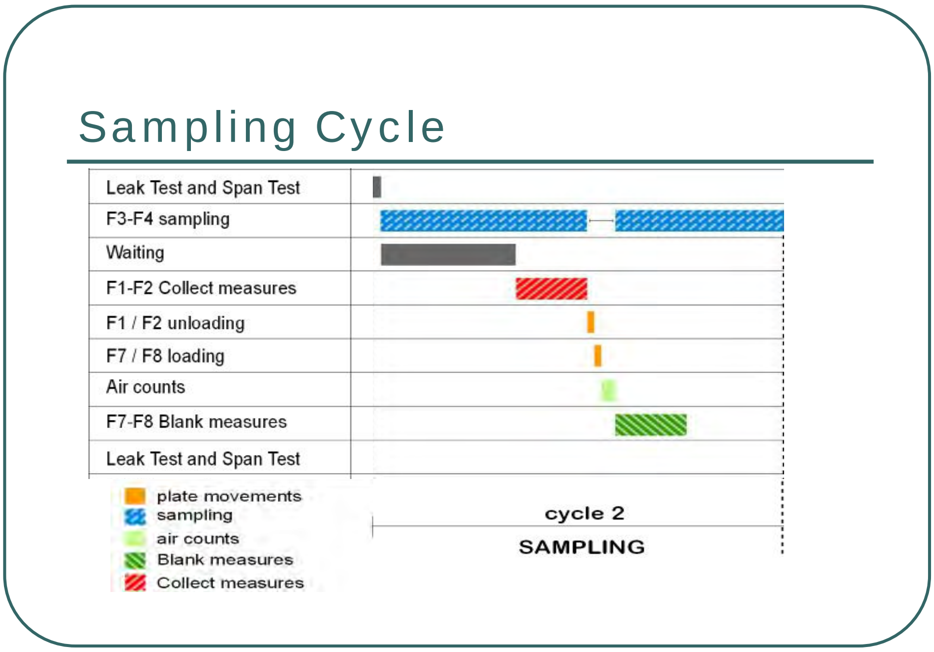
Filter holders of 5.20 cm^2 were used during suitability testing.

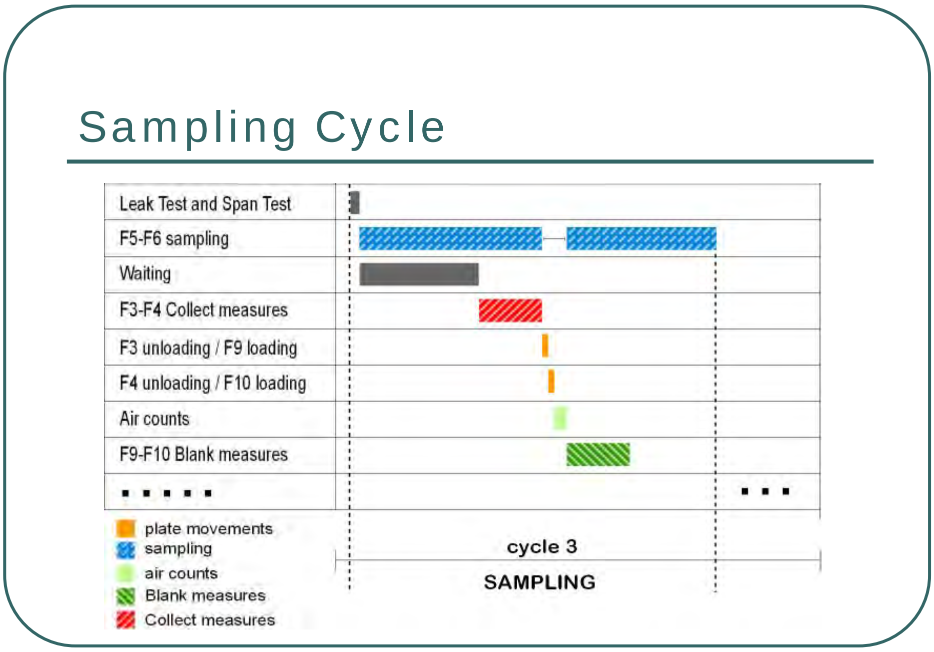
The filter holders with virgin filters are inserted to the loading device. 36 Filters were inserted for the suitability test. Within the given operating conditions of two parallel lines and an operating cycle of 24 h, the measuring system can operate for 18 days at most without filter reload. Filters can be reloaded at any time without interrupting AMS operations.

e) Schematic representation of the sequence of individual steps during 3 consecutive sampling cycles

The AMS functionality and the respective filter positions within the device are represented by the following schematics:




Sampling Cycle
Leak Test and Span Test
F3-F4 sampling
Waiting
F1-F2 Collect measures
F1 / F2 unloading
F7 / F8 loading
Air counts
F7-F8 Blank measures
Leak Test and Span Test
plate movements
sampling
air counts
Blank measures
Collect measures
cycle 2
SAMPLING


Sampling Cycle
Leak Test and Span Test
F5-F6 sampling
Waiting
F3-F4 Collect measures
F3 unloading / F9 loading
F4 unloading / F10 loading
Air counts
F9-F10 Blank measures
plate movements
sampling
air counts
Blank measures
Collect measures
cycle 3
SAMPLING

f) Quality control

The AMS comprises different internal control cycles in order to assure correct system functionality. The results of these internal checks can be reviewed in the saved data of each measurement. The AMS provides warning or alarm signals for some of the monitored parameters if the specified limit is overstepped. An index of warning or alarm signals is given in annex 7 and 8 of the operating manual.

The following parameters are monitored (among others):

- Pneumatic circuit seal, leak test (prior to each measuring cycle)
- Flow rate of the AMS (span test; prior to each measuring cycle)
- Inlet flow rate, stability (continuous measurement during each cycle)
- Filter pressure drop (continuous measurement during each cycle)
- Sensors (continuous measurement during each cycle)
- Background noise of the beta measurement (prior to each measuring cycle)
- Stability test of the Geiger-Müller detector (continuous measurement during each cycle)
- Mass calibration check (prior to each restart or, manually triggered, at the beginning of the next measuring cycle)
- Sensor check on the correct functionality of the system mechanics

3.3 AMS scope and layout

The AMS comprises two sampling inlets (PM_{10} & $PM_{2.5}$), two inlet tubes, two vacuum pumps, a measuring device, a compressor for compressed air generation and two filter magazines (loading and unloading device) for virgin and sampled filters.

A description of the single components is given below.

SWAM5a Dual Channel Monitor measuring device

The central unit of the AMS comprises all servo-mechanical parts as well as the pneumatic and radiometric measuring unit, and all electronic units and microprocessors for system operation, control, and monitoring. The operating panel and system display can be found on the front side of the AMS, whereas all pneumatic and electric ports as well as the communication interfaces can be found on the back. The filter magazines and inlet tubes are installed to the upper side of the AMS.

Figure 4: SWAM 5a Dual Channel Monitor measuring system

Vacuum pump

The two vacuum pump units take in ambient air through the sampling inlet, the sampling lines and the two filter membranes. They consist of a piston pump equipped with ballast to compensate on-line pressure fluctuations. An automatic flow rate regulation is carried out independently for each sampling line.

The sampler can be operated with other pumps (e.g. graphite vane pumps) if the required performance is guaranteed at any time.

Figure 5: Vacuum pump

Service air compressor unit

The AMS requires compressed air (200 to 300 kPa) to carry out several servo-mechanic movements such as loading and unloading of filters. For this reason the AMS is equipped with a service air compressor unit.

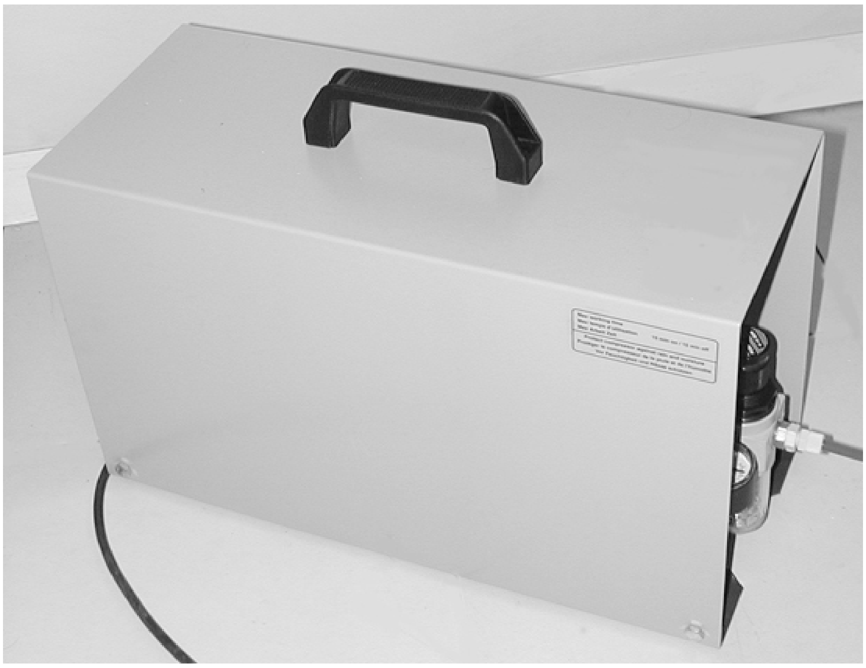


Figure 6: Service air compressor unit

Sampling inlets

The AMS is equipped with two sampling inlets for PM_{10} and $PM_{2.5}$. The sampling inlets are produced by the manufacturer of the AMS and are available for different flow rates (2.3 m³/h or 1 m³/h).

Sampling inlets for 2.3 m³/h were used during the suitability test. The design of these sampling inlets conforms to the specification of the Reference Standards EN 12341 (PM_{10} and EN 14907 ($PM_{2.5}$).

Figure 7: Sampling inlets FAI

Sampling line

After suction and passing the sampling inlet, the particle-loaded ambient air passes through the sampling line until it hits the filter.

Optionally the sampling line may be led through a coaxial chamber flowed by ambient air if a high proportion of volatile dust components is expected. Even active heating or cooling of the sampling line is possible.

The sampling line did neither pass through the coaxial chamber nor was it heated or cooled actively during suitability testing. It was simply wrapped in foam coating within the measuring cabinet as a means of isolation.

The AMS were placed in a measurement cabinet which was developed especially for the measuring system. The cabinet comprises at least the following 3 modules:

Module 1 retains the measuring device

Module 2 retains the climate control of the cabinet

Module 3 retains the pumps and the air compressor unit

It is possible to install the AMS in any conventional measuring station, taken into account that one roof opening is required for each sampling line. Thus, the measuring cabinet must provide two roof openings.

Figure 8: Outdoor measuring cabinets at the field test site in Bonn-Belderberg

Figure 9: SWAM 5a Dual Channel Monitor installed to the outdoor measuring cabinet

The AMS is operated *via* membrane keyboard which is combined with a display at the front side of the system. All relevant data (such as sampling time) are set *via* the keyboard. Furthermore it is possible to view necessary information about the current system status (ongoing sampling) as well as collected data of earlier measurements or numerous parameters for quality control purposes.

In addition to the direct communication *via* keyboard and display, the AMS offers a means of connection suited for a standard terminal (e.g. HyperTerminal) or a PC / modem *via* serial port RS-232. The AMS can be controlled, operated and parameterised through the terminal or with the help of the operating software Dr. FAI Manager, Version 0.6.6.0 (in suitability testing), either directly *via* PC or indirectly *via* GSM modem. This provides an easy and comfortable way for reading out collected data in text format and preparation for further processing.

Figure 10 to Figure 16 present an overview about available information, control- and monitoring options *via* Dr. FAI Manager.

Measured values and status messages can be displayed *via* an analogue output, if desired. Moreover, the AMS provides a means to keep the operator informed about the current system status and the latest measured values *via* SMS.

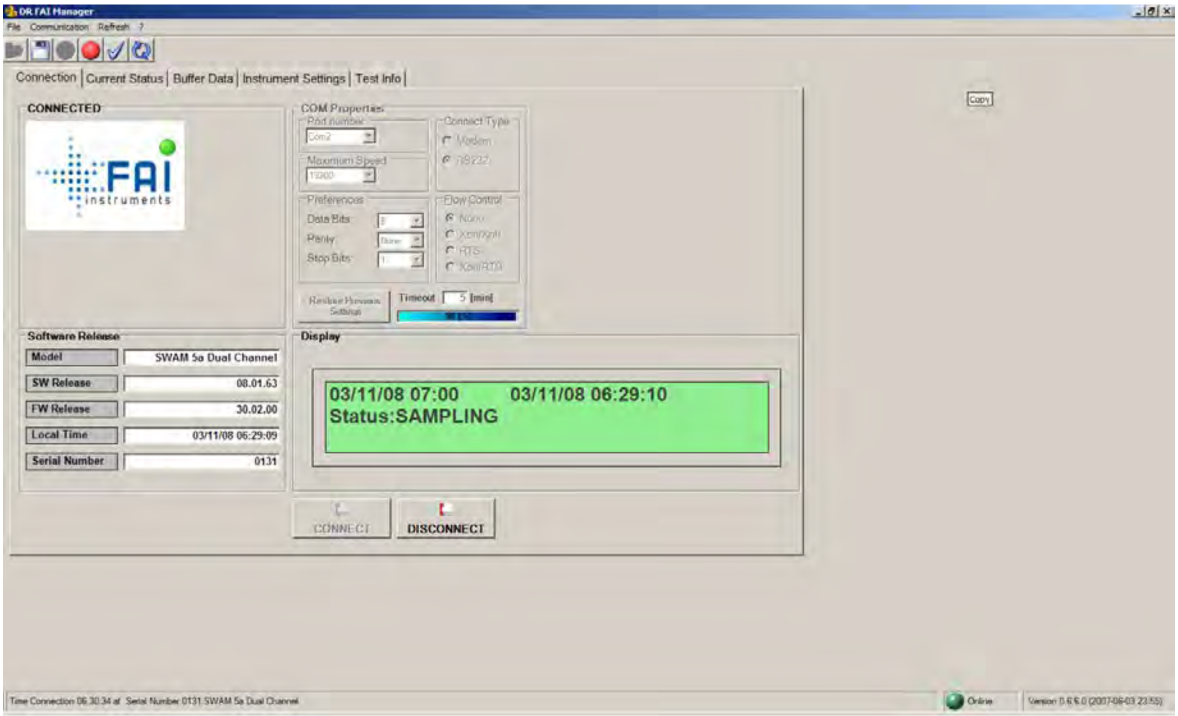


Figure 10: Operating software Dr. FAI Manager (Main screen)

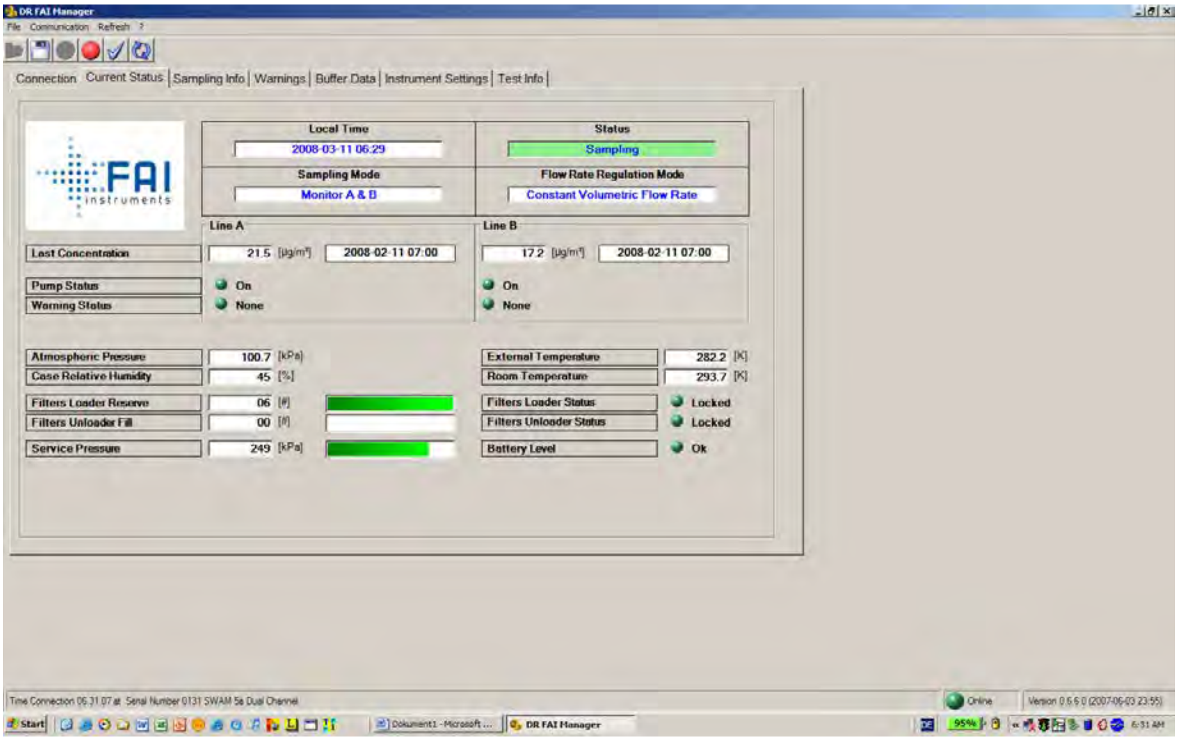


Figure 11: Operating software Dr. FAI Manager (current status)

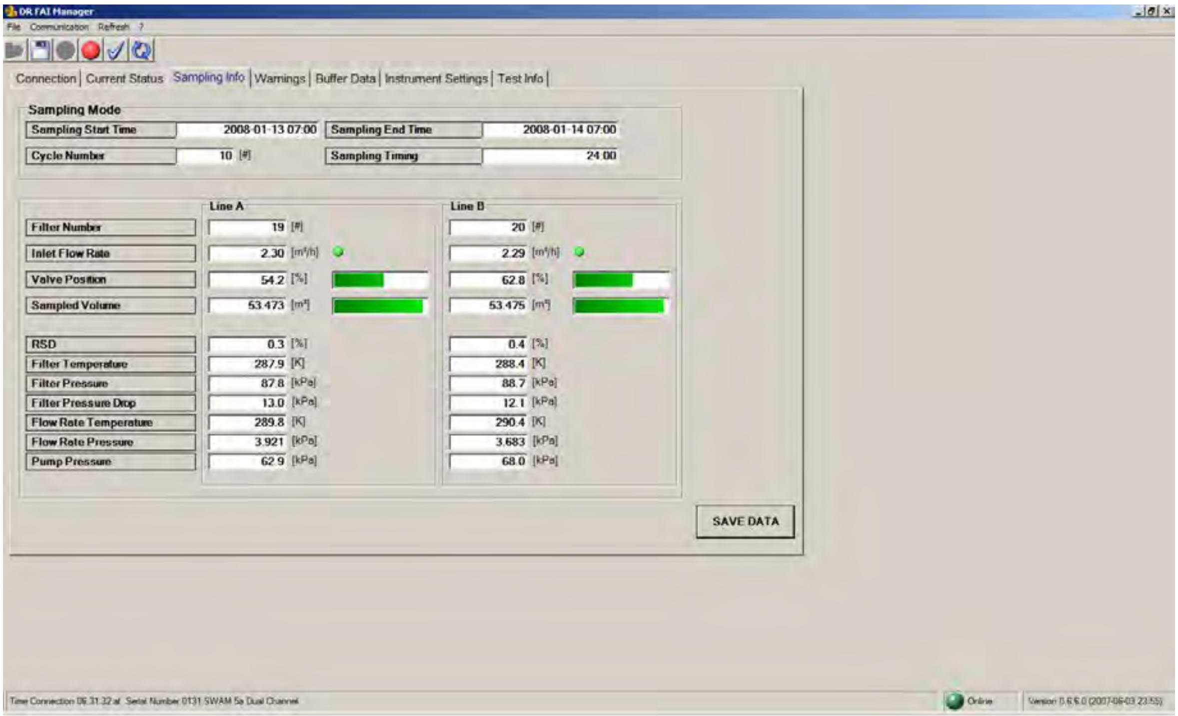


Figure 12: Operating software Dr. FAI Manager (Sampling information)

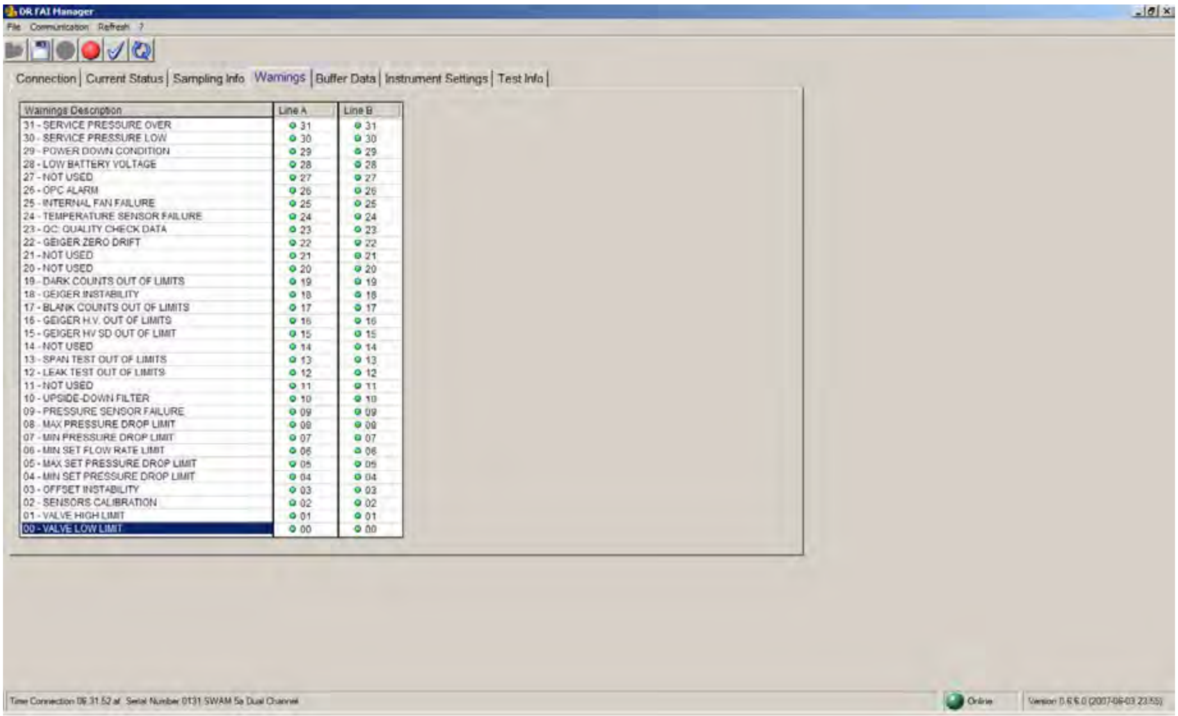


Figure 13: Operating software Dr. FAI Manager (Warnings)

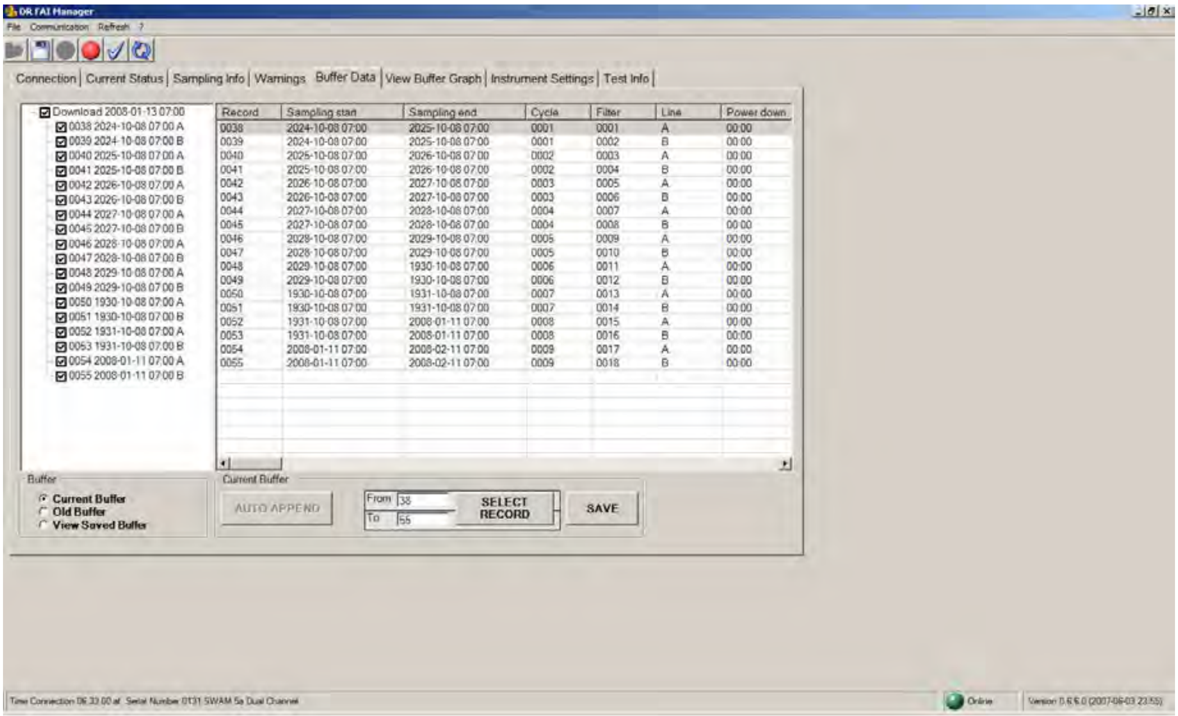


Figure 14: Operating software Dr. FAI Manager (Buffer data)

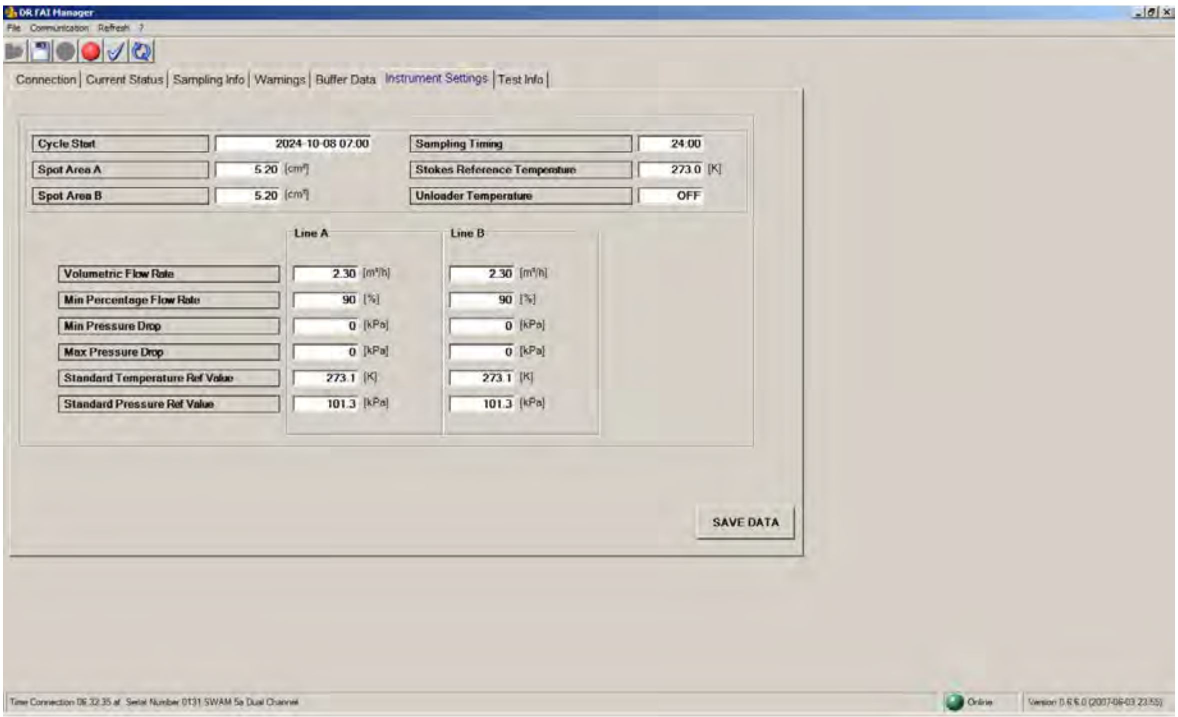


Figure 15: Operating software Dr. FAI Manager (instrument settings)

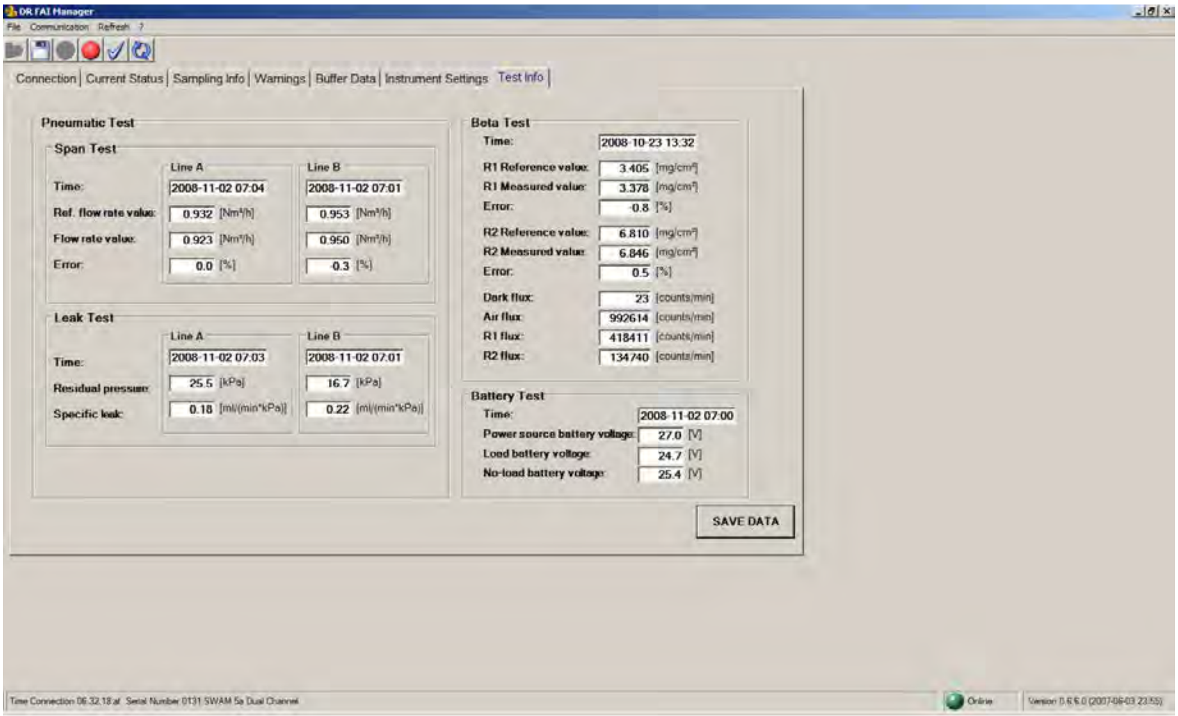


Figure 16: Operating software Dr. FAI Manager (test info)

A zero filter is installed to the AMS for the zero point check and offset determination instead of the sampling inlet. This filter allows feeding air to the system which is free from dust particles.

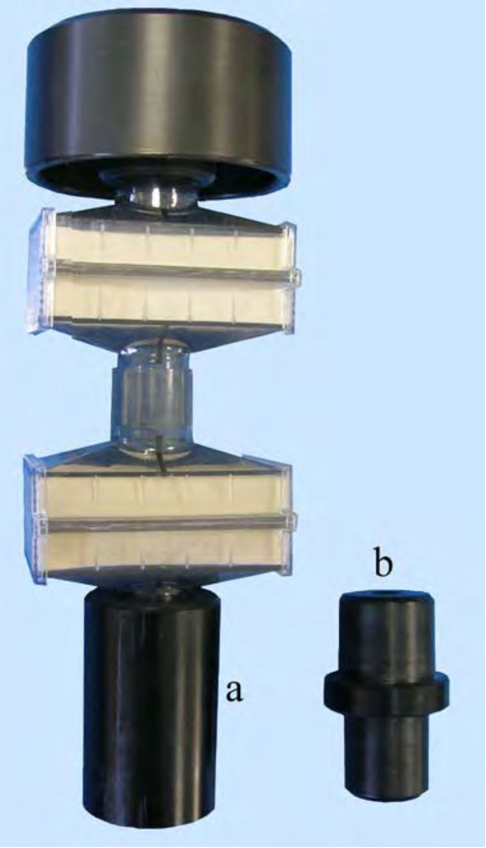


Figure 17: Zero filter (a = zero filter, b = Adapter to connect the filter to the sampling line)

After each system restart (or else manually activated at the beginning of each measuring cycle) a radiometric calibration can be performed with two reference aluminium foils of known mass density which are implemented in the system. The obtained results are compared with the respective reference values and presented as deviation in percent. The result of the last „beta span test“ can be accessed at any time.

In addition, the manufacturer provides a set of 6 aluminium reference foils for radiometric measurement checks and recalibration, if necessary. A detailed description of this procedure is given in the device manual.

Table 2 comprises a list of important device-related characteristics for SWAM 5a Dual Channel Monitor measuring system for continuous measurement of suspended particulate matter in ambient air.

Table 2: Device-related data SWAM 5a Dual Channel Monitor (Manufacturer’s data)

Dimensions / weight	SWAM 5a Dual Channel Monitor
Measuring system	430 x 540 x 370 mm / 36 kg
Vacuum pump	200 x 320 x 200 mm / 10 kg
Compressor	180 x 320 x 200 mm / 18 kg
Sampling line	1.5 m
Sampling inlet	FAI, 2.3 m³/h, PM_{10} & $PM_{2.5}$
Measurement cabinet (Outdoor)	700 x 700 x 1950 mm / 95 kg
Energy supply	230 V±10 %, 50 Hz
Input	max. 1200 W
Ambient conditions	
Temperature	+5 - +40 °C during suitability testing
Humidity	Non-condensing (<85 %)
Sampling flow rate	0.8 to 2.5 m³/h, programmable 2.3 m³/h = 38.33 l/min during suitability test
Radiometry **Radiator**	^{14}C, 3.7 MBq (100 µCi)
Detector	Geiger-Müller
Mass determination	
Mass density measuring range	10 mg/cm²
Reproducibility mass density	±2 µg/cm²
Reproducibility mass determination	±10 µg at β-equivalent spot area of 5.2 cm²

Sampling	
Filter exchange (cycle time)	adjustable, 8 – 12 – 24 – 48 – 72 – 96 – 120 – 144 – 168 h
Permitted maximum pressure drop (filter)	40 kPa at 2.3 m³/h
Data storage capacity (internal)	1500 data sets
Stored date / measurement	51 Parameters (see manual, annex 1)
Analogue output	0 to 5 V – configurable, Standard setting 200 µg/m³
Digital output	2 x RS 232 (for PC and Modem) – ports for data transmission and remote control
Status signals / Error messages	Available, see annex 7 & 8 of the manual

4 Test program

4.1 General

The suitability test has been performed with two identical devices of the serial numbers SN 127 and SN 131. The same tests were carried out according to the “Combined MCERTS and TÜV PM Equivalence Testing” program in parallel to the German tests at the location in Teddington, with two identical devices of the serial numbers SN 145 and SN 149.

Software version Rel 04-08.01.63-30.02.00 was installed on the candidates at the beginning of suitability testing. The software has been constantly developed and optimized up to version Rel 04-08.01.65-30.02.00 during the test program.

No influences on the system performance are expected from the changes which were made on the software up to version Rel 04-08.01.65-30.02.00.

The laboratory tests for the determination of system characteristics were followed by a field test of several months at different test sites.

All concentrations (PM_{10} & $PM_{2.5}$), determined under operation conditions, are presented in µg/m³. The concentration of PM_{10} was additionally tested under standard conditions (273 K, 101.3 kPa) according to standard EN 12341. The results are presented in µg/m³.

No structural changes were made on the candidates during the suitability testing.

The following report comprises a description of each minimum requirement according to standards [2,3,4,5,and 6] in number and wording.

4.2 Laboratory test

The laboratory test was carried out with two identical devices of SWAM 5a Dual Channel Monitor measuring system with the serial numbers SN127 and SN 131.

According to the Standard, the following test program was specified for the laboratory test:

- Description of system functions
- Determination of detection limits
- Determination of the dependence of zero point / sensitivity on ambient temperature
- Determination of the dependence of zero point / sensitivity on the system voltage

The following devices were used to determine the system characteristics during laboratory test:

- Climatic chamber (temperature range from –20 °C to +50 °C, precision better than 1 °C)
- Adjustable isolating transformer
- Zero filter (absolute filter) for generating particle-free air.
- Reference foils R1 & R2 (implemented to the system)

The measured values were read *via* the operating software DR FAI Manager with the help of a notebook.

Section 6 describes the laboratory tests and the results.

4.3 Field test

The field test was carried out in a parking lot in Koeln as well as in Bonn-Belderberg and Bruehl with two identical systems of the serial numbers:

Device 1: No. SN 127

Device 2: No. SN 131

The tests in Teddington (UK) were done according to the „Combined MCERTS and TÜV PM Equivalence Testing“ program with a second set of identical systems of the serial numbers:

Device 1: No. SN 145

Device 2: No. SN 149

The results of Teddington, UK were merged with the results of the three German test sites in the course of comparing all data.

The following test program was specified for the field test:

- Determination of the comparability of the candidates according to EN 12341 (PM_{10} only) and Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods” (PM_{10} & $PM_{2.5}$)
- Determination of the comparability of the candidates and the reference methods according to EN 12341 (PM_{10} only) and Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods” (PM_{10} & $PM_{2.5}$)
- Sampling flow stability check
- Determination of the calibration efficiency and analysis function record
- Determination of reproducibility

- Determination of temporal changes of zero point and sensitivity
- Leak test on the sampling system
- Inspection of the dependency of the measured values on humidity
- Determination of the maintenance interval
- Determination of availability
- Determination of the total uncertainty of the candidates.

The following devices were used for the field test (Koeln, Bonn, and Bruehl):

- Two outdoor measurement cabinets of the company FAI Instruments s.r.l.
- Measurement chamber of TÜV Rheinland Immissionsschutz und Energiesysteme GmbH, air-conditioned to approx. 20 °C
- Weather station (WS 777 of the company Conrad Elektronik AG) for the determination of meteorological characteristics such as air temperature, air pressure, air humidity, wind velocity, wind direction and rainfall
- Two reference equipment SEQ47/50 for PM_{10} according to point 5
- Two reference equipment LVS3 for $PM_{2.5}$ according to point 5
- Classification device according to point 5
- Gas meter, dry
- Mass flow rate measuring device Type 4043 (Manufacturer: TSI)
- Measuring device Metratester 5 (Manufacturer: company Gossen Metrawatt) for the determination of input
- Zero filter for particle-free air generation
- Reference foils R1&R2 (implemented to the system)

The following devices were used for the field test in Teddington, UK:

- Two outdoor measuring cabinets of the company FAI Instruments s.r.l.
- Two reference equipment LVS3 for PM_{10} according to point 5
- Two reference equipment LVS3 for $PM_{2.5}$ according to point 5
- Gas meter, dry
- Zero filter for particle-free air generation
- Reference foils R1&R2 (implemented to the system)

Two SWAM 5a Dual Channel Monitor systems, two reference equipment for PM_{10}, two reference equipment for $PM_{2.5}$ and a classifying device (Koeln, Bonn and Bruehl only) were simultaneously operated for 24 h each during the field test. The classifying device and the reference equipment for $PM_{2.5}$ (all four sites) as well as the reference equipment for PM_{10} (Teddington, UK only) were operating discontinuously, i.e. the filters must be manually changed after sampling.

The impaction plates of the PM_{10} and the $PM_{2.5}$ sampling inlets were cleaned and greased with silicone grease approx. every 2nd week to ensure a clean separation and deposition of particles.

The flow rate was tested on each candidate and each reference device prior to and after the field test, as well as prior to and after each change of location. A gas meter was connected to the air inlet of the systems *via* hose assembly for this reason.

Measurement sites and site of the measuring devices

The measuring devices were installed to separate outdoor measuring cabinets during the field test. The sites of the measuring cabinets were chosen preferably close to the reference equipment.

The field test was carried out at the following sites:

Table 3: Field test site

No.	Measurement site	Period	Characterisation
1	Koeln, Parking lot	10/2007 to 02/2008	Urban background
2	Bonn, Belderberg	02/2008 to 04/2008	Traffic
3	Teddington (UK)	07/2008 to 10/2008	Urban background
4	Bruehl	09/2008 to 11/2008	Gravel plant

Figure 18 to Figure 24 present the course of the PM-concentrations at the field test sites (recorded by the reference equipment).

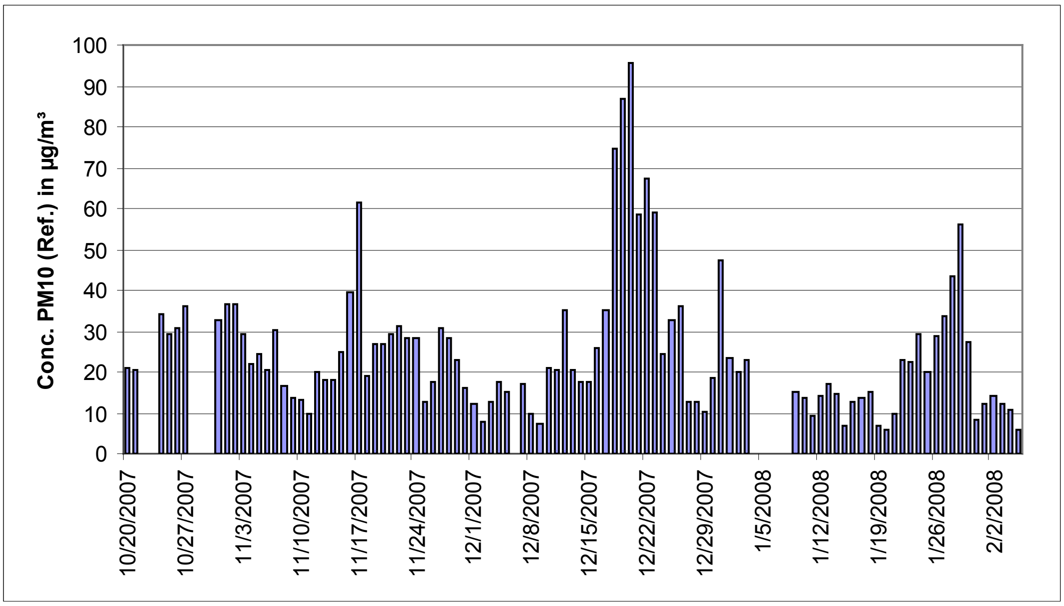


Figure 18: PM_{10}-concentration (reference) at the site „Koeln, Parking lot“

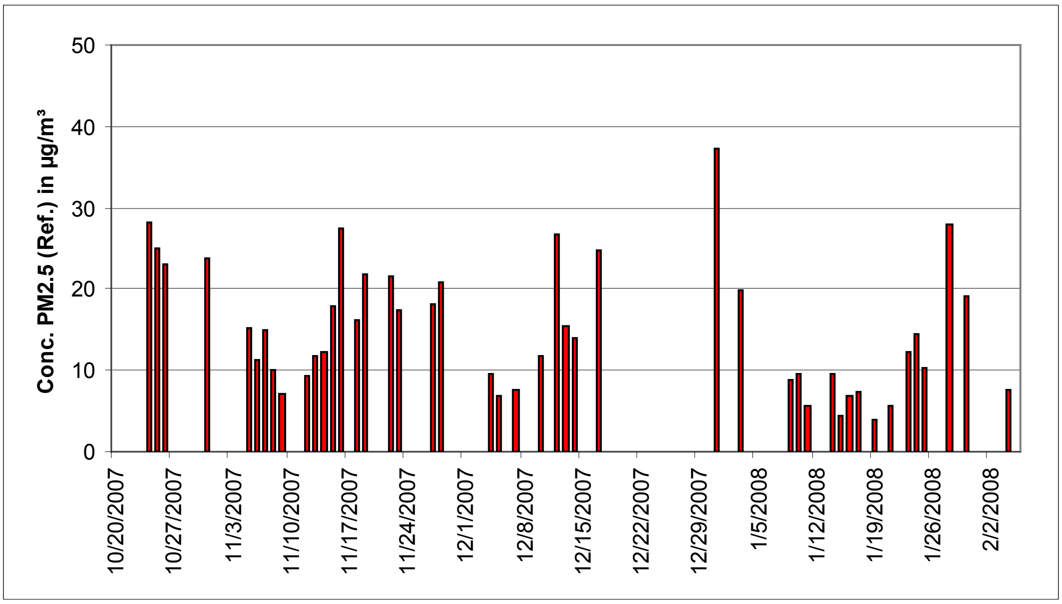


Figure 19: $PM_{2.5}$ concentration (reference) at the site „Koeln, Parking lot“

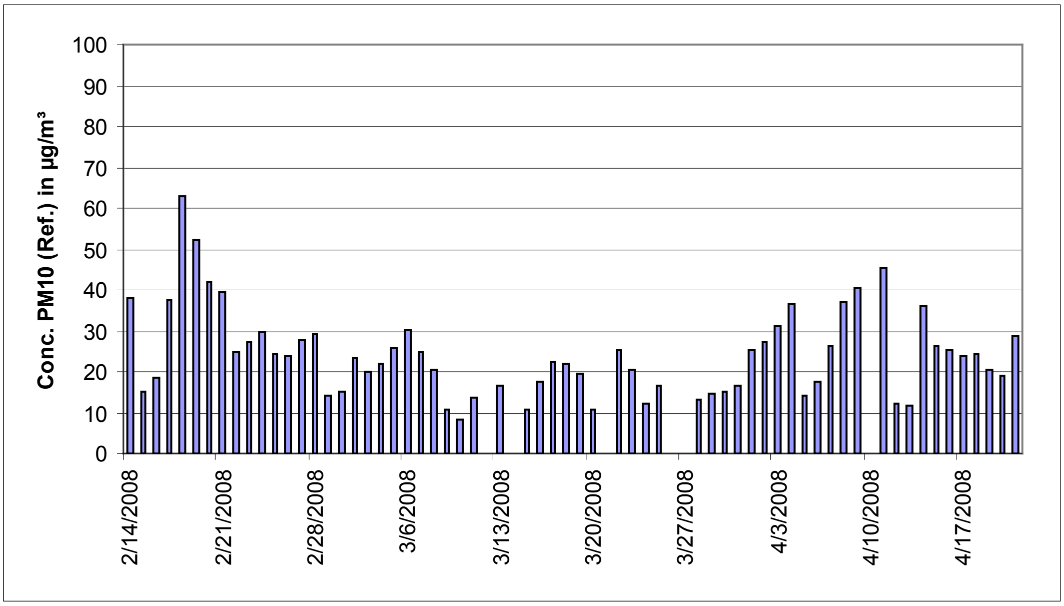


Figure 20: PM_{10}-concentration (reference) at the site „Bonn, Belderberg“

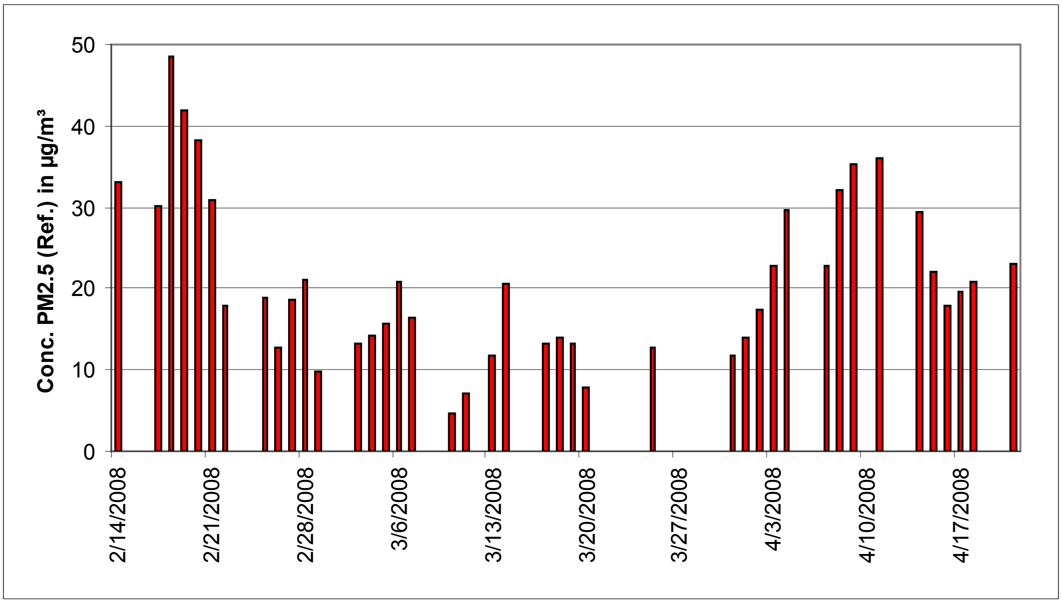


Figure 21: $PM_{2.5}$ concentration (reference) at the site „Bonn, Belderberg“

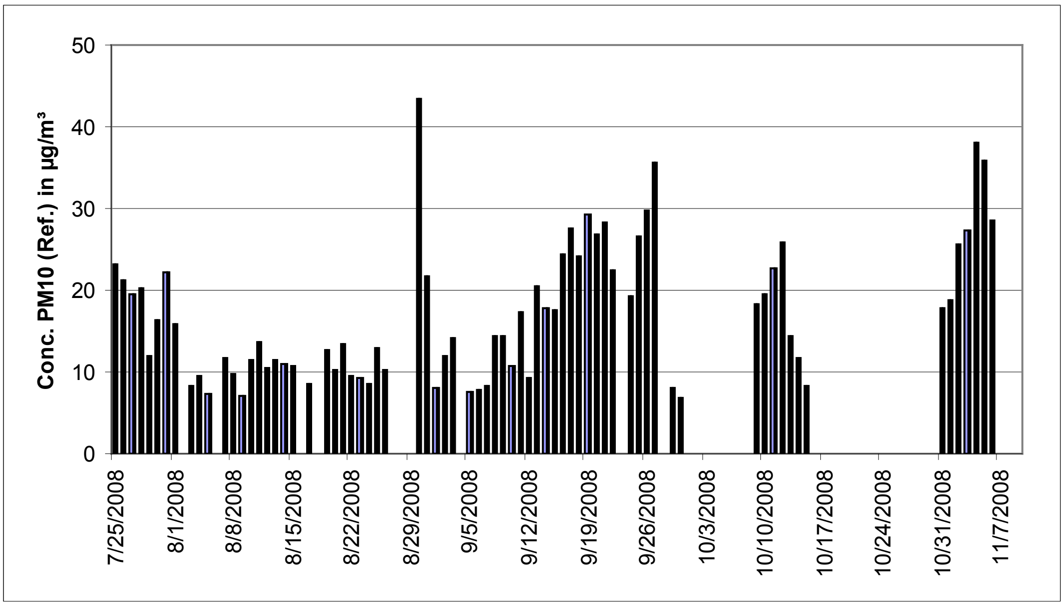


Figure 22: *PM_{10}-concentration (reference) at the site „Teddington (UK)"*

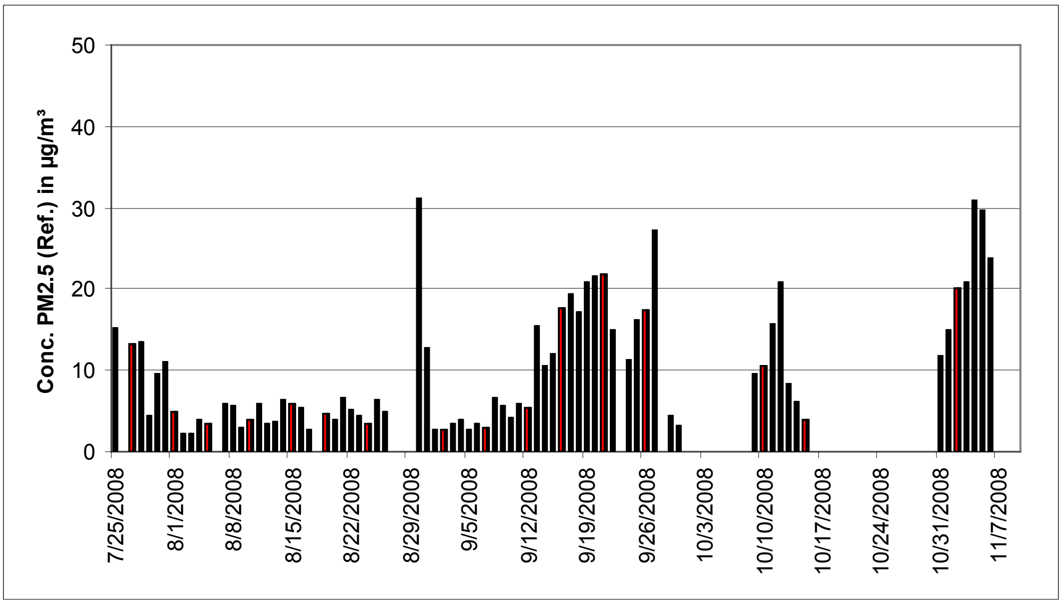


Figure 23: *$PM_{2.5}$ concentration (reference) at the site „Teddington (UK)"*

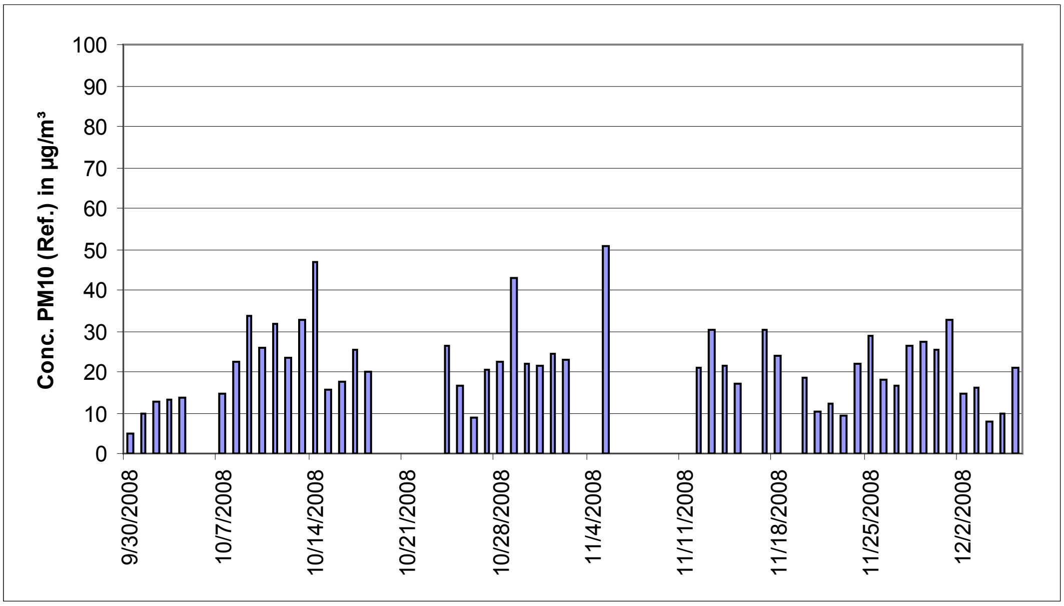


Figure 24: PM$_{10}$-concentration (reference) at the site „Bruehl“

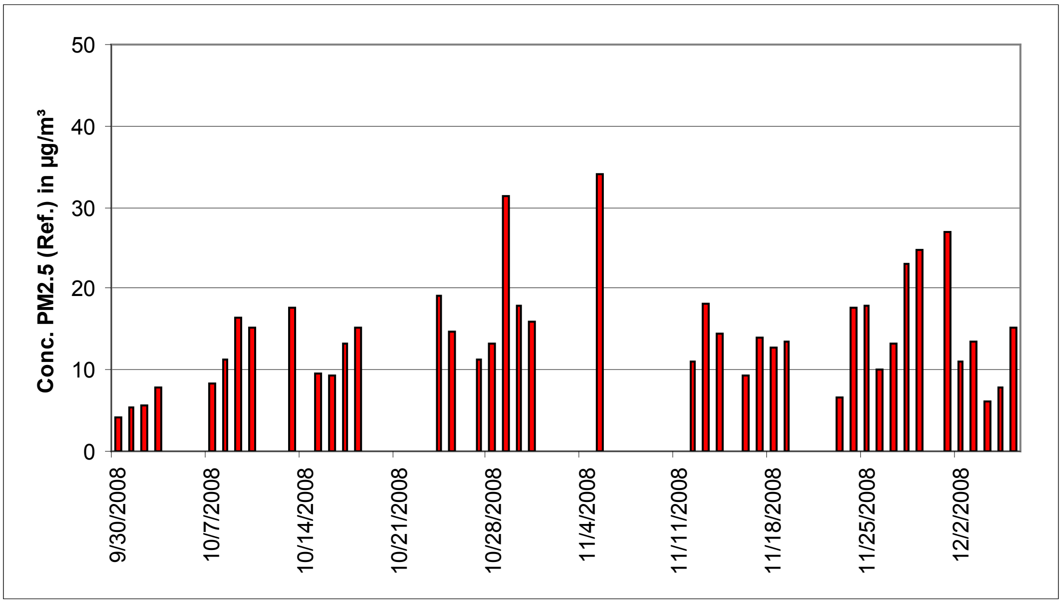


Figure 25: PM$_{2.5}$ concentration (reference) at the site „Bruehl“

The following figures show the measuring container at the field test sites in Koeln (parking lot), Bonn (Belderberg), Teddington (UK) and Bruehl.

Figure 26: Field test site Koeln, Parking lot

Figure 27: Field test site Bonn, Belderberg

Figure 28: Field test site Teddington

Figure 29: Field test site Bruehl

A data acquisition device for meteorological characteristics was installed to the container in addition to the devices for dust measurement. Data for air temperature, air pressure, air humidity, wind velocity, wind direction and rainfall were continuously collected and saved as half-hourly averages.

The installation of the measuring cabinets as well as the arrangement of the sampling probes were characterised by the following measures:

- Outdoor measuring cabinet: approx. 2.0 m above ground
- Sampling SWAM5a, Line A, PM_{10}: approx. 3.2 m above ground
- Sampling SWAM5a, Line B, $PM_{2.5}$: approx. 2.9 m above ground
- Container roof: approx. 2.7 m
- Sampling height for Ref. PM_{10}/ Ref. $PM_{2.5}$/TSP approx. 1.2 / 1.2 / 1.0 m above container roof (resp. approx. 3.9 / 3.9 / 3.7 m above ground)
- Vane: approx. 4.5 m above ground

The following Table 4 presents an overview on the most important meteorological data of the four sites and the particulate matter relations during the test. Occasional particulate matter proportions of more than 100% were not considered due to implausibility.

Due to an exchange of the TÜV measuring station meteorological measurements of the location in Bruehl could not be continued after November 3rd, 2008. No meteorological data are available for the location in Teddington, UK, prior to September 17th 2008. Moreover, TSP dust has not been measured in Teddington. See section 5 and 6 for detailed results.

Table 4: Ambient conditions at the field test site (daily averages)

	Koeln, Parking lot	**Bonn, Belderberg**	**Teddington (UK)***	**Bruehl****
No. of paired values Reference PM_{10} (total)	102	65	80	51
No. of paired values Reference $PM_{2.5}$ (total)	46	43	81	41
PM_{10} fraction under ambient conditions [%]				
Range	59.1 to 99.4	45.9 to 94.8	not tested	not tested
Average	77.3	67.5		
Air temperature [°C]				
Range	-3.4 to 12.4	0.6 to 13.6	4.2 to 15.4	4.4 to 16.2
Average	5.3	7.0	11.2	10.3
Air pressure [hPa]				
Range	982 to 1033	975 to 1034	984 to 1016	992 to 1024
Average	1012	1003	1000	1008
Rel. Air humidity [%]				
Range	55.2 to 86.9	45.3 to 81.0	64 to 95	61.6 to 82
Average	72.5	64.8	81.4	74.5
Wind velocity [m/s]				
Range	0.0 to 6.8	0.0 to 4.8	0.0 to 1.8	0 to 8.3
Average	2.1	1.3	0.5	2.2
Rainfall [mm]				
Range	0.0 to 31.0	0.0 to 20.4	0.0 to 13.2	0.0 to 16.5
Average	2.7	2.6	1.1	2.2

* Weather data available after 2008-09-17
** Weather data available until 2008-11-03

Sampling period

DIN EN 12341 defines a sampling period of 24 h. In case of lower concentrations the sampling period may be extended, in case of higher concentrations it may be shortened.

DIN EN 14907 defines a sampling period of 24 h ± 1 h.

While the sampling period was constantly set to 24 h during field test, it was reduced for some laboratory tests to obtain a higher no. of measured values.

Data handling

All paired reference values determined during the field tests were subject to statistical testing according to Grubbs (99 %) to prevent influences of obviously implausible data on the measuring results. Paired values which are identified as significant outliers can be discarded until the critical value of the test statistic is exceeded, though it is not permitted to leave out more than 5% of the paired values in total for each field test site.

Within the scope of the „Combined MCERTS and TÜV PM Equivalence Testing“ program we agreed with our British partners not to discard any measured value for the candidates unless the implausibility is caused due to technical reasons. Therefore no values for the candidates were discarded during the whole test.

Table 5 and Table 6 present an overview on the paired values (reference measurement) which were identified as significant outliers for each location. These values were not considered for further evaluation.

Table 5: Overview on outliers – reference, measured component PM_{10}

Test site	Reference PM10			
	n	Date	G1	G2
Cologne	102	no outlier		
Bonn	65	no outlier		
Teddington	80	8/2/2008 8/16/2008 9/4/2008	8.5 µg/m³ 13.9 µg/m³ 10.4 µg/m³	6.4 µg/m³ 21.0 µg/m³ 5.3 µg/m³
Bruehl	51	11/16/2008 11/19/2008	19.7 µg/m³ 32.1 µg/m³	16.3 µg/m³ 27.3 µg/m³

Table 6: Overview on outliers – reference, measured component $PM_{2.5}$

Test site	Reference PM2.5			
	n	Date	G1	G2
Cologne	46	10/20/2007	16.1 µg/m³	23 µg/m³
Bonn	43	no outlier		
Teddington	81	7/26/2008	16.1 µg/m³	13.8 µg/m³
Bruehl	41	10/11/2008 10/14/2008 11/21/2008	28.4 µg/m³ 17.5 µg/m³ 5.8 µg/m³	24.5 µg/m³ 21.2 µg/m³ 3.4 µg/m³

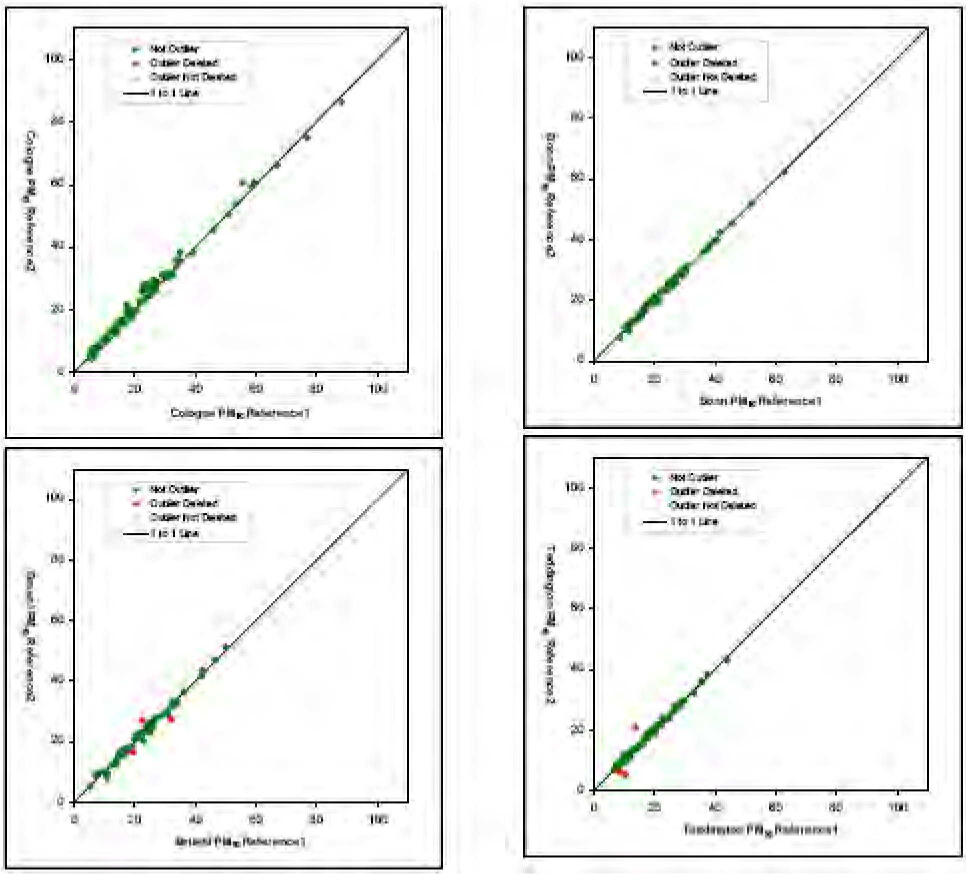


Figure 30: Grubbs results for the PM_{10} reference method of all 4 sites

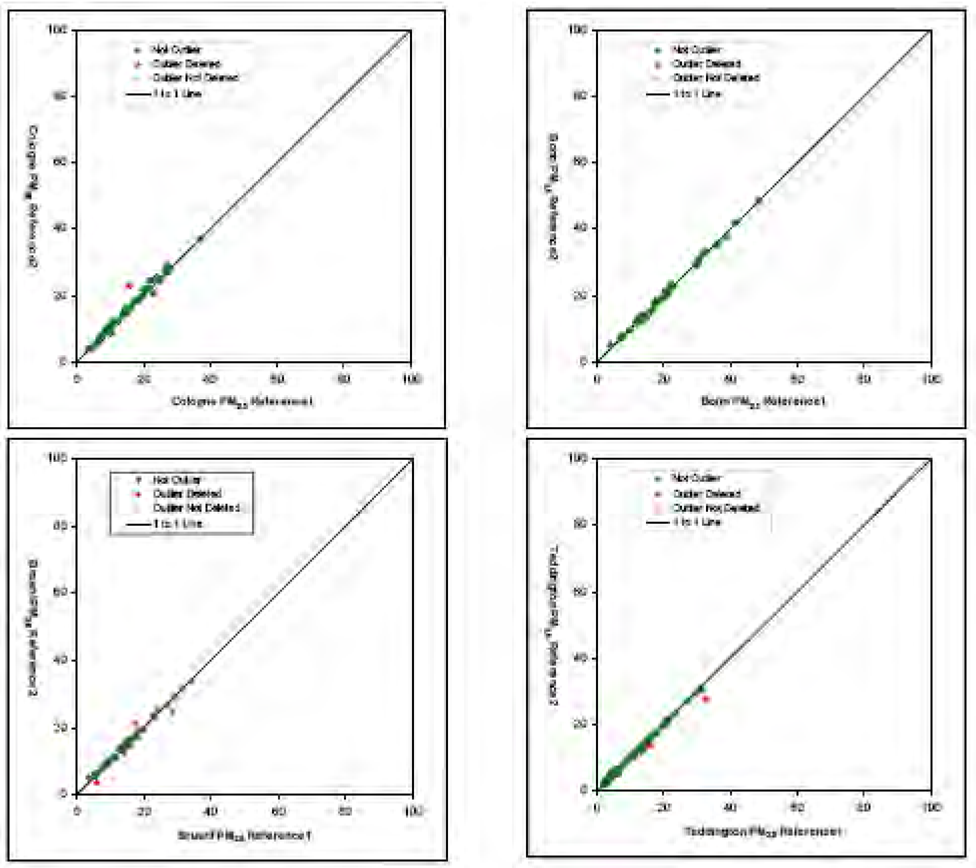


Figure 31: Grubbs results for the $PM_{2.5}$ reference method of all 4 sites

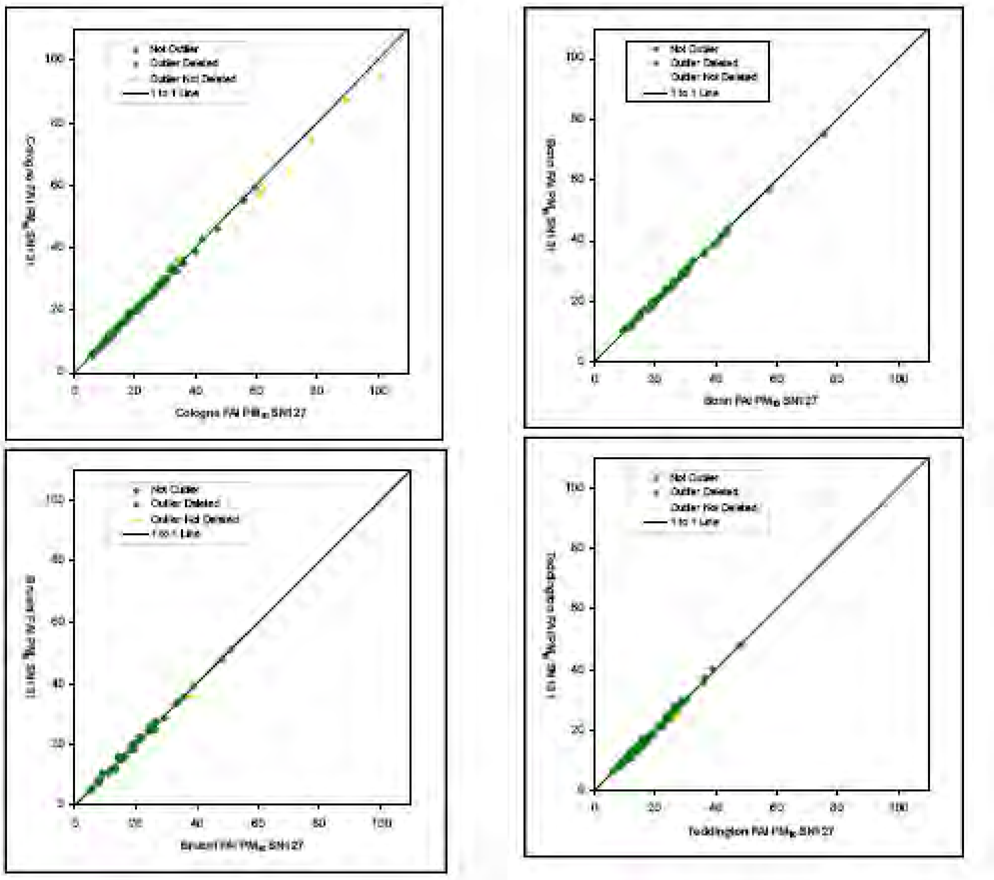


Figure 32: Grubbs results for the PM_{10} FAI of all 4 sites

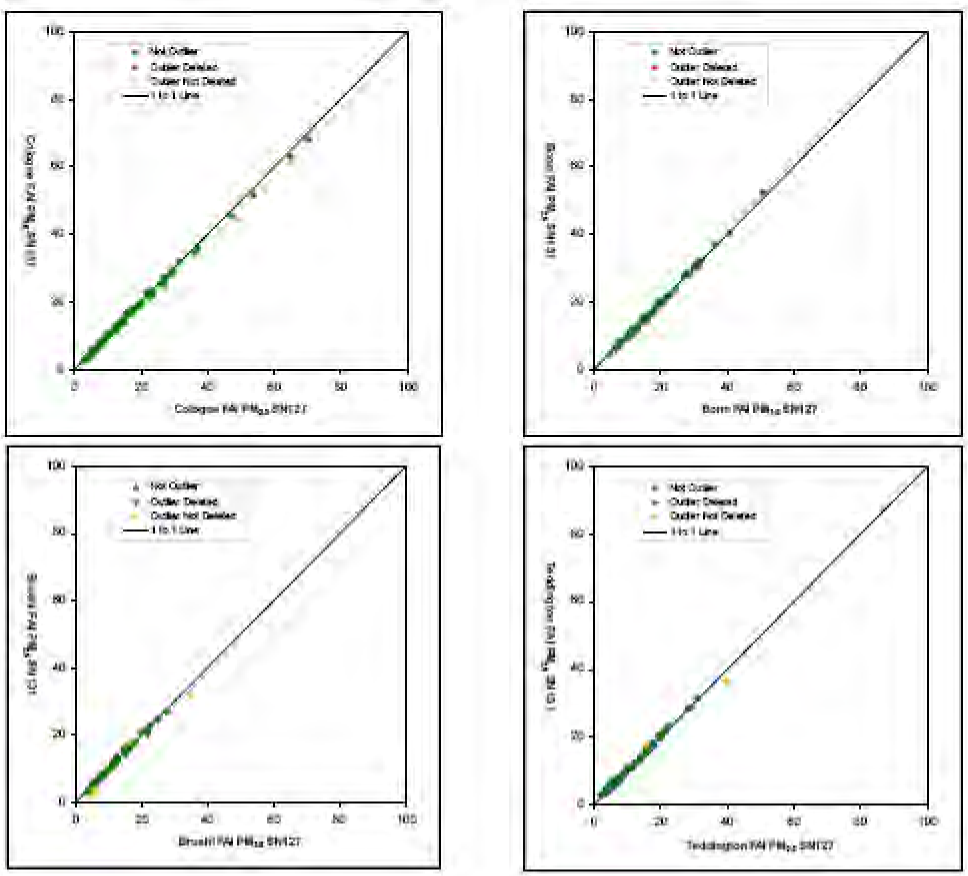


Figure 33: Grubbs results for the $PM_{2.5}$ FAI of all 4 sites

Handling of filters – mass determination

The following filters were used for the suitability test:

Table 7: Used filter material

Measuring device	Filter material, Type	Manufacturer
Reference devices LVS3 and SEQ47/50	Quartz fibre, ∅ 50 mm	Whatman
Classification device GS 050	Quartz fibre, ∅ 50 mm	Whatman
Reference devices LVS3 (Teddington only)	Emfab™, ∅ 47 mm	Pall

The filter material EMFAB™ was used in the scope of the „Combined MCERTS and TÜV PM Equivalence Testing“ program by special request of our British partner, because according to [11], they consider it most appropriate for the test.

The filter handling conforms to the requirements of DIN EN 14907 and DIN EN 12341, Annex C.

The procedures of filter handling and weighing are described in detail in Annex 3 of this report.

5 Reference measurement procedures

The following devices were used during the field test in accordance with DIN EN 12341 and DIN EN 14907:

1. Reference equipment for PM_{10}:

Filter changer SEQ47/50, Indoor version, (Site: Koeln, Bonn, Bruehl))
Manufacturer: Ingenieurbüro Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2005
PM_{10}-sampling inlet

and

Small filter device "Low Volume Sampler LVS3"
(Location: Teddington (UK))
Manufacturer: Ingenieurbüro Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2007
PM_{10}-Sampling inlet

2. Reference equipment for $PM_{2.5}$:

Small filter device"Low Volume Sampler LVS3"
Manufacturer: Ingenieurbüro Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2007
$PM_{2.5}$-Sampling inlet

3. Classification device:

Small filter device GS 050, (Site Koeln, Bonn, and Bruehl)
Manufacturer: Company Derenda, Xantener Str. 22, Berlin, Germany
Date of manufacture: 1992
TSP-Sampling inlet

Two reference devices were simultaneously operated with a controlled volume flow of 2.3 m³/h. The accuracy of the volume flow control is below <1% of the nominal volume flow under standard conditions.

Two reference measuring systems of the Filter changer SEQ47/50 were used for the measuring component PM_{10} at all three German sites. Installation was done indoors, e.g. the filter exchanger was installed in the measuring container and connected to the sampling inlet *via* a suction pipe. The whole sampling system is cooled by a mantle of ambient air. For this reason, the suction pipe is installed to an air-purged aluminium cladding tube.

Technically, the filter changer is based on the small filter device LVS3 and conforms to a reference sampler according to DIN EN 12341 due to its construction. The filter exchange mechanism combined with the filter supply device and the stacking device allows continuous 24h sampling cycles for up to 15 days.

The sampling air is sucked in *via* the rotary vane vacuum pump through the sampling inlet for the LVS3 as well as the SEQ47/50 device. The sampling air volume flow is measured with a measuring orifice which is installed between filter and vacuum pump. In order to collect the abrasion of the vanes, the incoming air passes a separator before flowing to the air outlet.

The electronic measuring equipment of the LVS3 small filter device displays the incoming sampling air volume in standard or operating m^3 as soon as the sampling is complete, while the filter exchanger SEQ47/50 merely saves the obtained results to its internal memory.

To determine the PM_{10} concentration, the laboratory performed a gravimetric determination of the amount of suspended particulate matter on the respective filters. The obtained result was then divided through the respective volume of sampling air in standard m^3 (EN12341) or in operating m^3 (Guide "Demonstration of equivalence of ambient air monitoring methods").

To determine the $PM_{2.5}$ concentration, the laboratory performed a gravimetric determination of the amount of suspended particulate matter on the respective filters. The obtained result was then divided through the respective volume of sampling air in operating m^3 (Guide "Demonstration of equivalence of ambient air monitoring methods").

Since two reference devices were simultaneously operated during each test, the respective results for PM_{10} and $PM_{2.5}$ were averaged for evaluation.

The classification device records suspended particulate matter in air according to Standard VDI 2463, sheet 7. Each particle size is collected (TSP = **T**otal **S**uspended **P**articulate Matter).

The function of the classification device conforms to that of the reference equipment during unregulated operation. The volume flow is displayed by a hydrometric vane and a linked electromechanical meter with a reading accuracy of 0.01 m^3. The nominal volume flow is 2.7 to 2.8 m^3/h. The hourly volume flow should not fall below 2.6 m^3/h during sampling. The sampling volume results from the difference of the displayed readings at the beginning and at the end of the test.

The sampling flow volume was converted to standard conditions *via* the continuously gathered air temperature and air pressure data from the meteorological station which was installed to the measuring container, as well as the low pressure adjacent to the gas meter.

To determine the TSP concentration, the laboratory performed a gravimetric determination of the amount of suspended particulate matter on the respective filters. The obtained result was then divided through the respective volume of sampling air in standard m^3. The amount of PM_{10} is calculated by dividing the PM_{10} concentration of the reference equipment through the respective TSP concentration.

The sampling time was set with the help of an electrical time switch.

NOTE:

The following should be taken into account for PM_{10} measurement:

Occasionally high deviations were detected between the results obtained with the candidates and the reference equipment within the scope of the suitability testing. These deviations were peculiarly high especially at days of high dust load (stable weather conditions during winter). Therefore, the extended measurement uncertainties which were determined for PM_{10} are significantly higher than the determined expanded uncertainties for $PM_{2.5}$.

The significantly worse PM_{10} results in comparison with those for $PM_{2.5}$ cannot be explained by system performance since the SWAM5a Dual Channel Monitor measuring device determines the separated particulate matter for PM_{10} as well as $PM_{2.5}$ with a single measuring module and all relevant parameters of the candidates (design of the sampling inlets, volume flow rates, tightness) conform to the requirements.

The same effect took place during the test in Bruehl (Summer 2008) with even higher deviations (nothing out of the ordinary for $PM_{2.5}$ but occasionally very high deviations for PM_{10}; see *annex 2, point C) Site Bruehl (Sampling head bias evaluation)*). The unacceptable results for PM_{10} in Bruehl led to the termination of the tests in this location and to an acute root cause analysis.

The evaluation of the data at hand (Koeln, Bonn, and especially Bruehl) proves significant deviations within the PM_{Coarse} – fraction (= PM_{10} to $PM_{2.5}$) between the candidates and the reference equipment. This indicates different separation behaviour of the respective sampling inlets. On close inspection of the used equipment, it was found out, that the PM_{10} nozzles of the reference equipment described in section 5 of this report differ from the specifications given in Standard EN12341. Instead of a straight inner diameter of 6.5 mm, the nozzles of the company Leckel GmbH comprise an inner diameter of 10 mm which narrows to 6.5 mm at the end of the nozzle. Figure 34 shows a schematic presentation of the different designs of the respective nozzles. The sampling inlet design of the FAI-candidates complies exactly with the specifications of Standard EN 12341.

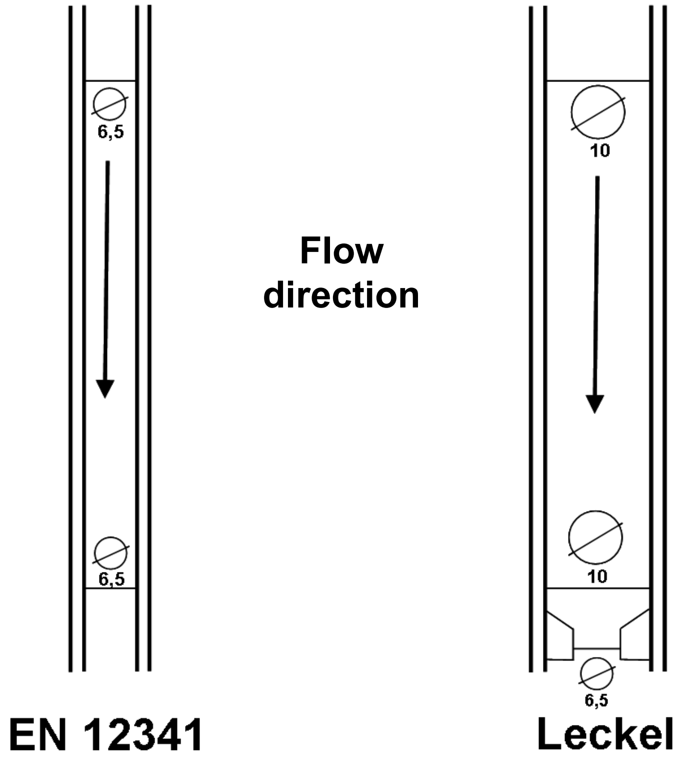


Figure 34: Schematic design of the impactor nozzles as specified in Standard 12341 in comparison with the impactor nozzles of the reference equipment

The used nozzles manufactured by LECKEL are different from the specifications given in Standard EN 12341. The manufacturer affirmed that his nozzles ensure a separation behaviour which is closer to the PM_{10} definition. Moreover, the influence caused by the different nozzle design did not show in former tests (suitability tests *et al.*) at commonly encountered levels and compositions of suspended particulate matter (e.g. no significantly high amount of coarse particles). Thus, no obvious problems were detected in the past while comparing the respective device under test with the reference equipment.

Nevertheless, the detected difference in the design of the sampling inlets could be proved as cause of the significantly different separation behaviour in comparison with the candidates, especially in the presence of a high amount of particles within the range of 10 µm.

The effects at the location in Bruehl were particularly significant since the devices were placed in the middle of a gravel-pit and thus were exposed to an extremely high amount of coarse particles especially in the dry season. Additional comparison measurements between a reference device with PM_{10}-standard head of LECKEL and a reference device with EN 12341-compliant nozzles show the possible difference in a significant way (please refer to figure 35).

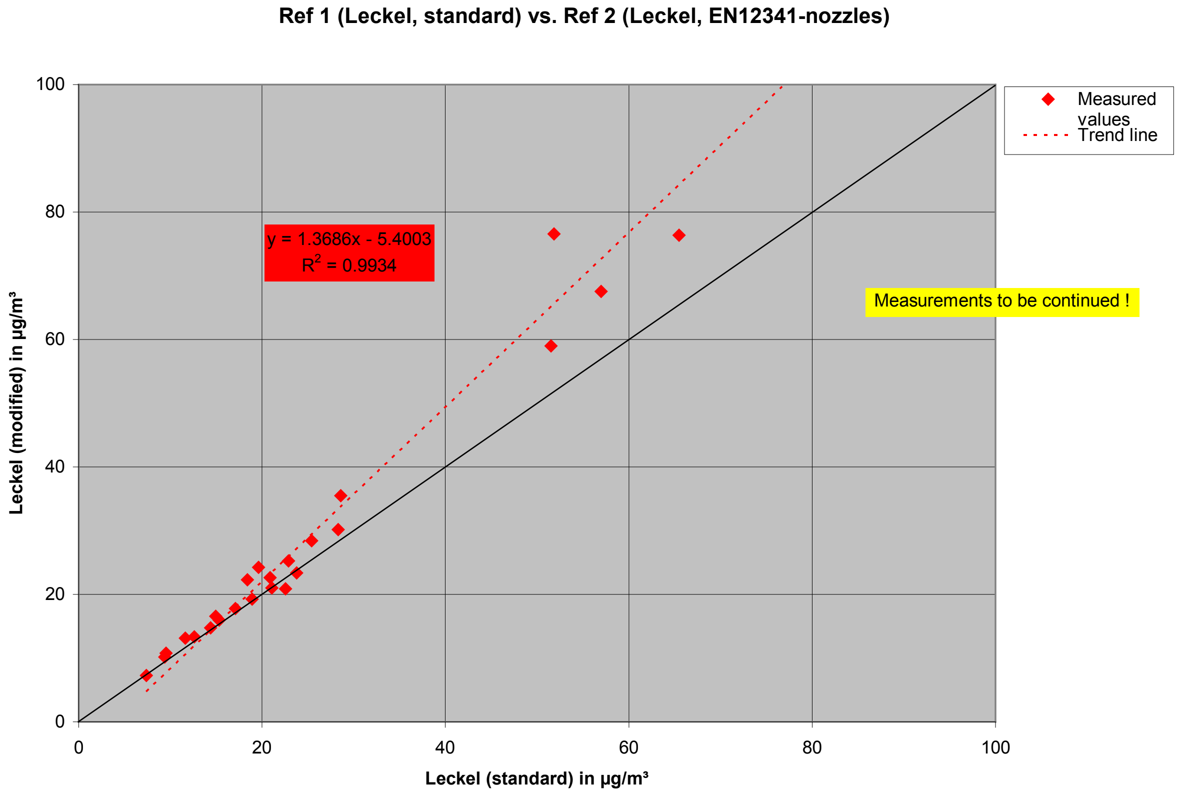


Figure 35: Exemplary comparison LECKEL, standard nozzles vs. LECKEL, EN12341-nozzles at test site Bruehl

The location in Teddington is not peculiar at first sight since the exposure to suspended particulate matter and the amount of coarse dust is generally low. A close inspection of the data however leads to the same influence of the nozzle design on the separation behaviour of the reference equipment.

Note that the deviation of the reference equipment for PM_{10} significantly contributes to the total measurement uncertainty of the candidates. This mainly concerns the test results for the site in Koeln and Bonn. An influence on the result for Teddington is determined as well, but to a negligible extent.

The (good) results for the location in Bruehl which are presented in this report are based on the fact that the whole test program was repeated with PM_{10} nozzles which comply with the specifications of Standard EN12341.

SWAM 5a measuring system conforms to the minimum requirements for PM_{10} measurement in spite of the described problem. Although the found measurement uncertainties were apparently increased, this was caused by the different nozzle head design of the reference equipment and therefore should not be for the detriment of the candidates. For this reason **annex 2** of this report comprises a detailed description of the found problem and a description of the correction procedure for theoretical consideration of the influence of the different separation behaviour, which was developed by TÜV Rheinland in cooperation with the manufacturer.

Important note:

The measured component $PM_{2.5}$ is not affected in any way by the described problem.

6 Test results

6.1 4.1.1 Display for measured values

The measuring system shall be fitted with a display for measured values.

6.2 Equipment

No additional equipment required.

6.3 Carrying out the test

The measuring device was checked on the presence of a display for measured values.

6.4 Evaluation

The measuring device comprises a display for measured values. Measured values can be recalled from the memory and displayed as averaged values over the whole sampling period at any time.

6.5 Assessment

The measuring device comprises a display for measured values.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Figure 36: Display for measured values, Line B ($PM_{2.5}$), data recall from buffer to display

6.1 4.1.2 Maintainability

Maintenance works should be feasible from outside without taking much time and effort.

6.2 Equipment

No additional equipment required.

6.3 Carrying out the test

Necessary regular maintenance works were carried out according to the instructions of the operating manual.

6.4 Evaluation

The following maintenance works should be carried out:

1. System status check
   The device status can be monitored and controlled by direct or online control.
2. The sampling inlets shall be cleaned according to the manufacturer's instructions under consideration of the local concentrations of suspended particulate matter. These works may be done parallel with exchanging the filters, which needs to be carried out every two weeks (for a filter supply of 36 filters).
3. Monthly device-internal beta span test in accordance with the manual, section 7.2.1. Standard operation is not interrupted by this procedure.
4. Monthly cleaning of the measuring device. In any case, the measuring system has to be cleaned after each measuring activity.
5. Inspection and (if necessary) cleaning of the suction pipe every 3 months.
   A tightness check is required after maintenance.
6. Oil level and air compressor filter check every 6 months
7. Annual pump maintenance works. An air flow rate check should be performed with the help of a flow transfer standard after maintenance. The system should be recalibrated if necessary.

The instructions of the manufacturer have to be followed.

The AMS performs an internal check on tightness and flow rate during each measuring cycle. In case of unacceptable deviations these parameters should be manually tested and (if required) corrected as soon as possible.

An external mass measurement check/calibration is not required unless the measuring device displays unacceptably high deviations during beta span test or system malfunction.

The instructions of the manual have to be followed in order to carry out the maintenance works. All works can be done with customary tools.

6.5 Assessment

External maintenance is possible. All works can be carried out with customary tools taking reasonable time and effort. The works according to point 5 to 7 cannot be carried out during operation and shall be done once in a quarter or year. In the meantime, necessary maintenance works are reduced to contamination or plausibility checks and status / error message monitoring.

Minimum requirements fulfilled? yes

6.6 Detailed representation of test results

The maintenance works were carried out during the test in accordance with the instructions given in the manual. No problems were noticed while following the described procedures. All maintenance works could be done with customary tools without taking much time and effort.

6.1 4.1.3 Function test

Particular instruments for function tests shall be considered as part of the device and thus shall be evaluated in the corresponding sub-tests.

Test gas units shall indicate readiness by status signals and shall allow direct or remote access to control functions via the measuring system.

The measurement uncertainty of the test gas unit shall not exceed 1% of B_2 within three months.

6.2 Equipment

Operating manual, zero filter, reference foils R1 & R2 (implemented to the device).

6.3 Carrying out the test

All instrument functions listed in the manual were checked on availability, activatability and full functionality.

A HEPA filter with adapter is used for performing an external zero point check. The HEPA-filter is mounted at the inlet of the system instead of the sampling inlet and allows supplying dust-free air by particle separation. Zero point can be checked as a concentration value in µg/m³.

Radiometric calibration can be checked (or manually triggered) with the help of two reference aluminium foils of known mass density which are implemented to the system. The obtained values are then compared with the respective standard values and presented as deviations in percent. The result of the last beta span test can be accessed at any time. An interruption of the measuring process is not necessary for this test.

Moreover, the manufacturer provides a second reference aluminium foil set for radiometric measurement control and recalibration, if necessary. The foil set comprises 6 foils. A detailed description of the required procedure is given in the manual. An interruption of the measuring process is necessary for this test.

The foil set merely allows mass density determination (unit: mg/cm²).

6.4 Evaluation

All system functions listed in the manual are available or can be activated. The current system status is permanently monitored and displayed by a set of different status messages (operation, warning and error messages).

An external calibration of the device zero point (*via* zero filters) and radiometric mass calibration (*via* the reference foils R1 & R2, which are implemented to the system, or the additional foil set for calibration) is possible at any time. Note that only mass density may be determined with the help of the reference foils. Thus, a direct comparison with given standard values is not possible. The percentile changes of the determined mass densities were calculated for evaluation purposes.

6.5 Assessment

All system functions listed in the manual are available, activatable and functioning. The current system status is continuously monitored and displayed by a set of different status messages (operation, warning and error messages).
The results for the external zero point check and radiometric measurement in the field are presented in section 6.1 5.2.9 Zero drift and section 6.1 5.2.10 Drift of the measured value of this report.

Minimum requirements fulfilled? yes

6.6 Detailed description of test results

See point 6.1 5.2.9 Zero drift
and 6.1 5.2.10 Drift of the measured value

6.1 4.1.4 Setup- and warm-up times

The set-up times and warm-up times shall be specified in the instruction manual.

6.2 Equipment

A clock was required for this test.

6.3 Carrying out the test

The AMS were started up according to the description given by the manufacturer. Necessary setup- and warm-up times were collected separately.

Necessary constructional works prior to the measurement, such as creating a breakthrough in the container roof, were not included in this test.

6.4 Evaluation

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

The measuring system must be protected from weather inconsistencies (e.g. in an outdoor cabinet of the system manufacturer or an acclimated measuring container). Extensive construction work is required in order to lead both suction pipes through the roof of a measuring container. For this reason, mobile use is impossible without the respective peripheral equipment.

The following steps are generally required for system installation:

- Unpacking and installation of the measuring device
- Connection of both sampling lines and sampling inlets
- Connection of the compressed air generator
- Connection of the vacuum pump
- Mounting of the ambient air sensor and radiation shield (nearby the sampling inlets)
- Connection of all connecting and control lines
- Connecting the power supply
- Starting the measuring system
- Installation of the Reference foils R1 & R2
- Installation of the spy filters S12, S34 & S56
- Installation of measurement filters
- Optional: Connection of peripheral acquisition or control devices (data logger, PC, GSM modem) to the respective ports

These works (and thus setup-time) usually take approx. 1-2 hours.

Warm-up time comprises the time required from system start-up to measuring readiness.

All Status LEDs at the front side of the measuring device should be indicating green (STATUS – SERVICE – AIR – BATTERY LEVEL) and the main menu should appear after system start. The menu „Instrument setting“ allows setting all relevant sampling and measuring parameters such as the flow rate or filter impact area. Moreover, the spy filters S and the reference foils R1 and R2 must be manually placed on the rotating plate. Afterwards the next measuring cycle may be programmed *via* the “start” menu (e.g. sampling time, starting time of the measuring cycle…). When setting the starting time note that the start of the cycle needs to be set to a couple of hours after current time due to several internal measurements (dark, blank) prior to sampling. This latency period depends on the chosen sampling time. The latency period for a sampling time of 8 h comprises 6 h and 23 min after programming, the next possible starting time lies at the next quarter of an hour after the respective latency period. For a sampling time of 12 hours or more, latency period comprises 9 h and 10 minutes after programming, and the next possible starting time lies at the next quarter of an hour after the respective latency period.

Example:

Sampling time: 24 h (= ≥12 h)

Programming finished at 13:27

Hypothetical system start: 22:37 (= 13:27 + 9 h 10 min)

The next real-time system start is possible at the next quarter of an hour, i.e. at 22:45.

The system displays the next possible starting time during parameterisation. Usually, 0:00 is chosen as starting time.

Possible changes (if required) of the standard parameterisation take a few minutes if done by experienced personnel.

6.5 Assessment

The setup- and warm-up times were determined.

The measuring device can be operated at different site with reasonable effort. Setup time comprises approx. 1-2 h; warm-up time comprises approx. 6.5 h for a sampling time of 8 h or approx. 9.5 h for a sampling time of 12 h and more.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Not required for this test.

6.1 4.1.5 Instrument design

The instruction manual shall include specifications of the manufacturer regarding the design of the measuring system. The main elements are:
Instrument shape (e.g. bench mounting, rack mounting, free mounting)
Mounting position (e.g. horizontal or vertical mounting)
Safety requirements
Dimensions
Weight
Power consumption

6.2 Equipment

A measuring device for power consumption measurement and a scale were used for this test.

6.3 Carrying out the test

The installation of the delivered systems was compared with the description given in the manuals. The specified power consumption was continuously tested (24h) under standard operation conditions during field test.

6.4 Evaluation

The measuring device must be installed horizontally and protected from weather inconsistencies. Make sure that the device is mounted at a flat surface (e.g. a table). It is also possible to mount the measuring system in a 19“rack or in a measuring cabinet suited for outdoor measurement.

Weight and measures of the AMS conform to the description given in the operating manual.

The manufacturer specifies a power demand of not more than 1200 W. This was tested in a 24h testing during winter, including the power demand of the outdoor measuring cabinet with heater/climate control. The specified value was not exceeded at any time during these tests. With approx. 500 W (without heater) or approx. 1000 W (all-out-operation of heater/climate control) the average power demand of the AMS was well within the manufacturer’s specification.

6.5 Assessment

The instrument design specifications listed in the operating manual are complete and correct..

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Not required for this minimum requirement.

6.1 4.1.6 Security

The AMS shall have a means of protection against unauthorized access to control functions.

6.2 Equipment

No additional equipment required.

6.3 Carrying out the test

The AMS was operated *via* the keyboard at the front side or *via* an external computer connected *via* RS232-interface and modem. Several key sequences are necessary to change sampling parameters of the measuring device. Moreover, certain parameters can only be changed *via* external RS232-commands.

Further protection is given by mounting the AMS in secluded locations (e.g. locked measuring containers or outdoor measuring cabinets) without access for unauthorized personnel.

6.4 Evaluation

Unauthorized or unintended adjustment of device parameters is prevented by operation *via* several key sequences. In addition, certain parameters can only be changed *via* external RS232-commands.

Further protection is given by mounting the AMS in secluded site (e.g. locked measuring containers or outdoor measuring cabinets) without access for unauthorized personnel.

6.5 Assessment

The AMS is protected against unauthorized and unintended adjustment. In addition, the AMS shall be locked in a measuring container or an outdoor measuring cabinet.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Not required for this minimum requirement.

6.1 4.1.7 Data output

The output signals shall be provided digitally (e.g. RS 232) and/or as analogue signals (e.g. 4 mA to 20 mA).

6.2 Equipment

PC with Software „DR FAI Manager“, Data logging device Yokogawa (for analogue signals)

6.3 Carrying out the test

The test was carried out with the help of a electronical data logging device of the type Yokogawa (analogue output, used during laboratory test only) and a PC with the operating software “DR FAI Manager” (digital output, serial port RS232).

The data logging devices were connected to the analogue and digital output. The test was carried out by comparison of the measured values displayed by the system with the measured values recorded *via* the analogue and digital output.

6.4 Evaluation

The measured signals are provided as follows (back side of the AMS):

Analogue: 0 to 5 V Concentration range may be chosen, default: 200 µg/m³

Digital: *via* 2 x RS232-interface or 1x Modem interface
A direct connection from measuring device to PC / Dr. FAI Manager *via* direct connection (RS232-interface) or connection *via* modem allows all-out control of the AMS. Data of past measurements may be read from the memory this way, for example.

The measured values collected *via* the analogue and digital output conformed to those displayed by the AMS.

6.5 Assessment

Measured signals are offered *via* analogue (0 to 5 V) and digital (*via* RS232) ports.

Connection of further data handling and acquisition devices is possible.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Figure 37 presents the front and back side of the device with the respective data outputs.

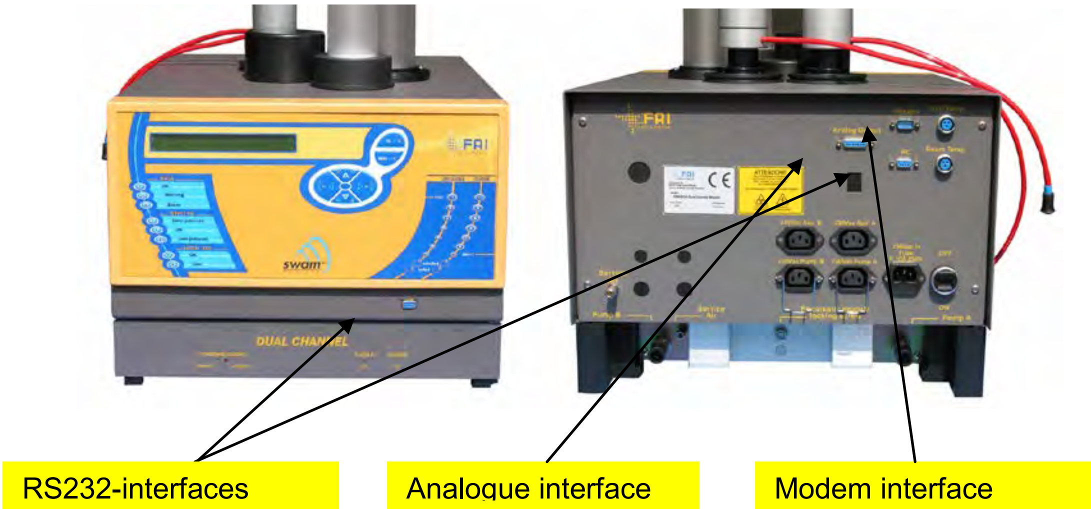


Figure 37: Front and back side of SWAM 5a Dual Channel Monitor measuring device

6.1 4.2 Requirements for mobile measuring systems

Measuring systems for mobile application shall also comply with the requirements on measuring systems for stationary application in the case of mobile application. The measuring system shall be in a permanent operational stand-by mode during mobile application, e.g. measurements in running traffic, time-limited measurements at different site or measurements on aircraft.

6.2 Equipment

No additional equipment required.

6.3 Carrying out the test

The AMS has been tested at three different sites during field test.

6.4 Evaluation

The AMS were designed for stationary mounting in a measuring station / measuring container or an outdoor measuring cabinet. Mobile use is restricted to a respective mounting possibility, which is provided by using an outdoor measuring cabinet.

Continuous availability is given even for temporary measurements in different locations as long as the mounting conditions (e.g. choice of the measuring site, infrastructure) are considered.

In addition to the mounting conditions, setup- and warm-up times must be taken into mind for mobile use.

6.5 Assessment

The AMS was operated in different site during the field test but cannot be operated in moving vehicles..

Minimum requirements fulfilled? no

6.6 Detailed representation of test results

Not required for this minimum requirement.

6.1 5.1 General

The manufacturer's specifications shall not be contrary to the results of the suitability test.

6.2 Equipment

No additional equipment required.

6.3 Carrying out the test

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

6.4 Evaluation

Found deviations between the first draft of the manual and the actual design were resolved.

6.5 Assessment

Differences between the instrument design and the descriptions given in the manual could not be detected.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

See point 6.4 of this module.

6.1 5.2.1 Measuring range

The upper limit of measurement range of the measuring systems shall be greater or equal to reference value B_2.

6.2 Equipment

No additional equipment required.

6.3 Carrying out the test

The upper limit of the measuring range was compared with reference value B_2 on equality or exceedance.

6.4 Evaluation

The theoretical upper limit of the measuring range for beta ray absorption is approx. 10 mg/cm² (calibration of the beta measurement with reference foils of up to 9.773 mg/cm² (foil F16)). This leads to a theoretical mass value of approx. 52 mg for a filter sampling surface size of 5.20 cm², which results in a dust concentration of approx. 950 µg/m³ for a 24h sampling period. A reference value of 200 µg/m³ was set by the manufacturer as parameterisation of the analogue output. Different adjustments are possible.

Measuring range: 0 to 200 µg/m³ (Standard)

Reference value: B_2 = 200 µg/m³.

6.5 Assessment

A measuring range of 0 to 200 µg/m³ is set by default.

The upper limit of the measuring range is equal to or higher than reference value B_2.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Not required for this minimum requirement.

6.1 5.2.2 Negative output signals

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

6.2 Equipment

No additional equipment required.

6.3 Carrying out the test

The AMS was tested on its ability to display negative output signals in the laboratory and in the field.

6.4 Evaluation

The AMS is able to display negative output signals for mass and concentration directly at the system display as well as *via* analogue and digital outputs.

6.5 Assessment

Negative output signals are displayed correctly by the measuring device and presented correctly by the respective measuring signal outputs.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Not required for this minimum requirement.

6.1 5.2.3 Analytical function

The relationship between the output signal and the value of the air quality characteristic shall be represented by the analytical function and determined by regression analysis.

6.2 Equipment

See module 5.3.1. (PM_{10}) or point 7.1 Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6] ($PM_{2.5}$)

6.3 Carrying out the test

The test should be carried out according to minimum requirement 5.3.1 „Equivalency of the sampling system“ for dust measuring devices for PM_{10} measurement.

For dust measuring devices for $PM_{2.5}$ measurements, the test should be carried out according to point 7.1 Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6].

6.4 Evaluation

PM_{10}:
The comparability of the measuring devices according to minimum requirement 5.3.1 „Equivalency of the sampling system“ was proved within the framework of the test (see module 5.3.1).

The complete data set (283 valid paired values) is used in order to determine the calibration or analytical function.

The characteristic data of the calibration function

$$y = m * x + b$$

was determined *via* linear regression. The analytical function is the reversed calibration function and described as follows:

$$x = 1/m * y – b/m$$

The slope m of the regression line characterizes the sensitivity of the measuring device; the ordinate intercept b characterizes zero point.

This results in the characteristic data presented in Table 8.

Table 8: Results of the calibration and analytical function, measured component PM_{10}

Device No.	Calibration function		Analytical function	
	Y = m * x + b		x = 1/m * y - b/m	
	m	B	1/m	b/m
	µg/m³ / µg/m³	µg/m³	µg/m³ / µg/m³	µg/m³
Device 1 (SN 127)	1.078	-0.119	0.928	0.110
Device 2 (SN 131)	1.053	0.213	0.950	-0.202

For $PM_{2.5}$:
The comparability of the measuring devices according to point 7.1 Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6] was proved within the framework of the test.

The entire data record (201 valid paired values) is used for determining the calibration or analytical function.

The characteristic data of the calibration function

$$y = m * x + b$$

were determined by orthogonal regression. The analytical function is the reversed calibration function and described as follows:

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

The slope m of the regression line characterizes the sensitivity of the measuring device; the ordinate intercept b characterizes zero point.

This results in the characteristic data presented in Table 9.

Table 9: Results of the calibration and analytical function, measured component $PM_{2.5}$

Device No.	Calibration function		Analytical function	
	Y = m * x + b		x = 1/m * y - b/m	
	m	B	1/m	b/m
	µg/m³ / µg/m³	µg/m³	µg/m³ / µg/m³	µg/m³
Device 1 & 2 (SN 127 & SN 131)	0.95	0.45	1.053	-0.477

6.5 Assessment

A statistically reliable correlation could be determined between the reference measuring procedure and the device display.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

See module 5.3.1. (PM_{10}) or point 7.1 Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6] ($PM_{2.5}$)

6.1 5.2.4 Linearity

Reliable linearity is given, if deviations of the group averages of measured values about the calibration function are smaller than 5 % of B_1 in the range of zero to B_1, and smaller than 1 % of B_2 in the range of zero to B_2.

6.2 Equipment

See module 5.3.1. (PM_{10}) or point 7.1 Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6] ($PM_{2.5}$)

6.3 Carrying out the test

The test should be carried out according to minimum requirement 5.3.1 „Equivalency of the sampling system“ for dust measuring devices for PM_{10} measurement.

For dust measuring devices for $PM_{2.5}$ measurement, the test should be carried out according to point 7.1 Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6].

6.4 Evaluation

See module 5.3.1. (PM_{10}) or point 7.1 Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6] ($PM_{2.5}$)

6.5 Assessment

The test should be carried out according to minimum requirement 5.3.1 „Equivalency of the sampling system“ for dust measuring devices for PM_{10} measurement.

For dust measuring devices for $PM_{2.5}$ measurements, the test should be carried out according to point 7.1 Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6].

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

See module 5.3.1. (PM_{10}) or point 7.1 Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6] ($PM_{2.5}$)

6.1 5.2.5 Detection limit

The detection limit of the measuring system shall be smaller or equal to reference value B_0. The detection limit shall be determined in the field.

6.2 Equipment

Zero filter for generating air free from suspended particulate matter.

6.3 Carrying out the test

The determination was carried out for the devices no. SN 127 and SN 131 with the help of zero filters which were installed to the inlet of each measuring device. The offerings of air free from suspended particulate matter were done over 18 days of continuous measurement (24h periods). The detection limits were determined during the laboratory tests since a dust-free air supply over 18 days was not possible under field conditions.

6.4 Evaluation

The detection limit X is determined from standard deviation s_{x0} of the measured values for both measuring devices and dust-free sampling air. It corresponds to the average value of the zero measurements after addition of the standard deviation of the average value x_0 of the measured values x_{0i} multiplied with the student factor.

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

Reference value: $B_0 = 2$ µg/m³

6.5 Assessment

A detection limit of 0.69 µg/m³ (sampling line A) and 0.77 µg/m³ (sampling line B) was determined for device 1 (SN 127), and a detection limit of 0.64 µg/m³ (sampling line A) and 0.69 µg/m³ (sampling line B) was determined for device 2 (SN 131) during the test.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Table 10: Detection limit

		Device SN 127		Device SN 131	
		Line A	Line B	Line A	Line B
No. of values n		18	18	18	18
Average of zero values $\overline{x_0}$	µg/m³	0.28	0.39	0.22	0.24
Standard deviation s_{x0}	µg/m³	0.20	0.18	0.20	0.21
Student factor $t_{n-1;0,95}$		2.11	2.11	2.11	2.11
Detection limit X	µg/m³	0.69	0.77	0.64	0.69

Appendix 1 in the annex shows the individual results of the test.

6.1 5.2.6 Response time

The response time (90%-time) of the measuring system shall be smaller or equal to 5 % of the averaging time (180 s).

According to Standard VDI Sheet 3, point 5.3, this test point is not relevant for particulate measuring systems with pre-separation, based on a physical measurement method.

6.2 Equipment

Not applicable.

6.3 Carrying out the test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of test results

Not applicable.

6.1 5.2.7 Ambient temperature dependency of zero point

The temperature dependency of the measured value at zero concentration shall not exceed the reference value B_0 if ambient temperature is changed by 15 K in the range of +5°C to +20°C or by 20 K in the range of +20°C to +40°C.

6.2 Equipment

Climate chamber adjusted to a temperature range of +5°C to +40°C, zero-filter for generating air free from suspended particulate matter.

6.3 Carrying out the test

The complete measuring systems were operated in a climate chamber in order to evaluate the dependency of zero point on ambient temperature. Both candidates SN 127 and SN 131 were supplied with dust-free sampling air by installing a HEPA-filter at the device inlet. The ambient temperatures in the climate chamber were varied according to the following sequence:

20 °C – 5 °C – 20 °C – 40 °C – 20 °C

This sequence was repeated three times.

The measured values at zero point were recorded after an equilibration time of approximately 3 h per temperature step. Relative humidity was kept constant.

6.4 Evaluation

The measured values for mass concentration of the individual measurements (8 h each) were read out and converted to concentration values related to the nominal flow rate of 24 h sampling. The absolute deviation in µg/m³ per temperature step, related to the start point of 20 °C, was considered.

Reference value: VDI: B_0 = 2 µg/m³.

6.5 Assessment

In consideration of the obtained results, the influence of ambient temperature on zero point did not exceed 0.6 µg/m³.

0.60 µg/m³ were used for SN 127 and 0.50 µg/m³ for SN 131 to calculate uncertainty for PM_{10} according to point 6.1 5.2.21 Total uncertainty.

0.40 µg/m³ were used for SN 127 and 0.60 µg/m³ for SN 131 to calculate uncertainty for $PM_{2.5}$ according to point 6.1 5.2.21 Total uncertainty.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Table 11: Ambient temperature dependency of zero point, deviation in µg/m³, average of three measurements

Temperature		Deviation			
Start temperature	End temperature	SN 127, Line A	SN 127, Line B	SN 131, Line A	SN 131, Line B
°C	°C	µg/m³	µg/m³	µg/m³	µg/m³
20	5	0.4	0.0	0.1	-0.1
5	20	0.1	0.0	-0.1	-0.1
20	40	0.6	0.4	0.5	0.6
40	20	0.3	0.0	0.2	0.0

The results of the three individual measurements are presented in Annex 2 of the annex.

6.1 5.2.8 Ambient temperature dependency of the measured value

The temperature dependency of the measured value in the range of reference value B_1 shall not exceed 5 % of the measured value if ambient temperature is changed by 15 K in the range of +5°C to +20°C or by 20 K in the range of +20°C to +40°C.

6.2 Equipment

Climate chamber adjusted to a temperature range of +5°C to +40°C, reference foils R1 & R2.

6.3 Carrying out the test

The complete measuring systems were operated in a climate chamber to evaluate the dependency of the measured values on ambient temperature. The internal procedure for stability testing of the radiometric measurement was carried out with the help of the two reference aluminium foils of known mass density which are already implemented to the device in order to realize a sensitivity test (BETA SPAN TEST).

The ambient temperatures in the climate chamber were varied in the following sequence:

20 °C – 5 °C – 20 °C – 40 °C – 20 °C

This sequence was repeated three times.

The measured values at zero point were recorded after an equilibration time of approximately 3 h per temperature step. Relative humidity was kept constant.

6.4 Evaluation

The determined mass density values of each temperature step were compared with the mass density at the beginning of the test (20 °C) and the difference was calculated in percent.

Note that it is impossible to simulate concentration values with the help of the reference foils. Therefore, a consideration in the range of B_1 (= 40 µg/m³ (PM_{10}) resp. 25 µg/m³ ($PM_{2.5}$)) was not possible.

6.5 Assessment

No deviations higher than > -1.3 % were determined for device 1 (SN 127). For device 2 (SN 131) deviations did not exceed -2.8 % of the initial value at 20 °C.

-0.57 µg/m³ (=-1.3 % of 40 µg/m³) were used for SN 127 and -1.12 µg/m³ (=-2.8 % of 40 µg/m³) for SN 131 to calculate uncertainty for PM_{10} according to point 6.1 5.2.21 Total uncertainty.

-0.33 µg/m³ (=-1.3 % of 25 µg/m³) were used for SN 127 and -0.70 µg/m³ (=-2.8 % of 25 µg/m³) for SN 131 to calculate uncertainty for $PM_{2.5}$ according to point 6.1 5.2.21 Total uncertainty.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Table 12: Ambient temperature dependency of sensitivity SN 127 & SN 131, deviation in %, average of three measurements

Temperature		Deviation			
Start temperature	End temperature	SN 127, R1	SN 127, R2	SN 131, R1	SN 131, R2
°C	°C	Nominal: 3.405 mg/cm²	Nominal: 6.810 mg/cm²	Nominal: 3.405 mg/cm²	Nominal: 6.810 mg/cm²
20	5	0.9	0.8	-1.1	-0.5
5	20	0.0	-0.1	0.0	-0.1
20	40	-1.3	-1.2	-2.8	-1.8
40	20	-0.3	-0.2	0.0	-0.1

The results of the three individual measurements are presented in appendix 3 of the annex.

6.1 5.2.9 Zero drift

The temporal change in the measured value at zero concentration shall not exceed the reference value B_0 in 24 h and in the maintenance interval.

6.2 Equipment

Zero-filter for generating air which is free from suspended particulate matter.

6.3 Carrying out the test

The field test was carried out for about 1 year in total at the test sites in Germany. A daily zero check required in the test plan takes considerably high external efforts for this particulate measuring system and thus is not reasonable. For this reason the measuring devices were operated with installed HEPA-filter either within the scope of a regular check once a month (sites Koeln and Bonn) or twice at the end of the field test (site Bruehl) for a time period of approximately 24 h and the measured zero values were recorded. In addition, the test was carried out at the site in Teddington for the systems SN 145 and SN 149.

6.4 Evaluation

Evaluation is based on the measured values obtained with the help of the zero filter. The respective values of the current measurement are compared to those of the previous and those of the first test.

6.5 Assessment

The detected values are within the allowed limits during the maintenance interval.

The measured value for SN 131, Line B, was outside the allowed tolerance on November 11th 2008. An explanation for this deviation was not found – perhaps the filter was contaminated when switching from sampling inlet to zero filter or vice versa. The effect was not observed during the subsequent testing in December 2008.

1.10 µg/m^3 were used for SN 127 and 0.90 µg/m^3 for SN 131 to calculate uncertainty for PM_{10} according to point 6.1 5.2.21 Total uncertainty.

0.80 µg/m^3 were used for SN 127 and 1.80 µg/m^3 for SN 131 to calculate uncertainty for $PM_{2.5}$ according to point 6.1 5.2.21 Total uncertainty.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Table 13 and Table 14 show the determined values for zero point and the calculated deviations in µg/m³, related to the previous value and the initial value, for the sites Koeln, Bonn and Bruehl.
Figure 38 and Figure 39 show a graphical representation of zero drift over the test period.

Furthermore, the zero values determined at the location in Teddington, UK, are listed in Table 15 and Table 16.

Table 13: Zero drift SN 127, Line A&B, Site Koeln, Bonn and Bruehl

	SN 127, Line A			SN 127, Line B		
Date	Measured value	Deviation from previous value	Deviation from initial value	Measured value	Deviation from previous value	Deviation from initial value
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
10/30/2007	0.1	-	-	0.3	-	-
12/06/2007	0.7	0.6	0.6	0.6	0.3	0.3
01/08/2008	1.1	0.4	1	0	-0.6	-0.3
02/13/2008	0.4	-0.7	0.3	0.6	0.6	0.3
03/12/2008	0.3	-0.1	0.2	0.5	-0.1	0.2
04/10/2008	1.2	0.9	1.1	0.7	0.2	0.4
11/11/2008	1.2	0	1.1	1.2	0.5	0.9
12/09/2008	1.1	-0.1	1	0.8	-0.4	0.5

Table 14: Zero drift SN 131, Line A&B, Site Koeln, Bonn and Bruehl

	SN 127, Line A			SN 127, Line B		
Date	Measured value	Deviation from previous value	Deviation from initial value	Measured value	Deviation from previous value	Deviation from initial value
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
10/30/2007	0.5	-	-	0.6	-	-
12/06/2007	0.4	-0.1	-0.1	0.7	0.1	0.1
01/08/2008	0	-0.4	-0.5	0.4	-0.3	-0.2
02/13/2008	0	0	-0.5	0.4	0	-0.2
03/12/2008	0	0	-0.5	0	-0.4	-0.6
04/10/2008	0.7	0.7	0.2	0.5	0.5	-0.1
11/11/2008	1.3	0.6	0.8	2.4	1.9	1.8
12/09/2008	0.3	-1	-0.2	0.4	-2	-0.2

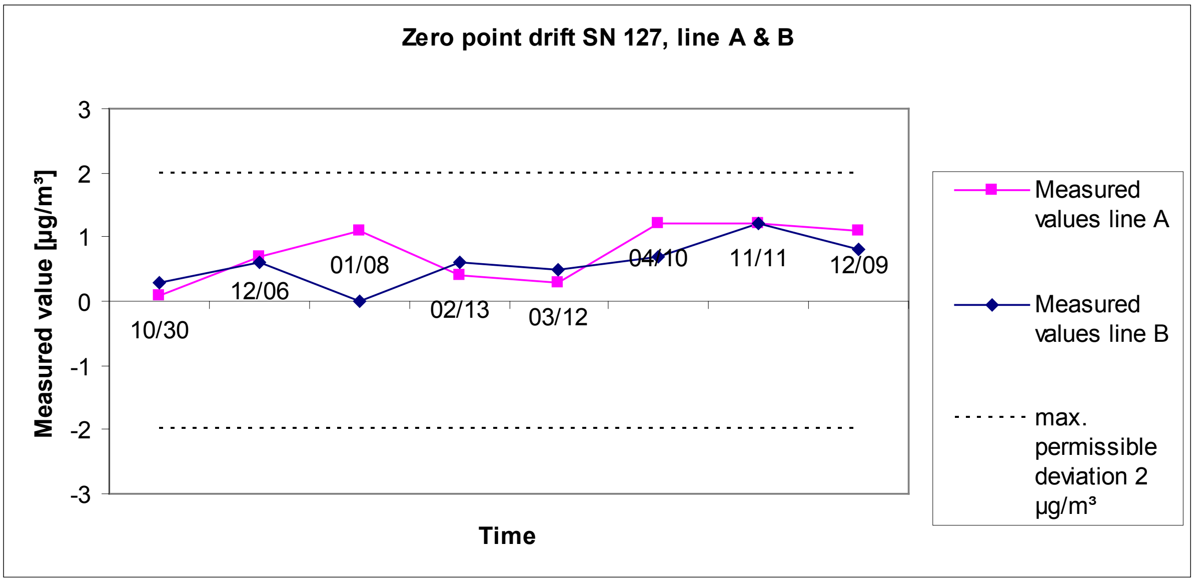


Figure 38: Zero drift SN 127, Line A & B

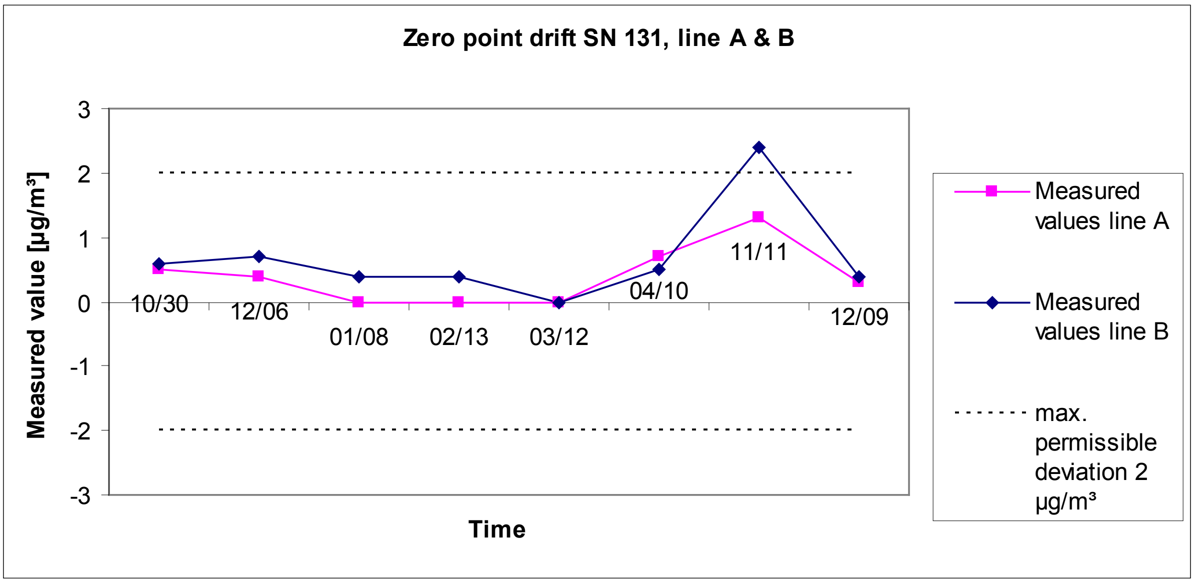


Figure 39: Zero drift SN 131, Line A & B

Table 15: Zero drift SN 145, Line A&B, Site Teddington

	SN 145, Line A			SN 145, Line B		
Date	Measured value	Deviation from previous value	Deviation from initial value	Measured value	Deviation from previous value	Deviation from initial value
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
07/24/2008	0.5	-	-	0.7	-	-
08/18/2008	0.4	-0.1	-0.1	0.3	-0.4	-0.4
09/23/2008	0	-0.4	-0.5	0.1	-0.2	-0.6

Table 16: Zero drift SN 149, Line A&B, Site Teddington

	SN 149, Line A			SN 149, Line B		
Date	Measured value	Deviation from previous value	Deviation from initial value	Measured value	Deviation from previous value	Deviation from initial value
	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
07/24/2008	0.8	-	-	0.6	-	-
08/18/2008	0.7	-0.1	-0.1	0.5	-0.1	-0.1
09/23/2008	0.5	-0.2	-0.3	0.1	-0.4	-0.5

6.1 5.2.10 Drift of the measured value

The temporal change in the measured value in the range of reference value B_1 shall not exceed 5 % of B_1 in 24 h and in the maintenance interval.

6.2 Equipment

Reference foils R1 & R2.

6.3 Carrying out the test

The field test was carried out for about 1 year in total at the sites in Germany. A sensitivity check of the radiometric measurement was performed regularly at the sites in Koeln and Bonn (nearly once a month) and twice at the end of the field testing in Bruehl. In order to realize the sensitivity test, the internal procedure for stability testing of the radiometric measurement was carried out with the help of the two reference aluminium foils of known mass density which are already implemented to the device in order to realize a sensitivity test (BETA SPAN TEST).

In addition, the test was carried out at the site in Teddington for the systems SN 145 and SN 149.

6.4 Evaluation

An evaluation of the daily drift of the measured value is impossible due to instrument specific reasons. Therefore, the percentile deviation of the determined mass density during the monthly maintenance interval as well as the percentile deviation in relation to the initial value is considered.

Note that it is impossible to simulate concentration values with the help of the reference foils. Therefore, a consideration within the range of B_1 (= 40 µg/m³) was not possible.

6.5 Assessment

The drift of the measured value did not exceed -1.1% (SN 127) resp. -1.3% (SN 131) during the maintenance interval.

-0.48 µg/m³ (=-1.2 % of 40 µg/m³) were used for SN 127 and -0.44 µg/m³ (=-1.1 % of 40 µg/m³) for SN 131 to calculate uncertainty for PM_{10} according to point 6.1 5.2.21 Total uncertainty.

-0.30 µg/m³ (=-1.2 % of 25 µg/m³) were used for SN 127 and -0.28 µg/m³ (=-1.1 % of 25 µg/m³) for SN 131 to calculate uncertainty for $PM_{2.5}$ according to point 6.1 5.2.21 Total uncertainty.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Table 17 and Table 18 show the determined values in µg/m³ and the deviations related to the previous value and the initial value in percent for the sites Koeln, Bonn and Bruehl.
Figure 40 and Figure 41 show a graphical representation of the drift of the measured value (related to the initial value) for both reference foils.

Furthermore, the measured values for the reference foils determined at the location in Teddington, UK, are listed in Table 19 and Table 20.

Table 17: Drift of the measured value SN 127, Site Koeln, Bonn and Bruehl

Date	Deviation SN 127					
	R1			R2		
	Measured value mg/cm²	Deviation from previous value %	Deviation from initial value %	Measured value mg/cm²	Deviation from previous value %	Deviation from initial value %
10/29/2007	3.477	-	-	6.864	-	-
12/06/2007	3.473	-0.1	-0.1	6.862	0.0	0.0
01/08/2008	3.474	0.0	-0.1	6.865	0.0	0.0
02/12/2008	3.487	0.4	0.3	6.890	0.4	0.4
04/10/2008	3.471	-0.5	-0.2	6.857	-0.5	-0.1
11/10/2008	3.451	-0.6	-0.7	6.784	-1.1	-1.2
12/08/2008	3.479	0.8	0.1	6.819	0.5	-0.7

Table 18: Drift of the measured value SN 127, Site Koeln, Bonn and Bruehl

Date	Deviation SN 131					
	R1			R2		
	Measured value mg/cm²	Deviation from previous value %	Deviation from initial value %	Measured value mg/cm²	Deviation from previous value %	Deviation from initial value %
10/29/2007	3.410	-	-	6.883	-	-
12/06/2007	3.400	-0.3	-0.3	6.875	-0.1	-0.1
01/08/2008	3.398	-0.1	-0.4	6.874	0.0	-0.1
02/12/2008	3.415	0.5	0.1	6.902	0.4	0.3
04/10/2008	3.372	-1.3	-1.1	6.840	-0.9	-0.6
11/10/2008	3.388	0.5	-0.6	6.863	0.3	-0.3
12/08/2008	3.383	-0.1	-0.8	6.853	-0.1	-0.4

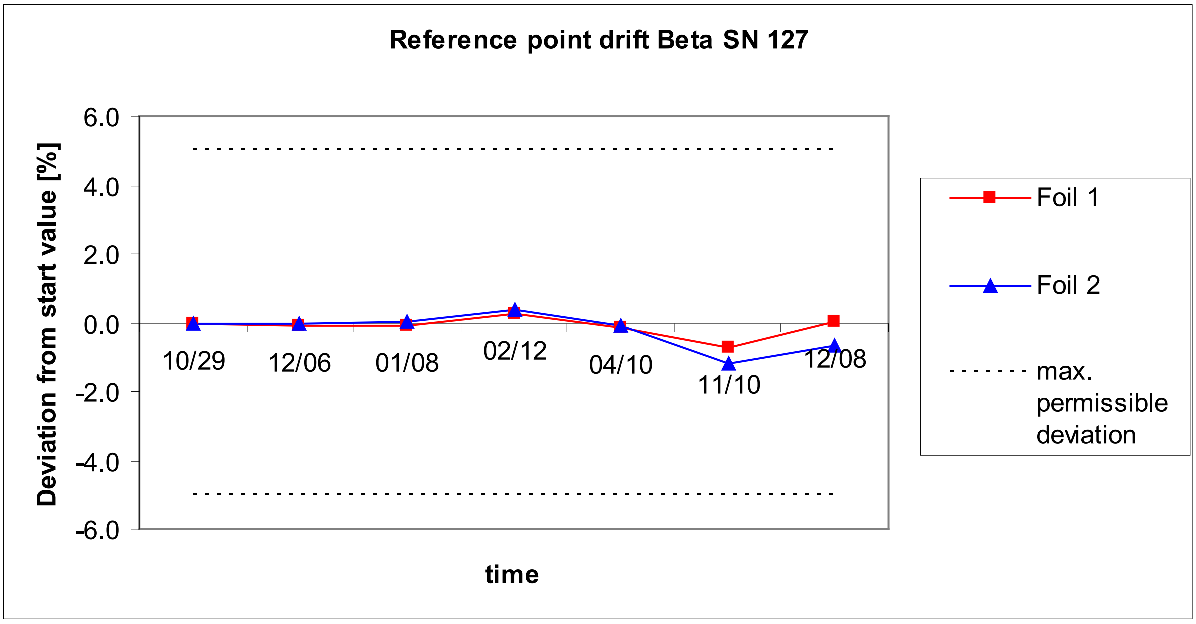


Figure 40: Drift of the measured value SN 127

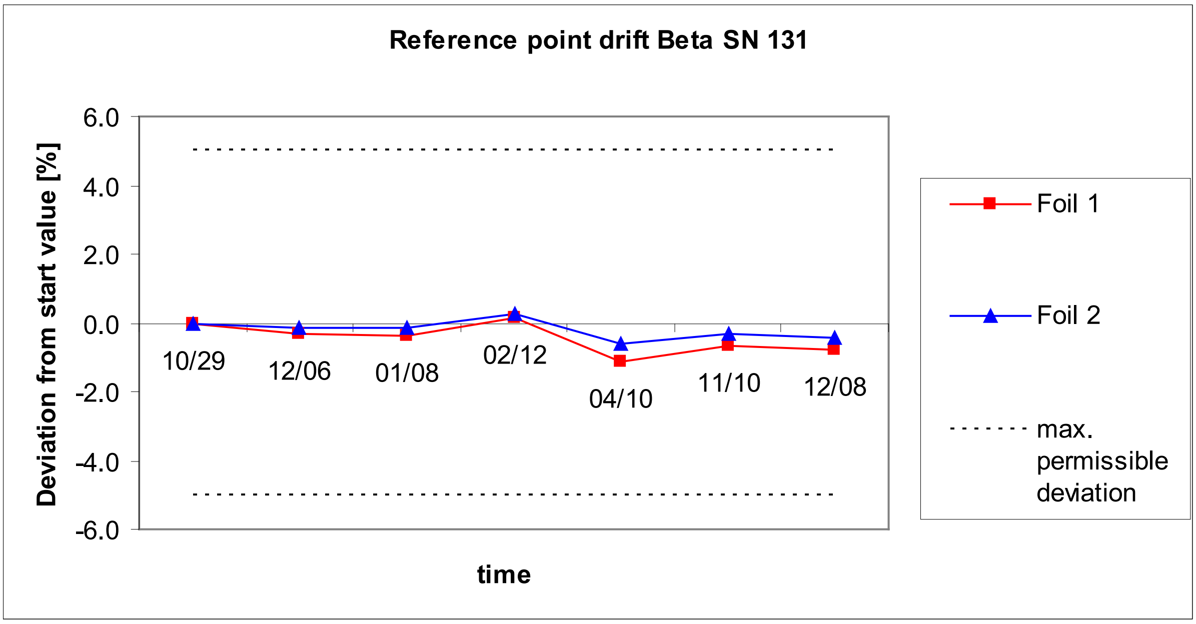


Figure 41: Drift of the measured value SN 131

Table 19: Drift of the measured value SN 145, Site Teddington

Date	Deviation SN 145					
	R1			R2		
	Measured value mg/cm²	Deviation from previous value %	Deviation from initial value %	Measured value mg/cm²	Deviation from previous value %	Deviation from initial value %
07/23/2008	3.472	-	-	6.896	-	-
08/16/2008	3.477	0.1	0.1	6.892	-0.1	-0.1
09/17/2008	3.478	0.0	0.2	6.902	0.1	0.1

Table 20: Drift of the measured value SN 149, Site Teddington

Date	Deviation SN 149					
	R1			R2		
	Measured value mg/cm²	Deviation from previous value %	Deviation from initial value %	Measured value mg/cm²	Deviation from previous value %	Deviation from initial value %
07/23/2008	3.415	-	-	6.822	-	-
08/16/2008	3.416	0.0	0.0	6.817	-0.1	-0.1
09/17/2008	3.431	0.4	0.5	6.838	0.3	0.2

6.1 5.2.11 Cross sensitivity

The absolute values of the sum of the positive and the sum of negative deviations caused by cross-sensitivities of interfering components in the measured sample shall not exceed B_0 at the zero point and shall not exceed 3 % of B_2 in the range of B_2. The concentration of interfering components shall correspond to the B_2 value of the respective interfering component. If reference values have not been specified, the test institute shall specify and declare suitable reference values in agreement with other test institutes.

This test point is not relevant for particulate measuring systems. Instead, minimum requirement 5.3.4. is essential. For this reason, the results of this test are presented in module 5.3.4.

6.2 Equipment

Not applicable.

6.3 Carrying out the test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of test results

Not applicable.

6.1 5.2.12 Reproducibility R_D

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

6.2 Equipment

The measuring devices described in chapter 5 were additionally used for this test.

6.3 Carrying out the test

Reproducibility R_D is defined as the maximum deviation of two randomly chosen single values which were obtained under equal conditions in relation to each other. This test has been carried out with two identical devices which were simultaneously operated during the field test. The measured data of the entire field testing was consulted for this test.

6.4 Evaluation

Reproducibility R_D is calculated as follows:

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

- R_D = Reproducibility R_D at B_1
- U = Uncertainty
- B_1 = 40 µg/m³ for PM_{10} and 25 µg/m³ for $PM_{2.5}$
- s_D = Standard deviation from parallel measurements
- n= No. of parallel measurements
- $t_{(n;0,95)}$ = Student factor for 95% certainty
- x_{1i} = Measured signal of device 1 (e.g. SN 127) at i^{th} concentration
- x_{2i} = Measured signal of device 2 (e.g. SN 131) at i^{th} concentration

.

6.5 Assessment

Reproducibility R_D in the field was at minimum 23 for PM_{10} and at minimum 19 for $PM_{2.5}$.

Minimum requirement fulfilled? yes

A value of 32 (all sites) was used to calculate uncertainty for PM_{10} according to point 6.1 5.2.21 Total uncertainty.

A value of 23 (all sites) was used to calculate uncertainty for $PM_{2.5}$ according to point 6.1 5.2.21 Total uncertainty.

6.6 Detailed representation of test results

Table 21 and Table 22 summarize the results of the test. Figure 52 to Figure 56 show a graphical representation of the test results.

Note: The determined uncertainties of each site are related to the reference value B_1.

Table 21: Concentration averages, standard deviation, uncertainty range and reproducibility R_D in the field, measured component PM_{10}

Site	No.	$\bar{c}$ (SN 127)	$\bar{c}$ (SN 131)	$\bar{c}_{ges}$	s_D	t	U	R_D
		µg/m³	µg/m³	µg/m³	µg/m³		µg/m³	
Koeln, Parking lot	100	24.8	24.4	24.6	0.87	1.984	1.72	23
Bonn, Belder-berg	64	26.1	25.8	26.0	0.43	1.998	0.87	46
Teddington*	83	18.0	17.8	17.9	0.50	1.989	0.99	41
Bruehl	55	20.3	20.3	20.3	0.50	2.004	1.01	40
All sites	302	22.4	22.2	22.3	0.64	1.968	1.25	**32**

* Site Teddington with SN 145 vs. SN 149

Table 22: Concentration averages, standard deviation, uncertainty range and reproducibility R_D in the field, measured component $PM_{2.5}$

Site	No.	$\bar{c}$ (SN 127)	$\bar{c}$ (SN 131)	$\bar{c}_{ges}$	s_D	t	U	R_D
		µg/m³	µg/m³	µg/m³	µg/m³		µg/m³	
Koeln, Parking lot	100	17.3	16.9	17.1	0.64	1.984	1.35	19
Bonn, Belder-berg	64	17.1	16.8	17.0	0.40	1.998	0.79	32
Teddington*	83	10.8	11.0	10.9	0.42	1.989	0.83	30
Bruehl	55	12.8	12.7	12.8	0.60	2.004	1.21	21
All sites	302	14.6	14.5	14.6	0.55	1.968	1.07	**23**

* Site Teddington with SN 145 vs. SN 149

- $\bar{c}$ (SN 127): concentration averages device SN 127
- $\bar{c}$ (SN 131): concentration averages device SN 131
- $\bar{c}_{ges}$: concentration averages of the devices SN 127 & SN 131

The results of the individual measurements are presented in appendix 5 of the annex.

6.1 5.2.13 Hourly mean values

The measurement method shall allow formation of hourly mean values.

6.2 Equipment

Not required for this minimum requirement.

6.3 Carrying out the test

The measuring systems were tested on the formation of hourly mean values.

6.4 Evaluation

According to the valid Directive [1], the limits for particulate matter PM_x are related to an averaging time of at least 24 hours. Hence, formation of hourly mean values is not required for measuring systems for monitoring the respective limits. The devices usually deliver one measured value per day under standard operating conditions. The minimum possible averaging time is 8 hours.

6.5 Assessment

Formation of hourly mean values is not required for the components particulate matter PM_{10} and $PM_{2.5}$ for monitoring the respective limits.

Minimum requirement fulfilled? -

6.6 Detailed representation of test results

Not required for this minimum requirement.

6.1 5.2.14 Mains voltage and frequency

The change in the measured values at reference value B_1 caused by normal changes in the mains voltage in the interval (230 +15/-20) V shall not exceed B_0. In addition, for mobile applications the change in the measured value caused by changes in frequency of the mains voltage in the interval (50 ± 2) Hz shall not exceed B_0.

6.2 Equipment

Variable isolating transformer, reference foils R1 & R2.

6.3 Carrying out the test

To evaluate the dependency of the measured signal, the mains voltage was reduced from 230 V to 210 V and afterwards increased to 245 V *via* the intermediate stage of 230 V.

The internal procedure for stability testing of the radiometric measurement was carried out with the help of the two reference aluminium foils of known mass density which are already implemented to the device in order to realize a sensitivity test (BETA SPAN TEST).

Since the measuring system is not intended for mobile use, an additional test on the dependency of the measured signal on frequency was omitted.

6.4 Evaluation

The percentile change of the determined mass density value at span point was considered in relation to the starting point at 230 V for each test step.

Note that it is impossible to simulate concentration values with the help of the reference foils. Therefore, a consideration within the range of B_1 (= 40 µg/m³) was not possible.

6.5 Assessment

The assessment of the minimum requirements was based on the statements above.

No significant deviations caused by frequency changes could be detected at the tested span points.

A value of -0.08 µg/m³ (=-0.2 % of 40 µg/m³) was used for SN 127 and 0.04 µg/m³ (=0.1 % of 40 µg/m³) for SN 131 to calculate uncertainty for PM_{10} according to point 6.1 5.2.21 Total uncertainty.

A value of -0.05 µg/m³ (=-0.2 % of 25 µg/m³) was used for SN 127 and 0.03 µg/m³ (=0.1 % of 25 µg/m³) for SN 131 to calculate uncertainty for $PM_{2.5}$ according to point 6.1 5.2.21 Total uncertainty.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Table 23 and Table 24 show a summary of the test results.

Table 23: Dependency of the measured value (Radiometry) on the mains voltage, Deviation in %, SN 127

Mains voltage		Deviations Radiometry Device 1 (SN 127)	
Start voltage	End voltage	R1	R2
V	V	%	%
230	210	-0.1	0.0
210	230	-0.1	0.0
230	245	-0.2	-0.1
245	230	-0.2	-0.1

Table 24: Dependency of the measured value (Radiometry) on the mains voltage, Deviation in %, SN 131

Mains voltage		Deviations Radiometry Device 2 (SN 131)	
Start voltage	End voltage	R1	R2
V	V	%	%
230	210	0.1	0.1
210	230	0.1	0.1
230	245	0.1	0.1
245	230	0.1	0.0

The results of the individual measurements are presented in appendix 4 of the annex.

6.1 5.2.15 Power outage

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

6.2 Equipment

Not required for this minimum requirement.

6.3 Carrying out the test

A power outage was simulated in order to determine whether the device will remain intact and is ready for measurement as soon as the mains voltage returns.

6.4 Evaluation

Uncontrolled gas emission is not possible as the devices neither need operation nor calibration gases.

All instrument parameters are protected against loss by buffering.

The AMS comprises two rechargeable floating batteries in case of power outages. Hence, the AMS is able to finish any beta-measurement in progress and allows smooth resumption of operation according to the adjusted cycle conditions.

In case of a power outage:

- Stop of current sampling (Pump switches off),
- Status check of batteries (charge condition, remaining time),
- Beta measurements in progress are finished (if enough battery capacity is available),
- Adjustment of ideal mechanical conditions for correct resumption of sampling and measurement after return of the mains voltage,
- Auto-switch-off of the AMS until the mains voltage returns after establishing the ideal mechanical configuration

Outage times due to power outage are saved in the memory for the respective measurements.

6.5 Assessment

All instrument parameters are protected against loss by buffering.
The measuring system is undamaged and ready for operation as soon as the mains voltage returns and independently continues measuring.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Not required for this minimum requirement.

6.1 5.2.16 Operating states

Measuring systems shall be able to telemetrically transmit important operating states by status signals.

6.2 Equipment

Modem, PC & software „DR FAI Manager“, hyper terminal.

6.3 Carrying out the test

A modem was connected to the measuring device. The status signals were recorded by data transfer (*et al.*).

The possible access to the measuring devices *via* Operating Software DR FAI Manager and *via* hyper terminal was tested.

6.4 Evaluation

The measuring system allows extensive telemetric control. For once, the system provides a number of reading, writing and control commands. A full list of commands can be found in the manual. On the other hand, the current system status can be monitored *via* the operating software DR FAI Manager, which also allows reading out stored data as a text file (see section 3.3 AMS scope and layout, Figure 10 to Figure 16).

6.5 Assessment

The measuring devices allow an extensive control *via* external PC and modem which is comparable to direct operation.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Not required for this minimum requirement.

6.1 5.2.17 Switchover

Switchover between measurement and functional check and/or calibration shall be possible telemetrically by computer control or manual intervention.

6.2 Equipment

Not required for this minimum requirement.

6.3 Carrying out the test

The measuring device allows direct operation and, likewise, operation *via* telemetric remote control.

6.4 Evaluation

All operating procedures can be accessed directly *via* the device and likewise *via* telemetric remote control. However, if external reference foils must be placed in the device (e.g. for mass measurement calibration), direct access by the operator is inevitable.

6.5 Assessment

Basically all activities for function control and calibration may be performed either by direct access or by telemetric remote control *via* external PC and modem.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Not required for this minimum requirement.

6.1 5.2.18 Availability

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

6.2 Equipment

Not required for this minimum requirement.

6.3 Carrying out the test

Starting time and ending time of the availability tests were defined by the start and end of the field tests at each site. All measurement interruptions, e.g. due to system outage or maintenance works, were considered for this test.

Two identical sets of the measuring system were used for this test:

- SN 127 & SN 131 at the field test sites in Koeln, Bonn and Bruehl

- SN 145 & SN 145 at the field test site in Teddington

Total availability thus was determined separately for the different sets.

6.4 Evaluation

a) SN 127 & SN 131 at the field test sites in Koeln, Bonn and Bruehl

Table 25 and Table 26 show an overview on the operating, maintenance and outage times at the sites in Koeln, Bonn and Bruehl. The measuring devices were operated for a period of 245 days during the field test. Outages caused by external influences which cannot be blamed on the devices were detected on November 28th and 29th, 2007 (changeover from summer time to winter time), on January 6th and 7th, 2008 (empty filter supply) on March 26th and 27th, 2008 (changeover from winter time to summer time), on November 3rd and 4th, 2008 (empty filter supply) and from November 6th to November 10th, 2008 due to an exchange of the TÜV measuring station. Hence, total operating time is reduced to 232 days.

Regular zero point checks within the scope of the drift tests led to seven more days of outage time in total.

Maintenance works were limited mainly to the cleaning of the sampling inlets (13 times), and additionally to flow rate control and tightness check during the field test (3 times in total). These works did not take more than 1 hour each (performed 16 times in total during the suitability test) which did not lead to necessary rejection of the respective daily mean value.

The measured values of device SN 127 from November 22nd and 23rd, 2007 had to be rejected due to water penetration.

A cable break at the rotary arm of the beta measurement caused an outage of device SN 131 from October 19th to 23rd, 2008. To avoid such outages in the future, the cable was exchanged by a more robust cable and was fixed to a better place within the system.

No other outages were detected.

b) SN 145 & SN 149 at the field test site in Teddington

Table 27 and Table 28 show an overview on the operating, maintenance and outage times at the site in Teddington. The measuring devices were operated for a period of 91 days during the field test. Outages caused by external influences which cannot be blamed on the devices were detected on August 6th, 2008 due to power outage. Hence, total operating time was reduced to 90 days.

Regular zero point checks within the scope of the drift tests led to three more days of outage time in total.

Maintenance works were limited mainly to the cleaning of the sampling inlets (7 times), and additionally to flow rate control and tightness check during the field test site (one time in total). These works did not take more than 1 hour each (performed 8 times in total during the suitability test) which did not lead to necessary rejection of the respective daily mean value.

An outage of device SN 145 was detected on August 27th to 29th, 2008 due to a defective sensor used for the positioning of the cover of the beta source. The defective sensor was replaced by the company service of FAI Instruments s.r.l.

No other outages were detected.

6.5 Assessment

At the field test sites in Koeln, Bonn and Bruehl, availability amounts 98.9% for device SN 127 and 97.6% for device SN 131 without test-related outage times. Those included availability amounts 95.8% for device SN 127 and 94.5% for device SN 131.

At the field test site in Teddington, availability amounts to 96.3% for device SN 145 and 99.6% for device SN 149 without test-related outage times. Those included availability amounts 93.0% for device SN 145 and 96.3% for device SN 149.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Table 25: Determination of availability (without test-related outages), Sites Koeln, Bonn and Bruehl

		Device 1 (SN 127)	Device 2 (SN 131)
Operating time	h	5568	5568
Outage time	h	48	120
Maintenance	h	16	16
Actual operating time	h	5504	5432
Availability	%	98.9	97.6

Table 26: Determination of availability (including test-related outages), Sites Koeln, Bonn and Bruehl

		Device 1 (SN 127)	Device 2 (SN 131)
Operating time	h	5568	5568
Outage time	h	48	120
Regular zero check	h	168	168
Maintenance	h	16	16
Actual operating time	h	5336	5264
Availability	%	95.8	94.5

Table 27: Determination of availability (without test-related outages), Site Teddington

		Device 1 (SN 145)	Device 2 (SN 149)
Operating time	h	2160	2160
Outage time	h	72	-
Maintenance	h	8	8
Actual operating time	h	2080	2152
Availability	%	96.3	99.6

Table 28: Determination of availability (including test-related outages), Site Teddington

		Device 1 (SN 145)	Device 2 (SN 149)
Operating time	h	2160	2160
Outage time	h	72	-
Regular zero check	h	72	72
Maintenance	h	8	8
Actual operating time	h	2008	2080
Availability	%	93.0	96.3

6.1 5.2.19 Converter efficiency

In case of measuring systems with a converter, the efficiency of the converter shall be at least 95 %.

According to Standard VDI Sheet 3, point 5.3, this test point is not relevant for particulate measuring systems with pre-separation, based on a physical measurement method for mass determination.

6.2 Equipment

Not applicable.

6.3 Carrying out the test

Not applicable.

6.4 Evaluation

Not applicable.

6.5 Assessment

Not applicable.

Minimum requirement fulfilled? -

6.6 Detailed representation of test results

Not applicable.

6.1 5.2.20 Maintenance interval

The maintenance interval of the measuring system shall be determined and specified. The maintenance interval should be 28 days, if possible, but at least 14 days.

6.2 Equipment

Not required for this minimum requirement.

6.3 Carrying out the test

This test was done in order to determine which maintenance works are required at which period to maintain correct functionality of the measuring system. Moreover, the results of the drift test for zero and span point according to module 5.2.9 and module 5.2.10 were included into the determination of the maintenance interval.

6.4 Evaluation

No unacceptable drifts were detected for the measuring devices during the entire field test period.

Therefore, the maintenance interval is determined by upcoming maintenance works (see module 4.1.2).

The measuring system comprises a supply of 36 filters. Thus, a maximum operating time of 18 days and 24h sampling cycles is possible. A regular filter exchange combined with cleaning the sampling inlets is recommended every 14 days.

During operation, the maintenance works can be limited to contamination, plausibility and status / error message checks.

6.5 Assessment

The maintenance interval is defined by necessary maintenance works (filter exchange / cleaning of the sampling inlets) and should be done every 2nd week.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Necessary maintenance works can be found in module 4.1.2 of this report and in chapter 8 of the operating manual.

6.1 5.2.21 Total uncertainty

The expanded uncertainty of the measuring system shall be determined. The value determined shall not exceed the corresponding data quality objectives in the EU Daughter Standards on air quality [G11 to G13].

6.2 Equipment

Not required for this minimum requirement.

6.3 Carrying out the test

The expanded total uncertainty of the AMS was determined for individual concentration values within the short time ambient air limit range and average concentration values within the long time ambient air limit range. The determined parameters of the measuring devices were compiled.

The following reference values were set:

Short time ambient air limit value:

PM_{10} 50 µg/m³

$PM_{2.5}$ 35 µg/m³ (Source: EN 14907, pt 9.4 in consideration of Table 2)

Long time ambient air limit value:

PM_{10} 40 µg/m³

$PM_{2.5}$ 25 µg/m³

6.4 Evaluation

The expanded total uncertainty of the measuring system was determined according to VDI Standard 4202, sheet 1, annex C [2].

6.5 Assessment

The individual uncertainties of each test parameter were included in the calculation of the expanded total uncertainty. The worst result as taken in case more than one individual result was available

For PM_{10}, the determined total uncertainties were 6.83 % (6.57 %) for U(c) and 7.22 % (7.16 %) for $U(\bar{c})$. For $PM_{2.5}$, the determined total uncertainties were 7.44 % (9.40 %) for U(c) and 6.77 % (7.75 %) for $U(\bar{c})$.

Table 29 to Table 36 show the individual values. All calculated values are below the required total uncertainties of 25%.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Table 29: Expanded measurement uncertainty U(c) for device SN 127, PM_{10}, reference value: 50 µg/m³

Performance characteristics for device SN 127	**Requirement**	**Result**		**Uncertainty u**	**Square of Uncertainty u²**
				µg/m³	(µg/m³)²
Reproducibility R_D	≥ 10	32		0.63	0.39
Confidance interval CI95 according to EN 12341	≤ 5 µg/m³	1.27	µg/m³	0.73	0.54
Temperature dependence at zero point	≤ 2 µg/m³	0.60	µg/m³	0.35	0.12
Temperature dependence at measured values (Beta)	≤ 5 % von B1	-0.52	µg/m³	-0.30	0.09
Drift at zero point	≤ 2 µg/m³	1.10	µg/m³	0.64	0.40
Drift at measured values (Beta)	≤ 5 % von B1	-0.48	µg/m³	-0.28	0.08
Mains voltage (measured value Beta)	≤ 2 µg/m³	-0.08	µg/m³	-0.05	0.00
Cross-sensitivities	≤ 4 µg/m³	1.70	µg/m³	0.98	0.96
Uncertainty of test standard	≤ 1 µg/m³	1.00	µg/m³	0.58	0.33
				Σu²	2.92
				U(c) = 2u(c)	3.42
				U(c) / Ref.	6.83

Table 30: Expanded measurement uncertainty U(c) for device SN 131, PM_{10}, reference value: 50 µg/m³

Performance characteristics for device SN 131	**Requirement**	**Result**		**Uncertainty u**	**Square of Uncertainty u²**
				µg/m³	(µg/m³)²
Reproducibility R_D	≥ 10	32		0.63	0.39
Confidance interval CI95 according to EN 12341	≤ 5 µg/m³	1.27	µg/m³	0.73	0.54
Temperature dependence at zero point	≤ 2 µg/m³	0.50	µg/m³	0.29	0.08
Temperature dependence at measured values (Beta)	≤ 5 % von B1	-1.12	µg/m³	-0.65	0.42
Drift at zero point	≤ 2 µg/m³	0.80	µg/m³	0.46	0.21
Drift at measured values (Beta)	≤ 5 % von B1	-0.44	µg/m³	-0.25	0.06
Mains voltage (measured value Beta)	≤ 2 µg/m³	0.04	µg/m³	0.02	0.00
Cross-sensitivities	≤ 4 µg/m³	1.40	µg/m³	0.81	0.65
Uncertainty of test standard	≤ 1 µg/m³	1.00	µg/m³	0.58	0.33
				Σu²	2.69
				U(c) = 2u(c)	3.28
				U(c) / Ref.	6.57

Table 31: Expanded measurement uncertainty U(c) for device SN 127, PM_{10}, reference value: 40 µg/m³

Performance characteristics for device SN 127	**Uncertainty (single value)**	**Time basis**	**Number nk**	**Square of uncertainty (mean value)**
				(µg/m³)²
Reproducibility R_D	0.63	24 h	365	0.001
Confidance interval CI95 according to EN 12341	0.73	1 year	1	0.538
Temperature dependence at zero point	0.35	1 year	1	0.120
Temperature dependence at measured values (Beta)	-0.30	1 year	1	0.090
Drift at zero point	0.64	1 month	12	0.034
Drift at measured values (Beta)	-0.28	1 month	12	0.006
Mains voltage (measured value Beta)	-0.05	1 year	1	0.002
Cross-sensitivities	0.98	1 year	1	0.963
Uncertainty of test standard	0.58	1 year	1	0.333
			$\Sigma u_m^2(c_k)$	2.088
			$U(\bar{c}) = 2u(\bar{c})$	2.89
			$\frac{U(\bar{c})}{Ref.}$	7.22

Table 32: Expanded measurement uncertainty U(c) for device SN 131, PM_{10}, reference value: 40 µg/m³

Performance characteristics for device SN 131	**Uncertainty (single value)**	**Time basis**	**Number nk**	**Square of uncertainty (mean value)**
				(µg/m³)²
Reproducibility R_D	0.63	24 h	365	0.001
Confidance interval CI95 according to EN 12341	0.73	1 year	1	0.538
Temperature dependence at zero point	0.29	1 year	1	0.083
Temperature dependence at measured values (Beta)	-0.65	1 year	1	0.418
Drift at zero point	0.46	1 month	12	0.018
Drift at measured values (Beta)	-0.25	1 month	12	0.005
Mains voltage (measured value Beta)	0.02	1 year	1	0.001
Cross-sensitivities	0.81	1 year	1	0.653
Uncertainty of test standard	0.58	1 year	1	0.333
			$\Sigma u_m^2(c_k)$	2.051
			$U(\bar{c}) = 2u(\bar{c})$	2.86
			$\frac{U(\bar{c})}{Ref.}$	7.16

Table 33: Expanded measurement uncertainty U(c) for device SN 127, $PM_{2.5}$, reference value: 35 µg/m³

Performance characteristics for device SN 127	**Requirement**	**Result**		**Uncertainty u**	**Square of Uncertainty u²**
				µg/m³	(µg/m³)²
Reproducibility R_D	≥ 10	23		0.87	0.76
In-between uncertainty u_{Bs} according to guide	≤ 3 µg/m³	0.57	µg/m³	0.33	0.11
Temperature dependence at zero point	≤ 2 µg/m³	0.40	µg/m³	0.23	0.05
Temperature dependence at measured values (Beta) (	≤ 5 % von B1	-0.33	µg/m³	-0.19	0.04
Drift at zero point	≤ 2 µg/m³	0.90	µg/m³	0.52	0.27
Drift at measured values (Beta)	≤ 5 % von B1	-0.30	µg/m³	-0.17	0.03
Mains voltage (measured value Beta)	≤ 2 µg/m³	-0.05	µg/m³	-0.03	0.00
Cross-sensitivities	≤ 2,5 µg/m³	-0.70	µg/m³	-0.40	0.16
Uncertainty of test standard	≤ 1 µg/m³	1.0	µg/m³	0.58	0.33
				Σu²	1.75
				U(c) = 2u(c)	2.65
				U(c) / Ref.	7.56

Table 34: Expanded measurement uncertainty U(c) for device SN 131, $PM_{2.5}$, reference value: 35 µg/m³

Performance characteristics for device SN 131	**Requirement**	**Result**		**Uncertainty u**	**Square of Uncertainty u²**
				µg/m³	(µg/m³)²
Reproducibility R_D	≥ 10	23		0.87	0.76
In-between uncertainty u_{Bs} according to guide	≤ 3 µg/m³	0.57	µg/m³	0.33	0.11
Temperature dependence at zero point	≤ 2 µg/m³	0.60	µg/m³	0.35	0.12
Temperature dependence at measured values (Beta) (	≤ 5 % von B1	-0.70	µg/m³	-0.40	0.16
Drift at zero point	≤ 2 µg/m³	1.80	µg/m³	1.04	1.08
Drift at measured values (Beta)	≤ 5 % von B1	-0.28	µg/m³	-0.16	0.03
Mains voltage (measured value Beta)	≤ 2 µg/m³	0.03	µg/m³	0.02	0.00
Cross-sensitivities	≤ 2,5 µg/m³	-0.60	µg/m³	-0.35	0.12
Uncertainty of test standard	≤ 1 µg/m³	1.00	µg/m³	0.58	0.33
				Σu²	2.71
				U(c) = 2u(c)	3.29
				U(c) / Ref.	9.40

Table 35: Expanded measurement uncertainty U(c) for device SN 127, $PM_{2.5}$, reference value: 25 µg/m³

Performance characteristics for device SN 127	**Uncertainty (single value)**	**Time basis**	**Number nk**	**Square of uncertainty (mean value)**
				(µg/m³)²
Reproducibility R_D	0.87	24 h	365	0.002
In-between uncertainty u_{Bs} according to guide	0.33	1 year	1	0.108
Temperature dependence at zero point	0.23	1 year	1	0.053
Temperature dependence at measured value (Beta)	-0.19	1 year	1	0.035
Drift at zero point	0.52	1 month	12	0.023
Drift at measured values (Beta)	-0.17	1 month	12	0.003
Mains voltage (measured value Beta)	-0.03	1 year	1	0.001
Cross-sensitivities	-0.40	1 year	1	0.163
Uncertainty of test standard	0.58	1 year	1	0.333
			$\Sigma u_m^2(c_k)$	0.721
			$U(\bar{c}) = 2u(\bar{c})$	1.70
			$\frac{U(\bar{c})}{Ref.}$	6.79

Table 36: Expanded measurement uncertainty U(c) for device SN 131, $PM_{2.5}$, reference value: 25 µg/m³

Performance characteristics for device SN 131	**Uncertainty (single value)**	**Time basis**	**Number nk**	**Square of uncertainty (mean value)**
				(µg/m³)²
Reproducibility R_D	0.87	24 h	365	0.002
In-between uncertainty u_{Bs} according to guide	0.33	1 year	1	0.108
Temperature dependence at zero point	0.35	1 year	1	0.120
Temperature dependence at measured values (Beta)	-0.40	1 year	1	0.163
Drift at zero point	1.04	1 month	12	0.090
Drift at measured values (Beta)	-0.16	1 month	12	0.002
Mains voltage (measured value Beta)	0.02	1 year	1	0.000
Cross-sensitivities	-0.35	1 year	1	0.120
Uncertainty of test standard	0.58	1 year	1	0.333
			$\Sigma u_m^2(c_k)$	0.939
			$U(\bar{c}) = 2u(\bar{c})$	1.94
			$\frac{U(\bar{c})}{Ref.}$	7.75

6.1 5.3.1 Equivalency of the sampling system

The equivalency between the PM_{10} sampling system and the reference method according to DIN EN 12 341 [T5] shall be demonstrated.

This test is not applicable for $PM_{2.5}$ sampling systems (see point 7 of this report.)

6.2 Equipment

The devices mentioned in section 5 of this report have been additionally used for this test.

6.3 Carrying out the test

The test has been performed at several sites during the field test (see point 4 of this report). Meteorological differences due to season, varying PM_{10} concentrations and different ratios between the concentration of TSP and PM_{10} were considered for evaluation.

At least 15 valid paired values were determined for each site.

6.4 Evaluation

Requirement of EN 12341

The calculated functional relationship y = f(x) between concentration values measured with the candidate sampler (y) and concentration values measured with the reference sampler (x) has to be limited by a two-sided acceptance range. This acceptance range is given by:

y = (x ± 10) µg/m³ for concentration averages ≤ 100 µg/m³ and

y = 0.9x µg/m³ respectively 1.1x µg/m³ for concentration averages > 100 µg/m³

Moreover, the variance coefficient R^2 of the calculated reference-equivalence-function shall be at least 0.95.

The test procedure focuses on the functional relationship between the concentration values which were determined through double measurements with candidate and reference sampler. Ideally both instruments sample the same fraction of suspended particulate matter which leads to the relation y = x. The evaluation process is as follows:

A linear regression analysis based on the measured values was done for every single test site and, after merging the overall measured data, for all four test sites together.

One receives for every measurement value y_i of the candidate sampler i and the concentration x, measured with the reference sampler – both in µg/m³ - a reference-equivalence-function according to the general relation:

$$y_i = m \cdot x + b$$ with i = candidate SWAM 5a DC

6.5 Assessment

The reference-equivalence-functions are within the limits of the respective acceptance range. Furthermore, the variation coefficient R^2 of the calculated reference-equivalence-functions for the respective concentration range is equal to 0.95 or higher.

Minimum requirement fulfilled? yes

Within the scope of the suitability testing we found occasionally high deviations between the results obtained for PM_{10} with the candidates and the reference equipment, especially at days with high amounts of dust. The cause of this significantly differing separation behaviour of the reference equipment in comparison with the candidates was found in the different design of the sampling inlets (impactor nozzle). Section 5 of this report describes the root-cause-analysis of the problem at hand and the assessment on these deviations in detail. All measured values are listed in Annex 2.

6.6 Detailed representation of test results

Table 37 and Table 38 list the results of the regression analysis. Figure 42 to Figure 51 show a graphical representation of the results. Next to the regression line, the diagrams show an image of the ideal curve and of the two-sided acceptance range. All individual values for the candidates as well as the reference devices are listed in appendix 5 of the annex.

Table 37: Results of the linear regression analysis of the measurements with both candidates (SN 127 & SN 131) at all four sites

SN 127	No. of paired values N	Slope m	Ordinate intercept b	R^2
Koeln	98	1.12	-0.17	0.987
Bonn	62	1.11	-0.78	0.977
Teddington*	72	0.94	2.92	0.962
Bruehl	51	1.03	-1.65	0.966
SN 131	**No. of paired values N**	**Slope m**	**Ordinate intercept b**	**R^2**
Koeln	98	1.07	0.52	0.988
Bonn	62	1.10	-0.71	0.979
Teddington*	72	0.96	2.39	0.962
Bruehl	51	1.03	-1.54	0.968

* SN 145 & SN 149

Table 38: Results of the linear regression analysis of the measurements with both candidates (SN 127 & SN 131 / Teddington: SN 145 & SN 149) (total)

Device under test	No. of paired values N	Slope m	Ordinate intercept b	R^2
SN 127 (SN 145)	283	1.08	-0.12	0.969
SN 131 (SN 149)	283	1.05	0.21	0.973

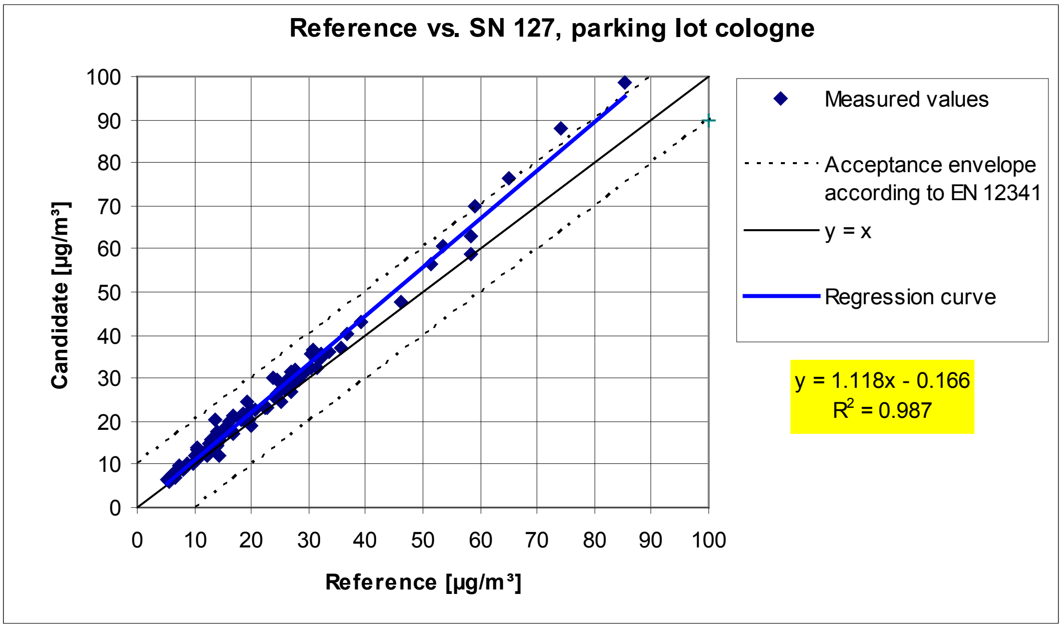


Figure 42: Reference- equivalence-function SN 127, PM_{10}, Site Koeln, Parking lot

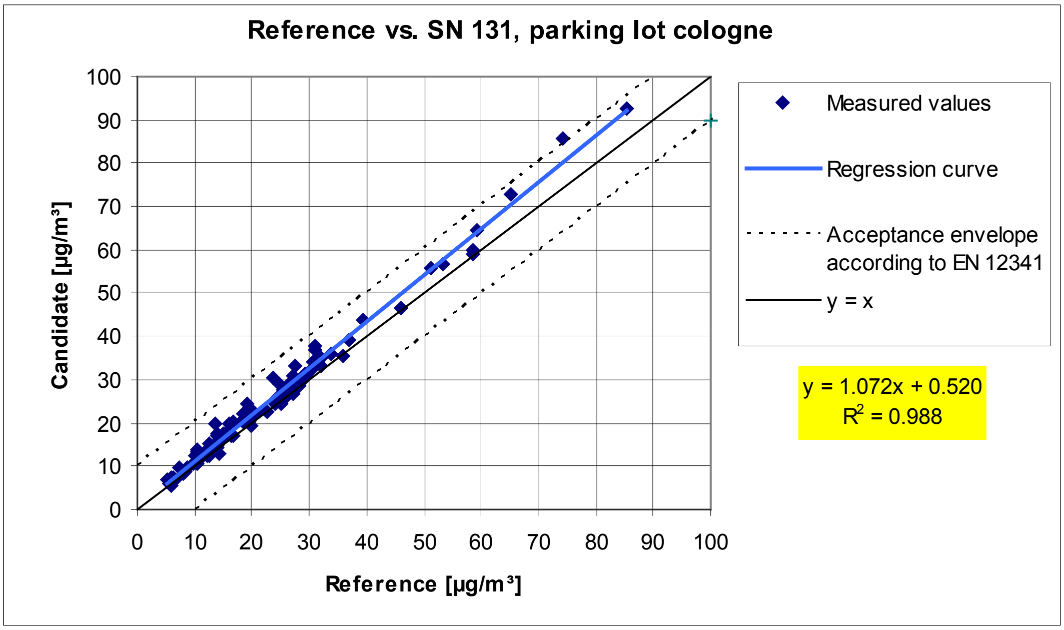


Figure 43: Reference- equivalence-function SN 131, PM_{10}, Site Koeln, Parking lot

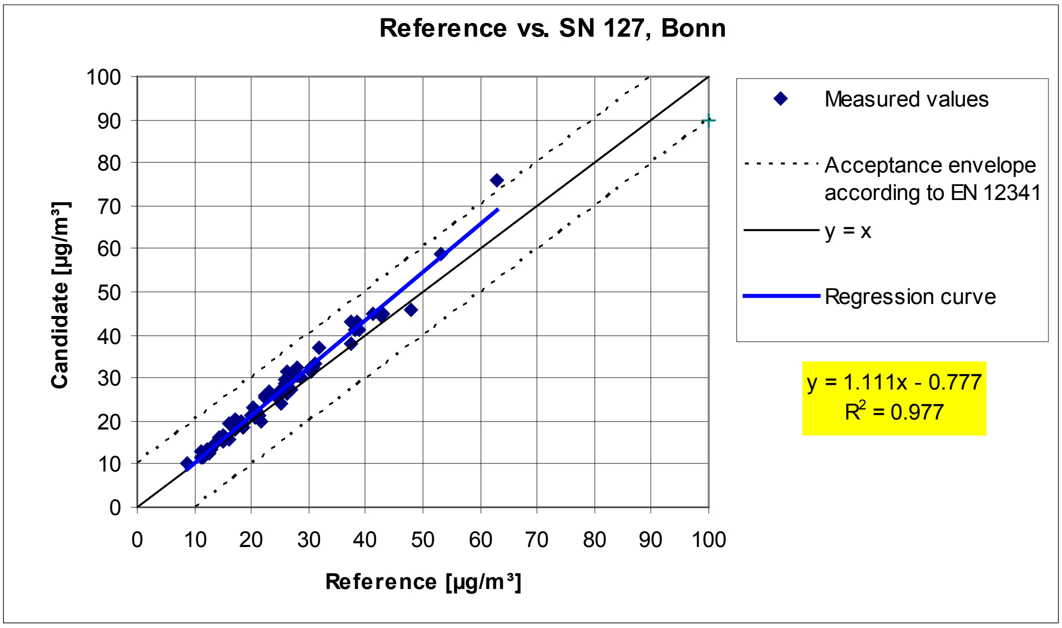


Figure 44: Reference- equivalence-function SN 127, PM_{10}, Site Bonn, Belderberg

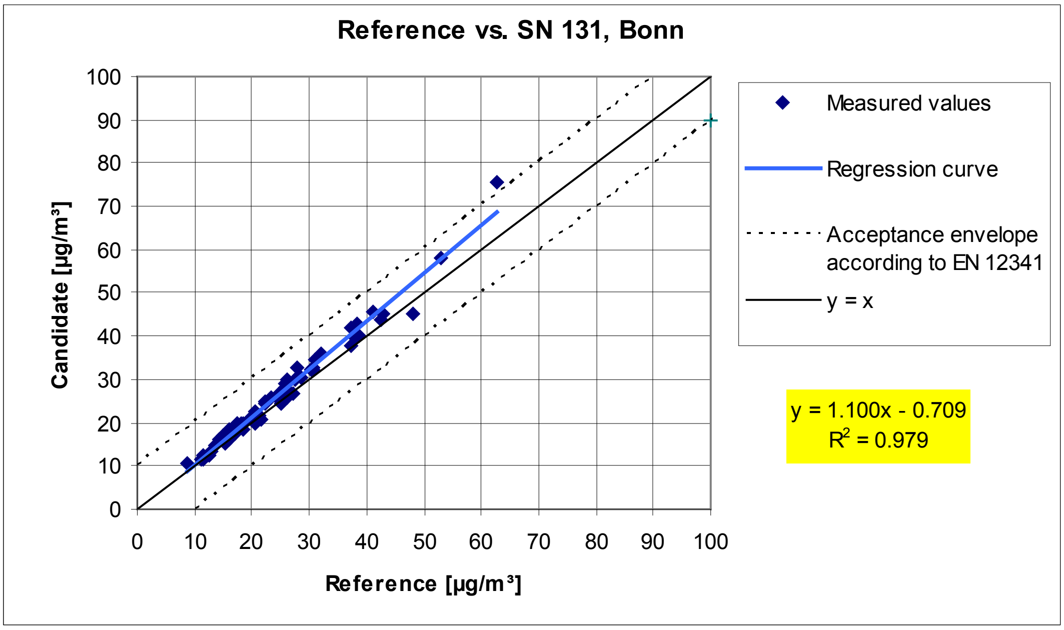


Figure 45: Reference- equivalence-function SN 131, PM_{10}, Site Bonn, Belderberg

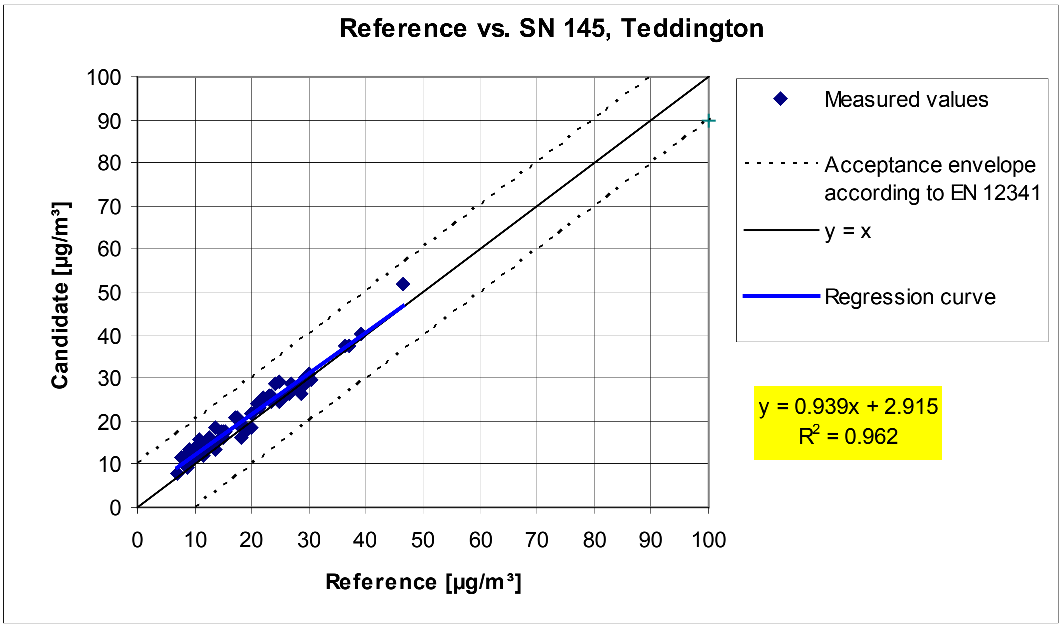


Figure 46: Reference- equivalence-function SN 145, PM_{10}, Site Teddington

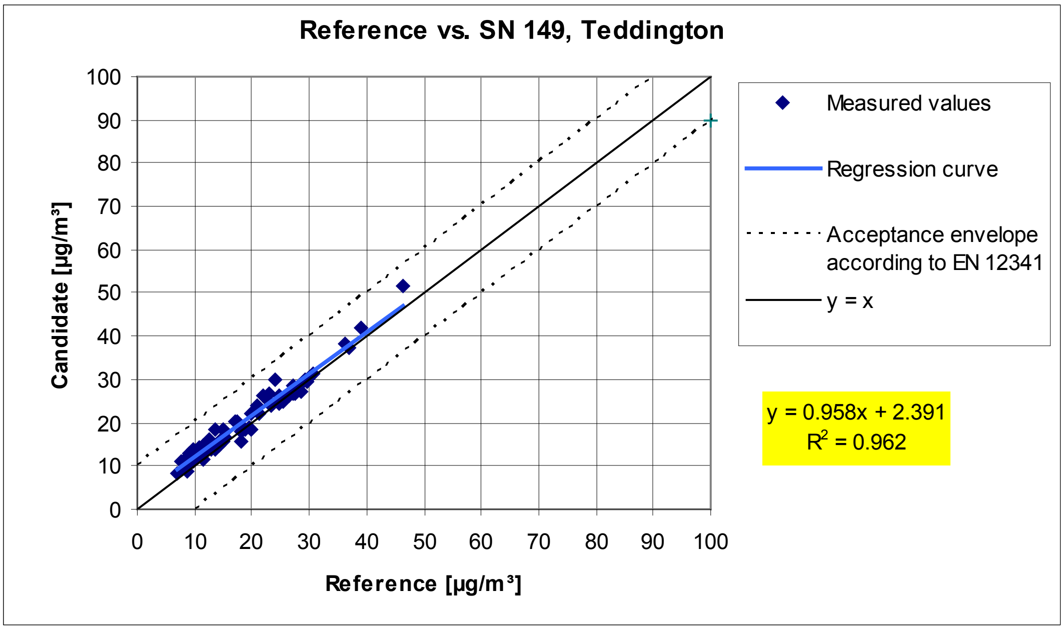


Figure 47: Reference- equivalence-function SN 149, PM_{10}, Site Teddington

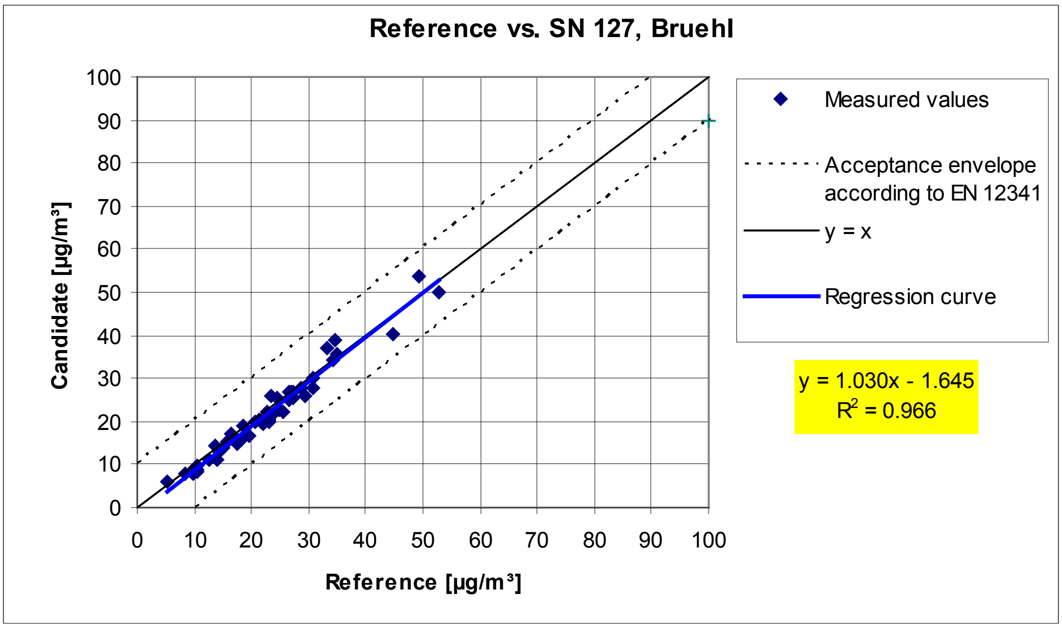


Figure 48: Reference- equivalence-function SN 127, PM_{10}, Site Bruehl

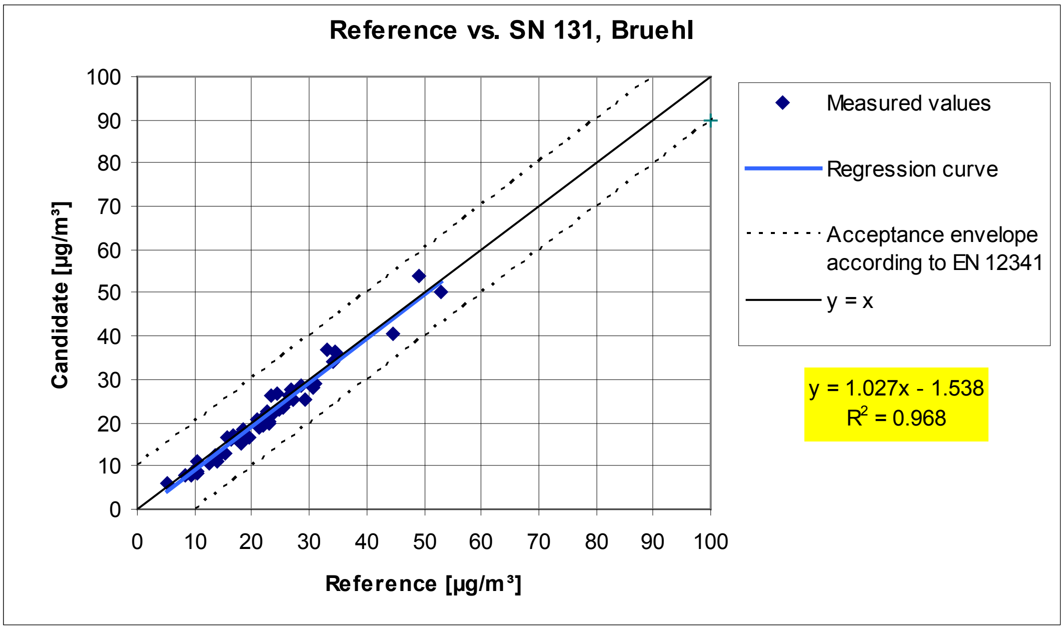


Figure 49: Reference- equivalence-function SN 131, PM_{10}, Site Bruehl

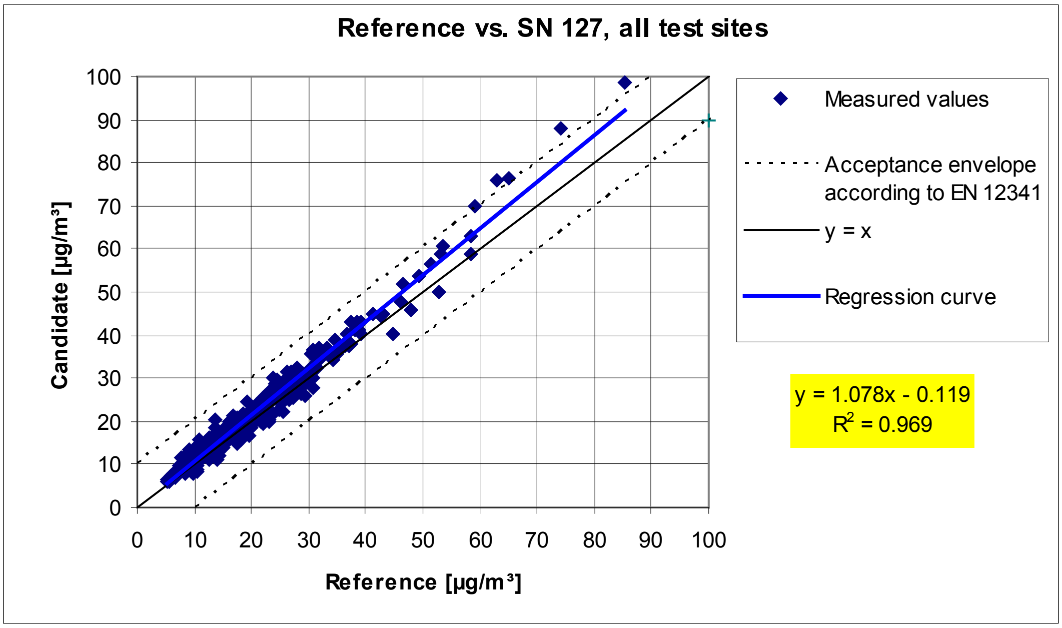


Figure 50: Reference- equivalence-function SN 127 (SN 145), PM_{10}, all sites

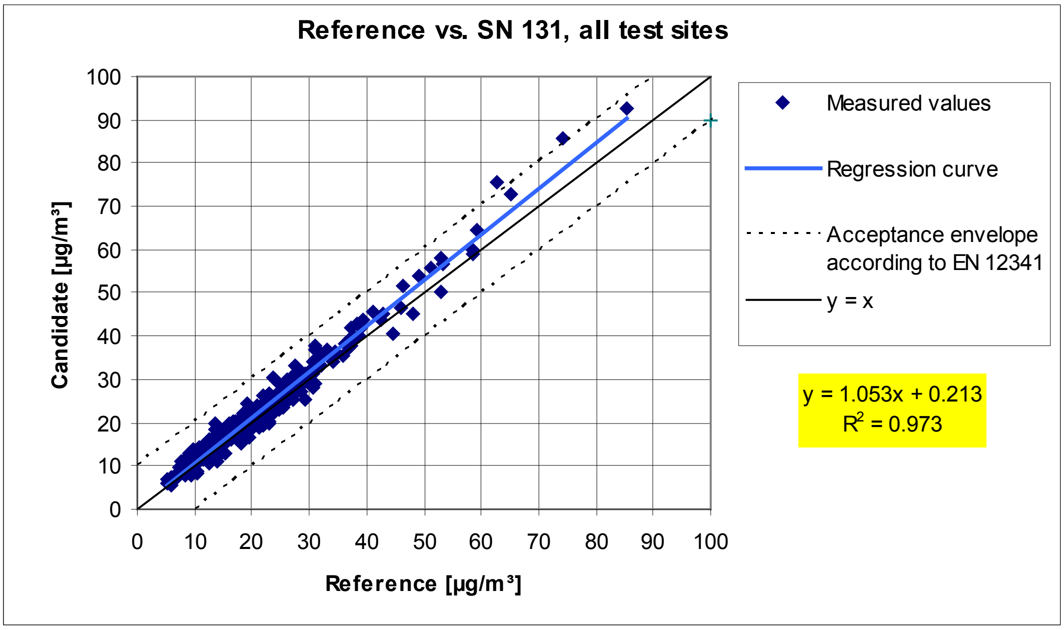


Figure 51: Reference- equivalence-function SN 131 (SN 149), PM_{10}, all sites

6.1 5.3.2 Reproducibility of the sampling system

The PM_{10} sampling systems of two identical candidate systems shall be reproducible among themselves according to DIN EN 12 341 [T5]. This shall be demonstrated in the field test.

6.2 Equipment

Not required for this minimum requirement.

6.3 Carrying out the test

The test has been performed at several sites during the field test (see point 4 of this report). Meteorological differences due to season, varying PM_{10} concentrations and different ratios between the concentration of TSP and PM_{10} were considered for evaluation.

At least 15 valid paired values were determined at each field test site.

6.4 Evaluation

The two-sided confidence interval CI_{95}, calculated from the concentration averages measured with the candidates, shall not exceed a value of 5 µg/m³ for concentration averages of 100 µg/m³ or less, and of 0.05 for concentration averages of more than 100 µg/m³.

The demonstration of comparability of the candidates is focused on the differences D_i of the concentration values Y_i. Ideally both candidates are equal and thus sample the same suspended particulate matter fraction, implying $D_i = 0$. The procedure is as follows:

The average concentrations Y_i of the i-th parallel measurement of the candidate samplers are calculated, followed by dividing the average concentrations Y_i into two separated data sets:

a) Data set with $Y_i \leq 100$ µg/m³ with number of paired values $n_{\leq}$ and
b) Data set with $Y_i > 100$ µg/m³ with number of paired values $n_{>}$

Re a):

The absolute standard deviation s_a is calculated from the paired values of the data set with $Y_i \leq 100$ µg/m³:

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

The corresponding Student factor $t_{f_{\leq};0,975}$ is used, defined as the 0.975 quintile of the two-sided 95% confidence interval of the Student t-distribution with $f_{\leq} = n_{\leq} - 2$ degrees of freedom.

The two-sided confidence interval CI_{95} for the average concentration values ≤ 100 µg/m³ is then calculated as follows:

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

Re b):

The relative standard deviation s_r is calculated from the paired values of the data set with Y_i > 100 µg/m³ as follows:

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

Once again the corresponding Student factor $t_{f_\leq;0,975}$, defined as the 0.975 quintile of the two-sided 95 % confidence interval of the Student t-distribution with $f_\leq = n_\leq - 2$ degrees of freedom, is used.

The two-sided confidence interval CI_{95} for the average concentration values > 100 µg/m³ is then calculated as follows:

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

Very few measured concentrations did exceed 100 µg/m³ during field test (test site Cologne, Parking lot: 3 paired values). A statistical evaluation for this concentration range is not possible due to the small number of values. For this reason, the assessment according to b) was omitted.

6.5 Assessment

Significant for all investigated sites:

The two-sided confidence interval CI_{95} is 1.64 µg/m³ which is below the specified value of 5 µg/m³.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Table 39 lists all calculated values of the standard deviation s_a and the two-sided confidence interval. Figure 52 to Figure 56 show a graphical representation of the results. Next to the regression line, the diagrams show an image of the ideal curve and of the two-sided acceptance range. All individual values for the candidates as well as the reference devices are listed in appendix 5 of the annex.

Table 39: Two-sided 95% confidence interval CI_{95} for the devices SN 127 and SN 131

Device under test	Site	No. of values	Standard deviation s_a	Student factor t_f	Confidence interval CI_{95}
SN			µg/m³		µg/m³
127 / 131	Koeln	100	0.83	1.984	1.64
127 / 131	Bonn	64	0.44	1.999	0.88
145 / 149	Teddington	83	0.56	1.990	1.12
127 / 131	Bruehl	55	0.58	2.006	1.17
127 (145) / 131 (149)	all sites	302	0.65	1.968	1.27

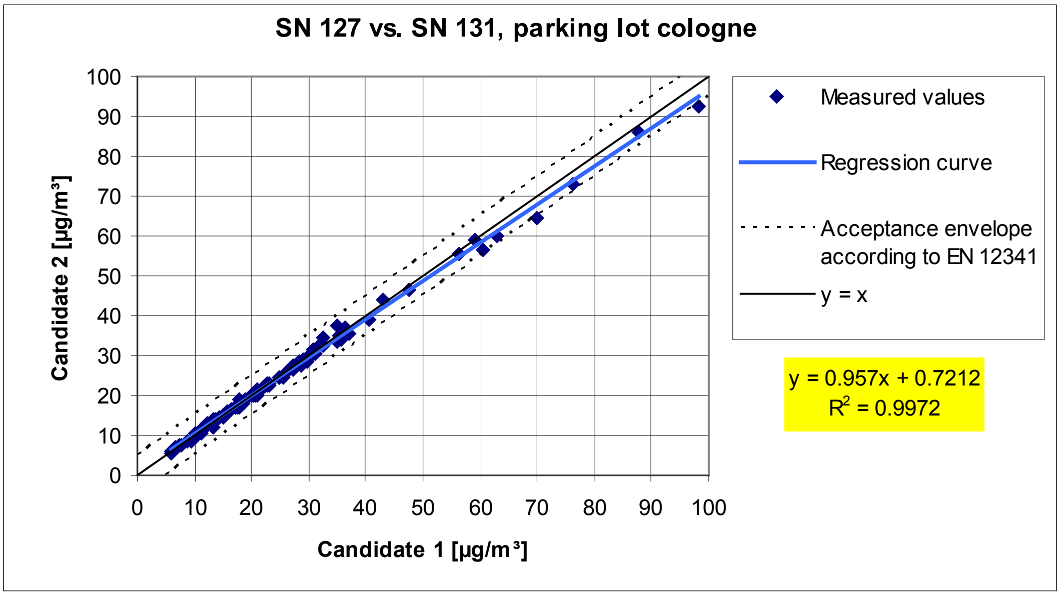


Figure 52: Result of the parallel measurement (device SN 127 / SN 131), PM_{10}, Site Koeln, Parking lot

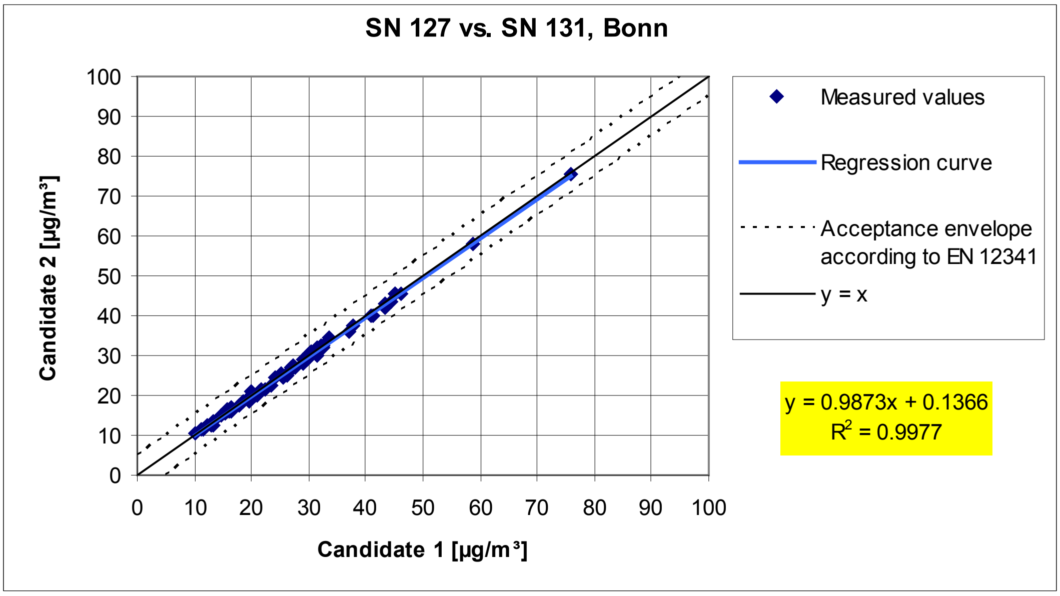


Figure 53: Result of the parallel measurement (device SN 127 / SN 131), PM_{10}, Site Bonn, Belderberg

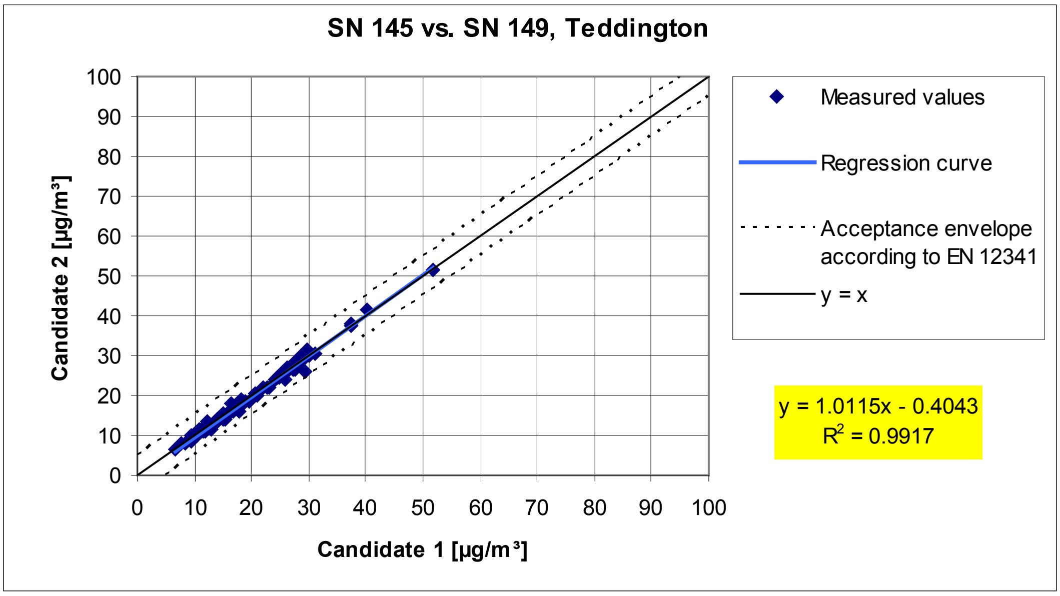


Figure 54: Result of the parallel measurement (device SN 145 / SN 149), PM_{10}, Site Teddington

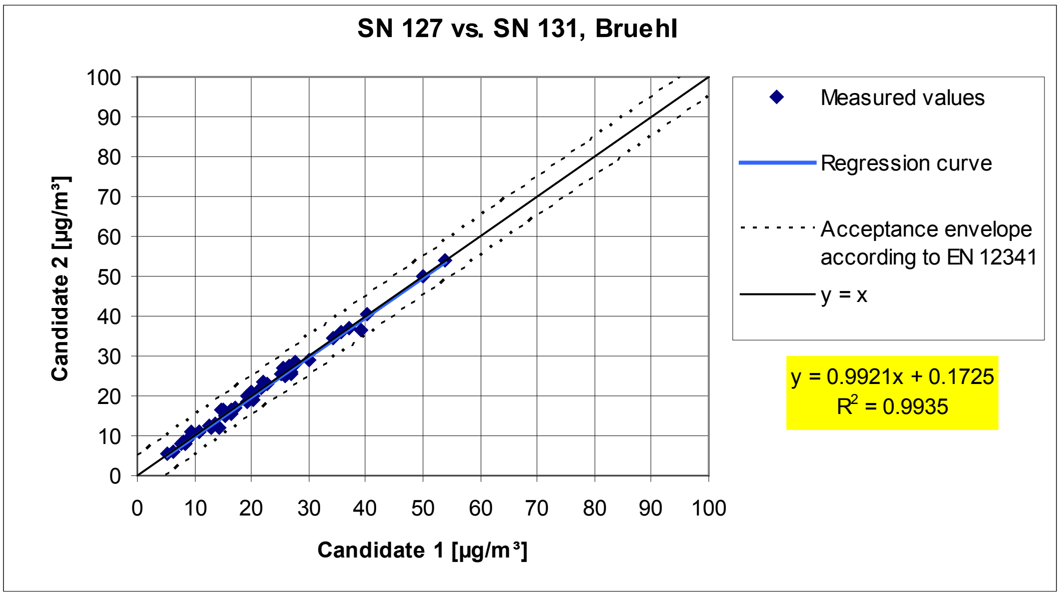


Figure 55: Result of the parallel measurement (device SN 127 / SN 131), PM_{10}, Site Bruehl

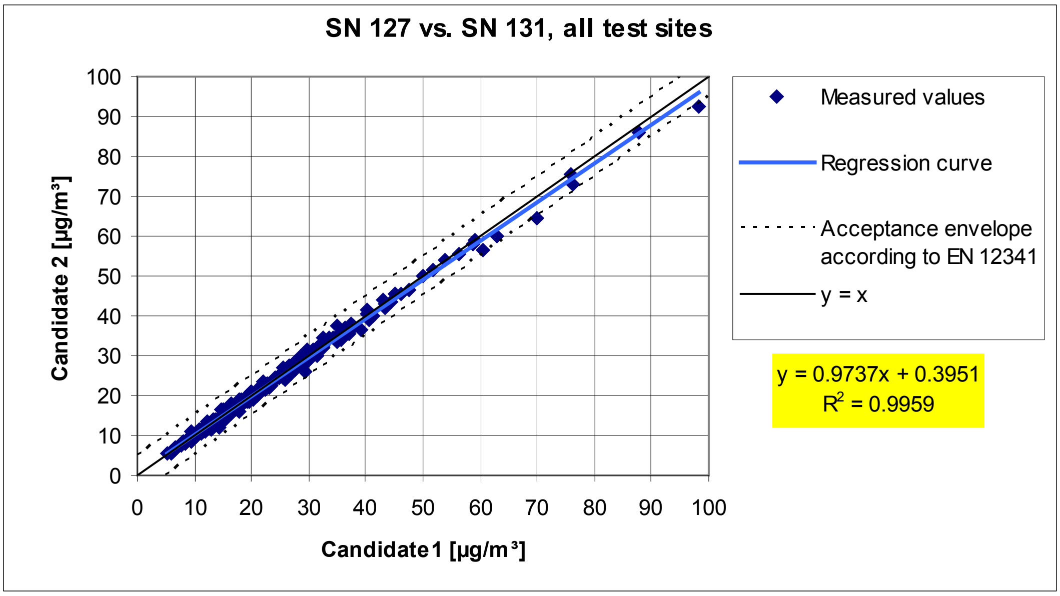


Figure 56: Result of the parallel measurement, device SN 127(SN 145) / SN 131 (SN 149), PM_{10}, all sites

6.1 5.3.3 Calibration

The PM_{10} candidate systems shall be calibrated in the field test by comparison measurements with a reference method according to DIN DIN EN 12341 [T5]. Here, the relationship between the output signal and the gravimetrically determined reference concentration shall be determined as a steady function.

In addition, the $PM_{2.5}$ candidate systems were calibrated by comparative measurement according to a reference method of DIN EN 14907.

The results of these investigations for PM_{10} and $PM_{2.5}$ can be found in module 5.2.3.

6.2 Equipment

See Module 5.2.3.

6.3 Carrying out the test

See Module 5.2.3.

6.4 Evaluation

See Module 5.2.3.

6.5 Assessment

See Module 5.2.3..

Minimum requirement fulfilled? -

6.6 Detailed representation of test results

See Module 5.2.3.

6.1 5.3.4 Cross sensitivity

The interference caused by humidity in the sample shall not exceed 10 % of B_1 in the range of B_1. In case of a heated sampling line, the reproducibility to the gravimetric reference method shall be determined at the specified temperature.

6.2 Equipment

Not required for this minimum requirement.

6.3 Carrying out the test

The interferences caused by humidity contained in the measured medium were not determined under laboratory conditions since a test at zero point did not lead to a reliable statement and the test is not feasible at span point (in the range of B_1).

Alternatively, the differences between the determined reference value (= nominal value) and the measured value of the respective candidate system were calculated for days of more than 70% relative humidity during field test, and the average difference was set as a conservative estimation of the interfering effect of humidity contained in the measured medium.

In addition, the reference-equivalence-functions were determined from the field investigations for days of more than 70% relative humidity for both candidate systems.

Neither purging the suction pipe nor active heating or cooling was part of this test. The suction pipe was simply wrapped with foam inside the measuring cabinet as a means of isolation.

The suction pipe may be coaxially purged (or, optionally, actively heated or cooled) if high proportions of volatile dust components are expected.

6.4 Evaluation

The average difference between the determined reference value (= nominal value) and the measured value of the respective candidate system was calculated for days of more than 70% relative humidity during field test, and the relative deviation of the average concentration was determined.

Reference value:	PM_{10}: B_1 = 40 µg/m³	10 % of B_1 = 4 µg/m³
	$PM_{2.5}$: B_1 = 25 µg/m³	10 % of B_1 = 2.5 µg/m³

Further investigations were made to determine whether the comparability of the candidate systems with the reference method according to Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods" is also given at days of more than 70% relative humidity.

6.5 Assessment

No interferences caused by humidity, contained in the measured medium, which led to deviations of more than 1.7 µg/m³ between nominal value and measured signal, could be detected. Negative influences on the measured value caused by varying relative air humidity were not detected. The comparability of the candidate systems is given even at days of more than 70% relative humidity.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Table 40 and Table 41 show a summary of the results.

Table 40: Deviation between the candidate system and the reference system at days of more than 70% relative humidity, PM_{10}

Field test, days of >70% relative humidity				
		Reference	SN 127	SN 131
No. of measured values		132	132	132
Average	µg/m³	23.7	25.4	25.1
Deviation from the average (reference)	µg/m³	-	1.7	1.4
Deviation from the average (reference)	%	-	7.2	5.9
Deviation from B1	%	-	4.3	3.5

Table 41: Deviation between the candidate system and the reference system at days of more than 70% relative humidity, $PM_{2.5}$

Field test, days of >70% relative humidity				
		Reference	SN 127	SN 131
No. of measured values		80	80	80
Average	µg/m³	16.1	15.4	15.5
Deviation from the average (reference)	µg/m³	-	-0.7	-0.6
Deviation from the average (reference)	%	-	-4.3	-3.7
Deviation from B1	%	-	-2.8	-2.4

The individual values are listed in appendix 5 and 6 of the annex.

The measurement uncertainties W_{CM} of days of more than 70% relative humidity are represented and assessed in Table 42 and Table 43. The individual values are listed in appendix 5 and 6 of the annex.

Table 42: Comparison candidate system vs. reference system, rel. humidity > 70%, all sites, PM_{10}, limit 40 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites, rF>70%	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.10**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**-0.75**	**not significant**		
Uncertainty of a	**0.38**			
Results of equivalence test				
Deviation at limit value	**3.16**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**3.75**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**9.37**	**%**		
Expanded uncertainty W_{CM}	**18.74**	**%**		
Status equivalence test	**passed**			

Table 43: Comparison candidate system vs. reference system, rel. humidity > 70%, all sites, $PM_{2.5}$, limit 20 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites, rF>70%	Limit value	20	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.97**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**-0.14**	**not significant**		
Uncertainty of a	**0.33**			
Results of equivalence test				
Deviation at limit value	**-0.77**	**µg/m³**		
Uncertainty $u_{c\_s\ at}$ limit value	**1.44**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**7.19**	**%**		
Expanded uncertainty W_{CM}	**14.39**	**%**		
Status equivalence test	**passed**			

6.1 5.3.5 Daily averages

The measuring system shall allow for formation of daily averages. In case of filter changes, the time needed for the filter changes shall not exceed 1 % of the averaging time.

6.2 Equipment

A clock was additionally used for this test.

6.3 Carrying out the test

The test was done in order to determine whether the measuring system allows calculating a daily average. In addition, the time needed for a filter exchange was determined.

6.4 Evaluation

The measuring system allows calculating average values for sampling cycles of at least 8h up to a cycle length of 168h. The filter exchange (including device-internal filter transport) takes about 11 or 12 minutes in total, which is approx. 0.8% of the averaging time.

The AMS determines the ratio between real and nominal sampling time (usually 24h) for each measurement or sampling.

6.5 Assessment

Calculation of daily averages is possible. The time needed for filter exchanges (including device-internal filter transport and all QS measures carried out for each cycle, such as an internal tightness or flow rate check) is not more than 0.8% of the averaging time. The determined time needed for filter exchange time thus takes less than the allowed limit (1% of the sampling period).

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Not required for this minimum requirement.

6.1 5.3.6 Constancy of sample volumetric flow

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

6.2 Equipment

Volumetric flow measuring systems according to point 4

6.3 Carrying out the test

The sample volumetric flow has been calibrated before the first field test sites (Koeln (SN127 & SN131) and Teddington (SN145 & SN149)) and afterwards checked on correctness before each field test site with the help of a dry gas meter.

By means of an example, line A of candidate SN127 was operated with varying pressure drops and the volumetric flow rate was continuously recorded and evaluated in order to determine the constancy of the sampling volumetric flow. The following filter configurations were used in order to generate varying pressure drops:

Table 44: Filter configurations

	No. of filters used	β-equivalent spot area [cm²]	Measured pressure drop Δp [kPa]
1	1	7.07	10.9
2	1	5.20	12.5
3	2	5.20	19.3
4	1	2.54	24.2
5	2	2.54	41.1
6	1	5.20	13.8

Configurations 2 and 6 (1 filter, sampling surface size 5.20 cm²) comply with the configuration used during the entire suitability testing.

According to manufacturer informations the AMS is able to safely maintain a nominal volume flow rate of 2.3 m³/h up to a maximum pressure drop of 40 kPa. Moreover, the AMS delivers an error message once the maximum pressure drop *via* filter is exceeded (> 60 kPa) and the pump is switched off.

6.4 Evaluation

An average and the deviation from the nominal value (38.33 l/min) were calculated from the measured values obtained in this test.

6.5 Assessment

Table 45 und Table 46 present the results of the check on volumetric flow rate prior to each field test site.

Table 45: Volumetric flow rate results, SN 127 / SN 149

Volumetric flow check prior to	SN 127, Line A		SN 127, Line B	
Site:	[l/min]	Deviation from nominal value [%]	[l/min]	Deviation from nominal value [%]
Koeln	38.33	-	38.33	-
Bonn	37.85	-1.3	37.95	-1.0
Bruehl	38.66	0.9	38.58	0.7
	SN 145 , Line A		SN 145 , Line B	
Teddington	38.33	-	38.33	-

Table 46: Volumetric flow rate results, SN 131 / SN 149

Volumetric flow check prior to	SN 131, Line A		SN 131, Line B	
Site:	[l/min]	Deviation from nominal value [%]	[l/min]	Deviation from nominal value [%]
Koeln	38.33	-	38.33	-
Bonn	38.15	-0.5	38.07	-0.7
Bruehl	38.49	0.4	38.66	0.9
	SN 149 , Line A		SN 149 , Line B	
Teddington	38.33	-	38.33	-

Graphical representations of the volumetric flow rates of all 6 days of testing indicate that all measured values taken during sampling deviate less than ± 5% from the nominal value (38.33%) even for pressure drops close to the maximum allowed limit. Moreover, the deviation of the daily averages from the nominal value is less than ±3 %.

All determined daily averages deviate less than ± 3%, all individual values less than ± 5% from the nominal value.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Table 47 presents the determined parameters of the volumetric flow for device SN 127, Line A. Figure 57 shows a graphical representation of the flow rate measurements for SN 127, Line A.

Table 47: Tested parameters for flow rate measurement, SN 127, Line A

Parameter	Unit	16.12.	17.12.*	18.12.	19.12.	20.12.	21.12.*
Configuration	-	1	2	3	4	5	6
Pressure drop	kPa	10.9	12.5	19.3	24.2	41.1	13.8
Average flow rate	l/min	38.7	38.2	38.3	38.2	38.2	38.3
Deviation average	% from nominal value	0.9	-0.4	-0.1	-0.3	-0.3	0.0

*17.12.2008 & 21.12.2008 = Configuration during suitability testing

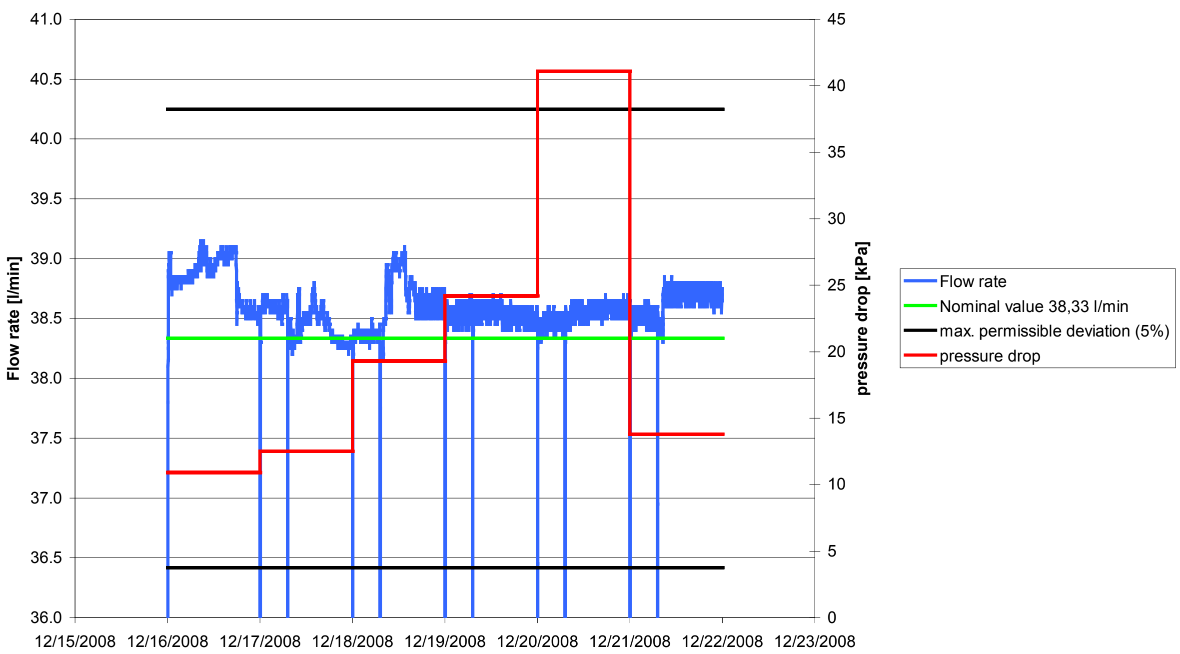


Figure 57: Flow rate of device SN 127, Line A from 12/16/2008 to 12/21/2008

6.1 5.3.7 Tightness of the sampling system

The complete sampling system shall be checked for tightness. Leakage shall not exceed 1 % of the in taken sample volume.

6.2 Equipment

Cap, clock

6.3 Carrying out the test

Tightness was checked according to the instructions given in the operating manual of the measuring device (manual tightness check, case 3). The inlet of the respective line under test was sealed with a cap. A filter was placed on the sampling position. The entire pneumatic system was evacuated with the help of a vacuum pump until the lowest possible residual pressure was reached. The internal pressure change was monitored over time after the pump was switched off. Internal pressure increases over time, with the speed of the pressure increase depending on possible leaks. The leak rate is determined in consideration of the total system volume.

The estimated total volume of the system amounts to 1.85 l for line A and 1.75 l for line B.

6.4 Evaluation

The leak rate $\dot{V}_L$ is calculated as follows:

$$\dot{V}_L = \frac{\Delta p}{p_0} \frac{V_{ges}}{\Delta t}$$

With

Δp difference (pressure decrease) monitored during time difference Δt

p_0 pressure at time t_0

V_{ges} total volume of the system (dead volume)

Δt time difference needed for the pressure decrease by difference Δp

The maximum value of all three leak rates was determined.

6.5 Assessment

The maximum leak rates were not more than 0.24% for device 1 (SN 127), not more than 0.30% for device 2 (SN 131) at a residual pressure p_0 within the system; and not more than 0.08% for device 1 (SN 127) or 0.06 % for device 2 (SN 131) at an atmospheric pressure of 102.8 kPa each. The determined values are significantly below the minimum requirement of 1%.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Table 48 and Table 49 show the determined values of the tightness check.

Table 48: Determination of the leak rate, SN 127

SN 127, line A									
No.	Date	p_0 [kPa]	p_t [kPa]	Δp [kPa]	Δt [min]	V_{ges} [m³]	leaking rate[l/min]	% of nominal value, at p0	% of nominal value, at pa = 102,8 kPa
1	12/08/2008	26.6	27.8	1.2	1	0.00185	0.083	0.218	0.056
2	12/08/2008	27.8	28.9	1.1	1	0.00185	0.073	0.191	0.052
3	12/08/2008	28.9	30	1.1	1	0.00185	0.070	0.184	0.052
4	12/08/2008	30	31	1	1	0.00185	0.062	0.161	0.047
5	12/08/2008	31	32.1	1.1	1	0.00185	0.066	0.171	0.052
1-5	12/08/2008	26.6	32.1	5.5	5	0.00185	0.077	0.200	0.052
SN 127, line B									
No.	Date	p_0 [kPa]	p_t [kPa]	Δp [kPa]	Δt [min]	V_{ges} [m³]	leaking rate[l/min]	% of nominal value, at p0	% of nominal value, at pa = 102,8 kPa
1	12/08/2008	32.9	34.6	1.7	1	0.00175	0.090	0.236	0.076
2	12/08/2008	34.6	36.4	1.8	1	0.00175	0.091	0.238	0.080
3	12/08/2008	36.4	37.9	1.5	1	0.00175	0.072	0.188	0.067
4	12/08/2008	37.9	39.4	1.5	1	0.00175	0.069	0.181	0.067
5	12/08/2008	39.4	41	1.6	1	0.00175	0.071	0.185	0.071
1-5	12/08/2008	32.9	41	8.1	5	0.00175	0.086	0.225	0.072

Table 49: Determination of the leak rate, SN 131

SN 131, line A									
No.	Date	p_0 [kPa]	p_t [kPa]	Δp [kPa]	Δt [min]	V_{ges} [m³]	leaking rate[l/min]	% of nominal value, at p0	% of nominal value, at pa = 102,8 kPa
1	12/08/2008	36.7	37.6	0.9	1	0.00185	0.045	0.118	0.042
2	12/08/2008	37.6	38.4	0.8	1	0.00185	0.039	0.103	0.038
3	12/08/2008	38.4	39.2	0.8	1	0.00185	0.039	0.101	0.038
4	12/08/2008	39.2	40.1	0.9	1	0.00185	0.042	0.111	0.042
5	12/08/2008	40.1	40.8	0.7	1	0.00185	0.032	0.084	0.033
1-5	12/08/2008	36.7	40.8	4.1	5	0.00185	0.041	0.108	0.039
SN 131, line B									
No.	Date	p_0 [kPa]	p_t [kPa]	Δp [kPa]	Δt [min]	V_{ges} [m³]	leaking rate[l/min]	% of nominal value, at p0	% of nominal value, at pa = 102,8 kPa
1	12/08/2008	19.9	21.2	1.3	1	0.00175	0.114	0.298	0.058
2	12/08/2008	21.2	22.4	1.2	1	0.00175	0.099	0.258	0.053
3	12/08/2008	22.4	23.7	1.3	1	0.00175	0.102	0.265	0.058
4	12/08/2008	23.7	25	1.3	1	0.00175	0.096	0.250	0.058
5	12/08/2008	25	26.3	1.3	1	0.00175	0.091	0.237	0.058
1-5	12/08/2008	19.9	26.3	6.4	5	0.00175	0.113	0.294	0.057

6.1 5.4 Requirements for multiple-component measuring systems

Multiple-component measuring systems shall comply with the requirements set for each component, also in the case of simultaneous operation of all measuring channels. In case of sequential operation, the formation of hourly averages shall be possible.

6.2 Equipment

Not applicable.

6.3 Carrying out the test

The SWAM 5a Dual Channel Monitor measuring system is an automatically and sequentially operating measuring device for dust measurement on filter membranes. The system operates with two completely independent sampling lines, which were configured for simultaneous measurement of PM_{10} (line A) and $PM_{2.5}$ (line B) for the present suitability test.

The test was carried out according to the testing procedure for each individual component. Both sampling lines were running throughout the entire test.

6.4 Evaluation

Both sampling lines were operating during each test. Evaluations in relation to single minimum requirements were done related to the respective measured components.

6.5 Assessment

The results of both components were simultaneously available for assessing the minimum requirements.

Minimum requirement fulfilled? yes

6.6 Detailed representation of test results

Not required for this minimum requirement.

7 Additional test criteria according to Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods“

7.1 Determination of the in-between-instrument uncertainty u_{bs} [9.5.2.1]

The between-sampler uncertainty u_{bs} has to be determined according to point 9.5.2.1 of the Guidance „Demonstration of Equivalence of Ambient Air Monitoring Methods“.

7.2 Equipment

Not required for this minimum requirement.

7.3 Carrying out the test

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

A minimum of 40 valid paired values were determined at each site. Of the entire data set (4 sites, 283 valid paired values for PM_{10} and 201 valid paired values for $PM_{2.5}$), a total of 32.2% / 47.3% are above 50% of the daily / annual average limits (50 µg/m³ / 40 µg/m³) for PM_{10}. A total of 53.2 % / 63.2 % of the measured values are above 50% of the annual average limits (25 µg/m³ / 20 µg/m³) for $PM_{2.5}$. The measured concentrations were referred to ambient conditions.

7.4 Evaluation

True according to point 9.5.2.1 of Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods“:

The in-between-instrument uncertainty u_{bs} shall be ≤ 3 µg/m³. An uncertainty larger than 3 µg/m³ between the candidate systems is an indication of unsuitable performance of one or both instruments and that equivalency cannot be declared.

Uncertainty is hereby determined for:

- Each test site separately (PM_{10} & $PM_{2.5}$)
- All sites (PM_{10} & $PM_{2.5}$)
- 1 data set with measured values ≥ 50 % of the daily average limit DL of 50 µg/m³ for PM_{10} (Basis: average values of the reference measurement)
- 1 data set with measured values ≥ 50 % of the annual average limit AL of 40 µg/m³ for PM_{10} (Basis: average values of the reference measurement)
- 1 data set with measured values ≥ 50 % of the daily average limit DL of 50 µg/m³ for PM_{10} (Basis: average values of the reference measurement)
- 1 data set with measured values ≥ 50 % of the annual average limit AL of 40 µg/m³ for PM_{10} (Basis: average values of the reference measurement)

- 1 data set with measured values ≥ 50 % of the annual average limit AL of 25 µg/m³ for $PM_{2.5}$ (Basis: average values of the reference measurement)
- 1 data set with measured values ≥ 50 % of the annual average limit AL of 20 µg/m³ for $PM_{2.5}$ (Basis: average values of the reference measurement)
- 1 data set with measured values ≥ 50 % of the annual average limit AL of 25 µg/m³ for $PM_{2.5}$ (Basis: average values of the reference measurement)
- 1 data set with measured values ≥ 50 % of the annual average limit AL of 20 µg/m³ for $PM_{2.5}$ (Basis: average values of the reference measurement)

The in-between-instrument uncertainty u_{bs} is calculated from the differences of all 24-hour results of the simultaneously operated candidate systems according to the following equation:

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

with $y_{i,1}$ and $y_{i,2}$ = results of the parallel measurements of individual 24h-values i
n = No. of 24h-values

7.5 Assessment

The in-between-instrument uncertainty between the candidates u_{bs} does not exceed 0.98 µg/m³ for PM_{10} and 0.69 µg/m³ for $PM_{2.5}$. This is significantly below the required value of 3 µg/m³.

Minimum requirement fulfilled? yes

7.6 Detailed representation of test results

Table 50 and Table 51 present the calculated in-between-instrument uncertainty u_{bs}. A graphical representation is given in Figure 58 to Figure 75.

Table 50: In-between-instrument uncertainty u_{bs} for the devices SN 127 (145) and SN 131 (149), measured component PM_{10}

Test devices	**Site**	**No. of values**	**Uncertainty u_{bs}**
SN			µg/m³
127 / 131	Koeln, Parking lot	100	0.87
127 / 131	Bonn, Belderberg	64	0.45
145 / 149	Teddington	83	0.53
127 131	Bruehl	55	0.56
127 (145) / 131 (149)	All sites	302	0.66
Classification *via* reference values			
127 (145) / 131 (149)	Values ≥ 50 % DL (≥ 25 µg/m³)	91	0.98
127 (145) / 131 (149)	Values ≥ 50 % AL (≥ 20 µg/m³)	134	0.87
127 (145) / 131 (149)	Values < 50 % DL (< 25 µg/m³)	192	0.46
127 (145) / 131 (149)	Values < 50 % AL (< 20 µg/m³)	149	0.42

Table 51: In-between-instrument uncertainty u_{bs} for the devices SN 127 (145) and SN 131 (149), measured component $PM_{2.5}$

Test device	**Site**	**No. of Values**	**Uncertainty u_{bs}**
SN			µg/m³
127 / 131	Koeln, Parking lot	100	0.69
127 / 131	Bonn, Belderberg	64	0.42
145 / 149	Teddington	83	0.44
127 131	Bruehl	55	0.63
127 (145) / 131 (149)	All sites	302	0.57
Classification *via* reference values			
127 (145) / 131 (149)	Values ≥ 50 % AL 1 (≥ 12,5 µg/m³)	107	0.57
127 (145) / 131 (149)	Values ≥ 50 % AL 2 (≥ 10 µg/m³)	127	0.54
127 (145) / 131 (149)	Values < 50 % AL 1 (< 12,5 µg/m³)	94	0.36
127 (145) / 131 (149)	Values < 50 % AL 2 (< 10 µg/m³)	74	0.38

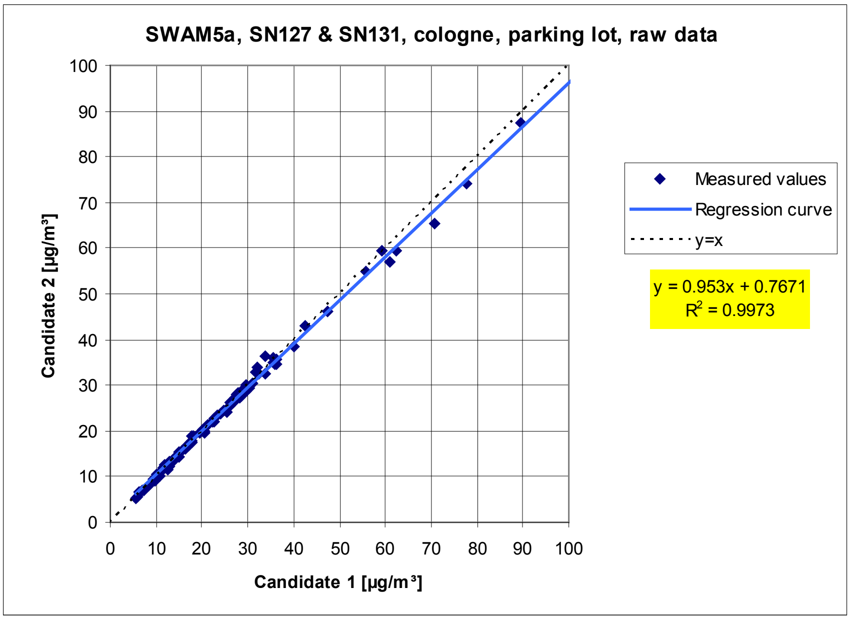


Figure 58: Results of the parallel measurements with device SN 127 / SN 131, Site Koeln, Parking lot, measured component PM_{10}

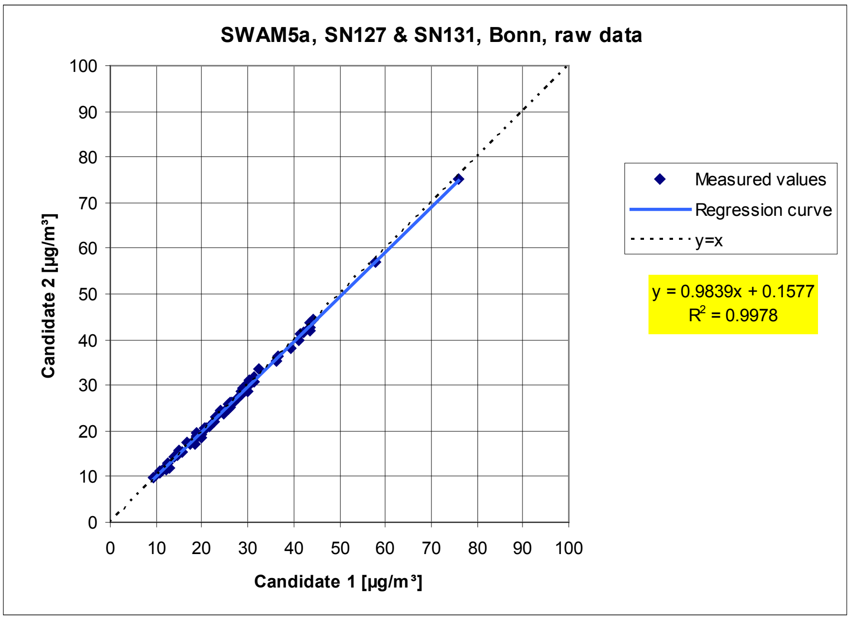


Figure 59: Results of the parallel measurements with device SN 127 / SN 131, Site Bonn, Belderberg, measured component PM_{10}

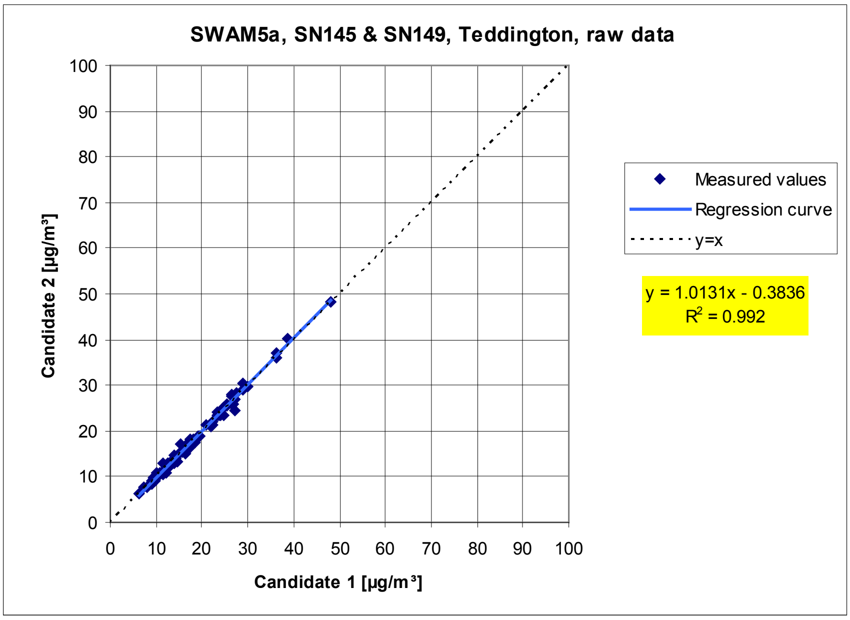


Figure 60: Results of the parallel measurements with device SN 145 / SN 149, Site Teddington, measured component PM_{10}

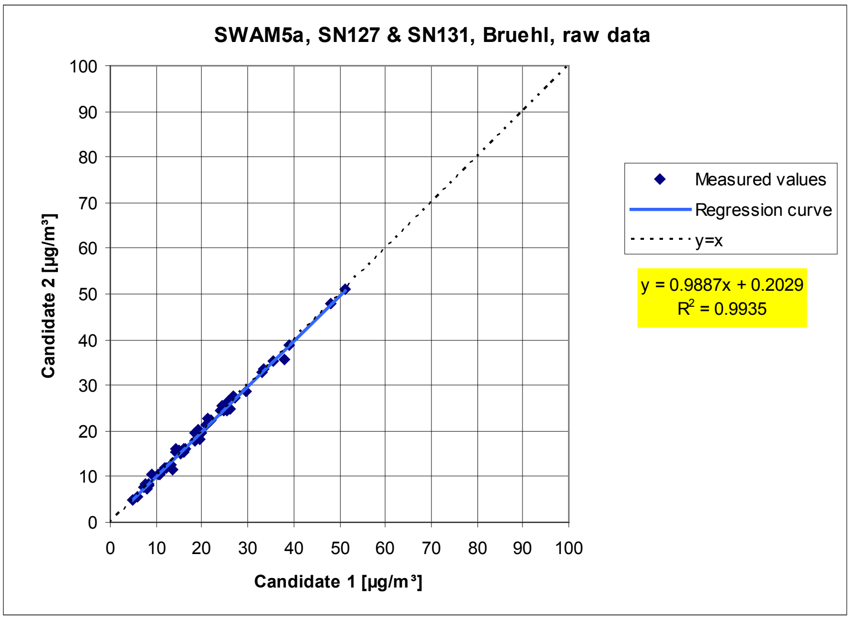


Figure 61: Results of the parallel measurements with device SN 127 / SN 131, Site Bruehl, measured component PM_{10}

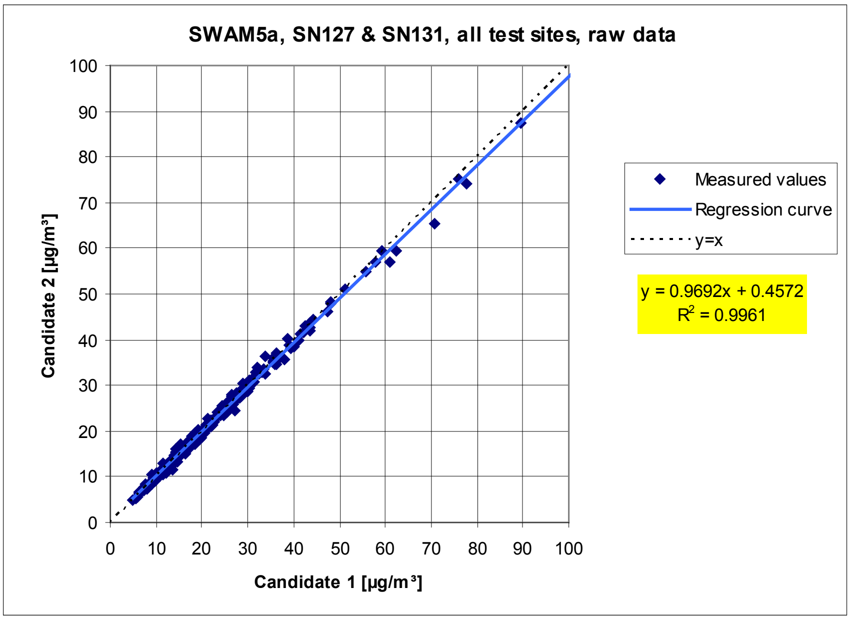


Figure 62: Results of the parallel measurements with device 127 / SN 131, all sites, measured component PM_{10}

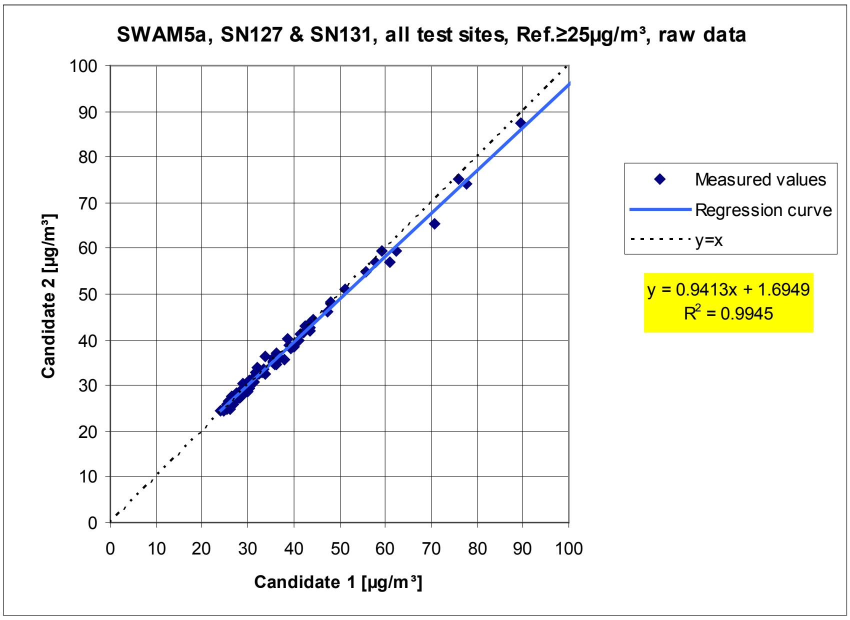


Figure 63: Results of the parallel measurements with device SN 127 / SN 131, all sites, values ≥ 50 % DL (≥ 25 µg/m³), measured component PM_{10}

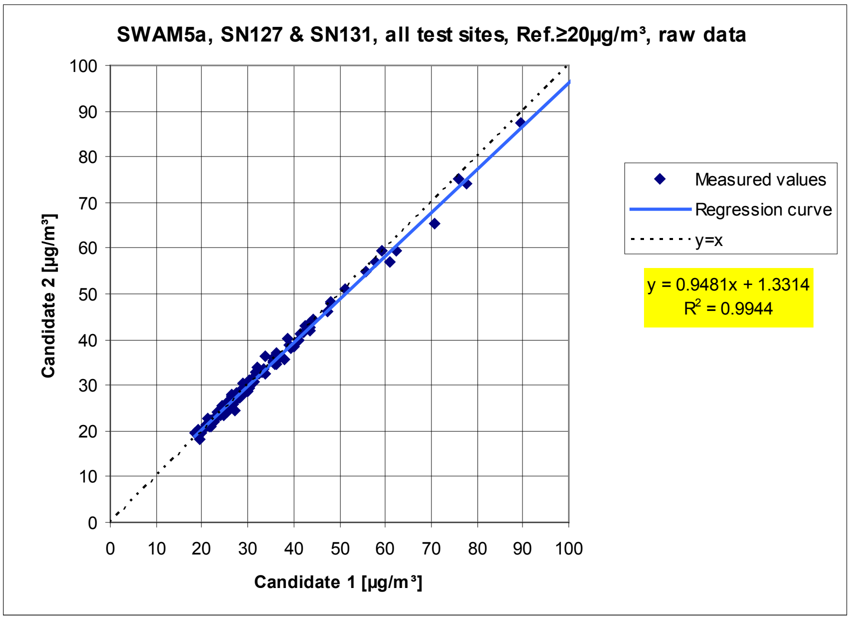


Figure 64: Results of the parallel measurements with device SN 127 / SN 131, all sites, values ≥ 50 % AL (≥ 20 µg/m³), measured component PM_{10}

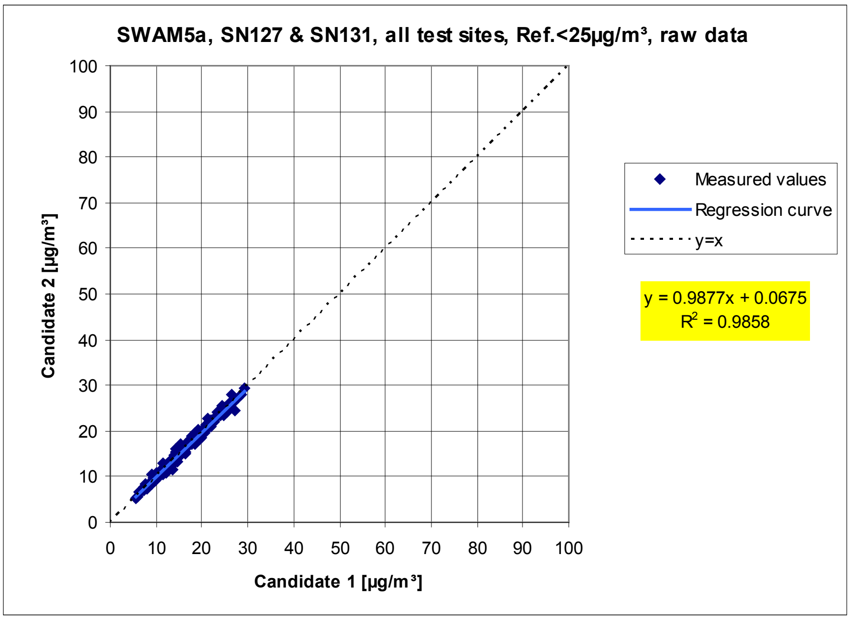


Figure 65: Results of the parallel measurements with device SN 127 / SN 131, all sites, values < 50 % DL (< 25 µg/m³), measured component PM_{10}

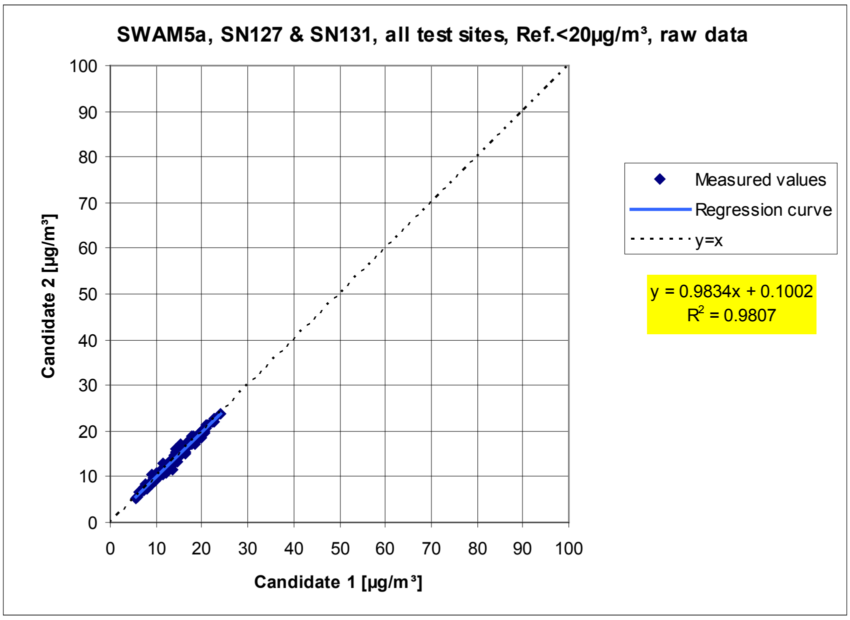


Figure 66: Results of the parallel measurements with device SN 127 / SN 131, all sites, values < 50 % AL (< 20 µg/m³), measured component PM_{10}

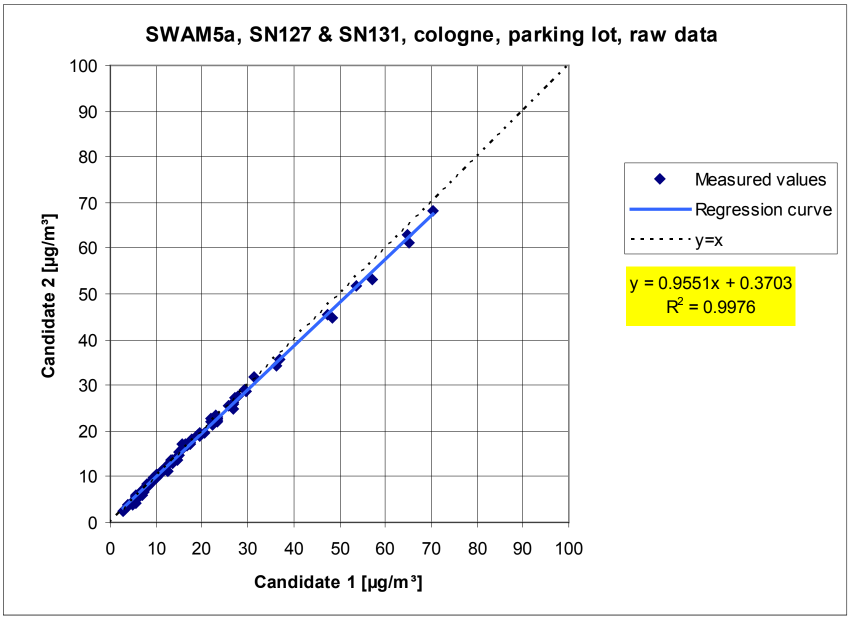


Figure 67: Results of the parallel measurements with device SN 127 / SN 131, Site Koeln, Parking lot, measured component $PM_{2.5}$

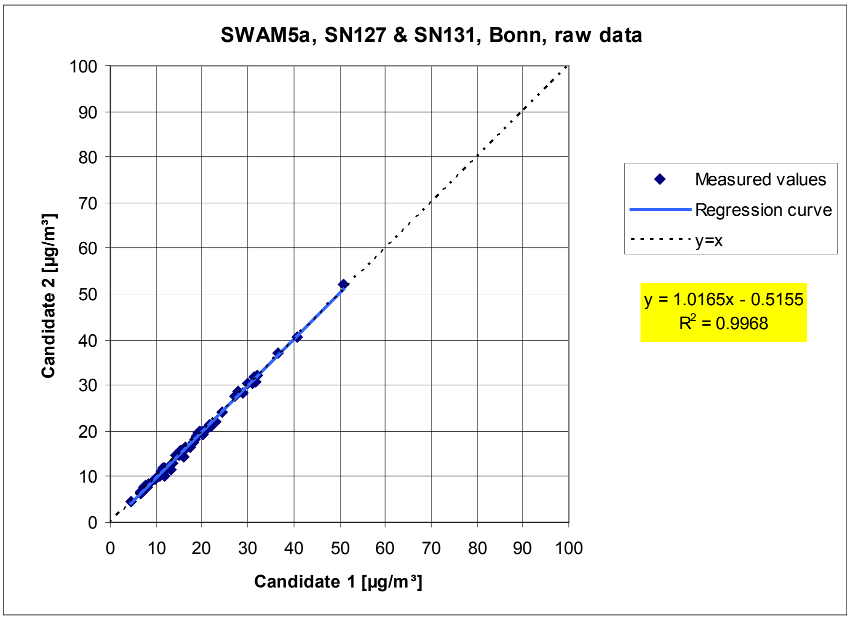


Figure 68: Results of the parallel measurements with device SN 127 / SN 131, Site Bonn, Belderberg, measured component $PM_{2.5}$

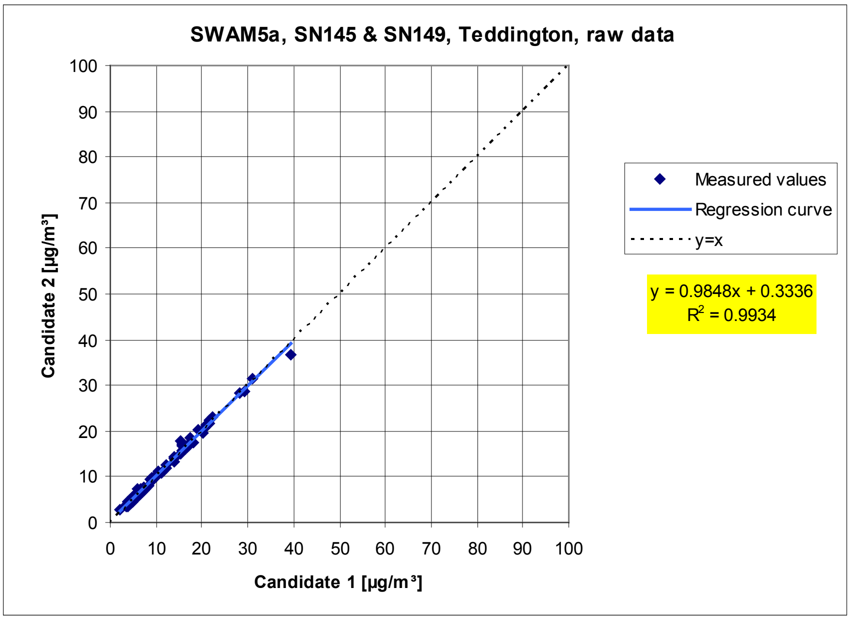


Figure 69: Results of the parallel measurements with device SN 145 / SN 149, Site Teddington, measured component $PM_{2.5}$

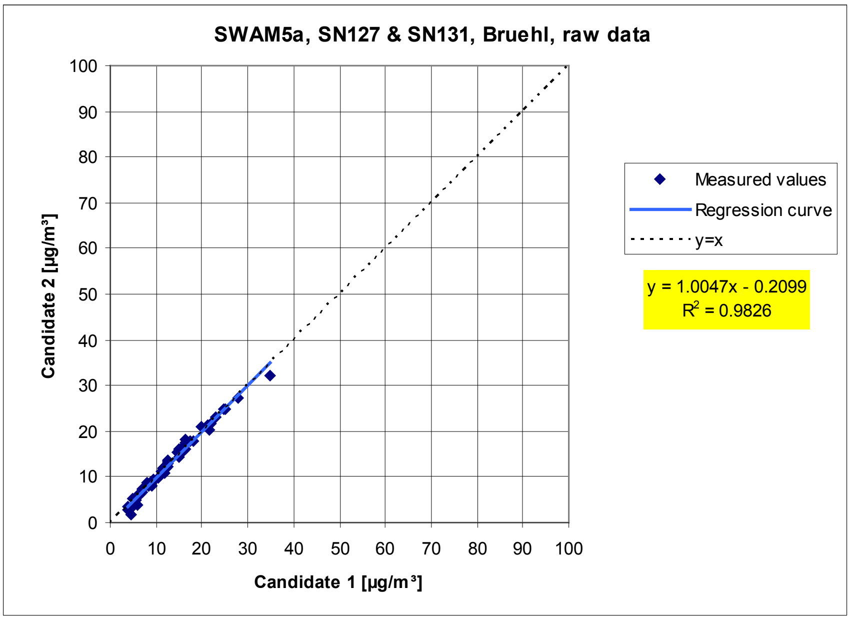


Figure 70: Results of the parallel measurements with device SN 127 / SN 131, Site Bruehl, measured component $PM_{2.5}$

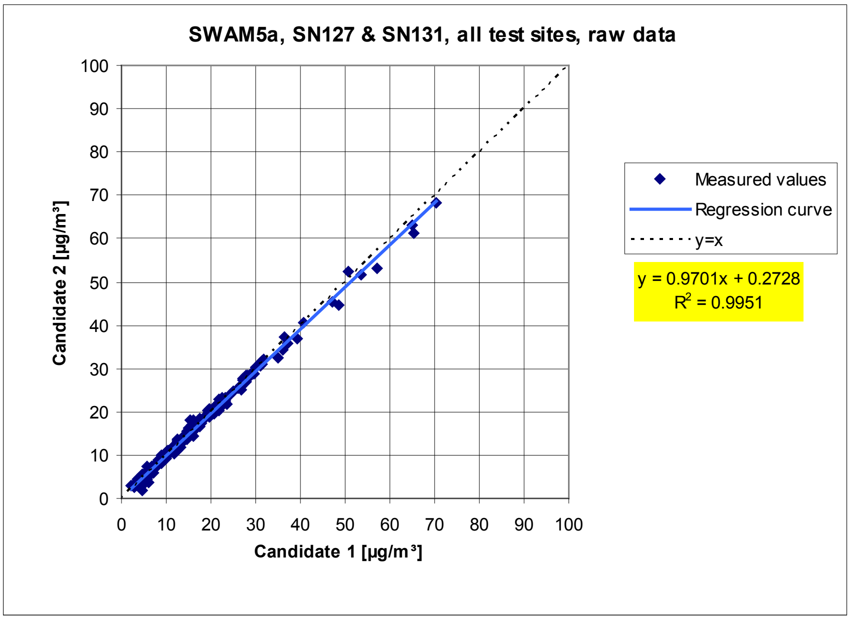


Figure 71: Results of the parallel measurements with device SN 127 / SN 131, all sites, measured component $PM_{2.5}$

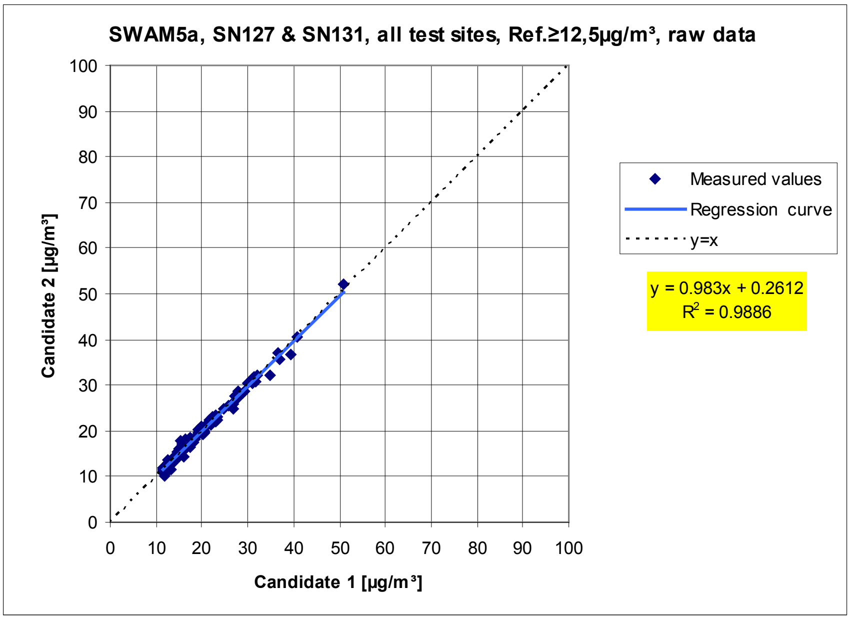


Figure 72: Results of the parallel measurements with device SN 127 / SN 131, all sites, values ≥ 50 % AL (≥ 12.5 µg/m³), measured component $PM_{2.5}$

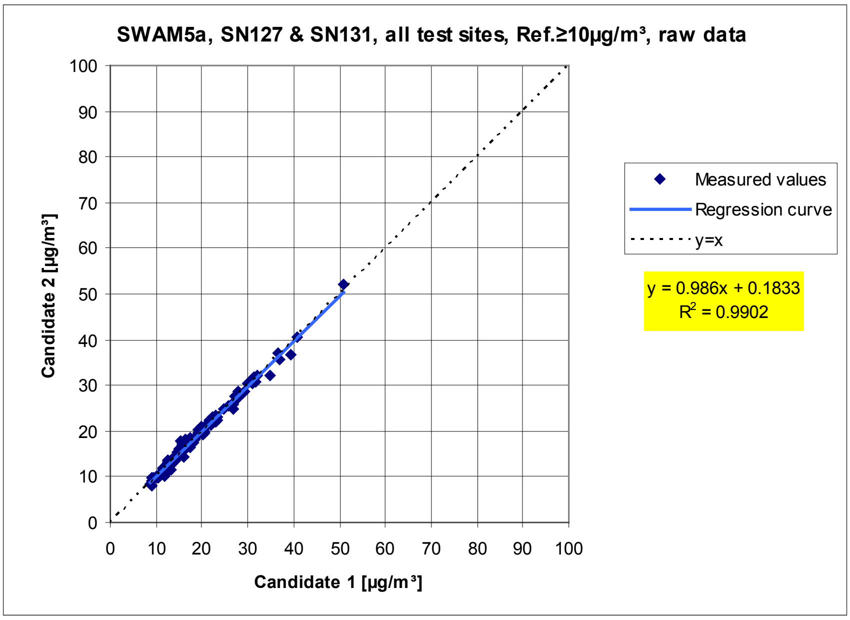


Figure 73: Results of the parallel measurements with device SN 127 / SN 131, all sites, values ≥ 50 % AL, level 2 (≥ 10 µg/m³), measured component $PM_{2.5}$

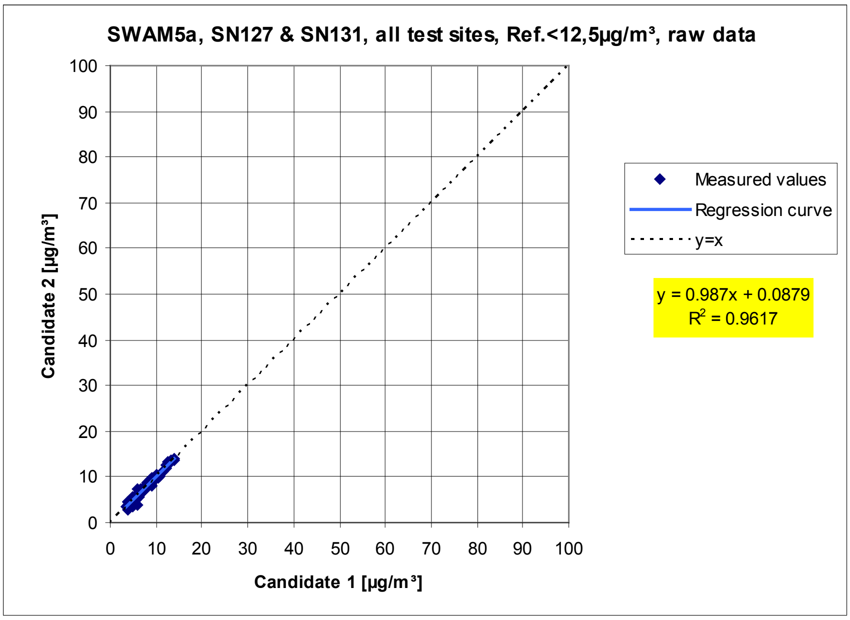


Figure 74: Results of the parallel measurements with device SN 127 / SN 131, all sites, values < 50 % AL (< 12.5 µg/m³), measured component $PM_{2.5}$

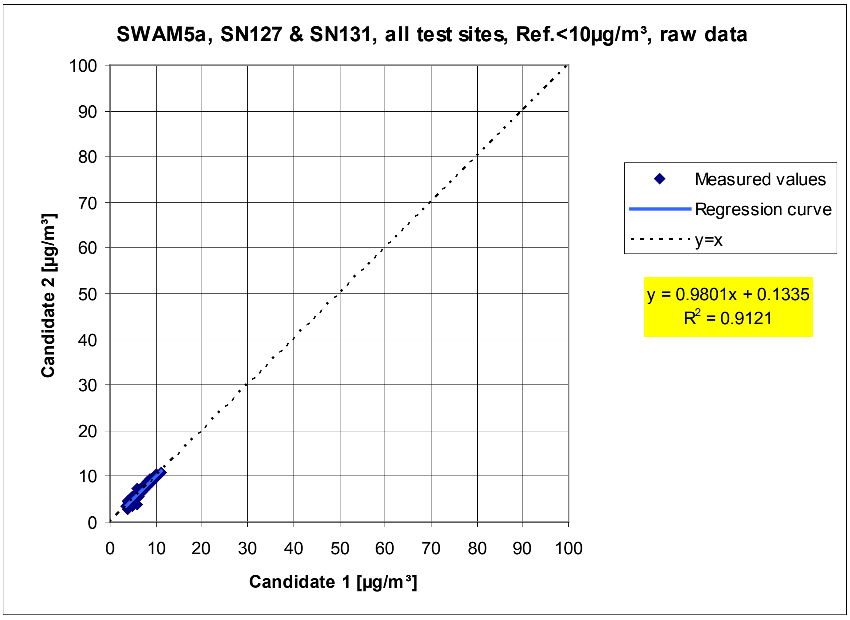


Figure 75: Results of the parallel measurements with device SN 127 / SN 131, all sites, values < 50 % AL, level 2 (< 10 µg/m³), measured component $PM_{2.5}$

7.1 Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6]

The equivalency of the candidate instruments to the reference method has to be demonstrated according to the points 9.5.2.2 to 9.5.4 of the Guidance „Demonstration of Equivalence of Ambient Air Monitoring Methods“. The highest resulting expanded uncertainty of the candidate method is to compare with the requirements on the data quality of ambient air measurements according to EU-guideline [7].

7.2 Equipment

The devices mentioned in point 5 of the present report were additionally used for this test.

7.3 Carrying out the test

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

A minimum of 40 valid paired values were determined at each site. Of the entire data set (4 sites, 283 valid paired values for PM_{10} and 201 valid paired values for $PM_{2.5}$), a total of 32.2% / 47.3% are above 50% of the daily / annual average limits (50 µg/m³ / 40 µg/m³) for PM_{10}. A total of 53.2 % / 63.2 % of the measured values are above 50% of the annual average limits (25 µg/m³ / 20 µg/m³) for $PM_{2.5}$. The measured concentrations were referred to ambient conditions.

7.4 Evaluation

[Point 9.5.2.2] The calculation of the in-between-instrument uncertainty u_{ref} of the reference devices is carried out prior to the calculation of the expanded uncertainty of the candidates. The in-between-instrument uncertainty u_{ref} of the reference devices shall be ≤ 2 µg/m³. Section 7.6 of this test point shows the evaluated results.

A linear correlation $y_i = a + bx_i$ is assumed between the results of both methods in order to evaluate the comparability of the candidates y and the reference procedure x. The correlation between the average values of the reference devices and the candidates is established by orthogonal regression [6].

Regression is calculated for:

- Each test site separately (PM_{10} & $PM_{2.5}$)
- All sites (PM_{10} & $PM_{2.5}$)
- 1 data set with measured values ≥ 50 % of the daily average limit DL of 50 µg/m³ for PM_{10} (Basis: average values of the reference measurement)
- 1 data set with measured values ≥ 50 % of the annual average limit AL of 40 µg/m³ for PM_{10} (Basis: average values of the reference measurement)
- 1 data set with measured values ≥ 50 % of the annual average limit AL, level 1 of 25 µg/m³ for $PM_{2.5}$ (Basis: average values of the reference measurement)
- 1 data set with measured values ≥ 50 % of the annual average limit AL, level 2 of 20 µg/m³ for $PM_{2.5}$ (Basis: average values of the reference measurement)

For further evaluation, the results of the uncertainty u_{c_s} of the candidates compared with the reference procedure are described with the following equation:

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

Here, u_{c_s} is described as a function of the concentration of particulate matter x_i.

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

$u(x_i)$ = random uncertainty of the reference procedure if value u_{bs}, which is calculated for using the candidates, can be used in this test (see Point 7.1 Determination of the in-between-instrument uncertainty u_{bs} [9.5.2.1])

Algorithm for the calculation of axis intercept a as well as slope b and its variances by orthogonal regression are described in detail in annex B of [6].

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

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

Uncertainty u_{c_s} is calculated for:

- Each test site separately (PM_{10} & $PM_{2.5}$)
- All sites (PM_{10} & $PM_{2.5}$)
- 1 data set with measured values ≥ 50 % of the daily average limit DL of 50 µg/m³ for PM_{10} (Basis: average values of the reference measurement)
- 1 data set with measured values ≥ 50 % of the annual average limit AL of 40 µg/m³ for PM_{10} (Basis: average values of the reference measurement)
- 1 data set with measured values ≥ 50 % of the annual average limit AL, level 1 of 25 µg/m³ for $PM_{2.5}$ (Basis: average values of the reference measurement)
- 1 data set with measured values ≥ 50 % of the annual average limit AL, level 2 of 20 µg/m³ for $PM_{2.5}$ (Basis: average values of the reference measurement)

[Point 9.5.3] The combined uncertainty of the candidates $w_{c,CM}$ is calculated for each data set by combining the contributions from 9.5.2.1 and 9.5.2.2 according to the following equation:

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

Uncertainty is calculated at the limit value for each data set, where y_i is used as the concentration at the limit.

[Point 9.5.4] The expanded relative uncertainty of the results of the candidates is calculated for each data set by multiplication of $w_{c,CM}$ with a coverage factor k according to the following equation:

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

In practice: k=2 for large n

[Point 9.6] The highest resulting uncertainty W_{CM} is compared and assessed with the requirements on data quality of ambient air measurements according to EU Standard [1].
Two results are possible:

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

The specified expanded relative uncertainty W_{dqo} for particulate matter is 25 % [1].

7.5 Assessment

The determined uncertainties W_{CM} are below the specified expanded relative uncertainty W_{dqo} of 25% (particulate matter) for all data sets without usage of corrective factors.

Minimum requirement fulfilled? yes

Within the scope of the suitability testing we found occasionally high deviations between the results obtained for PM_{10} with the candidates and the reference equipment, especially at days with high amounts of dust. The cause of this significantly differing separation behaviour of the reference equipment in comparison with the candidates was found in the different design of the sampling inlets (impactor nozzle). Section 5 of this report describes the root-cause-analysis of the problem at hand and the assessment on these deviations in detail. All measured values are listed in Annex 2 of the annex.

Important!

The measured component $PM_{2.5}$ is not affected in any way by the described problem.

7.6 Detailed representation of test results

Table 52 and Table 53 show an overview of the in-between-instrument uncertainties u_{ref} of the reference devices during field tests. A summarized representation and assessment of the extended measurement uncertainties during the field tests is shown in Table 54 and Table 55. Table 56 to Table 79 show the results of evaluation for the individual data sets. Figure 76 to Figure 89 show a graphical representation of the results.

Table 52: In-between-instrument uncertainty u_{ref} of the reference devices, measured component PM_{10}

Reference devices	Site	No. of values	Uncertainty u_{bs}
			µg/m³
	Koeln, Parking lot	102	1.12
	Bonn, Belderberg	65	0.53
	Teddington	80	0.40
	Bruehl	58	0.77
	All sites	305	0.80

Table 53: In-between-instrument uncertainty u_{ref} of the reference devices, measured component $PM_{2.5}$

Reference devices	Site	No. of Values	Uncertainty u_{bs}
			µg/m³
	Koeln, Parking lot	46	0.67
	Bonn, Belderberg	43	0.46
	Teddington	81	0.33
	Bruehl	46	0.49
	All sites	216	0.48

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

Table 54: Summary and assessment of the extended measurement uncertainties W_{CM} during field test, measured component PM_{10}, raw data

PM_{10} Site	**Limit** µg/m³	**Slope b** (µg/m³)/(µg/m³)	**Ordinate intercept a** µg/m³	**u_{c_s} at the limit** µg/m³	**w_{CM}** %	**W_{CM}** %	**$W_{CM} \leq W_{dqo}$** (W_{dqo} = 25 %)
Koeln, Parking lot	50	1.10	0.06	5.21	10.41	20.82	Yes
	40	1.10	0.06	4.25	10.64	21.27	Yes
Bonn	50	1.12	-1.11	5.29	10.57	21.14	Yes
	40	1.12	-1.11	4.14	10.35	20.69	Yes
Teddington	50	0.96	2.27	1.45	2.90	5.79	Yes
	40	0.96	2.27	1.54	3.86	7.71	Yes
Bruehl	50	1.04	-1.82	1.62	3.24	6.48	Yes
	40	1.04	-1.82	1.59	3.98	7.97	Yes
All sites	50	1.08	-0.35	4.29	8.58	17.15	Yes
	40	1.08	-0.35	3.57	8.92	17.85	Yes
values ≥ 50 % DL (≥ 25 µg/m³)	50	1.17	-3.64	5.13	10.25	20.51	Yes
values ≥ 50 % AL (≥ 20 µg/m³)	40	1.16	-3.17	3.79	9.48	18.96	Yes

Table 55: Summary and assessment of the extended measurement uncertainties W_{CM} during field test, measured component $PM_{2.5}$, raw data

$PM_{2.5}$ Site	Limit µg/m³	Slope b (µg/m³)/(µg/m³)	Ordinate intercept a µg/m³	u_{c_s} at the limit µg/m³	w_{CM} %	W_{CM} %	$W_{CM} \leq W_{dqo}$ (W_{dqo} = 25 %)
Koeln, Parking lot	25	0.98	-0.14	1.07	4.28	8.57	Yes
	20	0.98	-0.14	1.03	5.17	10.34	Yes
Bonn	25	1.01	-1.60	1.79	7.14	14.29	Yes
	20	1.01	-1.60	1.82	9.11	18.22	Yes
Teddington	25	0.97	1.28	1.41	5.66	11.31	Yes
	20	0.97	1.28	1.48	7.39	14.77	Yes
Bruehl	25	0.97	-0.86	1.98	7.93	15.86	Yes
	20	0.97	-0.86	1.86	9.32	18.64	Yes
All sites	25	0.95	0.45	1.67	6.67	13.35	Yes
	20	0.95	0.45	1.56	7.80	15.61	Yes
values ≥ 50 % AL 1 (≥ 12,5 µg/m³)	25	1.03	-1.46	-0.74	7.05	14.11	Yes
values ≥ 50 % AL 2 (≥ 10 µg/m³)	20	1.01	-0.99	1.76	8.79	17.57	Yes

Table 56: Comparison between candidate and reference device, Site Koeln, Parking lot, measured component PM_{10}, limit 50 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	cologne, parking lot	Limit value	50	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.10**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**0.06**	**not significant**		
Uncertainty of a	**0.32**			
Results of equivalence test				
Deviation at limit value	**5.02**	**µg/m³**		
Uncertainty $u_{c\_s\ at}$ limit value	**5.21**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**10.41**	**%**		
Expanded uncertainty W_{CM}	**20.82**	**%**		
Status equivalence test	**passed**			

Table 57: Comparison between candidate and reference device, Site Koeln, Parking lot, measured component PM_{10}, limit 40 µg/m³

Comparison candidatewith reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	Cologne, parking lot	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.10**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**0.06**	**not significant**		
Uncertainty of a	**0.32**			
Results of equivalence test				
Deviation at limit value	**4.03**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**4.25**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**10.64**	**%**		
Expanded uncertainty W_{CM}	**21.27**	**%**		
Status equivalence test	**passed**			

Table 58: Comparison between candidate and reference device, Site Bonn, Belderberg, measured component PM_{10}, limit 50 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	Bonn	Limit value	50	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.12**	**significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**-1.11**	**significant**		
Uncertainty of a	**0.55**			
Results of equivalence test				
Deviation at limit value	**5.02**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**5.29**	**µg/m³**		
Combined measurment uncertainty W_{CM}	**10.57**	**%**		
Expanded uncertainty W_{CM}	**21.14**	**%**		
Status equivalence test	**passed**			

Table 59: Comparison between candidate and reference device, Site Bonn, Belderberg, measured component PM_{10}, limit 40 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	Bonn	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.12**	**significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**-1.11**	**significant**		
Uncertainty of a	**0.55**			
Results of equivalence test				
Deviation at limit value	**3.79**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**4.14**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**10.35**	**%**		
Expanded uncertainty W_{CM}	**20.69**	**%**		
Status equivalence test	**passed**			

Table 60: Comparison between candidate and reference device, Site Teddington, measured component PM_{10}, limit 50 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN145 & SN149	
Test site	Teddington	Limit value	50	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.96**	**significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**2.27**	**significant**		
Uncertainty of a	**0.40**			
Results of equivalence test				
Deviation at limit value	**0.11**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.45**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**2.90**	**%**		
Expanded uncertainty W_{CM}	**5.79**	**%**		
Status equivalence test	**passed**			

Table 61: Comparison between candidate and reference device, Site Teddington, measured component PM_{10}, limit 40 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN145 & SN149	
Test site	Teddington	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.96**	**significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**2.27**	**significant**		
Uncertainty of a	**0.40**			
Results of equivalence test				
Deviation at limit value	**0.54**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.54**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**3.86**	**%**		
Expanded uncertainty W_{CM}	**7.71**	**%**		
Status equivalence test	**passed**			

Table 62: Comparison between candidate and reference device, Site Bruehl, measured component PM_{10}, limit 50 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	Bruehl	Limit value	50	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.04**	**not significant**		
Uncertainty of b	**0.03**			
Ordinate intercept a	**-1.82**	**significant**		
Uncertainty of a	**0.60**			
Results of equivalence test				
Deviation at limit value	**0.32**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.62**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**3.24**	**%**		
Expanded uncertainty W_{CM}	**6.48**	**%**		
Status equivalence test	**passed**			

Table 63: Comparison between candidate and reference device, Site Bruehl, measured component PM_{10}, limit 40 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	Bruehl	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.04**	**not significant**		
Uncertainty of b	**0.03**			
Ordinate intercept a	**-1.82**	**significant**		
Uncertainty of a	**0.60**			
Results of equivalence test				
Deviation at limit value	**-0.11**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.59**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**3.98**	**%**		
Expanded uncertainty W_{CM}	**7.97**	**%**		
Status equivalence test	**passed**			

Table 64: Comparison between candidate and reference device, all sites, measured component PM_{10}, limit 50 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	All test sites	Limit value	50	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.08**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**-0.35**	**not significant**		
Uncertainty of a	**0.25**			
Results of equivalence test				
Deviation at limit value	**3.81**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**4.29**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**8.58**	**%**		
Expanded uncertainty W_{CM}	**17.15**	**%**		
Status equivalence test	**passed**			

Table 65: Comparison between candidate and reference device, all sites, measured component PM_{10}, limit 40 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	All test sites	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.08**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**-0.35**	**not significant**		
Uncertainty of a	**0.25**			
Results of equivalence test				
Deviation at limit value	**2.98**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**3.57**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**8.92**	**%**		
Expanded uncertainty W_{CM}	**17.85**	**%**		
Status equivalence test	**passed**			

Table 66: Comparison between candidate and reference device, all sites, values ≥ 50 % DL (≥ 25 µg/m³), measured component PM_{10}, limit 50 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites, Ref.≥25µg/m³	Limit value	50	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.17**	**significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**-3.64**	**significant**		
Uncertainty of a	**0.78**			
Results of equivalence test				
Deviation at limit value	**4.64**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**5.13**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**10.25**	**%**		
Expanded uncertainty W_{CM}	**20.51**	**%**		
Status equivalence test	**passed**			

Table 67: Comparison between candidate and reference device, all sites, values ≥ 50 % AL (≥ 20 µg/m³), measured component PM_{10}, limit 40 µg/m³

Comparison candidatewith reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites, Ref.≥20µg/m³	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.16**	**significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**-3.17**	**significant**		
Uncertainty of a	**0.58**			
Results of equivalence test				
Deviation at limit value	**3.13**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**3.79**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**9.48**	**%**		
Expanded uncertainty W_{CM}	**18.96**	**%**		
Status equivalence test	**passed**			

Table 68: Comparison between candidate and reference device, Site Koeln, Parking lot, measured component $PM_{2.5}$; limit 25 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	cologne, parking lot	Limit value	25	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.98**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**-0.14**	**not significant**		
Uncertainty of a	**0.37**			
Results of equivalence test				
Deviation at limit value	**-0.53**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.07**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**4.28**	**%**		
Expanded uncertainty W_{CM}	**8.57**	**%**		
Status equivalence test	**passed**			

Table 69: Comparison between candidate and reference device, Site Koeln, Parking lot, measured component $PM_{2.5}$, limit 20 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	cologne, parking lot	Limit value	20	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.98**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**-0.14**	**not significant**		
Uncertainty of a	**0.37**			
Results of equivalence test				
Deviation at limit value	**-0.45**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.03**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**5.17**	**%**		
Expanded uncertainty W_{CM}	**10.34**	**%**		
Status equivalence test	**passed**			

Table 70: Comparison between candidate and reference device, Site Bonn, Belderberg, measured component $PM_{2.5}$, limit 25 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	Bonn	Limit value	25	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.01**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**-1.60**	**significant**		
Uncertainty of a	**0.45**			
Results of equivalence test				
Deviation at limit value	**-1.37**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.79**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**7.14**	**%**		
Expanded uncertainty W_{CM}	**14.29**	**%**		
Status equivalence test	**passed**			

Table 71: Comparison between candidate and reference device, Site Bonn, Belderberg, measured component $PM_{2.5}$, limit 20 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	Bonn	Limit value	20	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.01**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**-1.60**	**significant**		
Uncertainty of a	**0.45**			
Results of equivalence test				
Deviation at limit value	**-1.41**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.82**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**9.11**	**%**		
Expanded uncertainty W_{CM}	**18.22**	**%**		
Status equivalence test	**passed**			

Table 72: Comparison between candidate and reference device, Site Teddington, measured component $PM_{2.5}$, limit 25 µg/m³

Comparison candidatewith reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN145 & SN149	
Test site	Teddington	Limit value	25	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.97**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**1.28**	**significant**		
Uncertainty of a	**0.26**			
Results of equivalence test				
Deviation at limit value	**0.55**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.41**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**5.66**	**%**		
Expanded uncertainty W_{CM}	**11.31**	**%**		
Status equivalence test	**passed**			

Table 73: Comparison between candidate and reference device, Site Teddington, measured component $PM_{2.5}$, limit 20 µg/m³

Comparison candidatewith reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN145 & SN149	
Test site	Teddington	Limit value	20	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.97**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**1.28**	**significant**		
Uncertainty of a	**0.26**			
Results of equivalence test				
Deviation at limit value	**0.70**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.48**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**7.39**	**%**		
Expanded uncertainty W_{CM}	**14.77**	**%**		
Status equivalence test	**passed**			

Table 74: Comparison between candidate and reference device, Site Bruehl, measured component $PM_{2.5}$, limit 25 µg/m³

Comparison candidatewith reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	Bruehl	Limit value	25	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.97**	**not significant**		
Uncertainty of b	**0.03**			
Ordinate intercept a	**-0.86**	**not significant**		
Uncertainty of a	**0.47**			
Results of equivalence test				
Deviation at limit value	**-1.60**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.98**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**7.93**	**%**		
Expanded uncertainty W_{CM}	**15.86**	**%**		
Status equivalence test	**passed**			

Table 75: Comparison between candidate and reference device, Site Bruehl, measured component $PM_{2.5}$, limit 20 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	Bruehl	Limit value	20	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.97**	**not significant**		
Uncertainty of b	**0.03**			
Ordinate intercept a	**-0.86**	**not significant**		
Uncertainty of a	**0.47**			
Results of equivalence test				
Deviation at limit value	**-1.46**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.86**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**9.32**	**%**		
Expanded uncertainty W_{CM}	**18.64**	**%**		
Status equivalence test	**passed**			

Table 76: Comparison between candidate and reference device, all sites, measured component $PM_{2.5}$, limit 25 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites	Limit value	25	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.95**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**0.45**	**significant**		
Uncertainty of a	**0.20**			
Results of equivalence test				
Deviation at limit value	**-0.81**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.67**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**6.67**	**%**		
Expanded uncertainty W_{CM}	**13.35**	**%**		
Status equivalence test	**passed**			

Table 77: Comparison between candidate and reference device, all sites, measured component PM2.5, limit 20 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites	Limit value	20	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.95**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**0.45**	**significant**		
Uncertainty of a	**0.20**			
Results of equivalence test				
Deviation at limit value	**-0.56**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.56**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**7.80**	**%**		
Expanded uncertainty W_{CM}	**15.61**	**%**		
Status equivalence test	**passed**			

Table 78: Comparison between candidate and reference device, all sites, values ≥ 50 % AL 1 (≥ 12.5 µg/m³), measured component $PM_{2.5}$, limit 25 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites, Ref.≥12,5µg/m³	Limit value	25	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.03**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**-1.46**	**significant**		
Uncertainty of a	**0.49**			
Results of equivalence test				
Deviation at limit value	**-0.74**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.76**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**7.05**	**%**		
Expanded uncertainty W_{CM}	**14.11**	**%**		
Status equivalence test	**passed**			

Table 79: Comparison between candidate and reference device, all sites, values ≥ 50 % AL 2 (≥ 10 µg/m³), measured component $PM_{2.5}$, limit 20 µg/m³

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites, Ref.≥10µg/m³	Limit value	20	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.01**	**not significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**-0.99**	**significant**		
Uncertainty of a	**0.41**			
Results of equivalence test				
Deviation at limit value	**-0.75**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.76**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**8.79**	**%**		
Expanded uncertainty W_{CM}	**17.57**	**%**		
Status equivalence test	**passed**			

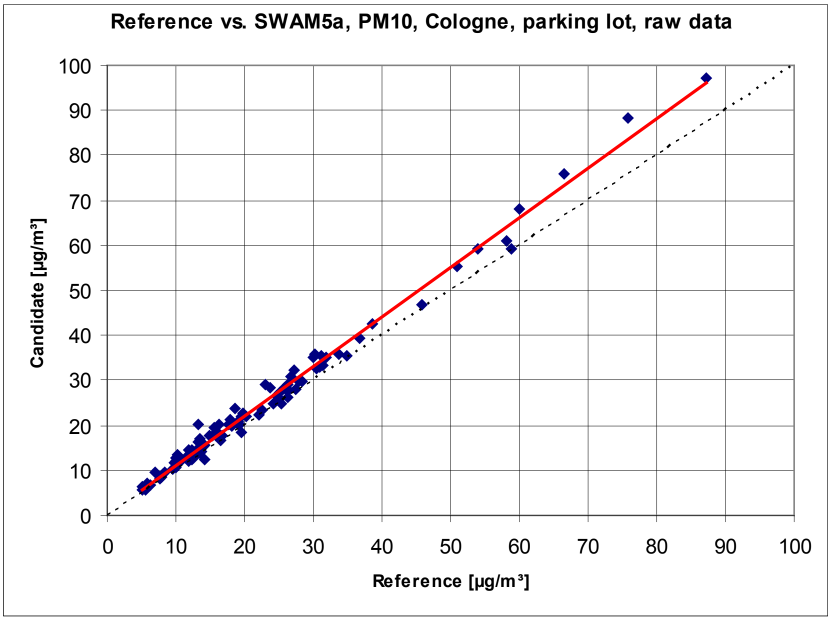


Figure 76: Reference device vs. candidate, Site Koeln, Parking lot, measured component PM_{10}

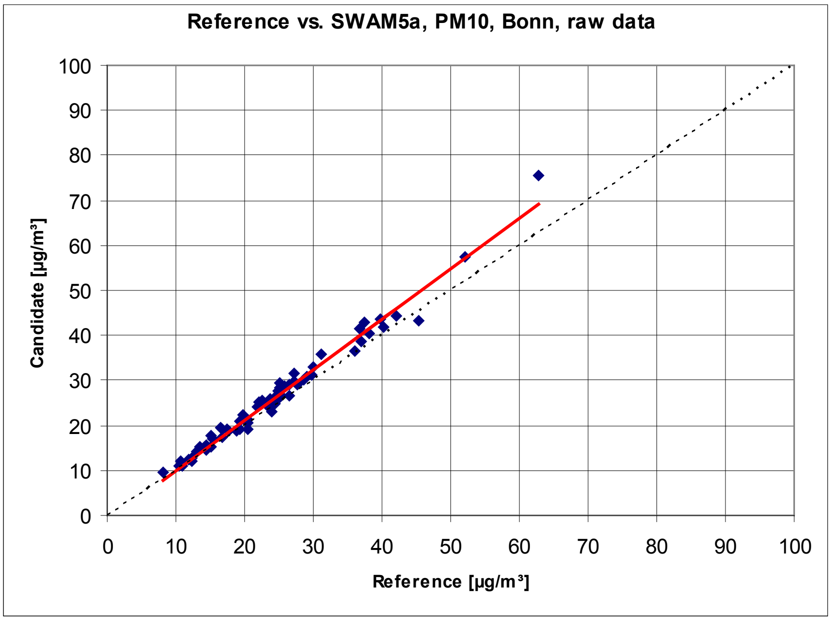


Figure 77: Reference device vs. candidate, Site Bonn, Belderberg, measured component PM_{10}

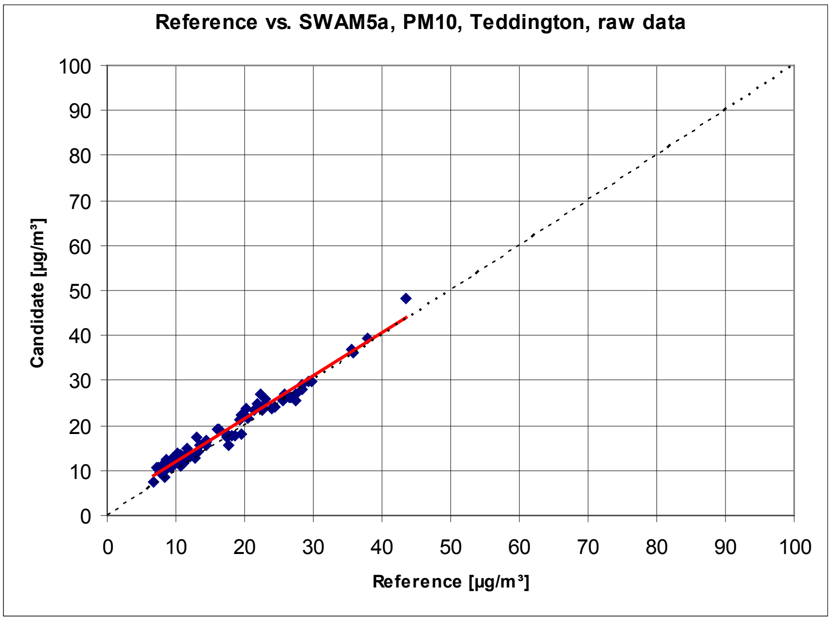


Figure 78: Reference device vs. candidate, Site Teddington, measured component PM_{10}

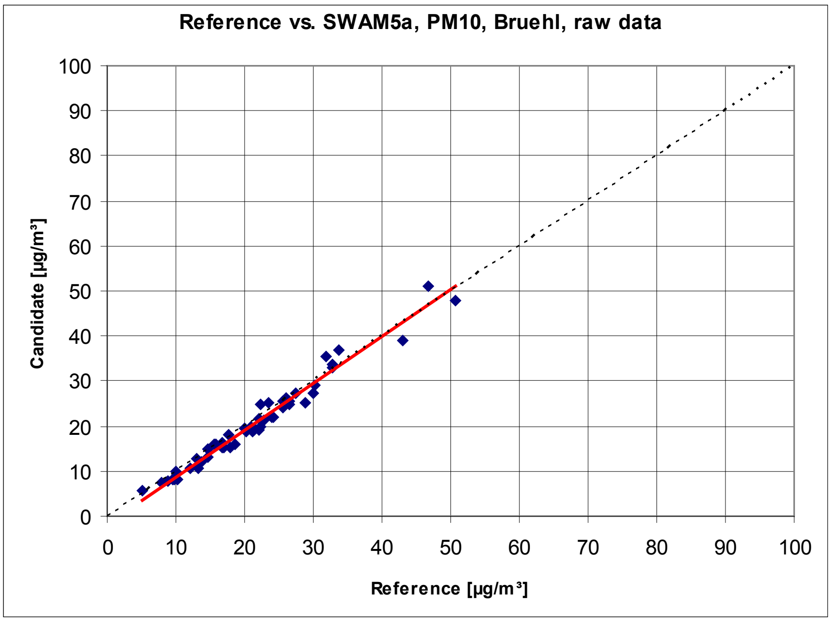


Figure 79: Reference device vs. candidate, Site Bruehl, measured component PM_{10}

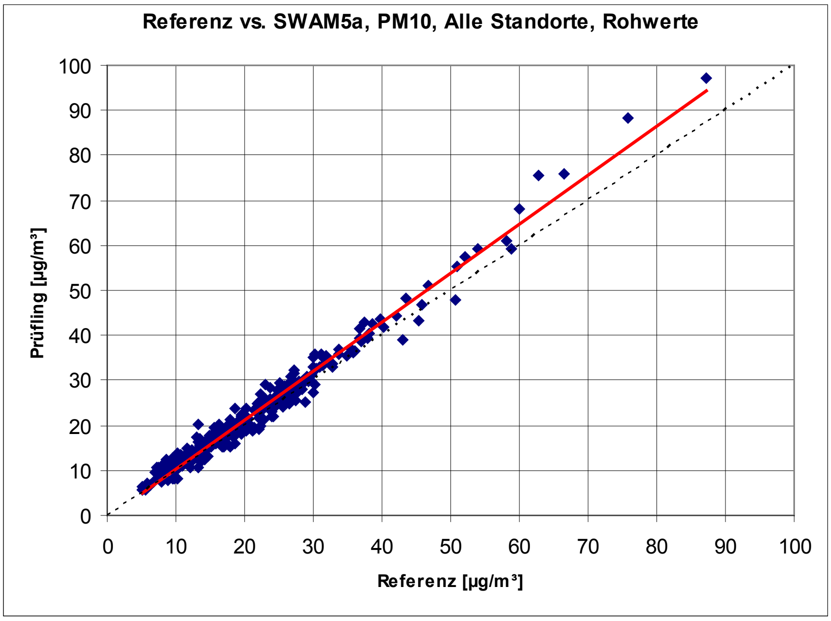


Figure 80: Reference device vs. candidate, all sites, measured component PM_{10}

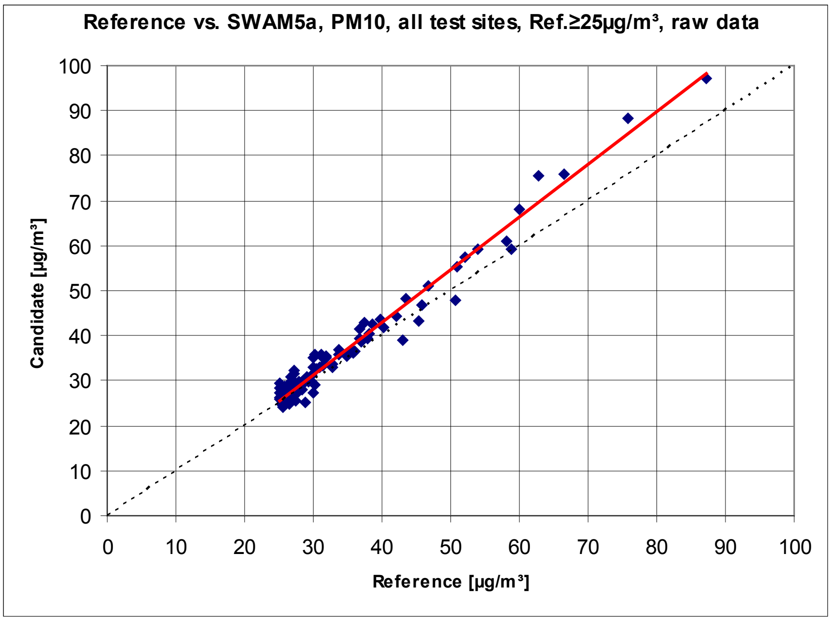


Figure 81: Reference device vs. candidate, all sites, values ≥ 50 % DL (≥ 25 µg/m³), measured component PM_{10}

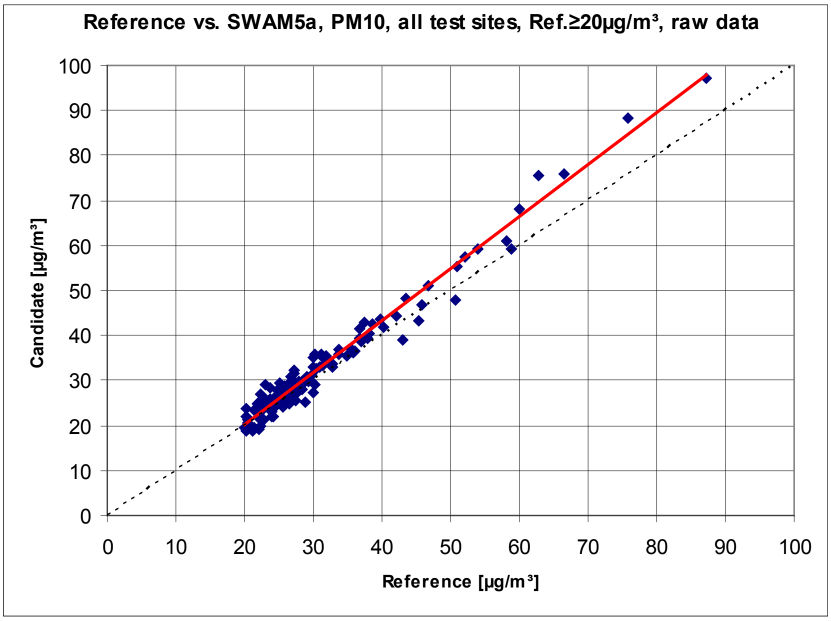


Figure 82: Reference device vs. candidate, all sites, values ≥ 50 % AL (≥ 20 µg/m³), measured component PM_{10}

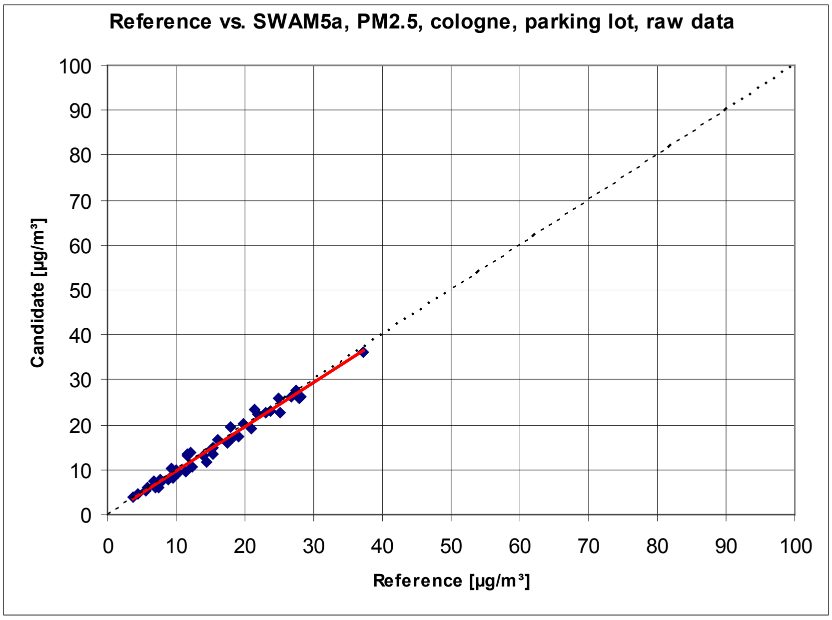


Figure 83: Reference device vs. candidate, Site Koeln, Parking lot, measured component $PM_{2.5}$

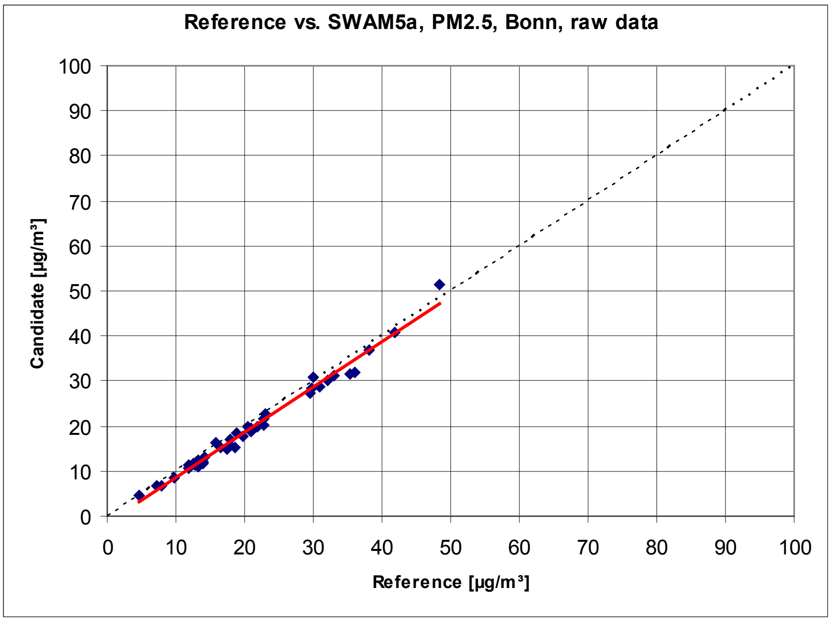


Figure 84: Reference device vs. candidate, Site Bonn, Belderberg, measured component $PM_{2.5}$

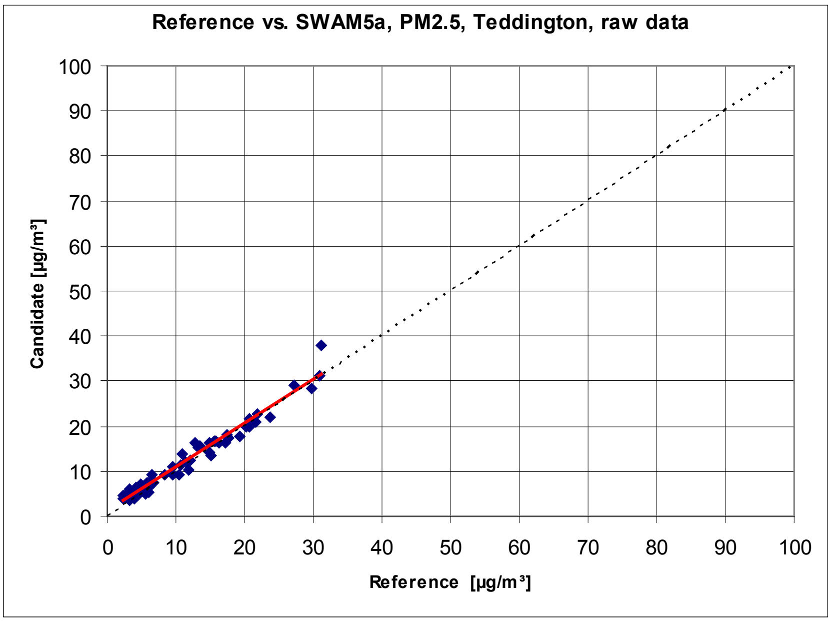


Figure 85: Reference device vs. candidate, Site Teddington, measured component $PM_{2.5}$

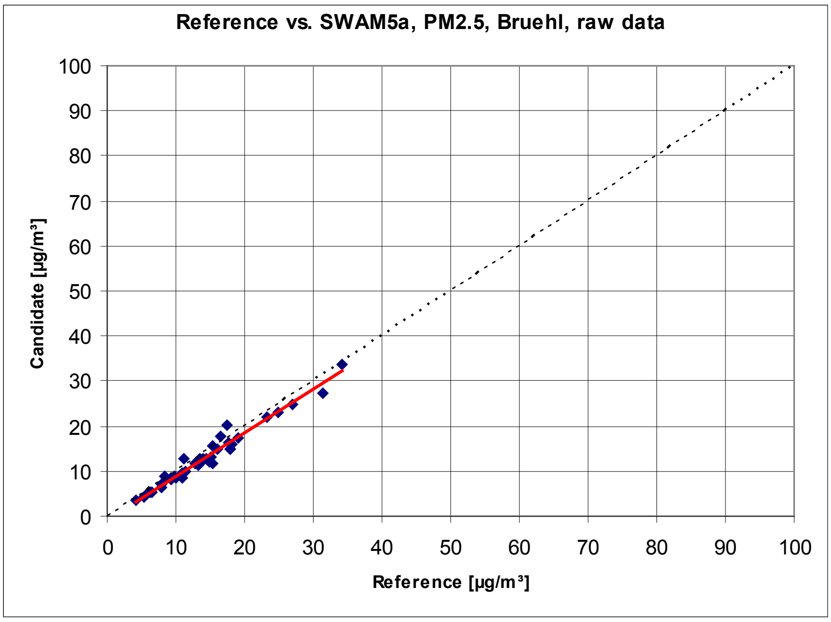


Figure 86: Reference device vs. candidate, Site Bruehl, measured component $PM_{2.5}$

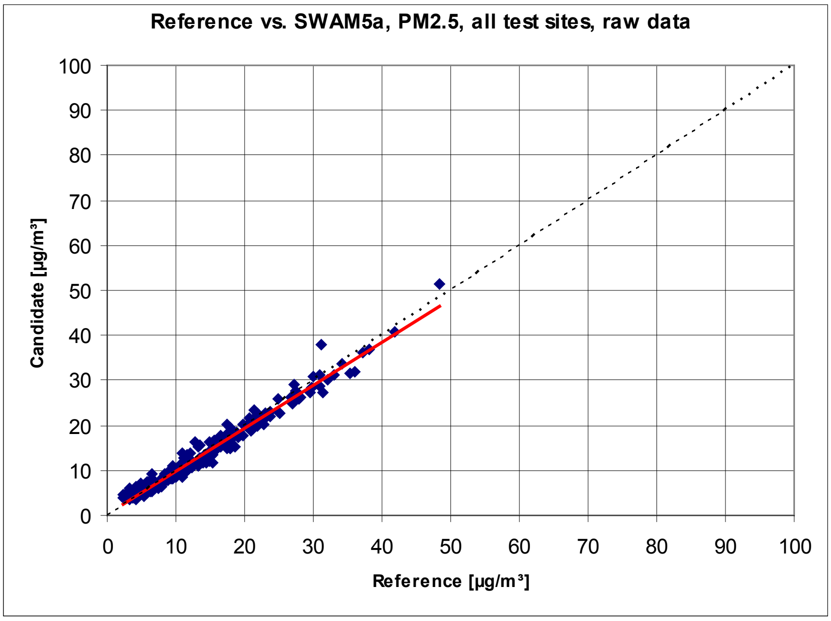


Figure 87: Reference device vs. candidate, all sites, measured component $PM_{2.5}$

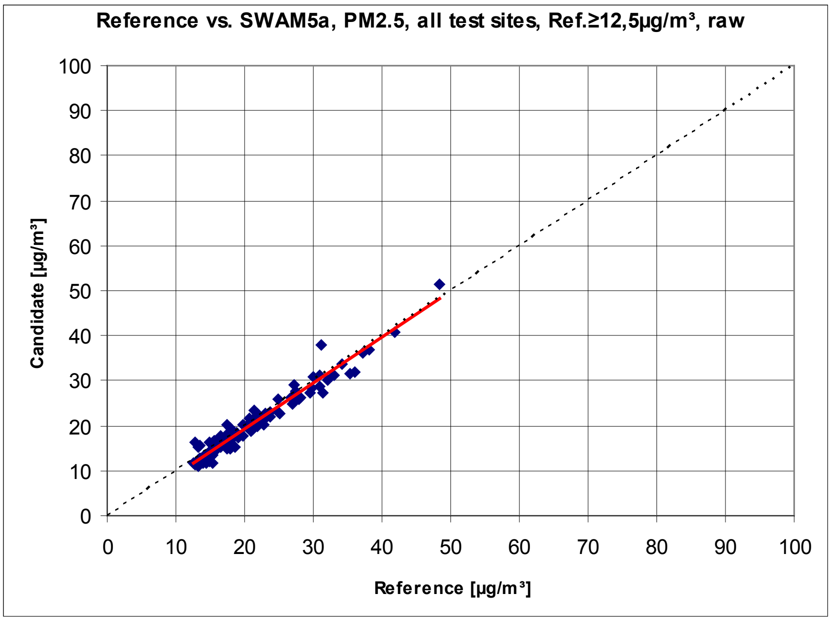


Figure 88: Reference device vs. candidate, all sites, values ≥ 50 % AL 1 (≥ 12.5 µg/m³), measured component $PM_{2.5}$

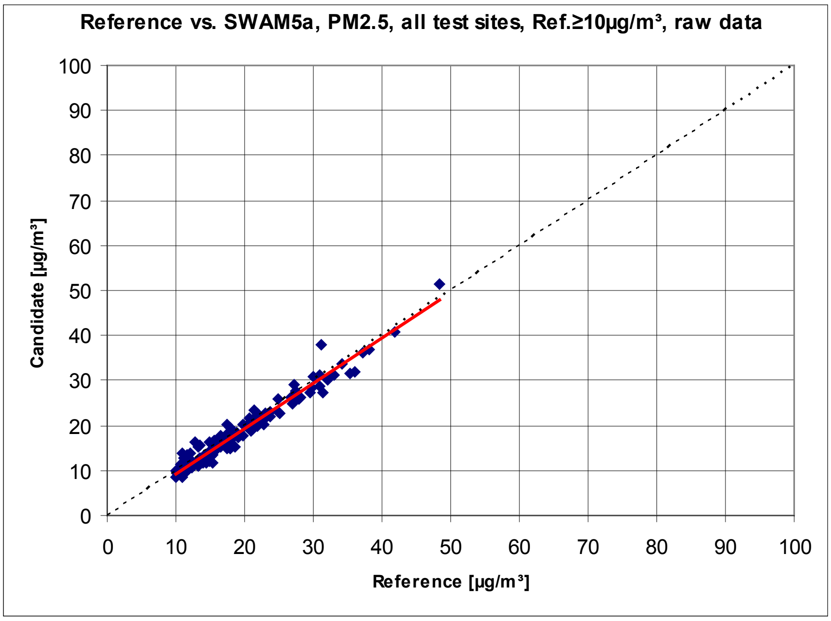


Figure 89: Reference device vs. candidate, all sites, values ≥ 50 % AL 2 (≥ 10 µg/m³), measured component $PM_{2.5}$

7.1 Application of correction factors or terms [9.7]

If the highest resulting expanded uncertainty of the candidate method is larger than the expanded relative uncertainty, which is defined in the requirements on the data quality of ambient air measurements according to EU-Guideline [7], the application of correction factors or terms is permitted. The corrected values have to fulfil the requirements according to point 9.5.2.2 et seqq. of the Guidance „Demonstration of Equivalence of Ambient Air Monitoring Methods“.

7.2 Equipment

Not required for this minimum requirement.

7.3 Carrying out the test

See Module 9.5.2.2 – 9.5.6.

7.4 Evaluation

If evaluation of the raw data according to module 9.5.2.2 – 9.5.6 leads to a case $W_{CM} > W_{dqo}$, which means that the candidate systems is not regarded equivalent to the reference method, it is permitted to apply a correction factor or –term resulting from the regression equation obtained from the full data set. The corrected values shall satisfy the requirements for all data sets or subsets (refer to module 9.5.2.2 – 9.5.6).
Moreover, a correction factor may be applied even for $W_{CM} \leq W_{dqo}$ in order to improve the accuracy of the candidate systems.

Three distinct situations may arise:

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

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

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

Re a)

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

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

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

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

and

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

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

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in annex B of [6]. RSS is determined analogue to the calculation in module 9.5.2.2 – 9.5.6.

Re b)

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

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

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

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

and

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

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

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in annex B of [6]. RSS is determined analogue to the calculation in module 9.5.2.2 – 9.5.6.

Re c)

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

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

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

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

and

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

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

Algorithms for the calculation of intercepts as well as slopes and their variances by orthogonal regression are described in detail in annex B of [6]. RSS is determined analogue to the calculation in module 9.5.2.2 – 9.5.6.

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

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

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

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

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

In practice: k=2 for large n

The highest resulting uncertainty W_{CM} is compared and assessed with the requirements on data quality of ambient air measurements according to EU Standard [1].
Two results are possible:

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

The specified expanded relative uncertainty W_{dqo} for particulate matter is 25 % [1]

7.5 Assessment

The candidate systems fulfil the requirements on the data quality of ambient air quality measurements during the test without application of correction factors. An additional correction of the complete data set may be carried out to show possible potential for improvements in the accuracy of the candidate systems.
Accuracy of the SWAM 5a Dual Channel Monitor measuring system for the measured component PM_{10} and the entire data set changed from 17.85 % (raw data) to 19.37 % (intercept correction), 9.33°% (slope correction) and 9.26 % (correction of intercept and slope) after applying correction factors.
For the measured component $PM_{2.5}$ and the entire data set, accuracy changed from 15.61% (raw data) to 17.87% (intercept correction), 16.36% (slope correction) and 15.76% (correction of intercept and slope) after applying correction factors.
Thus, no significant differences were determined in the respective measurement uncertainties.

The information given in point 5 and in annex 2 should be taken into account for the assessment of PM_{10}.

No significant differences between the respective measurement uncertainty types were found for the measured component $PM_{2.5}$ after applying correction factors or terms.

Minimum requirement fulfilled? yes

7.6 Detailed representation of test results

Table 80 to Table 87 show the results of evaluation for the entire data set after appliance of correction factors or terms.

Table 80: Comparison between candidate and reference device, all sites, measured component PM_{10}, AL = 40 µg/m³, raw data

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	All test sites	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.08**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**-0.35**	**not significant**		
Uncertainty of a	**0.25**			
Results of equivalence test				
Deviation at limit value	**2.98**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**3.57**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**8.92**	**%**		
Expanded uncertainty W_{CM}	**17.85**	**%**		
Status equivalence test	**passed**			

Table 81: Comparison between candidate and reference device, all sites, measured component PM_{10}, AL = 40 µg/m³, intercept correction

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	All test sites	Limit value	40	µg/m³
Status of measured values	Correction intercept	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.08**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**0.00**	**not significant**		
Uncertainty of a	**0.25**			
Results of equivalence test				
Deviation at limit value	**3.33**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**3.87**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**9.68**	**%**		
Expanded uncertainty W_{CM}	**19.37**	**%**		
Status equivalence test	**passed**			

Table 82: Comparison between candidate and reference device, all sites, measured component PM_{10}, AL = 40 µg/m³, slope correction

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	All test sites	Limit value	40	µg/m³
Status of measured values	Correction slope	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.00**	**not significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**-0.30**	**not significant**		
Uncertainty of a	**0.24**			
Results of equivalence test				
Deviation at limit value	**-0.34**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.87**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**4.67**	**%**		
Expanded uncertainty W_{CM}	**9.33**	**%**		
Status equivalence test	**passed**			

Table 83: Comparison between candidate and reference device, all sites, measured component PM_{10}, AL = 40 µg/m³, correction of intercept and slope

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	All test sites	Limit value	40	µg/m³
Status of measured values	Correction intercept & slope	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.00**	**not significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**0.02**	**not significant**		
Uncertainty of a	**0.24**			
Results of equivalence test				
Deviation at limit value	**-0.02**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.85**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**4.63**	**%**		
Expanded uncertainty W_{CM}	**9.26**	**%**		
Status equivalence test	**passed**			

Table 84: Comparison between candidate and reference device, all sites, measured component $PM_{2.5}$, AL 2 = 20 µg/m³, raw data

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites	Limit value	20	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.95**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**0.45**	**significant**		
Uncertainty of a	**0.20**			
Results of equivalence test				
Deviation at limit value	**-0.56**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.56**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**7.80**	**%**		
Expanded uncertainty W_{CM}	**15.61**	**%**		
Status equivalence test	**passed**			

Table 85: Comparison between candidate and reference device, all sites, measured component $PM_{2.5}$, AL 2= 20 µg/m³, intercept correction

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites	Limit value	20	µg/m³
Status of measured values	Correction intercept	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.95**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**0.00**	**not significant**		
Uncertainty of a	**0.20**			
Results of equivalence test				
Deviation at limit value	**-1.01**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.79**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**8.93**	**%**		
Expanded uncertainty W_{CM}	**17.87**	**%**		
Status equivalence test	**passed**			

Table 86: Comparison between candidate and reference device, all sites, measured component $PM_{2.5}$, AL 2 = 20 µg/m³, slope correction

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites	Limit value	20	µg/m³
Status of measured values	Correction slope	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.00**	**not significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**0.47**	**significant**		
Uncertainty of a	**0.21**			
Results of equivalence test				
Deviation at limit value	**0.48**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.64**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**8.18**	**%**		
Expanded uncertainty W_{CM}	**16.36**	**%**		
Status equivalence test	**passed**			

Table 87: Comparison between candidate and reference device, all sites, measured component $PM_{2.5}$, AL 2 = 20 µg/m³, correction of intercept and slope

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites	Limit value	20	µg/m³
Status of measured values	Correction intercept & slope	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.00**	**not significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**-0.01**	**not significant**		
Uncertainty of a	**0.21**			
Results of equivalence test				
Deviation at limit value	**0.00**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.58**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**7.88**	**%**		
Expanded uncertainty W_{CM}	**15.76**	**%**		
Status equivalence test	**passed**			

8 Recommendations for practical use

Works in the maintenance interval (4 weeks)

The following regular maintenance works are required for the tested system:

- Check of system status
  The system status may either be checked by direct control of the device or by on-line monitoring.
- Cleaning of the sampling inlets according to the instructions given by the manufacturer. Local concentrations of particulate matter must be taken into consideration.
  These works may be combined with the filter exchange, which is required at least every 14 days for a supply of 36 filters.
- Monthly conduction of the device internal BETA SPAN TEST (this does not interfere with standard operation) according to the manual, section 7.2.1)
- Monthly cleaning of the system. This is necessary in any case after each campaign.

The instructions of the manufacturer have to be followed.

By default, the AMS performs an internal tightness check and an internal measurement of the flow rate during each measuring cycle. In case of unduly high deviations these points must be manually checked in time and corrected if necessary.

An external check or calibration of the AMS is not required except for unduly high deviations of BETA SPAN TEST or system malfunction.

Further maintenance works

The following works are necessary in addition to the regular works in the maintenance interval:

- Every three months: visual inspection of the suction pipe and cleaning, if necessary
  A tightness check is required after maintenance.
- Semi-annual check of the oil level and filter of the compressed air generator
- Annual maintenance of the pump. An air flow check is required after maintenance. Re-calibrate if necessary.

Further details are provided in the user manual.

Department of Environmental Protection

Karsten Pletscher | Dr. Peter Wilbring

Koeln, March 23rd 2009
936/21207522/A

9 Literature

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

[2] Standard VDI 4202, Sheet 1, „Minimum requirements for suitability tests of automated ambient air quality measuring systems – Point-related measurement methods of gaseous and particulate pollutants “, June 2002

[3] Standard VDI 4203, Sheet 3, „Testing of automated measuring systems – Test procedures for point-related ambient air quality measuring systems of gaseous and particulate pollutants “, August 2004

[4] European Standard EN 12341, „Air quality – Determination of the PM_{10} fraction of suspended particulate matter – Reference method and field test procedure to demonstrate reference equivalence of measurement methods“, German version DIN EN 12341: 1998

[5] Standard EN 14907, „Ambient air quality - Standard gravimetric measurement method for the determination of the $PM_{2.5}$ mass fraction of suspended particulate matter“, German version EN 14907: 2005

[6] Guide “Demonstration of Equivalence of Ambient Air Monitoring Methods”, English version of November 2005 (http://ec.europa.eu/environment/air/pdf/equivalence_report3.pdf)

[7] Standard VDI 2463, Sheet 7, „Particulate measurement – Measurement of mass concentration in ambient air. Filter method. Small filter device GS 050, 1982

[8] Operating manual SWAM 5a Dual Channel Monitor, June 2008 – rev.20

[9] Operating manual SEQ47/50, 2004

[10] Operating manual LVS3, 2000

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

10 Annex

Annex 1 **Measured and calculated values**

Appendix 1: Detection limit

Appendix 2: Temperature dependency of zero point

Appendix 3: Temperature dependency of sensitivity

Appendix 4: Dependency on supply voltage

Appendix 5: Measured values at the field test sites

Appendix 6: Ambient conditions at the field test sites

Appendix 7: Software version SWAM 5a Dual Channel Monitor

Annex 2 **Root-cause-analysis on the different separation behaviour of the used PM_{10} sampling inlets**

Annex 3 **Filter weighing procedure**

Annex 4 **Manuals**

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

Manufacturer	FAI Instruments s.r.l.			
Meas. range	0 to 200	µg/m³	Temperature climate chamber	20 °C
Type	SWAM5a		Rel. humidity climate chamber	50%
Serial-No.	SN127 & SN131		Zero gas	particle-free air via Zero-Filter

No.	Date	24-h-Measured values [µg/m³] SN127, line A	SN 127, line B	24-h-Measured values [µg/m³] SN131, line A	SN 131, line B
1	6/29/2007	0.10	0.30	0.00	0.40
2	6/30/2007	0.00	0.10	0.40	0.00
3	7/1/2007	0.00	0.20	0.00	0.00
4	7/2/2007	0.50	0.00	0.60	0.20
5	7/3/2007	0.50	0.50	0.00	0.00
6	7/4/2007	0.40	0.20	0.00	0.60
7	7/5/2007	0.50	0.60	0.40	0.50
8	7/6/2007	0.10	0.40	0.20	0.10
9	7/7/2007	0.30	0.50	0.20	0.20
10	7/8/2007	0.10	0.50	0.00	0.50
11	7/9/2007	0.30	0.60	0.00	0.00
12	7/10/2007	0.20	0.50	0.30	0.10
13	7/11/2007	0.50	0.40	0.40	0.10
14	7/12/2007	0.30	0.40	0.10	0.00
15	7/13/2007	0.60	0.50	0.30	0.30
16	7/14/2007	0.30	0.60	0.30	0.50
17	7/15/2007	0.00	0.50	0.50	0.50
18	7/16/2007	0.30	0.20	0.30	0.30
	No. of values	18	18	18	18
	Mean	0.28	0.39	0.22	0.24
	Standard deviation sx0	0.20	0.18	0.20	0.21
	Detection limit X	**0.69**	**0.77**	**0.64**	**0.69**

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

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

Manufacturer FAI Instruments s.r.l.

Standards Zero filter

Meas. range 0 to 200 µg/m³
type SWAM 5a Dual Channel Monitor
Serial-No. SN 127 & SN 131

		Cycle 1		Cycle 2		Cycle 3		Mean	
SN 127, A No.	Temperature [°C]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]
1	20	0.0	-	0.1	-	0.0	-	0.03	-
2	5	0.5	0.5	0.2	0.1	0.7	0.7	0.47	0.4
3	20	0.2	0.2	0.2	0.1	0.0	0.0	0.13	0.1
4	40	0.3	0.3	0.5	0.4	1.0	1.0	0.60	0.6
5	20	0.2	0.2	0.7	0.6	0.0	0.0	0.30	0.3
SN 127, B No.	Temperature [°C]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]
1	20	0.1	-	0.0	-	0.6	-	0.23	-
2	5	0.3	0.2	0.0	0.0	0.5	-0.1	0.27	0.0
3	20	0.2	0.1	0.2	0.2	0.4	-0.2	0.27	0.0
4	40	0.5	0.4	0.7	0.7	0.7	0.1	0.63	0.4
5	20	0.4	0.3	0.4	0.4	0.0	-0.6	0.27	0.0
SN 131, A No.	Temperature [°C]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]
1	20	0.0	-	0.1	-	0.4	-	0.17	-
2	5	0.2	0.2	0.1	0.0	0.4	0.0	0.23	0.1
3	20	0.0	0.0	0.3	0.2	0.0	-0.4	0.10	-0.1
4	40	0.7	0.7	0.8	0.7	0.6	0.2	0.70	0.5
5	20	0.3	0.3	0.4	0.3	0.5	0.1	0.40	0.2
SN 131, B No.	Temperature [°C]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]	Measured value [µg/m³]	Dev. [µg/m³]
1	20	0.2	-	0.0	-	0.5	-	0.23	-
2	5	0.0	-0.2	0.4	0.4	0.0	-0.5	0.13	-0.1
3	20	0.0	-0.2	0.4	0.4	0.0	-0.5	0.13	-0.1
4	40	1.0	0.8	0.7	0.7	0.8	0.3	0.83	0.6
5	20	0.0	-0.2	0.6	0.6	0.2	-0.3	0.27	0.0

Annex 3 **Dependence of sensitivity on ambient temperature** **Page 1 of 1**

Manufacturer FAI Instruments s.r.l.

Meas. range 0 to 200 µg/m³
type SWAM 5a Dual Channel Monitor
Serial-No. SN 127 & SN 131

Standards			
SN 127	3.405	mg/cm²
	6.810	mg/cm²
SN 131	3.405	mg/cm²
	6.810	mg/cm²

		Cycle 1		Cycle 2		Cycle 3		Mean	
SN 127, R1 No.	Temperature [°C]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]
1	20	3.462	-	3.454	-	3.458	-	3.458	-
2	5	3.487	0.7	3.488	1.0	3.490	0.9	3.488	0.9
3	20	3.460	-0.1	3.454	0.0	3.457	0.0	3.457	0.0
4	40	3.415	-1.4	3.412	-1.2	3.410	-1.4	3.412	-1.3
5	20	3.448	-0.4	3.450	-0.1	3.450	-0.2	3.449	-0.3
SN 127, R2 No.	Temperature [°C]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]
1	20	6.845	-	6.840	-	6.840	-	6.842	-
2	5	6.890	0.7	6.892	0.8	6.900	0.9	6.894	0.8
3	20	6.840	-0.1	6.835	-0.1	6.838	0.0	6.838	-0.1
4	40	6.762	-1.2	6.762	-1.1	6.761	-1.2	6.762	-1.2
5	20	6.825	-0.3	6.831	-0.1	6.832	-0.1	6.829	-0.2
SN 131, R1 No.	Temperature [°C]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]
1	20	3.401	-	3.397	-	3.396	-	3.398	-
2	5	3.361	-1.2	3.356	-1.2	3.365	-0.9	3.361	-1.1
3	20	3.405	0.1	3.392	-0.1	3.393	-0.1	3.397	0.0
4	40	3.305	-2.8	3.308	-2.6	3.297	-2.9	3.303	-2.8
5	20	3.404	0.1	3.394	-0.1	3.392	-0.1	3.397	0.0
SN 131, R2 No.	Temperature [°C]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]
1	20	6.875	-	6.877	-	6.877	-	6.876	-
2	5	6.843	-0.5	6.840	-0.5	6.839	-0.6	6.841	-0.5
3	20	6.875	0.0	6.865	-0.2	6.866	-0.2	6.869	-0.1
4	40	6.764	-1.6	6.751	-1.8	6.745	-1.9	6.753	-1.8
5	20	6.873	0.0	6.870	-0.1	6.863	-0.2	6.869	-0.1

Annex 4 **Dependence of sensitivity on mains voltage** **Page 1 of 1**

Manufacturer FAI Instruments s.r.l.

Meas. Range 0 to 200 µg/m³
Type SWAM 5a Dual Channel Monitor
Serial-No. SN 127 & SN 131

Standards			
	SN 127	3.405	mg/cm²
		6.810	mg/cm²
	SN 131	3.405	mg/cm²
		6.810	mg/cm²

		Cycle 1		Cycle 2		Cycle 3		Mean	
SN 127, R1 No.	Mains voltage [V]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]
1	230	3.457	-	3.455	-	3.451	-	3.45	-
2	210	3.453	-0.1	3.453	-0.1	3.448	-0.1	3.45	-0.1
3	230	3.451	-0.2	3.450	-0.1	3.454	0.1	3.45	-0.1
4	245	3.448	-0.3	3.446	-0.3	3.450	0.0	3.45	-0.2
5	230	3.443	-0.4	3.454	0.0	3.448	-0.1	3.45	-0.2
SN 127, R2 No.	Mains voltage [V]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]
1	230	6.833	-	6.838	-	6.828	-	6.83	-
2	210	6.833	0.0	6.830	-0.1	6.829	0.0	6.83	0.0
3	230	6.833	0.0	6.829	-0.1	6.828	0.0	6.83	0.0
4	245	6.826	-0.1	6.828	-0.1	6.825	0.0	6.83	-0.1
5	230	6.821	-0.2	6.829	-0.1	6.826	0.0	6.83	-0.1
SN 131, R1 No.	Mains voltage [V]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]
1	230	3.396	-	3.399	-	3.401	-	3.40	-
2	210	3.399	0.1	3.404	0.1	3.403	0.1	3.40	0.1
3	230	3.401	0.1	3.398	0.0	3.406	0.1	3.40	0.1
4	245	3.406	0.3	3.402	0.1	3.401	0.0	3.40	0.1
5	230	3.402	0.2	3.400	0.0	3.405	0.1	3.40	0.1
SN 131, R2 No.	Mains voltage [V]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]	Measured value [mg/cm²]	Dev. [%]
1	230	6.863	-	6.873	-	6.871	-	6.87	-
2	210	6.871	0.1	6.875	0.0	6.874	0.0	6.87	0.1
3	230	6.874	0.2	6.875	0.0	6.873	0.0	6.87	0.1
4	245	6.874	0.2	6.873	0.0	6.874	0.0	6.87	0.1
5	230	6.870	0.1	6.870	0.0	6.867	-0.1	6.87	0.0

Annex 5 **Measured values from the field test sites, related to ambient conditions**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10 & PM2,5, Ambient air
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.B.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		

No.	Date	Ref. 1	Ref. 2	Ref. 1	Ref 2.	TSP	SN 127		SN 131		Remark	Test site
		PM2,5 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
1	10/20/2007			18.0	20.2	25.2	15.9	20.8	16.4	21.0	Outlier Ref. PM2,5	Koeln,
2	10/21/2007			18.1	19.8		15.8	20.2	17.1	20.1		parking lot
3	10/22/2007			21.6	22.9						water inleakage SN127	
4	10/23/2007	23.1	20.9	24.4	26.6	33.5					water inleakage SN127	
5	10/24/2007	27.1	29.2	30.7	32.0	42.1	26.8	34.0	26.1	32.4		
6	10/25/2007	24.2	25.8	26.7	28.3	36.1	23.2	28.6	22.4	27.7		
7	10/26/2007	21.8	24.5	27.7	28.9	40.8	22.8	30.2	22.4	29.5		
8	10/27/2007			33.9	35.9		29.5	36.0	28.8	34.7		
9	10/28/2007			34.4	35.7						change to wintertime	
10	10/29/2007										change to wintertime	
11	10/30/2007										ZP/RP-Check	
12	10/31/2007	22.8	24.6	26.4	28.2	36.6	23.1	31.7	23.3	32.7		
13	11/01/2007			29.1	31.3		27.3	35.6	27.2	36.0		
14	11/02/2007			29.1	31.0		21.9	34.0	22.8	36.3		
15	11/03/2007			23.7	23.8		17.9	28.5	18.0	28.1		
16	11/04/2007			16.9	19.1		11.8	21.4	11.8	21.3		
17	11/05/2007	14.5	16.1	18.4	18.9	30.4	13.5	24.0	13.6	23.7		
18	11/06/2007	10.8	11.9	15.8	16.8	24.8	9.6	20.7	9.8	19.7		
19	11/07/2007	15.0	15.0	23.1	23.0	32.7	14.7	29.1	14.4	29.2		
20	11/08/2007	9.5	10.6	13.5	14.7	19.6	10.0	15.8	9.8	15.7		
21	11/09/2007	7.1	7.1	10.0	10.6	15.5	7.0	13.4	6.8	13.7		
22	11/10/2007			9.8	10.3		7.5	13.0	7.5	12.7		
23	11/11/2007			6.3	7.8		5.4	9.6	5.8	9.3		
24	11/12/2007	8.8	9.6	15.1	16.2	25.6	10.2	19.5	10.6	19.5		
25	11/13/2007	11.7	11.7	15.8	15.7	19.9	13.2	17.9	13.5	17.6		
26	11/14/2007	12.2	12.2	14.7	14.9	22.8	14.0	17.8	13.7	17.5		
27	11/15/2007	17.6	18.5	22.4	25.8	32.1	19.7	25.3	19.5	24.3		
28	11/16/2007	27.5	27.2	35.0	38.3	50.7	28.0	40.1	27.7	38.6		
29	11/17/2007			55.7	60.5		47.3	62.4	45.4	59.4		
30	11/18/2007	16.0	16.3	17.4	21.5	22.7	16.3	18.3	17.3	18.8		

Annex 5 **Measured values from the field test sites, related to ambient conditions** **Page 2 of 24**

Manufacturer	FAI Instruments s.r.l.		
		Measured object	SPM PM10 & PM2,5, Ambient air
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.B.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		

No.	Date	Ref. 1	Ref. 2	Ref. 1	Ref 2.	TSP	SN 127		SN 131		Remark	Test site
		PM2,5	PM2,5	PM10	PM10		PM2,5	PM10	PM2,5	PM10		
		[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]		
31	11/19/2007	21.6	22.3	24.5	28.3	28.6	22.6	26.3	22.1	26.2		Koeln,
32	11/20/2007			22.5	27.5		22.3	26.2	21.4	25.5		parking lot
33	11/21/2007			24.0	28.0		21.9	28.1	22.1	27.9		
34	11/22/2007	20.8	22.2	26.2	29.5	30.7	23.4	29.6	23.1	30.2		
35	11/23/2007	17.0	17.8	24.1	28.4	36.6	15.5	27.7	16.1	28.1		
36	11/24/2007			23.8	28.2		16.0	27.9	16.3	28.2		
37	11/25/2007			13.8	14.4		5.6	12.0	6.1	12.5		
38	11/26/2007			15.3	15.4		8.3	17.5	8.1	17.7		
39	11/27/2007	18.2	18.3	26.5	27.1		16.8	31.0	16.9	30.4		
40	11/28/2007	20.1	21.6	26.4	26.2	35.4	19.3	28.3	19.1	27.3		
41	11/29/2007			19.2	19.7		14.8	22.3	13.8	22.0		
42	11/30/2007			14.0	13.8		8.4	15.1	8.2	15.5		
43	12/01/2007			10.0	9.6		4.7	11.5	4.2	11.7		
44	12/02/2007			6.0	5.7		2.9	7.3	2.5	7.0		
45	12/03/2007			10.6	10.8		5.4	12.6	5.7	11.5		
46	12/04/2007	9.4	9.4	13.2	13.9	20.8	8.1	17.0	8.4	16.9		
47	12/05/2007	6.8	7.0	11.9	12.8	18.6	6.1	14.9	5.6	14.2		
48	12/06/2007			5.8	7.6						ZP/RP-Check	
49	12/07/2007	7.4	7.8	13.3	13.4	22.5	7.0	16.5	7.2	16.2		
50	12/08/2007			8.0	8.5		4.8	9.4	3.8	9.3		
51	12/09/2007			5.6	5.9		3.9	7.1	3.8	7.1		
52	12/10/2007	11.2	12.3	17.7	17.5	22.9	13.2	20.4	13.1	19.8		
53	12/11/2007			13.2	13.3		12.1	20.4	11.5	19.8		
54	12/12/2007	26.5	27.1	32.6	31.2		26.8	35.4	25.7	35.0		
55	12/13/2007	15.2	15.6	18.9	17.8		14.9	20.3	15.2	20.3		
56	12/14/2007	13.8	14.0	17.0	15.8		13.5	17.9	13.1	17.4		
57	12/15/2007			17.2	16.2		14.9	17.7	14.5	17.7		
58	12/16/2007			25.0	24.5		23.4	26.7	22.8	26.2		
59	12/17/2007	25.0	24.6	31.1	31.0		26.7	36.2	24.9	34.8		
60	12/18/2007			66.9	66.3		57.1	77.9	53.1	74.0		

Annex 5 **Measured values from the field test sites, related to ambient conditions** **Page 3 of 24**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10 & PM2,5, Ambient air
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.B.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		

No.	Date	Ref. 1	Ref. 2	Ref. 1	Ref 2.	TSP	SN 127		SN 131		Remark	Test site
		PM2,5 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
61	12/19/2007			77.0	74.9		64.8	89.6	63.0	87.3		Koeln,
62	12/20/2007			88.2	86.3		70.3	100.4	68.2	94.2		parking lot
63	12/21/2007			53.5	54.2		53.5	61.0	51.6	57.1		
64	12/22/2007			59.4	60.6		65.3	70.8	61.2	65.2		
65	12/23/2007			58.6	59.2		48.6	59.3	44.6	59.4		
66	12/24/2007			25.2	25.5		23.4	24.9	21.9	24.5		
67	12/25/2007			30.3	30.6		29.3	32.6	29.1	32.4		
68	12/26/2007			33.6	34.0		31.4	36.1	31.9	35.8		
69	12/27/2007			12.3	12.7		10.9	12.7	10.7	12.5		
70	12/28/2007			12.0	12.7		11.2	12.8	11.3	12.1		
71	12/29/2007			8.9	10.0		7.2	10.0	6.7	10.4		
72	12/30/2007			16.2	16.0		9.8	17.7	9.8	18.9		
73	12/31/2007	37.2	37.2	46.0	45.6		37.0	47.3	35.6	46.1		
74	01/01/2008			22.7	22.5		19.6	23.4	19.0	23.3		
75	01/02/2008			19.4	19.3		17.3	20.2	17.0	20.1		
76	01/03/2008	19.8	19.8	21.9	22.4		20.5	22.7	19.7	22.1		
77	01/04/2008						23.1	26.5	22.7	26.4		
78	01/05/2008						7.0	11.2	6.0	11.4		
79	01/06/2008										filter supply ran out	
80	01/07/2008										filter supply ran out	
81	01/08/2008										ZP/RP-Check	
82	01/09/2008	8.3	9.2	12.4	13.4	13.9	7.6	14.9	7.8	14.5		
83	01/10/2008	9.4	9.6	11.3	12.1	13.0	9.1	12.8	8.7	13.3		
84	01/11/2008	6.0	5.4	7.5	8.3	10.0	6.0	8.8	6.0	8.2		
85	01/12/2008			14.1	12.7		9.1	13.8	9.0	13.8		
86	01/13/2008			16.2	16.6		12.8	16.8	13.0	16.8		
87	01/14/2008	10.3	8.8	13.2	13.6	14.5	10.1	14.3	9.9	14.0		
88	01/15/2008	4.6	4.1	7.0	5.8	8.3	4.8	6.6	4.7	6.7		
89	01/16/2008	6.8	6.6	10.0	10.1	11.9	7.4	12.1	7.4	12.3		
90	01/17/2008	7.2	7.6	12.3	11.7	14.0	5.9	12.8	6.1	13.0		

Annex 5 **Measured values from the field test sites, related to ambient conditions** **Page 4 of 24**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10 & PM2,5, Ambient air
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.B.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		

No.	Date	Ref. 1	Ref. 2	Ref. 1	Ref 2.	TSP	SN 127		SN 131		Remark	Test site
		PM2,5 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
91	01/18/2008			12.0	11.8		5.7	14.4	4.3	14.5		Koeln, parking lot
92	01/19/2008	3.4	4.2	5.6	4.4	8.5	4.0	6.3	3.8	6.6		
93	01/20/2008			5.7	5.3		3.7	5.7	3.4	5.4		
94	01/21/2008	5.6	5.4	8.5	8.4	10.4	5.6	9.9	5.4	9.0		
95	01/22/2008			20.3	19.4		9.4	22.7	9.6	22.8		
96	01/23/2008	12.2	12.4	20.6	20.0	20.4	10.8	22.2	10.5	21.9		
97	01/24/2008	14.1	14.7	26.7	26.0	31.5	12.5	29.5	11.1	28.7		
98	01/25/2008	10.1	10.3	18.3	18.0	21.7	9.0	20.0	9.2	20.0		
99	01/26/2008			26.3	25.5		17.1	28.4	17.0	28.6		
100	01/27/2008			31.6	30.3		17.3	32.1	17.0	33.8		
101	01/28/2008	27.5	28.3	39.2	38.1	44.2	25.9	42.5	25.6	42.9		
102	01/29/2008			51.0	50.8		36.2	55.8	34.4	55.0		
103	01/30/2008	18.8	19.4	24.7	25.7	25.4	17.4	27.2	17.5	27.3		
104	01/31/2008			7.7	7.7		5.6	8.4	5.6	8.1		
105	02/01/2008			10.8	10.2		5.4	11.9	5.0	12.1		
106	02/02/2008			13.4	14.2		7.1	14.1	6.8	14.4		
107	02/03/2008			11.5	12.2		9.1	11.9	8.9	12.3		
108	02/04/2008	7.6	7.6	9.7	10.4	8.7	8.1	10.9	7.7	10.3		
109	02/05/2008			5.2	5.3		3.3	5.8	2.8	5.7		
110	02/14/2008	32.6	33.3	38.2	38.2	54.0	31.6	41.2	30.9	39.8		Bonn
111	02/15/2008			15.0	15.5		11.6	16.7	11.9	17.5		
112	02/16/2008			18.3	19.2		15.0	19.0	14.9	18.6		
113	02/17/2008	30.3	29.9	37.7	37.4	47.6	31.0	43.5	30.4	42.0		
114	02/18/2008	48.4	48.5	63.0	62.4	81.2	50.8	75.8	52.2	75.1		
115	02/19/2008	41.7	42.1	52.0	51.9	60.4	40.7	57.7	40.6	56.9		
116	02/20/2008	38.8	37.6	41.6	42.6	44.4	36.6	44.2	37.1	44.4		
117	02/21/2008	30.7	31.0	39.9	39.5	56.5	29.0	43.5	28.5	43.9		
118	02/22/2008	17.8	17.9	24.8	25.1	41.8	15.5	27.9	15.7	27.2		
119	02/23/2008			27.4	27.2		21.4	29.6	21.5	30.1		
120	02/24/2008			30.1	29.2		24.4	31.3	24.0	30.9		

Annex 5 **Measured values from the field test sites, related to ambient conditions** **Page 5 of 24**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10 & PM2,5, Ambient air
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.B.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		

No.	Date	Ref. 1	Ref. 2	Ref. 1	Ref 2.	TSP	SN 127		SN 131		Remark	Test site
		PM2,5	PM2,5	PM10	PM10		PM2,5	PM10	PM2,5	PM10		
		[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]		
121	02/25/2008	19.0	18.8	24.1	24.6	38.3	18.6	26.1	18.3	26.1		Bonn
122	02/26/2008	12.5	13.0	23.9	23.4	40.1	11.6	25.9	11.4	25.7		
123	02/27/2008	18.8	18.6	27.6	27.8	42.3	16.2	29.0	14.5	29.3		
124	02/28/2008	20.8	21.5	28.4	30.0	38.4	19.1	30.5	19.4	31.0		
125	02/29/2008	9.8	9.8	14.7	14.0	23.4	8.2	14.7	8.5	14.5		
126	03/01/2008			15.6	14.8		7.2	15.1	6.9	15.4		
127	03/02/2008			23.3	23.1		11.2	24.1	10.9	24.5		
128	03/03/2008	12.9	13.5	20.1	19.6	32.3	13.3	22.8	11.7	22.1		
129	03/04/2008	13.9	14.4	22.2	22.2	42.2	13.4	25.9	13.0	24.8		
130	03/05/2008	16.2	15.2	26.1	25.4	41.0	16.4	28.7	16.0	28.6		
131	03/06/2008	20.8	21.1	30.0	30.2	42.3	18.7	32.5	18.8	33.5		
132	03/07/2008	16.9	15.9	25.5	24.5	39.7	15.2	28.6	15.6	27.9		
133	03/08/2008			20.7	20.1		14.4	20.6	14.6	20.7		
134	03/09/2008			11.5	9.9		6.8	12.2	6.1	11.6		
135	03/10/2008	4.1	5.4	8.6	7.6	17.6	4.5	9.4	4.5	9.8		
136	03/11/2008	7.1	7.3	13.6	13.4	22.6	6.9	15.2	6.8	15.2		
137	03/12/2008			19.1	19.2						ZP/RP-Check	
138	03/13/2008	12.0	11.6	16.5	16.9	28.2	10.9	19.1	10.2	18.9		
139	03/14/2008	20.8	20.3				19.5	30.1	19.9	29.9		
140	03/15/2008			10.7	11.1		8.0	10.8	7.6	11.0		
141	03/16/2008			16.9	18.4		11.9	18.7	11.3	18.8		
142	03/17/2008	13.5	12.9	22.0	23.3	43.8	11.4	26.0	11.0	25.1		
143	03/18/2008	14.8	13.1	21.6	22.0	38.2	12.5	24.8	11.7	23.6		
144	03/19/2008	12.8	13.7	18.7	20.0	29.1	11.7	21.1	10.2	20.6		
145	03/20/2008	8.0	7.8	10.3	10.8	16.6	6.7	11.0	6.5	11.1		
146	03/21/2008						7.5	10.7	7.8	10.9		
147	03/22/2008			24.7	26.0		22.0	26.7	21.1	26.3		
148	03/23/2008			19.8	21.1		15.3	21.6	14.9	21.1		
149	03/24/2008			12.0	12.5		7.7	12.0	7.9	11.9		
150	03/25/2008	13.0	12.4	16.6	16.7	20.1	11.5	17.5	11.7	17.3		

Annex 5 **Measured values from the field test sites, related to ambient conditions** **Page 6 of 24**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10 & PM2,5, Ambient air
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.B.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	TSP [µg/m³]	SN 127 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
151	03/26/2008	20.1	20.3	22.2	22.6						Change to summertime	Bonn
152	03/27/2008	7.6	7.6								Change to summertime	
153	03/28/2008			12.8	13.2	23.0	6.5	13.9	6.6	14.2		
154	03/29/2008			14.3	14.6		7.9	15.5	7.6	15.4		
155	03/30/2008			15.0	15.3		9.8	18.6	9.3	17.2		
156	03/31/2008	11.6	12.1	16.7	16.5	33.0	11.4	19.7	11.4	19.1		
157	04/01/2008	14.3	13.5	25.0	25.4	46.6	11.9	30.1	11.8	28.6		
158	04/02/2008	17.2	17.6	26.6	27.7	43.7	14.9	31.5	14.6	31.7		
159	04/03/2008	22.2	23.3	30.9	31.5	52.5	20.6	36.3	19.8	35.3		
160	04/04/2008	30.1	29.4	36.9	36.8	47.1	27.8	41.6	28.6	41.3		
161	04/05/2008			14.4	13.9		11.1	15.0	11.1	15.7		
162	04/06/2008			17.3	17.5		12.7	19.3	12.3	19.2		
163	04/07/2008	22.5	23.0	26.3	26.7	38.5	21.9	29.3	21.3	28.7		
164	04/08/2008	31.7	32.3	37.3	36.7	44.8	30.1	39.3	30.3	38.2		
165	04/09/2008	35.6	35.0	40.8	39.9	50.1	31.3	42.1	31.7	41.5		
166	04/10/2008			30.5	30.2						ZP/RP-Check	
167	04/11/2008	36.4	35.7	45.5	45.3	67.5	31.9	43.7	32.1	42.8		
168	04/12/2008			12.6	12.1		7.7	12.6	7.6	12.8		
169	04/13/2008			11.7	11.9		10.0	12.8	9.8	12.0		
170	04/14/2008	29.3	29.6	36.2	36.0	44.0	27.0	36.6	27.7	36.4		
171	04/15/2008	22.0	21.9	27.2	25.8	33.0	20.1	26.6	19.9	26.3		
172	04/16/2008	17.6	18.3	25.6	24.7	39.0	17.4	26.4	16.5	26.2		
173	04/17/2008	20.1	19.2	23.9	23.9	30.3	18.0	23.0	17.3	23.1		
174	04/18/2008	21.2	20.7	25.0	24.0	31.1	20.2	25.1	19.2	24.4		
175	04/19/2008			21.4	19.6		16.3	18.8	16.4	19.7		
176	04/20/2008			19.7	18.8		15.7	19.7	14.6	18.7		
177	04/21/2008	23.2	22.7	29.1	28.0	46.5	23.1	30.2	22.1	30.3		
178	09/30/2008	3.5	5.0	5.0	5.0		3.9	5.8	2.9	5.5		Bruehl
179	10/01/2008	5.6	5.2	10.4	9.2		4.9	8.3	3.3	8.4		
180	10/02/2008	5.3	6.2	13.2	12.6		6.1	13.6	3.7	11.6		

Annex 5 **Measured values from the field test sites, related to ambient conditions** **Page 7 of 24**

Manufacturer	FAI Instruments s.r.l.
Meas. Range	0 to 200 µg/m³
Type	SWAM5a Dual Channel Monitor
Serial-No.	SN 127 & SN 131
Measured object	SPM PM10 & PM2,5, Ambient air
	Measured values in µg/m³ i.B.

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	TSP [µg/m³]	SN 127 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
181	10/03/2008	7.8	8.0	13.8	12.6		7.0	10.5	7.2	10.5		Bruehl
182	10/04/2008			13.8	13.6		5.6	12.3	4.9	11.7		
183	10/05/2008						4.7	4.8	1.7	4.9		
184	10/06/2008						6.5	11.9	6.4	12.0		
185	10/07/2008	8.3	8.5	14.7	14.8		8.6	14.2	8.8	15.5		
186	10/08/2008	11.6	10.9	22.5	22.3		12.5	24.9	13.2	25.0		
187	10/09/2008	16.2	16.6	34.1	33.2		17.4	38.1	18.0	35.6		
188	10/10/2008	15.4	15.2	25.8	26.3		14.8	25.8	16.1	26.6		
189	10/11/2008			32.4	31.4		25.1	35.6	24.8	35.3	Outlier Ref. PM2,5	
190	10/12/2008			23.7	23.4		16.5	24.3	17.4	25.7		
191	10/13/2008	18.0	17.1	33.7	32.1		19.8	33.6	20.8	33.6		
192	10/14/2008			46.6	47.0		21.7	51.2	20.4	51.2	Outlier Ref. PM2,5	
193	10/15/2008	9.7	9.7	15.0	16.2		9.2	16.2	8.9	16.0		
194	10/16/2008	9.4	9.1	17.8	17.5		8.1	18.3	8.7	17.9		
195	10/17/2008	12.9	13.4	25.9	25.2		11.9	25.9	10.9	25.3		
196	10/18/2008	16.1	14.5	19.7	20.5		11.4	19.3	11.8	20.0		
197	10/19/2008			16.7	17.2						failure SN131 - cable break	
198	10/20/2008	13.9	13.3	22.6	20.3						failure SN131 - cable break	
199	10/21/2008	9.4	9.8	16.1	15.5						failure SN131 - cable break	
200	10/22/2008			25.8	24.3						failure SN131 - cable break	
201	10/23/2008										failure SN131 - cable break	
202	10/24/2008	18.9	19.3	26.3	26.6		16.2	24.8	18.2	24.6		
203	10/25/2008	15.2	14.3	16.3	17.3		12.1	14.9	12.0	15.6		
204	10/26/2008			8.0	9.7		5.7	8.1	5.2	7.4		
205	10/27/2008	11.4	11.4	19.9	20.8		10.4	19.5	9.8	18.3		
206	10/28/2008	14.0	12.7	21.9	22.9		11.5	19.9	11.4	19.6		
207	10/29/2008	31.5	31.5	42.4	43.4		27.8	38.9	27.1	38.9		
208	10/30/2008	17.6	18.1	21.6	22.7		15.1	19.2	14.5	19.0		
209	10/31/2008	15.6	16.5	21.0	21.6		14.8	18.5	15.3	19.5		
210	11/01/2008			23.8	24.8		18.0	21.2	17.9	22.6		

Annex 5 **Measured values from the field test sites, related to ambient conditions** **Page 8 of 24**

Manufacturer FAI Instruments s.r.l.

Meas. Range 0 to 200 µg/m³
Type SWAM5a Dual Channel Monitor
Serial-No. SN 127 & SN 131

Measured object SPM PM10 & PM2,5, Ambient air
Measured values in µg/m³ i.B.

No.	Date	Ref. 1	Ref. 2	Ref. 1	Ref 2.	TSP	SN 127		SN 131		Remark	Test site
		PM2,5 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
211	11/02/2008			22.5	23.0		16.5	21.0	16.2	21.3		Bruehl
212	11/03/2008	19.9	19.4	30.3	29.7						SN127 - filter depleted	
213	11/04/2008	29.0	29.2	41.9	41.8						SN127 - filter depleted	
214	11/05/2008	34.5	33.8	50.1	51.3		34.9	48.0	32.3	48.1		
215	11/06/2008	22.8	23.7	36.1	36.5						replacement TÜV-station	
216	11/07/2008										replacement TÜV-station	
217	11/08/2008										replacement TÜV-station	
218	11/09/2008										replacement TÜV-station	
219	11/10/2008										replacement TÜV-station	
220	11/11/2008										ZP/RP-Check	
221	11/12/2008	10.9	11.1	20.2	22.0		8.7	19.2	8.4	18.7		
222	11/13/2008	17.9	18.5	31.2	28.8		16.0	27.0	15.9	27.4		
223	11/14/2008	14.3	14.5	20.9	21.8		12.7	19.3	13.0	19.4		
224	11/15/2008			17.4	16.4		11.1	14.3	10.8	16.0		
225	11/16/2008	8.9	9.8				8.2	16.0	8.1	15.3	Outlier Ref. PM10	
226	11/17/2008	13.8	14.0	30.8	29.9		12.5	29.6	12.8	28.5		
227	11/18/2008	12.5	13.2	25.1	22.7		11.4	22.1	11.9	22.2		
228	11/19/2008	12.8	14.1				12.7	25.3	12.8	24.6	Outlier Ref. PM10	
229	11/20/2008			19.3	17.9		8.5	16.1	8.0	15.7		
230	11/21/2008			10.8	9.5		3.8	8.3	3.6	8.0	Outlier Ref. PM2,5	
231	11/22/2008			12.2	12.1		7.0	10.8	6.7	10.6		
232	11/23/2008	6.4	6.8	10.9	8.1		5.0	7.7	5.3	8.5		
233	11/24/2008	17.7	17.5	22.2	21.9		16.1	21.5	16.8	21.9		
234	11/25/2008	17.7	17.9	28.9	28.7		14.7	25.5	15.4	24.8		
235	11/26/2008	9.6	10.4	18.0	17.9		9.0	15.3	8.1	14.9		
236	11/27/2008	13.4	13.0	16.5	17.1		12.6	16.1	12.2	16.2		
237	11/28/2008	23.1	23.2	26.3	26.6		22.0	26.2	21.6	24.9		
238	11/29/2008	24.3	25.4	27.1	28.0		22.9	26.8	22.9	27.7		
239	11/30/2008			24.8	26.2		21.4	24.2	21.2	24.4		
240	12/01/2008	27.2	26.8	32.4	33.3		24.9	33.2	24.7	33.0		

Annex 5 **Measured values from the field test sites, related to ambient conditions** **Page 9 of 24**

Manufacturer	FAI Instruments s.r.l.
Meas. Range	0 to 200 µg/m³
Type	SWAM5a Dual Channel Monitor
Serial-No.	SN 127 & SN 131
	SN 145 & SN 149 (Teddington)
Measured object	SPM PM10 & PM2,5, Ambient air Measured values in µg/m³ i.B.

No.	Date	Ref. 1	Ref. 2	Ref. 1	Ref 2.	TSP	SN 127 / SN145		SN 131 / SN149		Remark	Test site
		PM2,5	PM2,5	PM10	PM10		PM2,5	PM10	PM2,5	PM10		
		[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]	[µg/m³]		
241	12/02/2008	10.9	11.1	14.5	14.9		9.6	13.3	9.6	12.6		Bruehl
242	12/03/2008	13.6	13.6	15.2	16.6		11.4	16.0	11.8	15.7		
243	12/04/2008	6.0	6.4	7.1	8.8		5.6	7.3	4.9	7.5		
244	12/05/2008	7.5	8.1	9.8	10.1		6.2	9.1	6.3	10.5		
245	12/06/2008	14.5	15.8	20.6	21.3		12.6	19.2	13.5	20.3		
246	07/24/2008			32.9	32.0						ZP/RP-Check	Teddington
247	07/25/2008	15.4	15.1	22.5	23.6		13.9	27.1	13.2	24.4		
248	07/26/2008			21.0	21.6		14.1	23.3	14.2	23.3	Outlier Ref. PM2,5	
249	07/27/2008	13.1	13.2	19.0	19.9		15.3	22.4	15.0	22.0		
250	07/28/2008	13.5	13.6	20.3	20.3		15.7	23.5	15.8	24.1		
251	07/29/2008	4.2	4.7	11.8	12.1		6.0	14.0	6.4	14.7		
252	07/30/2008	9.6	9.5	16.2	16.5		11.3	19.4	10.9	18.8		
253	07/31/2008	10.8	11.0	22.2	22.4		14.0	26.4	14.0	27.8		
254	08/01/2008	4.2	5.5	16.3	15.5		6.8	19.3	7.5	18.9		
255	08/02/2008	2.4	2.2				4.8	8.9	4.5	8.9	Outlier Ref. PM10	
256	08/03/2008	2.0	2.5	8.2	8.4		3.9	10.2	3.6	10.8		
257	08/04/2008	3.4	4.4	9.4	9.6		6.0	13.2	5.6	12.5		
258	08/05/2008	3.1	3.6	7.5	7.3		5.8	10.8	6.0	10.6		
259	08/06/2008										Failure in the mains voltage	
260	08/07/2008	5.4	6.2	11.9	11.4		7.7	15.0	7.5	15.0		
261	08/08/2008	5.2	6.2	9.9	9.6		7.5	12.5	6.9	11.9		
262	08/09/2008	2.3	3.3	7.1	7.3		4.9	10.7	4.5	10.4		
263	08/10/2008	3.9	4.1	11.7	11.2		4.8	13.8	5.4	13.0		
264	08/11/2008	5.6	6.0	13.7	13.5		6.5	16.3	7.1	15.0		
265	08/12/2008	3.5	3.5	10.6	10.5		4.5	12.8	4.6	12.6		
266	08/13/2008	3.5	3.8	11.8	11.4		4.7	13.1	5.0	13.4		
267	08/14/2008	6.1	6.5	11.0	11.1		7.0	12.3	6.6	11.0		
268	08/15/2008	5.6	6.3	10.0	11.6		5.5	11.2	5.3	10.9		
269	08/16/2008	5.5	5.5				4.7	9.1	5.1	9.0	Outlier Ref. PM10	
270	08/17/2008	2.7	2.7	8.7	8.5		3.9	12.7	4.5	12.2		

Annex 5 **Measured values from the field test sites, related to ambient conditions** **Page 10 of 24**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10 & PM2,5, Ambient air
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.B.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 145 & SN 149		

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	TSP [µg/m³]	SN 145 PM2,5 [µg/m³]	SN 145 PM10 [µg/m³]	SN 149 PM2,5 [µg/m³]	SN 149 PM10 [µg/m³]	Remark	Test site
271	08/18/2008										ZP/RP-Check	Teddington
272	08/19/2008	4.6	4.7	12.5	13.0		5.7	12.6	5.7	12.8		
273	08/20/2008	3.9	4.1	10.2	10.1		5.3	14.6	5.6	13.2		
274	08/21/2008	6.5	6.8	13.2	13.5		7.3	14.3	7.7	13.8		
275	08/22/2008	5.2	4.9	9.5	9.3		6.1	10.7	5.9	10.8		
276	08/23/2008	4.5	4.4	9.2	9.5		6.2	11.4	6.5	12.9		
277	08/24/2008	3.5	3.5	8.6	8.7		4.7	11.7	5.6	11.4		
278	08/25/2008	6.5	6.5	12.9	13.0		9.2	17.6	9.1	17.4		
279	08/26/2008	4.8	4.9	10.7	9.5		7.3	13.3	7.0	13.3		
280	08/27/2008	7.4	7.0	13.4	13.6						SN145 sensor defect	
281	08/28/2008	9.6	9.3	14.1	14.2						SN145 sensor defect	
282	08/29/2008	13.7	12.8	20.1	19.1						SN145 sensor defect	
283	08/30/2008	31.6	30.5	43.8	43.2		39.3	48.2	36.8	48.2		
284	08/31/2008	13.3	12.1	22.0	21.6		15.7	24.6	16.6	25.3		
285	09/01/2008	2.9	2.6	8.1	8.1		4.3	11.7	4.5	11.2		
286	09/02/2008	3.0	2.4	11.8	12.4		3.8	13.3	4.7	12.8		
287	09/03/2008	3.6	3.3	14.2	14.3		5.0	16.4	5.1	15.4		
288	09/04/2008	4.1	3.7				5.7	12.7	5.4	12.8	Outlier Ref. PM10	
289	09/05/2008	2.6	2.7	7.5	7.6		4.8	10.4	4.5	10.0		
290	09/06/2008	3.4	3.6	8.0	7.6		4.1	9.9	4.8	9.2		
291	09/07/2008	3.1	2.7	8.4	8.2		5.0	9.7	4.6	9.8		
292	09/08/2008	6.4	6.6	14.7	14.2		8.4	16.5	8.1	16.8		
293	09/09/2008	6.0	5.2	14.4	14.2		6.8	15.3	7.4	17.2		
294	09/10/2008	4.3	4.1	11.0	10.6		5.8	13.5	7.2	13.6		
295	09/11/2008	6.5	5.4	17.2	17.5		6.6	18.4	6.3	17.4		
296	09/12/2008	5.5	5.1	9.4	9.1		6.8	11.4	6.7	10.5		
297	09/13/2008	15.5	15.4	20.4	20.7		16.8	22.0	16.5	20.9		
298	09/14/2008	10.9	10.3	18.1	17.4		11.6	18.0	11.3	17.7		
299	09/15/2008	11.8	12.3	17.5	17.5		12.1	17.7	12.5	17.2		
300	09/16/2008	17.7	17.4	24.6	24.2		17.3	23.9	17.5	24.1		

Annex 5 **Measured values from the field test sites, related to ambient conditions** **Page 11 of 24**

Manufacturer: FAI Instruments s.r.l.
Meas. Range: 0 to 200 µg/m³
Type: SWAM5a Dual Channel Monitor
Serial-No.: SN 145 & SN 149

Measured object: SPM PM10 & PM2,5, Ambient air
Measured values in µg/m³ i.B.

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	TSP [µg/m³]	SN 145 PM2,5 [µg/m³]	SN 145 PM10 [µg/m³]	SN 149 PM2,5 [µg/m³]	SN 149 PM10 [µg/m³]	Remark	Test site
301	09/17/2008	19.4	19.2	26.9	28.1		18.0	25.4	17.6	25.8		Teddington
302	09/18/2008	17.0	17.2	24.5	23.6		16.3	23.9	16.6	23.5		
303	09/19/2008	20.7	20.9	29.3	29.4		20.4	30.0	20.6	29.7		
304	09/20/2008	21.7	21.4	26.9	26.6		20.7	26.8	21.2	25.7		
305	09/21/2008	21.6	22.0	28.6	28.1		22.3	29.0	23.2	28.9		
306	09/22/2008	14.8	15.0	22.3	22.6		15.8	23.5	17.0	23.5		
307	09/23/2008	6.3	6.1	18.0	17.8						ZP/RP-Check	
308	09/24/2008	11.4	11.4	18.8	19.7		12.3	21.0	11.8	21.3		
309	09/25/2008	16.1	16.5	26.7	26.4		16.1	26.5	16.2	25.8		
310	09/26/2008	17.5	17.4	29.9	29.7		17.5	28.9	18.4	30.4		
311	09/27/2008	27.2	27.2	35.7	35.6		29.1	36.4	28.7	37.2		
312	09/28/2008						16.9	24.7	16.8	25.1		
313	09/29/2008	4.3	4.4	7.4	8.5		4.8	9.7	4.6	10.1		
314	09/30/2008	3.2	3.3	6.9	6.7		3.3	7.3	3.5	7.6		
315	10/01/2008						3.5	8.8	3.7	8.4		
316	10/02/2008						4.5	8.0	4.3	7.8		
317	10/03/2008						5.2	9.4	6.0	9.8		
318	10/04/2008						2.1	6.2	2.9	6.3		
319	10/05/2008										not operating	
320	10/06/2008										not operating	
321	10/07/2008										not operating	
322	10/08/2008						10.4	17.3	11.1	16.5		
323	10/09/2008	8.9	10.1	18.4	18.0		8.9	17.8	9.3	18.0		
324	10/10/2008	10.5	10.6	19.5	19.6		9.0	18.1	9.8	18.0		
325	10/11/2008	15.6	15.8	22.6	22.6		15.5	24.8	17.9	23.4		
326	10/12/2008	20.4	21.1	25.9	25.9		21.6	27.2	21.7	27.0		
327	10/13/2008	8.3	8.4	14.6	14.4		9.2	16.2	9.3	15.3		
328	10/14/2008	6.1	6.4	11.4	12.2		7.2	14.1	7.5	13.6		
329	10/15/2008	3.9	3.8	8.2	8.6		3.7	9.0	4.5	8.3		
330	10/16/2008										Zero measurement	

Annex 5 **Measured values from the field test sites, related to ambient conditions** **Page 12 of 24**

Manufacturer: FAI Instruments s.r.l.

Measured object: SPM PM10 & PM2,5, Ambient air
Measured values in µg/m³ i.B.

Meas. Range: 0 to 200 µg/m³
Type: SWAM5a Dual Channel Monitor
Serial-No.: SN 145 & SN 149

No.	Date	Ref. 1	Ref. 2	Ref. 1	Ref 2.	TSP	SN 145		SN 149		Remark	Test site
		PM2,5 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
331	10/17/2008										Zero measurement	Teddington
332	10/18/2008										Zero measurement	
333	10/19/2008										not operating	
334	10/20/2008										not operating	
335	10/21/2008										not operating	
336	10/22/2008										not operating	
337	10/23/2008										not operating	
338	10/24/2008										not operating	
339	10/25/2008										not operating	
340	10/26/2008										not operating	
341	10/27/2008										not operating	
342	10/28/2008										not operating	
343	10/29/2008						16.3	22.1	16.1	21.2		
344	10/30/2008						10.2	13.9	10.5	13.8		
345	10/31/2008	11.7	12.0	16.9	18.5		10.2	15.8	10.3	15.2		
346	11/01/2008	14.8	15.1	18.3	19.2		14.1	17.6	14.3	18.2		
347	11/02/2008	20.4	20.0	25.5	25.8		20.0	25.6	19.7	25.5		
348	11/03/2008	20.7	20.9	27.0	27.8		19.2	26.7	20.4	27.4		
349	11/04/2008	31.1	30.9	37.5	38.4		31.1	38.7	31.5	40.2		
350	11/05/2008	29.7	29.6	35.5	36.2		28.3	36.2	28.4	36.2		
351	11/06/2008	23.5	23.8	28.2	28.6		21.7	27.5	22.3	28.2		
352	11/07/2008	6.8	6.7	15.2	14.7						filter supply ran out	
353	11/08/2008	3.5	3.5	8.6	9.4						filter supply ran out	
354	11/09/2008	4.1	4.0	11.5	11.9						filter supply ran out	

Annex 5 **Measured values PM10 from the test sites, related to standard conditions (EN12341)** **Page 13 of 24**

Manufacturer FAI Instruments s.r.l.

Meas. Range 0 to 200 µg/m³

Type SWAM5a Dual Channel Monitor

Serial-No. SN 127 & SN 131

Measured object SPM PM10

Measured values in µg/m³ i.N.

No.	Date	Ref. 1	Ref. 2	TSP	SN 127		SN 131		Remark	Test site
		PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
1	10/20/2007	18.2	20.5	25.5	-	21.0	-	21.3	Outlier Ref. PM2,5	Koeln, parking lot
2	10/21/2007	18.3	20.2		-	20.5	-	20.4		
3	10/22/2007	21.7	23.1		-		-		water inleakage SN127	
4	10/23/2007	24.6	27.1	33.9	-		-		water inleakage SN127	
5	10/24/2007	31.4	32.9	43.2	-	34.8	-	33.3		
6	10/25/2007	27.5	29.2	37.2	-	29.5	-	28.6		
7	10/26/2007	28.5	29.8	42.0	-	31.1	-	30.4		
8	10/27/2007	34.6	36.9		-	36.9	-	35.7		
9	10/28/2007	35.5	36.9		-		-		change to wintertime	
10	10/29/2007				-		-		change to wintertime	
11	10/30/2007				-		-		ZP/RP-Check	
12	10/31/2007	26.6	28.5	37.0	-	32.1	-	33.2		
13	11/01/2007	29.6	32.1		-	36.5	-	36.9		
14	11/02/2007	30.0	32.1		-	35.1	-	37.6		
15	11/03/2007	24.5	24.7		-	29.5	-	29.1		
16	11/04/2007	17.3	19.6		-	22.0	-	21.9		
17	11/05/2007	18.9	19.5	31.3	-	24.7	-	24.5		
18	11/06/2007	16.2	17.2	25.4	-	21.2	-	20.2		
19	11/07/2007	23.8	23.8	33.9	-	30.1	-	30.2		
20	11/08/2007	14.0	15.3	20.5	-	16.5	-	16.4		
21	11/09/2007	10.3	10.9	15.9	-	13.7	-	14.0		
22	11/10/2007	10.1	10.7		-	13.5	-	13.3		
23	11/11/2007	6.4	8.1		-	9.9	-	9.6		
24	11/12/2007	15.5	16.6	26.2	-	20.0	-	20.0		
25	11/13/2007	16.2	16.2	20.4	-	18.4	-	18.1		
26	11/14/2007	14.8	15.1	23.0	-	18.0	-	17.7		
27	11/15/2007	22.4	25.9	32.1	-	25.4	-	24.4		
28	11/16/2007	35.1	38.6	51.0	-	40.4	-	39.0		
29	11/17/2007	55.9	61.0		-	62.9	-	60.1		
30	11/18/2007	17.8	22.1	23.3	-	18.8	-	19.2		

Annex 5 **Measured values PM10 from the test sites, related to standard conditions (EN12341)** **Page 14 of 24**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.N.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		

No.	Date	Ref. 1	Ref. 2	TSP	SN 127		SN 131		Remark	Test site
		PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
31	11/19/2007	25.1	29.0	29.3	-	26.9	-	26.8		Koeln, parking lot
32	11/20/2007	23.4	28.6		-	27.2	-	26.4		
33	11/21/2007	25.1	29.2		-	29.3	-	29.1		
34	11/22/2007	27.4	30.9	32.1	-	30.9	-	31.5		
35	11/23/2007	24.6	29.0	37.2	-	28.2	-	28.6		
36	11/24/2007	24.2	28.7		-	28.3	-	28.7		
37	11/25/2007	14.2	14.7		-	12.2	-	12.8		
38	11/26/2007	15.5	15.6		-	17.7	-	17.9		
39	11/27/2007	26.7	27.3		-	31.3	-	30.7		
40	11/28/2007	26.7	26.6	35.8	-	28.6	-	27.7		
41	11/29/2007	19.8	20.4		-	22.9	-	22.7		
42	11/30/2007	14.6	14.3		-	15.7	-	16.1		
43	12/01/2007	10.5	10.0		-	12.0	-	12.2		
44	12/02/2007	6.4	6.1		-	7.8	-	7.4		
45	12/03/2007	11.0	11.2		-	13.1	-	11.9		
46	12/04/2007	13.6	14.4	21.5	-	17.5	-	17.4		
47	12/05/2007	12.4	13.4	19.5	-	15.5	-	14.8		
48	12/06/2007	6.2	8.0		-		-		ZP/RP-Check	
49	12/07/2007	13.9	14.0	23.5	-	17.3	-	17.0		
50	12/08/2007	8.4	8.9		-	9.8	-	9.7		
51	12/09/2007	5.9	6.3		-	7.5	-	7.6		
52	12/10/2007	18.4	18.2	23.7	-	21.1	-	20.6		
53	12/11/2007	13.4	13.5		-	20.6	-	20.0		
54	12/12/2007	32.7	31.3		-	35.5	-	35.1		
55	12/13/2007	18.8	17.8		-	20.2	-	20.3		
56	12/14/2007	16.8	15.7		-	17.7	-	17.2		
57	12/15/2007	16.9	15.9		-	17.4	-	17.5		
58	12/16/2007	24.5	24.1		-	26.2	-	25.8		
59	12/17/2007	30.6	30.4		-	35.6	-	34.2		
60	12/18/2007	65.4	65.0		-	76.3	-	72.8		

Annex 5 **Measured values PM10 from the test sites, related to standard conditions (EN12341)** **Page 15 of 24**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.N.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		

No.	Date	Ref. 1	Ref. 2	TSP	SN 127		SN 131		Remark	Test site
		PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
61	12/19/2007	75.2	73.3		-	87.8	-	85.9		Koeln, parking lot
62	12/20/2007	86.2	84.5		-	98.4	-	92.7		
63	12/21/2007	53.1	53.8		-	60.5	-	56.7		
64	12/22/2007	58.6	59.9		-	70.0	-	64.6		
65	12/23/2007	58.2	58.8		-	58.9	-	59.2		
66	12/24/2007	25.0	25.3		-	24.7	-	24.4		
67	12/25/2007	30.2	30.6		-	32.5	-	32.4		
68	12/26/2007	33.5	33.9		-	36.0	-	35.8		
69	12/27/2007	12.4	12.7		-	12.8	-	12.6		
70	12/28/2007	12.2	12.9		-	13.0	-	12.3		
71	12/29/2007	9.2	10.3		-	10.2	-	10.6		
72	12/30/2007	16.5	16.3		-	18.0	-	19.2		
73	12/31/2007	46.4	46.0		-	47.6	-	46.6		
74	01/01/2008	22.6	22.3		-	23.2	-	23.2		
75	01/02/2008	19.5	19.4		-	20.2	-	20.2		
76	01/03/2008	22.3	22.8		-	23.1	-	22.5		
77	01/04/2008				-	27.1	-	27.0		
78	01/05/2008				-	11.7	-	11.8		
79	01/06/2008				-		-		filter supply ran out	
80	01/07/2008				-		-		filter supply ran out	
81	01/08/2008				-		-		ZP/RP-Check	
82	01/09/2008	12.7	13.8	14.2	-	15.2	-	14.8		
83	01/10/2008	11.8	12.7	13.6	-	13.4	-	13.8		
84	01/11/2008	8.0	8.9	10.6	-	9.4	-	8.7		
85	01/12/2008	14.4	13.0		-	14.1	-	14.1		
86	01/13/2008	16.6	17.0		-	17.1	-	17.1		
87	01/14/2008	13.7	14.2	15.1	-	14.9	-	14.6		
88	01/15/2008	7.4	6.2	8.8	-	6.9	-	7.1		
89	01/16/2008	10.4	10.5	12.5	-	12.6	-	12.9		
90	01/17/2008	12.9	12.2	14.6	-	13.4	-	13.5		

Annex 5 **Measured values PM10 from the test sites, related to standard conditions (EN12341)** **Page 16 of 24**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.N.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		

No.	Date	Ref. 1 PM10 [µg/m³]	Ref. 2 PM10 [µg/m³]	TSP [µg/m³]	SN 127 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
91	01/18/2008	12.5	12.3		-	15.0	-	15.1		Koeln, parking lot
92	01/19/2008	5.9	4.6	8.9	-	6.6	-	6.9		
93	01/20/2008	6.0	5.6		-	6.0	-	5.6		
94	01/21/2008	8.9	8.7	10.9	-	10.3	-	9.5		
95	01/22/2008	20.5	19.6		-	22.8	-	23.0		
96	01/23/2008	20.9	20.3	20.7	-	22.5	-	22.3		
97	01/24/2008	27.0	26.4	31.9	-	29.9	-	29.0		
98	01/25/2008	18.5	18.3	21.9	-	20.2	-	20.2		
99	01/26/2008	26.8	26.0		-	28.9	-	29.0		
100	01/27/2008	32.1	30.8		-	32.6	-	34.3		
101	01/28/2008	39.8	38.8	44.9	-	43.1	-	43.8		
102	01/29/2008	51.4	51.3		-	56.3	-	55.7		
103	01/30/2008	24.8	25.9	25.5	-	27.3	-	27.5		
104	01/31/2008	7.9	8.0		-	8.6	-	8.4		
105	02/01/2008	11.2	10.5		-	12.3	-	12.5		
106	02/02/2008	13.6	14.3		-	14.2	-	14.5		
107	02/03/2008	11.8	12.6		-	12.2	-	12.6		
108	02/04/2008	10.0	10.7	9.0	-	11.2	-	10.6		
109	02/05/2008	5.4	5.5		-	6.1	-	5.9		
110	02/14/2008	38.1	38.2	53.7	-	41.1	-	39.8		Bonn
111	02/15/2008	14.8	15.3		-	16.5	-	17.2		
112	02/16/2008	18.0	18.9		-	18.7	-	18.4		
113	02/17/2008	37.5	37.2	47.2	-	43.2	-	42.0		
114	02/18/2008	63.1	62.6	81.2	-	76.0	-	75.6		
115	02/19/2008	53.0	53.0	61.5	-	58.8	-	58.1		
116	02/20/2008	42.4	43.5	45.2	-	45.1	-	45.4		
117	02/21/2008	41.3	41.0	58.4	-	45.1	-	45.5		
118	02/22/2008	25.7	26.1	43.3	-	28.9	-	28.2		
119	02/23/2008	28.2	28.1		-	30.6	-	31.0		
120	02/24/2008	31.2	30.4		-	32.5	-	32.1		

Annex 5 **Measured values PM10 from the test sites, related to standard conditions (EN12341)** **Page 17 of 24**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.N.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		

No.	Date	Ref. 1 PM10 [µg/m³]	Ref. 2 PM10 [µg/m³]	TSP [µg/m³]	SN 127 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
121	02/25/2008	25.3	25.8	40.1	-	27.4	-	27.4		Bonn
122	02/26/2008	25.0	24.5	41.8	-	27.0	-	26.9		
123	02/27/2008	28.4	28.7	43.6	-	29.9	-	30.3		
124	02/28/2008	29.5	31.2	39.8	-	31.6	-	32.2		
125	02/29/2008	15.6	14.8	24.7	-	15.5	-	15.4		
126	03/01/2008	16.5	15.6		-	15.9	-	16.2		
127	03/02/2008	24.4	24.3		-	25.3	-	25.7		
128	03/03/2008	20.7	20.2	33.1	-	23.4	-	22.7		
129	03/04/2008	22.4	22.4	42.5	-	26.1	-	25.1		
130	03/05/2008	26.3	25.6	41.2	-	28.9	-	28.9		
131	03/06/2008	30.9	31.1	43.5	-	33.4	-	34.6		
132	03/07/2008	26.5	25.5	41.2	-	29.7	-	29.1		
133	03/08/2008	21.7	21.1		-	21.5	-	21.7		
134	03/09/2008	12.2	10.5		-	12.9	-	12.3		
135	03/10/2008	9.2	8.1	18.7	-	10.0	-	10.5		
136	03/11/2008	14.5	14.3	24.1	-	16.1	-	16.2		
137	03/12/2008	19.9	20.0		-		-		ZP/RP-Check	
138	03/13/2008	17.2	17.7	29.4	-	19.9	-	19.8		
139	03/14/2008				-	31.2	-	31.1		
140	03/15/2008	11.4	11.8		-	11.5	-	11.7		
141	03/16/2008	17.7	19.2		-	19.5	-	19.6		
142	03/17/2008	22.6	23.9	44.8	-	26.7	-	25.8		
143	03/18/2008	22.3	22.6	39.2	-	25.4	-	24.3		
144	03/19/2008	19.1	20.4	29.6	-	21.5	-	21.0		
145	03/20/2008	10.8	11.4	17.5	-	11.6	-	11.7		
146	03/21/2008				-	11.2	-	11.5		
147	03/22/2008	25.6	26.8		-	27.5	-	27.2		
148	03/23/2008	20.4	21.7		-	22.3	-	21.7		
149	03/24/2008	12.4	12.9		-	12.3	-	12.3		
150	03/25/2008	17.0	17.1	20.5	-	17.9	-	17.7		

Annex 5 **Measured values PM10 from the test sites, related to standard conditions (EN12341)** **Page 18 of 24**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.N.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		

No.	Date	Ref. 1	Ref. 2	TSP	SN 127		SN 131		Remark	Test site
		PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
151	03/26/2008	23.1	23.5		-		-		Change to summertime	Bonn
152	03/27/2008				-		-		Change to summertime	
153	03/28/2008	13.4	13.8	24.1	-	14.6	-	14.9		
154	03/29/2008	15.1	15.4		-	16.3	-	16.2		
155	03/30/2008	15.9	16.2		-	19.6	-	18.3		
156	03/31/2008	17.4	17.2	34.4	-	20.5	-	20.0		
157	04/01/2008	26.0	26.5	48.5	-	31.3	-	29.8		
158	04/02/2008	27.4	28.6	44.9	-	32.4	-	32.6		
159	04/03/2008	31.6	32.3	53.6	-	37.1	-	36.1		
160	04/04/2008	38.4	38.3	48.9	-	43.3	-	43.0		
161	04/05/2008	14.9	14.5		-	15.6	-	16.3		
162	04/06/2008	18.0	18.3		-	20.0	-	20.0		
163	04/07/2008	27.1	27.6	39.7	-	30.2	-	29.7		
164	04/08/2008	39.0	38.4	46.7	-	41.1	-	40.0		
165	04/09/2008	42.9	42.1	52.6	-	44.3	-	43.7		
166	04/10/2008	32.3	32.0		-		-		ZP/RP-Check	
167	04/11/2008	48.0	47.8	71.1	-	46.0	-	45.3		
168	04/12/2008	13.3	12.7		-	13.2	-	13.5		
169	04/13/2008	12.3	12.4		-	13.4	-	12.5		
170	04/14/2008	37.4	37.2	45.3	-	37.7	-	37.6		
171	04/15/2008	27.8	26.4	33.6	-	27.1	-	26.9		
172	04/16/2008	26.4	25.5	40.1	-	27.2	-	27.0		
173	04/17/2008	25.1	25.1	31.8	-	24.1	-	24.3		
174	04/18/2008	26.6	25.6	33.1	-	26.6	-	26.0		
175	04/19/2008	22.6	20.7		-	19.8	-	20.8		
176	04/20/2008	21.0	20.0		-	21.0	-	19.9		
177	04/21/2008	31.2	30.0	49.7	-	32.3	-	32.5		
178	09/30/2008	5.3	5.3		-	6.2	-	5.9		Bruehl
179	10/01/2008	11.1	9.8		-	8.8	-	8.9		
180	10/02/2008	13.9	13.3		-	14.3	-	12.2		

Annex 5 **Measured values PM10 from the test sites, related to standard conditions (EN12341)** **Page 19 of 24**

Manufacturer	FAI Instruments s.r.l.		
		Measured object	SPM PM10
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.N.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		

No.	Date	Ref. 1	Ref. 2	TSP	SN 127		SN 131		Remark	Test site
		PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
181	10/03/2008	14.4	13.2		-	11.0	-	11.0		Bruehl
182	10/04/2008	14.4	14.2		-	12.8	-	12.2		
183	10/05/2008				-	5.1	-	5.3		
184	10/06/2008				-	12.5	-	12.7		
185	10/07/2008	15.6	15.8		-	15.2	-	16.5		
186	10/08/2008	23.5	23.4		-	26.1	-	26.2		
187	10/09/2008	35.0	34.1		-	39.1	-	36.6		
188	10/10/2008	26.7	27.1		-	26.6	-	27.6		
189	10/11/2008	33.7	32.7		-	37.1	-	36.9	Outlier Ref. PM2,5	
190	10/12/2008	24.7	24.4		-	25.4	-	26.9		
191	10/13/2008	35.8	34.1		-	35.7	-	35.8		
192	10/14/2008	49.1	49.5		-	53.9	-	53.9	Outlier Ref. PM2,5	
193	10/15/2008	15.9	17.2		-	17.2	-	17.0		
194	10/16/2008	18.6	18.2		-	19.1	-	18.6		
195	10/17/2008	26.8	26.1		-	26.7	-	26.2		
196	10/18/2008	20.4	21.2		-	20.0	-	20.7		
197	10/19/2008	17.3	17.8		-		-		failure SN131 - cable break	
198	10/20/2008	24.0	21.6		-		-		failure SN131 - cable break	
199	10/21/2008	16.9	16.2		-		-		failure SN131 - cable break	
200	10/22/2008	26.4	25.0		-		-		failure SN131 - cable break	
201	10/23/2008				-		-		failure SN131 - cable break	
202	10/24/2008	27.1	27.5		-	25.6	-	25.4		
203	10/25/2008	16.8	17.8		-	15.4	-	16.0		
204	10/26/2008	8.4	10.2		-	8.6	-	7.8		
205	10/27/2008	20.7	21.7		-	20.3	-	19.1		
206	10/28/2008	22.5	23.7		-	20.5	-	20.1		
207	10/29/2008	44.0	45.1		-	40.3	-	40.5		
208	10/30/2008	22.5	23.6		-	19.9	-	19.8		
209	10/31/2008	21.9	22.5		-	19.3	-	20.2		
210	11/01/2008	24.8	25.9		-	22.1	-	23.6		

Annex 5 **Measured values PM10 from the test sites, related to standard conditions (EN12341)** **Page 20 of 24**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.N.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		

No.	Date	Ref. 1	Ref. 2	TSP	SN 127		SN 131		Remark	Test site
		PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
211	11/02/2008	23.4	23.9		-	21.8	-	22.2		Bruehl
212	11/03/2008	31.4	30.8		-		-		SN127 - filter depleted	
213	11/04/2008	43.5	43.5		-		-		SN127 - filter depleted	
214	11/05/2008	52.2	53.5		-	50.0	-	50.2		
215	11/06/2008	37.4	37.8		-		-		replacement TÜV-station	
216	11/07/2008				-		-		replacement TÜV-station	
217	11/08/2008				-		-		replacement TÜV-station	
218	11/09/2008				-		-		replacement TÜV-station	
219	11/10/2008				-		-		replacement TÜV-station	
220	11/11/2008				-		-		ZP/RP-Check	
221	11/12/2008	20.8	22.8		-	19.8	-	19.3		
222	11/13/2008	32.0	29.6		-	27.7	-	28.1		
223	11/14/2008	21.5	22.5		-	19.8	-	19.9		
224	11/15/2008	18.0	17.1		-	14.8	-	16.6		
225	11/16/2008				-	16.3	-	15.7	Outlier Ref. PM10	
226	11/17/2008	31.4	30.5		-	30.0	-	29.0		
227	11/18/2008	26.0	23.5		-	22.8	-	23.0		
228	11/19/2008				-	26.2	-	25.5	Outlier Ref. PM10	
229	11/20/2008	20.2	18.8		-	16.8	-	16.4		
230	11/21/2008	11.1	9.8		-	8.5	-	8.2	Outlier Ref. PM2,5	
231	11/22/2008	12.5	12.3		-	11.0	-	10.8		
232	11/23/2008	11.2	8.4		-	7.9	-	8.7		
233	11/24/2008	22.9	22.6		-	22.1	-	22.5		
234	11/25/2008	29.4	29.3		-	25.9	-	25.2		
235	11/26/2008	18.3	18.2		-	15.5	-	15.2		
236	11/27/2008	16.8	17.5		-	16.4	-	16.6		
237	11/28/2008	27.0	27.4		-	26.9	-	25.6		
238	11/29/2008	28.1	29.1		-	27.7	-	28.6		
239	11/30/2008	25.8	27.3		-	25.0	-	25.3		
240	12/01/2008	33.7	34.7		-	34.3	-	34.3		

Annex 5 **Measured values PM10 from the test sites, related to standard conditions (EN12341)** **Page 21 of 24**

Manufacturer FAI Instruments s.r.l.

Meas. Range 0 to 200 µg/m³
Type SWAM5a Dual Channel Monitor
Serial-No. SN 127 & SN 131
SN 145 & SN 149 (Teddington)

Measured object SPM PM10
Measured values in µg/m³ i.N.

No.	Date	Ref. 1	Ref. 2	TSP	SN 127 (SN 145)		SN 131 (SN 149)		Remark	Test site
		PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
241	12/02/2008	14.9	15.4		-	13.7	-	13.0		Bruehl
242	12/03/2008	15.6	17.0		-	16.4	-	16.1		
243	12/04/2008	7.5	9.2		-	7.7	-	7.9		
244	12/05/2008	10.3	10.7		-	9.5	-	11.0		
245	12/06/2008	21.2	22.0		-	19.8	-	20.8		
246	07/24/2008	35.4	34.6		-		-		ZP/RP-Check	Teddington
247	07/25/2008	24.1	25.4		-	29.3	-	26.2		
248	07/26/2008	22.5	23.2		-	25.2	-	25.1	Outlier Ref. PM2,5	
249	07/27/2008	20.4	21.4		-	24.3	-	23.8		
250	07/28/2008	21.8	22.0		-	25.5	-	26.2		
251	07/29/2008	12.4	12.9		-	15.0	-	15.6		
252	07/30/2008	17.3	17.6		-	20.9	-	20.2		
253	07/31/2008	23.9	24.0		-	28.6	-	30.1		
254	08/01/2008	17.4	16.5		-	20.7	-	20.3		
255	08/02/2008				-	9.6	-	9.5	Outlier Ref. PM10	
256	08/03/2008	8.7	8.9		-	10.9	-	11.5		
257	08/04/2008	9.9	10.2		-	14.0	-	13.3		
258	08/05/2008	8.0	7.8		-	11.6	-	11.3		
259	08/06/2008				-		-		Failure in the mains voltage	
260	08/07/2008	12.8	12.2		-	16.1	-	16.2		
261	08/08/2008	10.5	10.1		-	13.2	-	12.7		
262	08/09/2008	7.5	7.8		-	11.4	-	11.1		
263	08/10/2008	12.5	12.0		-	14.9	-	14.0		
264	08/11/2008	14.7	14.5		-	17.7	-	16.2		
265	08/12/2008	11.4	11.3		-	13.8	-	13.6		
266	08/13/2008	12.4	12.1		-	14.0	-	14.2		
267	08/14/2008	11.5	11.6		-	13.0	-	11.6		
268	08/15/2008	10.5	12.3		-	11.9	-	11.6		
269	08/16/2008				-	9.8	-	9.7	Outlier Ref. PM10	
270	08/17/2008	9.3	9.1		-	13.7	-	13.1		

Annex 5 **Measured values PM10 from the test sites, related to standard conditions (EN12341)** **Page 22 of 24**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.N.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 145 & SN 149		

No.	Date	Ref. 1	Ref. 2	TSP	SN 145		SN 149		Remark	Test site
		PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
271	08/18/2008				-		-		ZP/RP-Check	Teddington
272	08/19/2008	13.3	13.9		-	13.6	-	13.7		
273	08/20/2008	10.8	10.7		-	15.6	-	14.0		
274	08/21/2008	14.0	14.3		-	15.3	-	14.7		
275	08/22/2008	10.0	9.8		-	11.3	-	11.4		
276	08/23/2008	9.7	10.1		-	12.2	-	13.7		
277	08/24/2008	9.1	9.3		-	12.5	-	12.1		
278	08/25/2008	13.6	13.8		-	18.7	-	18.4		
279	08/26/2008	11.3	10.1		-	14.1	-	14.1		
280	08/27/2008	14.1	14.3		-		-		SN145 sensor defect	
281	08/28/2008	14.9	15.0		-		-		SN145 sensor defect	
282	08/29/2008	21.3	20.3		-		-		SN145 sensor defect	
283	08/30/2008	46.7	46.2		-	51.9	-	51.7		
284	08/31/2008	23.2	22.8		-	26.1	-	26.8		
285	09/01/2008	8.6	8.7		-	12.5	-	12.0		
286	09/02/2008	12.4	13.2		-	14.2	-	13.6		
287	09/03/2008	15.2	15.3		-	17.6	-	16.5		
288	09/04/2008				-	13.6	-	13.7	Outlier Ref. PM10	
289	09/05/2008	8.0	8.2		-	11.3	-	10.8		
290	09/06/2008	8.5	8.1		-	10.6	-	9.9		
291	09/07/2008	8.8	8.6		-	10.3	-	10.4		
292	09/08/2008	15.4	15.0		-	17.5	-	17.8		
293	09/09/2008	15.2	15.0		-	16.3	-	18.2		
294	09/10/2008	11.7	11.4		-	14.5	-	14.6		
295	09/11/2008	18.1	18.5		-	19.5	-	18.4		
296	09/12/2008	9.8	9.5		-	11.9	-	11.0		
297	09/13/2008	21.2	21.6		-	23.0	-	21.9		
298	09/14/2008	18.7	18.0		-	18.8	-	18.4		
299	09/15/2008	18.1	18.1		-	18.4	-	17.9		
300	09/16/2008	25.5	25.1		-	25.0	-	25.1		

Annex 5 **Measured values PM10 from the test sites, related to standard conditions (EN12341)** **Page 23 of 24**

Manufacturer	FAI Instruments s.r.l.
Meas. Range	0 to 200 µg/m³
Type	SWAM5a Dual Channel Monitor
Serial-No.	SN 145 & SN 149
Measured object	SPM PM10
	Measured values in µg/m³ i.N.

No.	Date	Ref. 1	Ref. 2	TSP	SN 145		SN 149		Remark	Test site
		PM10 [µg/m³]	PM10 [µg/m³]	[µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]	PM2,5 [µg/m³]	PM10 [µg/m³]		
301	09/17/2008	27.9	29.2		-	26.5	-	27.0		Teddington
302	09/18/2008	25.2	24.3		-	24.7	-	24.3		
303	09/19/2008	30.0	30.2		-	31.0	-	30.6		
304	09/20/2008	27.6	27.7		-	27.7	-	26.6		
305	09/21/2008	29.5	29.1		-	30.1	-	30.0		
306	09/22/2008	23.2	23.5		-	24.6	-	24.5		
307	09/23/2008	18.6	18.5		-		-		ZP/RP-Check	
308	09/24/2008	19.5	20.4		-	21.9	-	22.2		
309	09/25/2008	27.3	27.1		-	27.3	-	26.5		
310	09/26/2008	30.6	30.5		-	29.8	-	31.3		
311	09/27/2008	36.3	36.5		-	37.4	-	38.2		
312	09/28/2008				-	25.8	-	26.1		
313	09/29/2008	7.7	9.0		-	10.2	-	10.6		
314	09/30/2008	6.8	7.1		-	7.8	-	8.1		
315	10/01/2008				-	9.3	-	8.8		
316	10/02/2008				-	8.3	-	8.1		
317	10/03/2008				-	9.6	-	10.0		
318	10/04/2008				-	6.6	-	6.7		
319	10/05/2008				-		-		not operating	
320	10/06/2008				-		-		not operating	
321	10/07/2008				-		-		not operating	
322	10/08/2008				-	17.7	-	16.9		
323	10/09/2008	18.8	18.6		-	18.4	-	18.5		
324	10/10/2008	20.0	20.1		-	18.7	-	18.5		
325	10/11/2008	23.3	23.3		-	25.7	-	24.2		
326	10/12/2008	27.0	27.1		-	28.6	-	28.3		
327	10/13/2008	15.1	14.9		-	16.9	-	15.9		
328	10/14/2008	11.9	12.8		-	14.8	-	14.3		
329	10/15/2008	8.6	8.9		-	9.4	-	8.6		
330	10/16/2008				-		-		Zero measurement	

Annex 5 **Measured values PM10 from the test sites, related to standard conditions (EN12341)** **Page 24 of 24**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM10
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ i.N.
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 145 & SN 149		

No.	Date	Ref. 1 PM10 [µg/m³]	Ref. 2 PM10 [µg/m³]	TSP [µg/m³]	SN 145 PM2,5 [µg/m³]	SN 145 PM10 [µg/m³]	SN 149 PM2,5 [µg/m³]	SN 149 PM10 [µg/m³]	Remark	Test site
331	10/17/2008				-		-		Zero measurement	Teddington
332	10/18/2008				-		-		Zero measurement	
333	10/19/2008				-		-		not operating	
334	10/20/2008				-		-		not operating	
335	10/21/2008				-		-		not operating	
336	10/22/2008				-		-		not operating	
337	10/23/2008				-		-		not operating	
338	10/24/2008				-		-		not operating	
339	10/25/2008				-		-		not operating	
340	10/26/2008				-		-		not operating	
341	10/27/2008				-		-		not operating	
342	10/28/2008				-		-		not operating	
343	10/29/2008				-	22.8	-	21.8		
344	10/30/2008				-	14.4	-	14.2		
345	10/31/2008	17.3	19.0		-	16.2	-	15.6		
346	11/01/2008	18.9	19.9		-	18.3	-	18.9		
347	11/02/2008	26.3	26.7		-	26.5	-	26.4		
348	11/03/2008	27.8	28.7		-	27.6	-	28.4		
349	11/04/2008	38.6	39.7		-	40.1	-	41.7		
350	11/05/2008	36.5	37.4		-	37.6	-	37.5		
351	11/06/2008	29.2	29.7		-	28.7	-	29.4		
352	11/07/2008	15.7	15.3		-		-		filter supply ran out	
353	11/08/2008	8.9	9.8		-		-		filter supply ran out	
354	11/09/2008	11.9	12.4		-		-		filter supply ran out	

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

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
1	10/20/2007	Koeln, parking lot	6.6	1027	65.3	0.0	153	0.3
2	10/21/2007		5.4	1020	81.5	0.0	197	3.0
3	10/22/2007		3.1	1020	71.8	0.5	155	0.0
4	10/23/2007		4.5	1018	68.1	0.0	99	0.0
5	10/24/2007		7.6	1017	70.7	0.0	66	0.3
6	10/25/2007		9.2	1015	68.3	0.3	110	0.0
7	10/26/2007		8.7	1016	69.3	0.0	201	0.0
8	10/27/2007		8.7	1020	69.9	0.2	182	0.0
9	10/28/2007		8.7	1012	68.4	2.3	154	0.0
10	10/29/2007		8.9	1005	82.0	0.9	208	31.0
11	10/30/2007		7.1	1015	76.7	0.3	235	0.3
12	10/31/2007		5.8	1023	80.8	0.1	136	0.0
13	11/01/2007		9.0	1024	79.5	0.0	168	0.0
14	11/02/2007		12.0	1023	86.9	0.0	262	5.7
15	11/03/2007		11.5	1019	80.2	0.0	291	0.9
16	11/04/2007		9.3	1021	70.6	0.0	153	0.0
17	11/05/2007		9.3	1016	70.1	1.0	228	3.0
18	11/06/2007		7.7	1019	71.7	1.9	261	2.7
19	11/07/2007		9.2	1012	78.2	2.6	254	5.9
20	11/08/2007		8.7	1003	73.8	2.4	260	9.8
21	11/09/2007		5.5	1009	73.7	5.4	266	5.0
22	11/10/2007		8.6	1003	76.6	3.8	254	17.4
23	11/11/2007		6.2	1005	73.7	4.0	289	3.6
24	11/12/2007		5.7	1011	71.4	3.0	272	1.5
25	11/13/2007		3.6	999	79.0	1.1	184	10.9
26	11/14/2007		2.0	1010	69.8	1.5	173	0.0
27	11/15/2007		1.7	1019	69.5	0.6	101	0.0
28	11/16/2007		3.6	1021	67.4	0.0	217	0.0
29	11/17/2007		2.5	1016	78.6	0.0	175	0.0
30	11/18/2007		4.0	1002	70.1	5.2	133	0.0

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

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
31	11/19/2007	Koeln, parking lot	3.8	1004	74.7	4.1	136	6.2
32	11/20/2007		6.9	1002	62.0	4.9	128	0.3
33	11/21/2007		7.9	1001	76.6	1.4	133	0.9
34	11/22/2007		8.5	1000	79.4	1.2	155	0.0
35	11/23/2007		4.8	1013	78.4	0.6	209	1.2
36	11/24/2007		4.4	1014	75.1	0.5	216	2.1
37	11/25/2007		5.4	1013	74.9	4.3	284	6.2
38	11/26/2007		4.4	1019	73.2	2.6	273	2.4
39	11/27/2007		3.6	1020	76.2	0.4	196	0.0
40	11/28/2007		2.2	1010	73.9	2.7	143	0.0
41	11/29/2007		4.8	1002	79.5	1.3	203	4.7
42	11/30/2007		7.7	1000	76.4	1.6	188	5.1
43	12/01/2007		8.1	999	69.4	1.9	217	3.2
44	12/02/2007		9.2	984	70.4	3.8	226	7.1
45	12/03/2007		6.2	996	71.4	3.6	271	11.8
46	12/04/2007		7.8	1010	75.8	1.3	202	0.6
47	12/05/2007		10.9	1007	70.3	3.1	191	0.9
48	12/06/2007		11.1	997	76.7	2.4	209	21.0
49	12/07/2007		7.9	995	67.5	3.4	251	1.8
50	12/08/2007		6.7	991	69.5	4.0	192	6.5
51	12/09/2007		7.2	982	71.3	2.9	187	6.5
52	12/10/2007		6.1	1001	81.4	2.0	271	5.4
53	12/11/2007		4.6	1021	76.7	1.9	292	0.6
54	12/12/2007		4.8	1031	72.7	0.4	126	0.0
55	12/13/2007		3.8	1033	68.6	0.0	83	0.0
56	12/14/2007		1.1	1030	63.2	0.9	56	0.0
57	12/15/2007		-0.5	1029	64.1	1.2	59	0.0
58	12/16/2007		-0.8	1030	68.3	0.2	69	0.0
59	12/17/2007		-1.7	1028	68.8	0.8	81	0.0
60	12/18/2007		-2.4	1030	74.3	0.0	118	0.0

Annex 6 **Ambient conditions at the field test sites**

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
61	12/19/2007	Koeln, parking lot	-1.9	1031	74.8	0.0	104	0.0
62	12/20/2007		-3.4	1026	81.5	0.0	121	0.0
63	12/21/2007		-0.9	1020	71.0	0.7	133	0.0
64	12/22/2007		-2.2	1020	70.5	1.5	151	0.0
65	12/23/2007		-0.4	1022	76.7	0.6	142	0.0
66	12/24/2007		-0.5	1020	78.2	2.5	124	0.0
67	12/25/2007		-0.9	1014	71.0	3.6	133	0.3
68	12/26/2007		1.2	1023	80.3	1.2	143	0.6
69	12/27/2007		3.9	1024	76.0	3.8	150	0.3
70	12/28/2007		4.1	1016	75.0	4.8	154	0.6
71	12/29/2007		4.9	1009	76.1	1.7	198	5.0
72	12/30/2007		5.1	1018	75.3	1.9	248	1.5
73	12/31/2007		3.3	1021	81.8	0.0	150	0.6
74	01/01/2008		-1.5	1017	79.6	0.5	115	0.0
75	01/02/2008		-0.7	1008	65.4	3.5	106	0.0
76	01/03/2008		1.2	1001	59.9	4.9	142	0.0
77	01/04/2008		3.3	1001	62.8	5.9	139	0.9
78	01/05/2008		6.3	997	75.6	1.3	183	4.8
79	01/06/2008		4.4	1005	74.0	1.5	192	4.1
80	01/07/2008		6.8	1008	67.5	3.0	243	1.8
81	01/08/2008		5.4	1010	72.8	3.6	155	0.0
82	01/09/2008		4.8	1008	76.2	0.6	186	3.8
83	01/10/2008		8.7	1003	68.5	4.5	173	0.0
84	01/11/2008		10.4	993	64.5	5.5	164	2.4
85	01/12/2008		4.0	1006	72.1	1.8	190	0.3
86	01/13/2008		3.6	1005	69.1	4.7	138	0.0
87	01/14/2008		7.4	1000	68.7	4.7	162	0.9
88	01/15/2008		9.2	988	63.6	6.8	173	0.0
89	01/16/2008		6.8	995	76.5	0.6	188	7.4
90	01/17/2008		8.3	1000	70.6	3.9	199	5.6

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

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
91	01/18/2008	Koeln, parking lot	11.1	1008	72.2	2.7	217	3.6
92	01/19/2008		12.4	1014	75.8	2.9	235	4.5
93	01/20/2008		11.7	1013	72.3	4.5	239	0.0
94	01/21/2008		9.0	1003	70.6	4.3	233	6.5
95	01/22/2008		3.3	1020	71.0	1.6	220	0.0
96	01/23/2008		6.0	1021	68.9	2.7	153	0.0
97	01/24/2008		5.9	1024	74.4	1.0	225	2.7
98	01/25/2008		7.1	1029	62.7	1.7	233	0.0
99	01/26/2008		7.5	1024	64.8	3.5	244	0.0
100	01/27/2008		7.5	1025	73.7	2.0	246	0.0
101	01/28/2008		7.4	1025	65.8	0.0	230	0.0
102	01/29/2008		3.4	1018	71.6	0.1	220	0.0
103	01/30/2008		2.2	1017	80.7	0.6	224	3.9
104	01/31/2008		4.7	999	67.7	5.6	190	2.4
105	02/01/2008		4.1	994	70.1	3.0	227	6.5
106	02/02/2008		1.3	1011	69.1	1.9	195	1.2
107	02/03/2008		3.8	1001	55.2	5.9	131	0.0
108	02/04/2008		4.0	1002	77.0	2.1	171	5.6
109	02/05/2008		8.2	1003	73.8	4.0	175	19.2
110	02/14/2008	Bonn	2.5	1028	70.7	1.0	187	0.0
111	02/15/2008		0.6	1033	54.3	1.9	188	0.0
112	02/16/2008		0.8	1034	46.4	0.7	187	0.0
113	02/17/2008		1.7	1028	54.8	0.2	197	0.0
114	02/18/2008		2.0	1021	53.1	0.2	161	0.0
115	02/19/2008		4.6	1013	63.9	0.6	157	0.9
116	02/20/2008		4.9	1013	77.5	0.2	160	0.9
117	02/21/2008		10.1	1015	66.3	0.4	179	0.6
118	02/22/2008		11.1	1017	65.5	1.7	127	0.0
119	02/23/2008		8.6	1015	69.4	0.3	134	0.0
120	02/24/2008		9.7	1011	70.3	0.4	188	0.3

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

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
121	02/25/2008	Bonn	11.3	1006	65.2	0.8	153	0.0
122	02/26/2008		9.3	1004	65.5	2.2	72	2.4
123	02/27/2008		7.9	1012	60.6	0.7	150	0.0
124	02/28/2008		8.9	1009	72.4	0.5	117	7.7
125	02/29/2008		9.7	994	66.8	4.7	132	9.2
126	03/01/2008		10.5	999	63.7	4.8	121	0.6
127	03/02/2008		9.6	1001	66.1	1.8	124	2.1
128	03/03/2008		4.4	1004	64.3	1.0	150	9.1
129	03/04/2008		2.9	1017	65.8	2.2	147	0.9
130	03/05/2008		2.8	1019	59.1	0.3	131	0.0
131	03/06/2008		7.1	1010	66.9	0.3	131	0.0
132	03/07/2008		7.7	1004	63.4	0.3	139	0.0
133	03/08/2008		8.1	998	59.4	0.4	153	0.0
134	03/09/2008		8.6	989	58.8	0.8	120	0.0
135	03/10/2008		8.2	979	63.2	2.8	159	2.1
136	03/11/2008		9.7	984	63.5	4.0	122	4.8
137	03/12/2008		7.7	1001	59.9	4.3	122	0.0
138	03/13/2008		9.0	1002	69.2	1.7	134	10.3
139	03/14/2008		8.1	1005	67.8	1.0	173	0.0
140	03/15/2008		11.6	993	66.7	0.4	148	7.7
141	03/16/2008		7.3	998	72.8	2.1	183	16.5
142	03/17/2008		4.3	1005	62.6	2.0	123	0.0
143	03/18/2008		4.7	1005	65.6	2.3	164	0.9
144	03/19/2008		3.6	1007	72.5	1.7	105	5.1
145	03/20/2008		5.5	983	69.0	3.4	133	5.6
146	03/21/2008		2.5	975	75.2	1.2	123	6.8
147	03/22/2008		1.7	989	63.9	3.1	233	1.8
148	03/23/2008		0.7	988	60.3	0.4	171	2.1
149	03/24/2008		1.2	990	74.2	2.5	126	2.7
150	03/25/2008		1.1	995	74.4	0.7	141	7.7

Annex 6 **Ambient conditions at the field test sites**

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
151	03/26/2008	Bonn	3.8	991	81.0	0.3	178	4.2
152	03/27/2008		6.8	997	69.5	0.5	131	0.0
153	03/28/2008		9.5	1002	55.4	2.7	124	0.3
154	03/29/2008		11.4	1003	45.3	1.4	107	0.0
155	03/30/2008		12.3	1002	56.5	0.6	181	0.0
156	03/31/2008		10.8	1012	58.3	0.6	171	0.0
157	04/01/2008		10.6	1011	62.8	2.2	184	2.7
158	04/02/2008		8.0	1014	70.2	2.6	194	1.5
159	04/03/2008		7.7	1019	70.3	0.7	160	2.1
160	04/04/2008		9.4	1009	70.8	0.0	125	3.9
161	04/05/2008		4.9	996	76.8	0.6	136	13.6
162	04/06/2008		4.3	991	67.7	0.9	241	2.1
163	04/07/2008		4.1	997	65.3	1.0	150	0.3
164	04/08/2008		6.5	993	61.7	0.6	220	0.0
165	04/09/2008		7.1	990	68.4	0.3	219	2.4
166	04/10/2008		8.8	990	58.1	0.7	224	0.0
167	04/11/2008		9.8	996	52.9	0.7	129	0.0
168	04/12/2008		10.3	1002	61.9	1.0	110	1.5
169	04/13/2008		8.6	1002	77.7	0.5	163	20.4
170	04/14/2008		7.0	1009	75.7	0.5	112	8.6
171	04/15/2008		4.7	1013	75.0	0.3	188	5.9
172	04/16/2008		5.6	1006	57.7	0.8	214	0.0
173	04/17/2008		8.5	995	51.2	2.2	171	0.0
174	04/18/2008		10.2	989	55.6	1.5	190	0.0
175	04/19/2008		9.0	996	73.0	1.7	175	0.0
176	04/20/2008		12.1	995	60.9	2.0	211	0.0
177	04/21/2008		13.6	995	56.0	1.5	259	0.0
178	09/30/2008	Bruehl	11.4	996	74.2	2.0	214	16.5
179	10/01/2008		12.4	992	68.9	6.6	241	5.0
180	10/02/2008		9.4	996	67.4	4.6	217	0.6

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

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
181	10/03/2008	Bruehl	8.7	1001	72.6	3.4	216	2.1
182	10/04/2008		9.6	1006	61.6	6.1	225	0.0
183	10/05/2008		12.6	997	71.2	8.3	213	9.8
184	10/06/2008		13.4	1007	79.7	0.8	200	2.7
185	10/07/2008		15.4	1005	75.3	2.3	144	0.3
186	10/08/2008		12.5	1012	82.0	1.2	254	5.3
187	10/09/2008		10.1	1024	78.8	0.5	246	0.0
188	10/10/2008		11.6	1024	77.6	0.2	185	0.3
189	10/11/2008		13.0	1020	78.0	0.8	145	0.0
190	10/12/2008		12.9	1017	79.4	1.0	163	0.3
191	10/13/2008		16.2	1011	74.4	1.5	174	0.3
192	10/14/2008		14.1	1012	72.5	1.9	206	0.0
193	10/15/2008		14.3	1006	72.8	4.4	203	4.1
194	10/16/2008		9.3	1005	75.9	3.2	246	6.2
195	10/17/2008		8.3	1012	71.4	2.3	228	0.0
196	10/18/2008		8.7	1012	71.0	0.2	199	0.0
197	10/19/2008		9.5	1013	70.0	1.8	196	0.0
198	10/20/2008		14.2	1004	68.9	3.6	171	0.0
199	10/21/2008		10.3	1006	76.2	1.7	228	2.1
200	10/22/2008		7.8	1017	72.7	1.3	208	0.0
201	10/23/2008		7.5	1019	73.0	2.6	151	0.0
202	10/24/2008		9.7	1018	73.3	1.3	158	0.3
203	10/25/2008		9.9	1021	78.6	1.2	161	0.3
204	10/26/2008		12.6	1007	70.2	3.5	191	7.4
205	10/27/2008		8.0	1000	76.8	1.4	249	3.9
206	10/28/2008		4.5	1002	74.9	0.9	209	0.0
207	10/29/2008		4.7	996	76.8	0.0	212	0.0
208	10/30/2008		4.4	992	77.9	1.5	109	1.8
209	10/31/2008		6.5	998	78.3	1.6	122	4.2
210	11/01/2008		8.4	1001	80.1	0.7	139	1.8

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

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
211	11/02/2008	Bruehl	8.9	1006.4	79.3	0.2	193.8	0.0
212	11/03/2008		No weather data available					
213	11/04/2008							
214	11/05/2008							
215	11/06/2008							
216	11/07/2008							
217	11/08/2008							
218	11/09/2008							
219	11/10/2008							
220	11/11/2008							
221	11/12/2008							
222	11/13/2008							
223	11/14/2008							
224	11/15/2008							
225	11/16/2008							
226	11/17/2008							
227	11/18/2008							
228	11/19/2008							
229	11/20/2008							
230	11/21/2008							
231	11/22/2008							
232	11/23/2008							
233	11/24/2008							
234	11/25/2008							
235	11/26/2008							
236	11/27/2008							
237	11/28/2008							
238	11/29/2008							
239	11/30/2008							
240	12/01/2008							

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

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
241	12/02/2008	Bruehl	No weather data available					
242	12/03/2008							
243	12/04/2008							
244	12/05/2008							
245	12/06/2008							
246	07/24/2008	Teddington	No weather data available					
247	07/25/2008							
248	07/26/2008							
249	07/27/2008							
250	07/28/2008							
251	07/29/2008							
252	07/30/2008							
253	07/31/2008							
254	08/01/2008							
255	08/02/2008							
256	08/03/2008							
257	08/04/2008							
258	08/05/2008							
259	08/06/2008							
260	08/07/2008							
261	08/08/2008							
262	08/09/2008							
263	08/10/2008							
264	08/11/2008							
265	08/12/2008							
266	08/13/2008							
267	08/14/2008							
268	08/15/2008							
269	08/16/2008							
270	08/17/2008							

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

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
271	08/18/2008	Teddington	No weather data available					
272	08/19/2008							
273	08/20/2008							
274	08/21/2008							
275	08/22/2008							
276	08/23/2008							
277	08/24/2008							
278	08/25/2008							
279	08/26/2008							
280	08/27/2008							
281	08/28/2008							
282	08/29/2008							
283	08/30/2008							
284	08/31/2008							
285	09/01/2008							
286	09/02/2008							
287	09/03/2008							
288	09/04/2008							
289	09/05/2008							
290	09/06/2008							
291	09/07/2008							
292	09/08/2008							
293	09/09/2008							
294	09/10/2008							
295	09/11/2008							
296	09/12/2008							
297	09/13/2008							
298	09/14/2008							
299	09/15/2008							
300	09/16/2008							

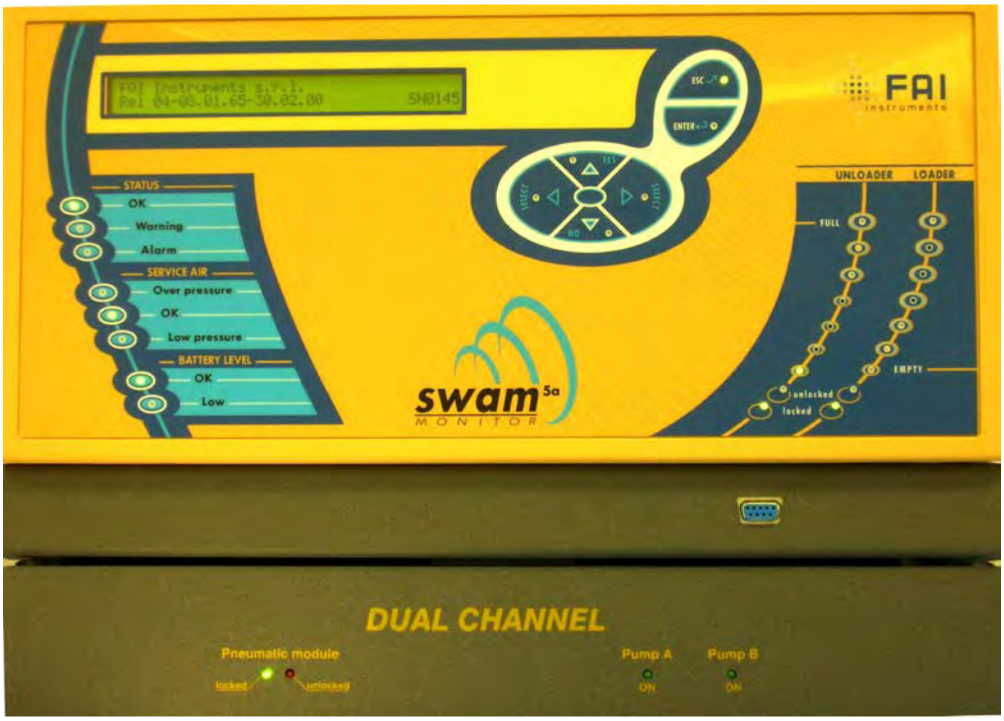
Annex 6 **Ambient conditions at the field test sites** **Page 11 of 12**

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
301	09/17/2008	Teddington	14.5	1005	68.1	0.6	153	
302	09/18/2008		11.6	1007	72.0	0.5	195	
303	09/19/2008		12.8	1012	70.1	0.3	170	
304	09/20/2008		13.1	1011	70.5	0.5	116	
305	09/21/2008		13.2	1008	70.0	0.6	168	
306	09/22/2008		14.8	1006	76.5	1.1	211	
307	09/23/2008		14.4	1006	76.0	1.8	228	
308	09/24/2008		14.8	1010	81.9	0.8	168	
309	09/25/2008		13.3	1016	74.7	0.7	89	
310	09/26/2008		13.4	1016	75.6	0.7	146	
311	09/27/2008		12.0	1011	80.6	0.1	206	
312	09/28/2008		13.9	1005	70.7	0.2	300	
313	09/29/2008		14.0	997	71.7	0.3	235	
314	09/30/2008		13.7	984	83.8	0.4	210	
315	10/01/2008		10.4	985	71.9	0.4	232	
316	10/02/2008		9.5	988	69.7	0.7	272	
317	10/03/2008		9.3	999	64.0	0.6	279	
318	10/04/2008		14.1	985	87.0	1.1	179	
319	10/05/2008		10.1	987	88.7	0.6	259	
320	10/06/2008		14.8	991	87.0	0.9	161	
321	10/07/2008		12.7	991	89.6	0.6	219	
322	10/08/2008		9.6	1008	80.6	0.2	276	
323	10/09/2008		13.3	1013	80.2	0.3	184	
324	10/10/2008		12.0	1009	84.4	0.4	210	
325	10/11/2008		12.8	1007	85.9	0.2	198	
326	10/12/2008		15.4	1001	86.5	0.3	206	
327	10/13/2008		12.5	1001	90.9	0.1	209	
328	10/14/2008		14.4	998	90.5	0.3	192	
329	10/15/2008		12.1	994	86.8	0.3	255	
330	10/16/2008		8.2	1001	78.7	0.4	241	

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

No.	Date	Test site	Ambient temperature [°C]	Ambient pressure [kPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
331	10/17/2008	Teddington	9.0	1002.0	83.8	0.0	228.9	
332	10/18/2008		10.6	1001	83.3	0.1	213	
333	10/19/2008		14.0	995	76.3	0.8	192	
334	10/20/2008		11.2	989	90.2	0.4	203	
335	10/21/2008		6.7	999	80.5	0.2	214	
336	10/22/2008		9.4	1006	80.9	0.2	226	
337	10/23/2008		13.6	1000	79.8	1.0	195	
338	10/24/2008		6.5	1011	85.1	0.2	250	
339	10/25/2008		14.1	1002	81.8	0.9	194	
340	10/26/2008		9.2	995	95.0	0.0	227	
341	10/27/2008		4.2	994	85.6	0.1	285	
342	10/28/2008		4.3	994	81.7	0.5	253	
343	10/29/2008		4.3	984	77.8	0.4	153	
344	10/30/2008		5.3	985	79.6	1.1	161	
345	10/31/2008		5.7	992	80.1	0.9	245	
346	11/01/2008		8.8	989	91.5	1.2	233	
347	11/02/2008		10.1	997	88.9	0.8	224	
348	11/03/2008		10.6	998	93.6	0.9	151	
349	11/04/2008		11.4	1001	86.2	0.8	179	
350	11/05/2008		10.5	998	92.6	0.5	284	
351	11/06/2008		10.5	992	90.7	0.4	161	
352	11/07/2008		No weather data available					
353	11/08/2008							
354	11/09/2008							

Annex 7: Software version



Note:
The software has been constantly developed and optimized up to version Rel 04-08.01.65-30.02.00 during the test program. No influences on the system performance are expected from the changes which were made on the software up to version Rel 04-08.01.65-30.02.00.

Annex 2

Investigation on the different separation behaviour of the PM_{10} sampling inlets of the reference system in comparison with the PM_{10} sampling inlets of the candidate system SWAM5a DC Monitor

Description of the Problem – Data and Root Cause Analysis – Corrective Action

A) Description and summary of the problem

The following should be taken into account for PM_{10} measurement:

Occasionally high deviations were detected between the results obtained with the candidates and the reference equipment within the scope of the suitability testing. These deviations were peculiarly high especially at days of high dust load (stable weather conditions during winter). Therefore, the extended measurement uncertainties which were determined for PM_{10} are significantly higher than the determined expanded uncertainties for $PM_{2.5}$.

The significantly worse PM_{10} results in comparison with those for $PM_{2.5}$ cannot be explained by system performance since the SWAM5a Dual Channel Monitor measuring device determines the separated particulate matter for PM_{10} as well as $PM_{2.5}$ with a single measuring module and all relevant parameters of the candidates (design of the sampling inlets, volume flow rates, tightness) conform to the requirements.

The same effect took place during the test in Bruehl (Summer 2008) with even higher deviations (nothing out of ordinary for $PM_{2.5}$ but occasionally very high deviations for PM_{10}; see annex 2, point C) Site Bruehl (Sampling head bias evaluation)). The unacceptable results for PM_{10} in Bruehl led to the termination of the tests in this location and to an acute root cause analysis.

The evaluation of the data at hand (Koeln, Bonn, and especially Bruehl) proves significant deviations within the PM_{Coarse} – fraction (= PM_{10} to $PM_{2.5}$) between the candidates and the reference equipment. This indicates different separation behaviour of the respective sampling inlets. On close inspection of the used equipment we found out that the PM_{10} nozzles of the reference equipment described in section 5 of this report differ from the specifications given in Standard EN12341. Instead of a straight inner diameter of 6.5 mm, the nozzles of the company Leckel GmbH comprise an inner diameter of 10 mm which narrows to 6.5 mm at the end of the nozzle. Figure 34 shows a schematic presentation of the different designs of the respective nozzles. The sampling inlet design of the FAI-candidates complies exactly with the specifications of Standard EN 12341.

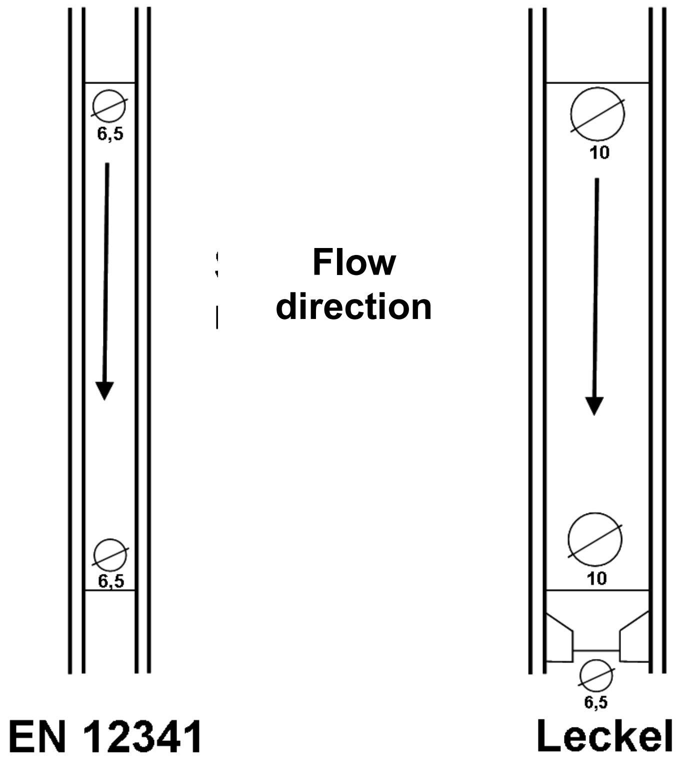


Figure 90: Schematic design of the impactor nozzles as specified in Standard 12341 in comparison with the impactor nozzles of the reference equipment

The used nozzles manufactured by LECKEL are different from the specifications given in Standard EN 12341. The manufacturer affirmed that his nozzles ensure a separation behaviour which is closer to the PM_{10} definition. Moreover, the influence caused by the different nozzle design did not show in former tests (suitability tests *et al.*) at commonly encountered levels and compositions of suspended particulate matter (e.g. no significantly high amount of coarse particles). Thus, no obvious problems were detected in the past while comparing the respective device under test with the reference equipment.

Nevertheless, the detected difference in the design of the sampling inlets could be proved as cause of the significantly different separation behaviour in comparison with the candidates, especially in the presence of a high amount of particles within the range of 10 µm.

The effects at the location in Bruehl were particularly significant since the devices were placed in the middle of a gravel pit and thus were exposed to an extremely high amount of course particles especially in the dry season. The location in Teddington is not peculiar at first sight since the exposure to suspended particulate matter and the amount of coarse dust is generally low. A close inspection of the data however leads to the same influence of the nozzle design on the separation behaviour of the reference equipment.

Note that the deviation of the reference equipment for PM_{10} significantly contributes to the total measurement uncertainty of the candidates. This mainly concerns the test results for the site in Koeln and Bonn. An influence on the result for Teddington is determined as well, but to a negligible extent.

The (good) results for the location in Bruehl which are presented in this report are based on the fact that the whole test program was repeated with PM_{10} nozzles which comply with the specifications of Standard EN12341.

SWAM 5a measuring system conforms to the minimum requirements for PM_{10} measurement in spite of the described problem. Although the found measurement uncertainties were apparently increased, this was caused by the different nozzle head design of the reference equipment and therefore should not be for the detriment of the candidates. For this reason annex 2 of this report comprises a detailed description of the found problem and a description of the correction procedure for theoretical consideration which was developed by TÜV Rheinland in cooperation with the manufacturer of the reference equipment.

Important note:

The measured component $PM_{2.5}$ is not affected in any way by the described problem.

B) Data analysis

B1. Introduction

Occasionally high deviations were detected between the results obtained with the candidates and the reference equipment within the scope of the suitability testing. These deviations were peculiarly high especially at days of high dust load (stable weather conditions during winter). Therefore, the extended measurement uncertainties which were determined for PM_{10} are significantly higher than the determined expanded uncertainties for $PM_{2.5}$.

On close inspection of the used equipment we found out that the impactor nozzles of the reference equipment differ from the specifications given in Standard EN12341, while the impactor nozzle design of the FAI-candidates complies with the specifications of Standard EN 12341.

- Considering the dimensional non-conformity to the EN1234.1 Standard of the Leckel PM_{10} sampling head used in the reference method during the Koeln, Bonn and Teddington certification campaigns;
- considering that this non-conformity causes an underestimation of the PM_{10} concentration values in comparison with the nominal values obtainable using a compliant sampling head and causes in particular an impoverishment relative to the coarse fraction of the samples;
- considering that the tests carried out at the site in Bruehl did experimentally demonstrate that this impoverishment can exceed 50% in case of high coarse concentrations (see B3);
- considering that this negative bias is contained in the uncertainty evaluation (relative expanded uncertainty) associated with the candidate system in comparison with the reference equipment;
- considering that this bias can not and absolutely must not have a negative impact on the evaluation of the candidates;

find below an evaluation of the experimental field data, aimed at the quantitative determination of this bias and at removing the contribution of this bias to the estimation of the Relative Expanded Uncertainty associated with the candidate system.

This data analysis regarding the different separation behaviour of the PM_{10} sampling inlets as well as the development of adequate corrective actions was done in close collaboration with an expert of FAI Instruments s.r.I, Dr. Antonio Febo.

B2. Data analysis

B2.1 Exemplary procedure (Site Koeln)

Considering the data of the Koeln campaign, a first descriptive analysis of the PM_{10} and $PM_{2.5}$ concentration values compared with the RM (see graphs 1, 2, 3, 4 and table 1) results as follows:

1. The level of the combined uncertainty associated with the PM_{10} raw data of the candidate compared with the reference system is much higher than the one associated with the $PM_{2.5}$ data (5.20 vs. 1.07 µg/m³);
2. the PM_{10} data dispersion is higher than that relative to $PM_{2.5}$ data;
3. the PM_{10} concentration values of the reference equipment are lower, in a statistically significant way, than the corresponding values of the candidates (22.4 vs. 24.7 µg/m³).

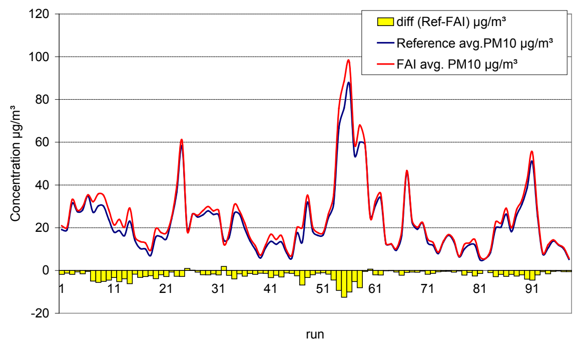


Figure 1: PM_{10} reference and candidates: temporal trend and differences

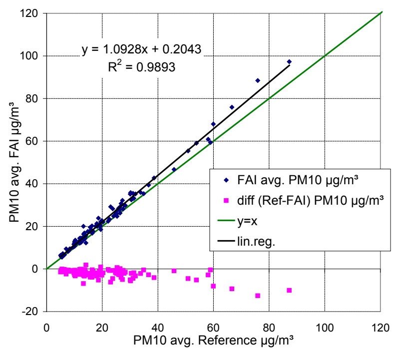


Figure 2: PM_{10} candidates and differences vs. reference

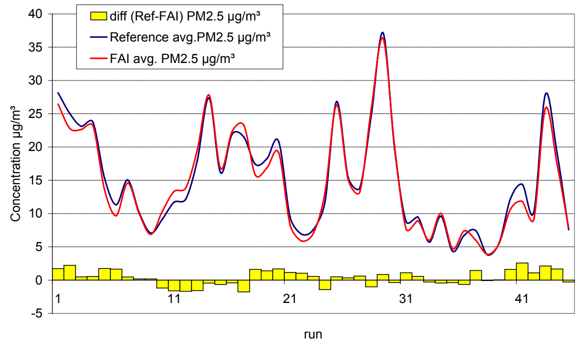


Figure 3: $PM_{2.5}$ reference and candidates: temporal trend and differences

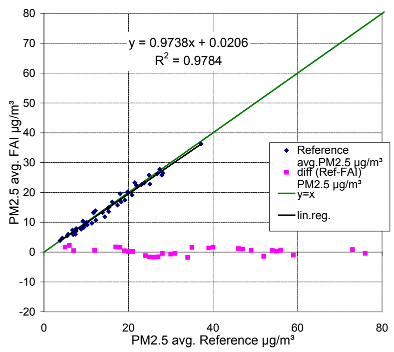


Figure 4: $PM_{2.5}$ candidates and differences vs. reference

These results confirm the presence of a negative bias in the determination of the reference PM_{10} concentration (underestimation of the coarse fraction), but they do not allow a quantitative estimation of this bias.

B2.1.1 Bias evaluation method

The availability of $PM_{2.5}$ concentration data contextual to the PM_{10} data, both for the reference and for the candidate system, allows implementing a data analysis method based on an appropriate vector approach in order to achieve the aim of bias quantification. In this approach the PM_x samples are considered as vector quantities decomposable into two components, fine and coarse (see Annex 2). Therefore, each PM_{10} sample is considered to be made of the sum of the correspondent $PM_{2.5}$ sample and of the $PM_{10-2.5}$ fraction (coarse fraction of the PM_{10} sample, complementary to the $PM_{2.5}$).

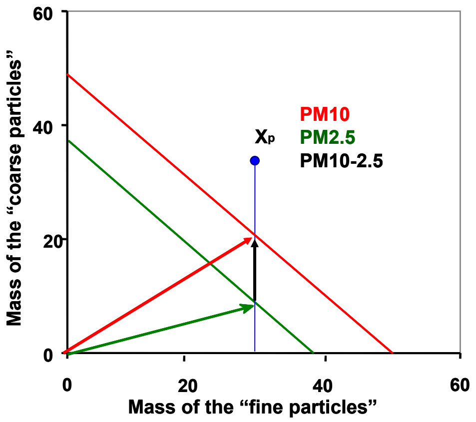


Figure 1: Vector representation of a PM_{10} sample

Thus, the quantitative determination of the $PM_{10-2.5}$ fractions can be done using the PM_{10} and $PM_{2.5}$ concentration data:

$$PM_{10-2.5} = PM_{10} - PM_{2.5} \text{ (coarse fraction mass concentration)} \qquad (0.1)$$

Moreover we suggest a representation of the differences ΔPM_{10} and $\Delta PM_{2.5}$ (between candidate and reference system) in function of the terms contributing to their determination:

$$\Delta PM_x \rightarrow \delta T_x, \delta L, \delta M_{\beta G}, \varepsilon, unknown \qquad (0.2)$$

Where:

δT_x	is the contribution due to the differences in the granulometric cut (with nominal value "x") of the sampling heads between candidate and reference system;
δL	is the contribution due to possible differences between candidate and reference system in the artifacts during the sampling and storage phases of the filtering media;
$\delta M_{\beta G}$	is the contribution due to the functional differences between the two mass measurement techniques (β attenuation and gravimetric);
ε	is the random contribution at normal distribution connected with the measurement processes;
$unknown$	is the term representing any kind of possible hidden biases

In this specific case (0.2), relative to the ΔPM_{10} and $\Delta PM_{2.5}$ data, takes the form:

$$\Delta PM_{10} = \delta T_{10} + \delta L + \delta M_{\beta G} + \varepsilon + unknown \qquad (0.3)$$

$$\Delta PM_{2.5} = \delta L + \delta M_{\beta G} + \varepsilon + unknown \qquad (0.4)$$

Since the following statements can be considered valid:

1. $\delta T_{10} \neq 0$ since a sampling head not compliant with EN12341 was used for the reference measurement in the Koeln, Bonn and Teddington campaigns
2. $\delta T_{2.5} = 0$ since the PM2.5 sampling heads of the candidate and reference system are equivalent;
3. $\delta L_{10} = \delta L_{2.5} = \delta L$ since the candidate and reference system used different filter types (glass for candidate; quartz in GE site and EMFAB in UK site for reference system), since they have been working at the same operative flow rate and since the artifacts due to the volatile material loss, essentially connected with the fine fraction, can be considered quantitatively equivalent in the PM_{10} and $PM_{2.5}$ samples;

Figure 2 shows the vector representation of (0.3).

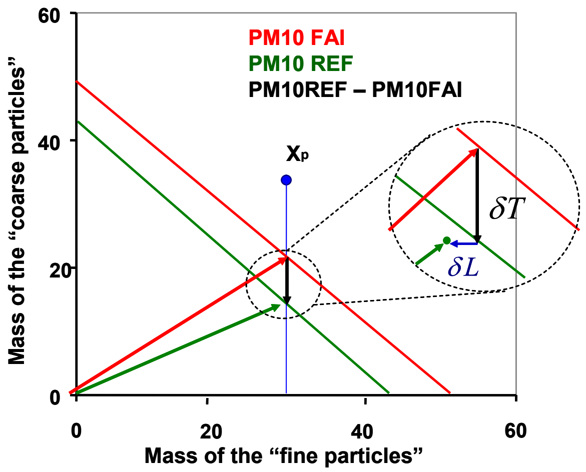


Figure 2

The PM_{10} data of both candidate and reference measurement can be expressed as identities in the form:

$$PM_{10RM} = PM_{2.5RM} + \left(PM_{10RM} - PM_{2.5RM}\right)$$
$$PM_{10CM} = PM_{2.5CM} + \left(PM_{10CM} - PM_{2.5CM}\right) \qquad (0.5)$$

that is as the sum of the $PM_{2.5}$ concentration data and of the coarse fraction data.

Therefore, the differences between the RM and CM PM_{10} concentration data take the form:

$$\Delta PM_{10} = \Delta PM_{2.5} + \Delta PM_{10-2.5} \qquad (0.6)$$

Figure 5 represents the experimental results of the Koeln campaign as expressed in (0.6).

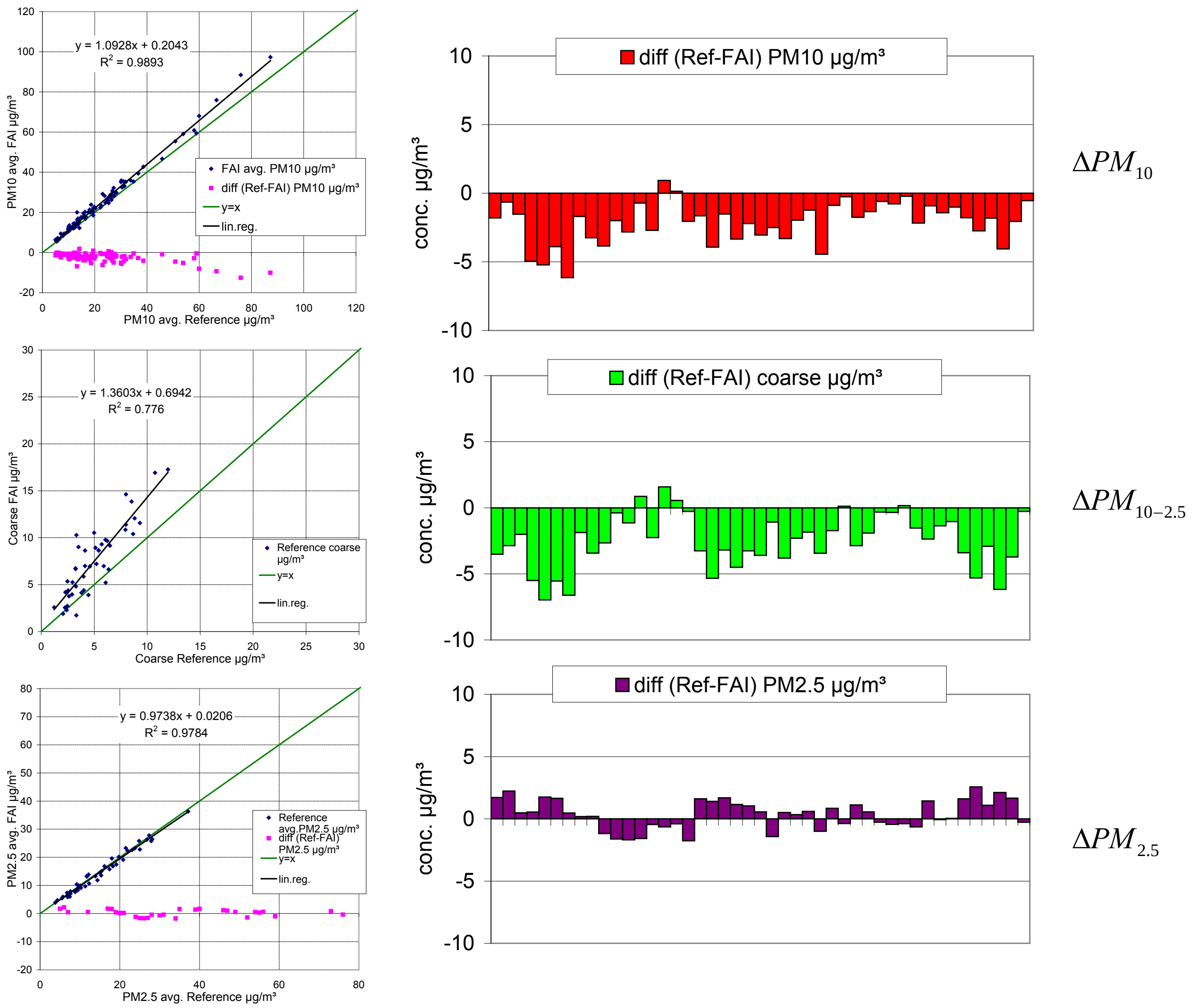


Figure 5

Evidently, the ΔPM_{10} differences are essential due to differences in the evaluation of the coarse fraction between the candidate and the reference system.

Moreover, for an analytic evaluation of the bias connected with the differences between the PM_{10} sampling heads it's useful to note that by subtraction of (0.4) from (0.3) we get a "D" variable which is functionally connected to δT_{10}:

$$\Delta PM_{10} - \Delta PM_{2.5} = D \rightarrow \delta T_{10} + \delta M_{\beta G} + \varepsilon + unknown \qquad (0.7)$$

Please also note that "D" coincides with the differences between the coarse fraction values determined with the reference system and the candidate:

$$\begin{aligned} D &= \Delta PM_{10} - \Delta PM_{2.5} = (PM_{10RM} - PM_{10CM}) - (PM_{2.5RM} - PM_{2.5CM}) = \\ &= (PM_{10RM} - PM_{2.5RM}) - (PM_{10CM} - PM_{2.5CM}) = PM_{10-2.5RM} - PM_{10-2.5CM} \end{aligned} \qquad (0.8)$$

On the other hand, the expected connection between δT_{10} and the coarse fraction $\left(PM_{10CM} - PM_{2.5CM}\right)$ is expressed by the relation:

$$\left(\delta T_{10}\right)_i = \alpha_i \left(PM_{10CM} - PM_{2.5CM}\right)_i \qquad (0.9),$$

where α_i is a coefficient depending on the granulometric distribution of the particulate matter, with "i" indicating the i^{th} daily sampling cycle.

Comparing the D_i and the $\left(PM_{10CM} - PM_{2.5CM}\right)_i$ data, graphs 6 and 7, it's evident that the second term of the (0.7) is quantitatively represented by $\left(\delta T_{10}\right)_i$

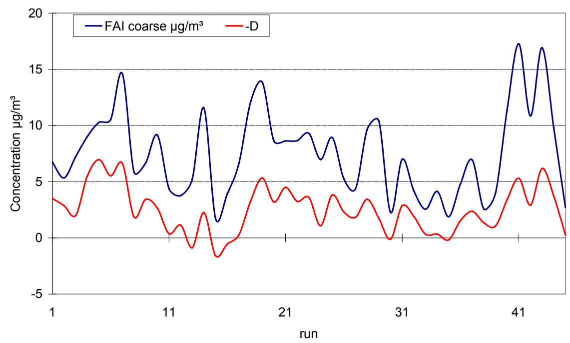


Figure 6

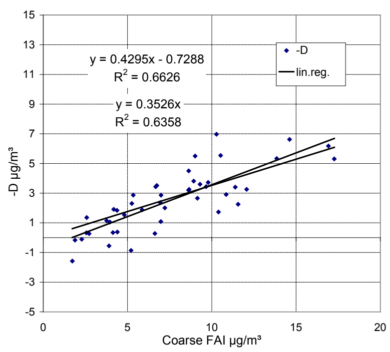


Figure 7

Indeed we can see that the "D" variable and the PM_{10} coarse fraction have a temporal modulation characterized by a common carrier. This statement is also backed by the significant value of the Pearson correlation coefficient (D vs. Coarse). Is therefore demonstrated that the connection between D_i and $\left(PM_{10CM} - PM_{2.5CM}\right)_i$ is of the kind:

$$D_i = a + b_i (PM_{10} - PM_{2.5}) \qquad (0.10)$$

By comparing (0.10) with (0.9), we conclude that the main contribution to the D_i value determination comes from $(\delta T_{10})_i$, thus it is connected with the inhomogeneity between the PM_{10} sampling heads used on the reference system and on the candidates.

Remembering (0.3) and (0.9)

$$\Delta PM_{10} = \delta T_{10} + \delta L + \delta M_{\beta G} + \varepsilon + unknown \qquad (0.3)$$

$$(\delta T_{10})_i = \alpha_i (PM_{10CM} - PM_{2.5CM})_i \qquad (0.9)$$

we can define:

$$(PM_{10RM} - PM_{10CM}) = \alpha_i (PM_{10CM} - PM_{2.5CM})_i + (\delta L + \delta M_{\beta G} + \varepsilon + unknown) \qquad (0.11)$$

where the term "$\alpha_i (PM_{10CM} - PM_{2.5CM})_i$" represents the bias connected with the inhomogeneity between the sampling heads (contribution to the combined uncertainty not imputable to the candidate), while only the term "$(\delta L + \delta M_{\beta G} + \varepsilon + unknown)$" determines the real value of the combined uncertainty to be associated with the candidate.

Therefore, in order to determine the term "$(\delta L + \delta M_{\beta G} + \varepsilon + unknown)$" it's necessary to estimate "$\alpha_i (PM_{10CM} - PM_{2.5CM})_i$" and then to know the $\alpha_i \; \forall i$ value. On the other hand, it's obviously impossible to determine the α_i value for each sampling cycle with neither detailed information about the granulometric distribution in the coarse mass accumulation mode for each i[th] day, neither information about the real cut efficiency of the head used on the reference system. However it is possible to determine an $\overline{\alpha}$ average value of α_i representing it's best estimation, by a regression analysis where the independent variable is represented by $(PM_{10CM} - PM_{2.5CM})_i$ and the dependent one is represented by ΔPM_{10}.

For the campaign in Koeln we get $\overline{\alpha}$ = -0.32 ± 0.03.

B2.1.2 Bias removal

The connection between the PM_{10} experimental data determined with the reference method and the data PM^*_{10RMi} corrected for the bias $(\delta T_{10})_i$ is given by the relation:

$$PM^*_{10RMi} = PM_{10RMi} - (\delta T_{10})_i = PM_{10RMi} - \alpha_i (PM_{10CMi} - PM_{2.5CMi}) \quad (0.12)$$

Since it's obviously impossible to know the α_i value for each i[th] sampling cycle, the best estimation of "PM^*_{10RMi}" is given by the relation:

$$\boxed{PM^*_{10RMi} = PM_{10RMi} - \overline{\alpha}(PM_{10CMi} - PM_{2.5CMi})} \quad (0.13)$$

So we can define again (0.11)

$$(PM^*_{10RM} - PM_{10CM}) = \left[(\alpha_i - \overline{\alpha})(PM_{10CMi} - PM_{2.5CMi})\right] + (\delta L + \delta M_{\beta G} + \varepsilon + unknown) \quad (0.14)$$

Where the term $\left[(\alpha_i - \overline{\alpha})(PM_{10CMi} - PM_{2.5CMi})\right]$ represents the remainder of the bias correction

$$(PM^*_{10RM} - PM_{10CM}) = (\delta L + \delta M_{\beta G} + \varepsilon + unknown) + residual\ bias \quad (0.15)$$

from which we deduce that (0.15) allows an estimation of the real value of the combined uncertainty to be associated with the candidate.
Please note that this estimation is an overestimation of the real combined uncertainty, since it contains the term due to the "residual bias".

A re-evaluation of the data obtained for the site in Koeln is then possible by means of (0.15) (see graphs 8, 9, 10, 11 and table 2).

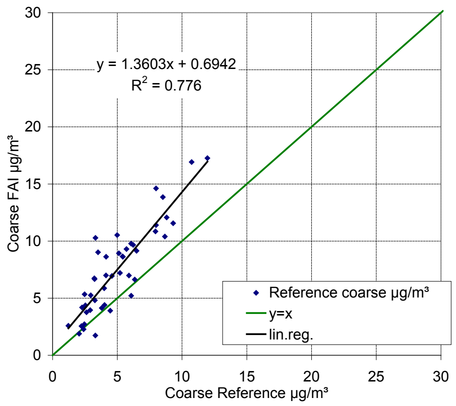


Figure 8: coarse particles FAI vs. reference

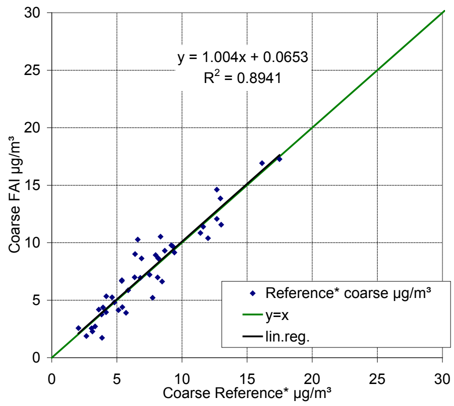


Figure 9: coarse particles FAI vs. reference *

We observe that, after the bias removal, the scatter plot between the candidates and the reference coarse shows a unitary slope and a clear increase of the R^2 value in comparison with the not corrected data; this increase represents the clear demonstration that the performed correction is a functional correction and it does not represent a simple "correction factor".
These considerations can be extended also to the PM_{10} data analysis and to the analysis of the ΔPM_{10} differences.

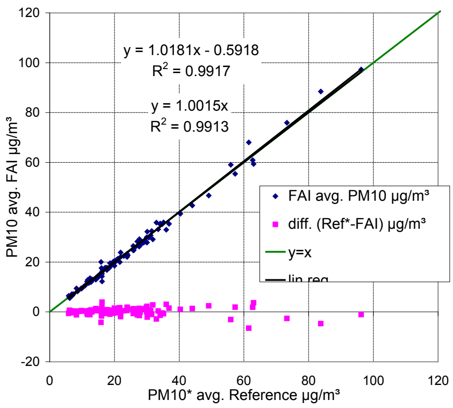


Figure 10: PM_{10} FAI vs. PM_{10}Ref*

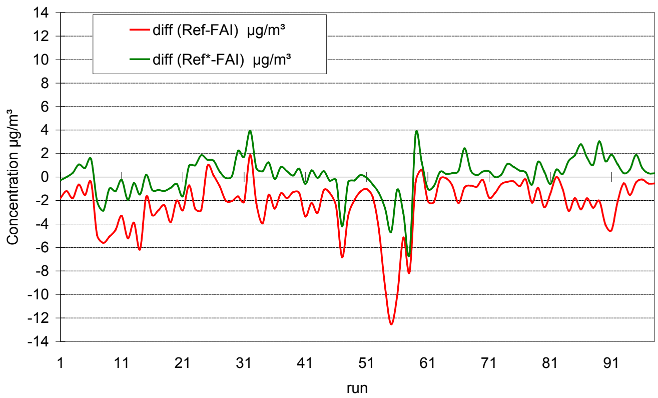


Figure 11: temporal trend differences of the PM_{10} concentration data (Ref-FAI) and (Ref*-FAI)

As regards the scatter plot between the PM_{10} concentration data, we observe that the slope takes an almost unit value and that the Pearson correlation coefficient even passes from 0.98 (see graph 2 raw data) to values higher than 0.99 (see graph 10).

B2.1.3 Conclusions

1. The presence of a bias connected with $\left(\delta T_{10}\right)_i$ has been underlined and evaluated.
2. After the removal of this bias, the combined uncertainty value associated with the candidate passes from 5.21 to 1.16 µg/m³ (raw data), showing therefore that in that case the was determined a good 78% of the uncorrected combined uncertainty value.
3. Section C and D of Annex 2 present the re-evaluated data of the “equivalency of the sampling system (DIN EN12341)” and of the “Calculation of the expanded uncertainty of the instruments (Guideline)” based on the corrected values.

B2.2 Site Bonn

The same data analysis method described for the Koeln campaign is used also in the Bonn campaign.

From a first descriptive analysis of the PM_{10} and $PM_{2.5}$ concentration values compared with the reference measurements (see graphs 12, 13, 14, 15 and table 3) it's clear that:

1. the uncertainty combined level associated with the candidate PM_{10} raw data in comparison with the reference measurement is much higher than that associated with the $PM_{2.5}$ data (5.29 vs. 1.79 µg/m³);
2. the PM_{10} data dispersion is higher than the dispersion relative to the $PM_{2.5}$ data;
3. the RM PM_{10} concentration values are statistically much lower in comparison with the correspondent candidate values (24.2 vs. 25.9 µg/m³).

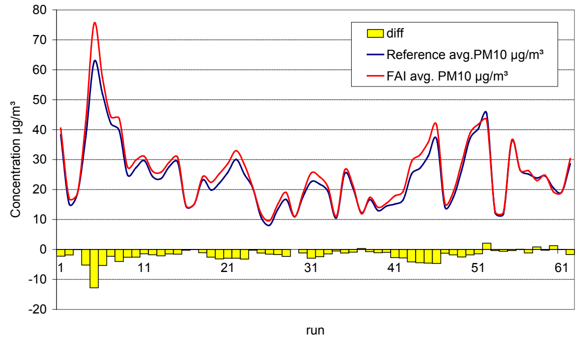


Figure 12: PM_{10} reference and candidates: temporal trend and differences

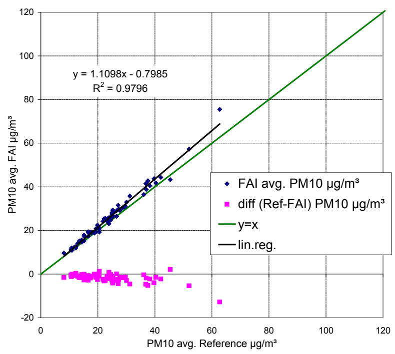


Figure 13: PM_{10} candidates and differences vs. reference

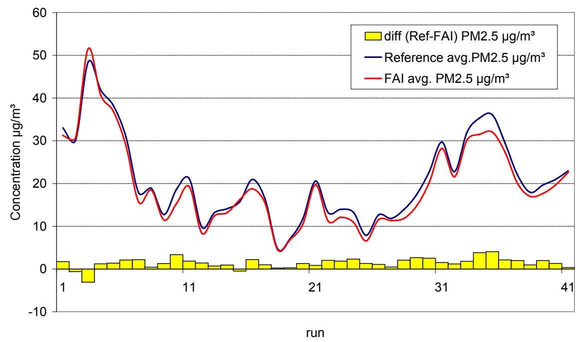


Figure 14: $PM_{2.5}$ reference and candidates: temporal trend and differences

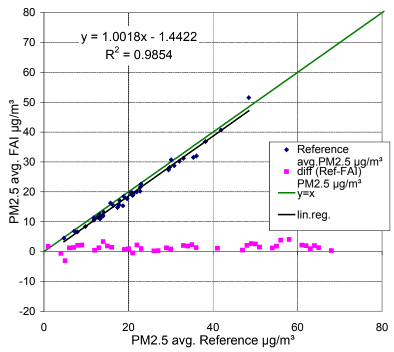


Figure 15: $PM_{2.5}$ candidates and differences vs. reference

Even in this case, the results confirm the presence of the negative bias in the determination of the PM_{10} concentration in the reference method (underestimation of the coarse fraction).

The experimental results of the campaign as expressed in (0.6) are represented in figure 16.

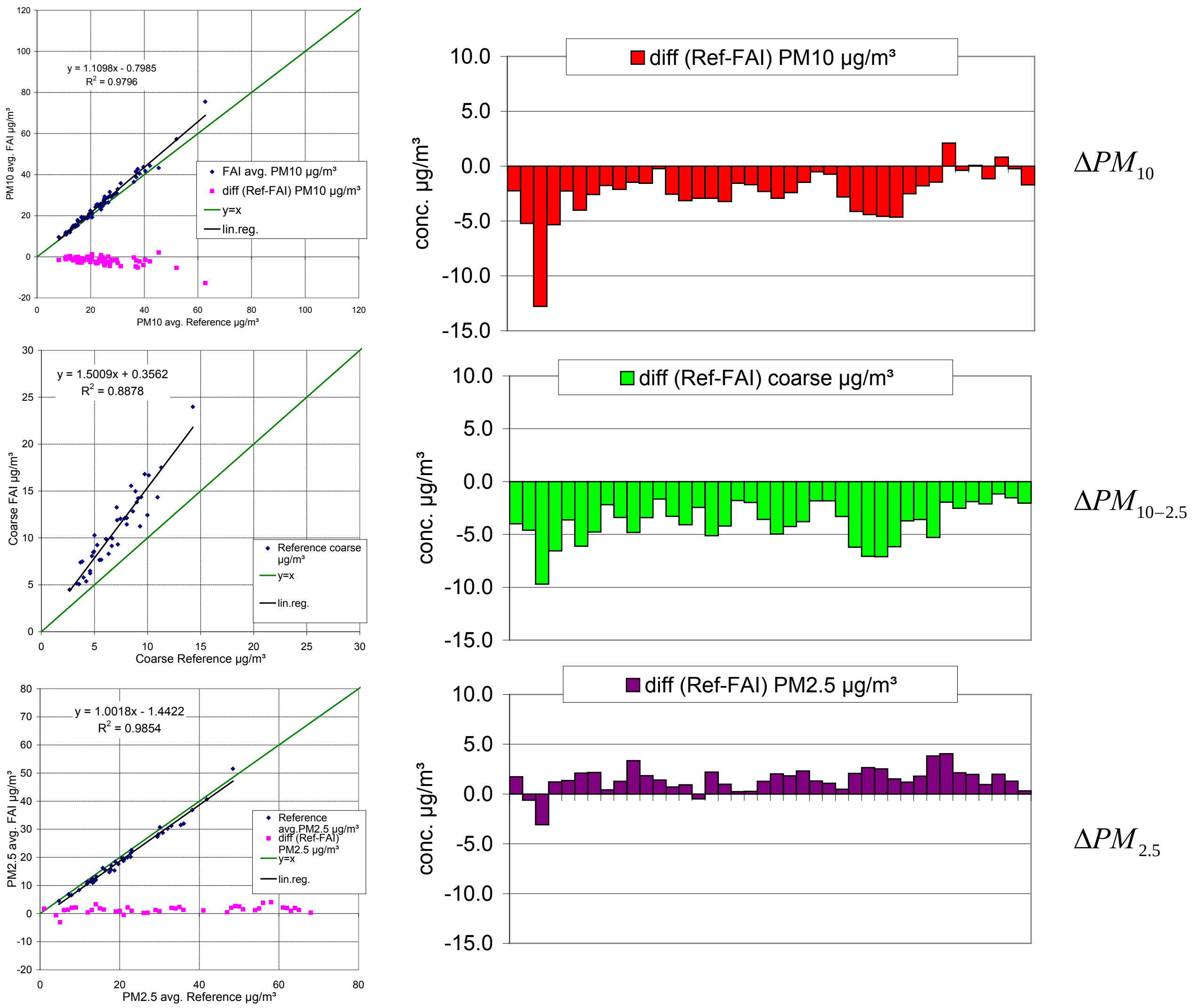


Figure 16

The importance of the $(\delta T_{10})_i$ bias contribution in the determination of the ΔPM_{10} differences is evident, even though in this case the contribution of δL connected with the differences between the filtering media used in the CM and in the RM (see $\Delta PM_{2.5}$), is quantitatively not negligible.

As expected, even in this case, from the comparison between the D_i and the $(PM_{10CM} - PM_{2.5CM})_i$ data (see Figure 17 and 18) it's evident that the second term of the (0.7) is quantitatively represented by $(\delta T_{10})_i$.

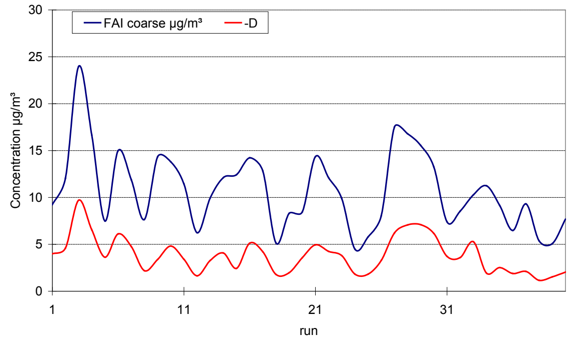


Figure 17

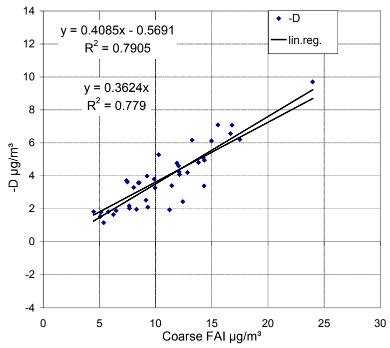


Figure 18

As a consequence, even for the data relative to the Bonn campaign it's possible to determine an $\overline{\alpha}$ average value of α_i using a regression analysis where the independent variable is represented by $(PM_{10CM} - PM_{2.5CM})_i$ and the dependent one is represented by ΔPM_{10}.

For the campaign in Bonn we get $\overline{\alpha}$ = -0.38 ± 0.03.

Then, applying (0.13), it's possible to recalculate the PM^*_{10RMi} concentration data. Figure 19, 20, 21 and 22 as well as Table 4 show the results of the data analysis of the Bonn campaign, using the corrected RM PM_{10} values [bias removal $\left(\delta T_{10}\right)_i$].

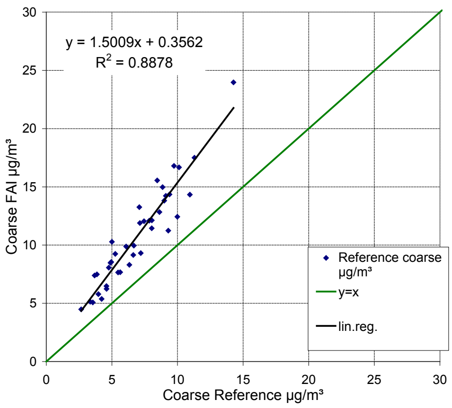


Figure 19: coarse particles FAI vs. reference

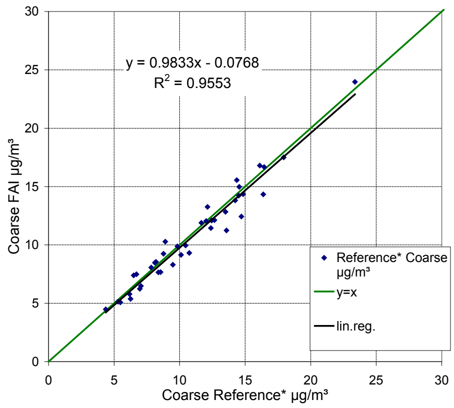


Figure 20: coarse particles FAI vs. reference *

Even for the Bonn campaign data, after the bias removal, the scatter plot between candidate and reference coarse shows an almost unit slope value and a clear increase of the R^2 value in comparison with the non corrected data.

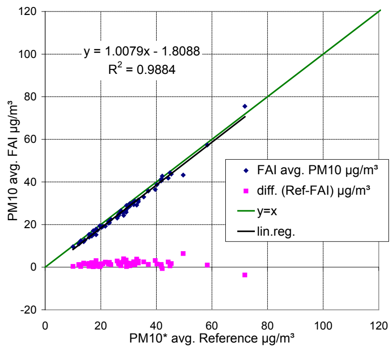


Figure 21: PM_{10} FAI vs. PM_{10}Ref*

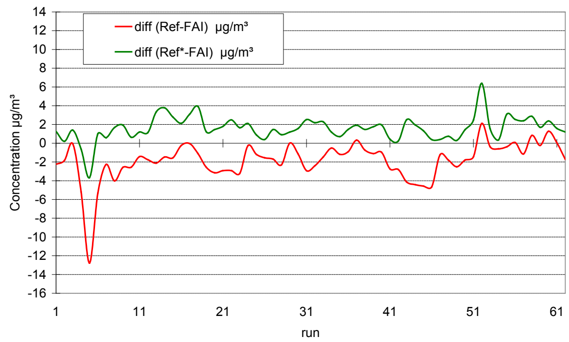


Figure 22: temporal trend differences in the PM_{10} concentration data (Ref-FAI) and (Ref*-FAI)

As regards the scatter plot between the PM_{10} concentration data, we observe that the slope takes a unit value and that the Pearson correlation coefficient passes from 0.98 (see graph 13 raw data) to about 0.99 (see graph 21).

Conclusion

1. The presence of a bias connected with $\left(\delta T_{10}\right)_i$ has been underlined and evaluated.
2. After the removal of this bias, the combined uncertainty value associated with the candidate passes from 5.29 to 1.73 µg/m³ (raw data), showing that in this case the bias determined a good 67% of the uncorrected combined uncertainty value.
3. The data demonstrate that on the site and in the specific conditions of the Bonn campaign the δL contribution to the combined uncertainty is quantitatively appreciable, as it comes both from the intercept value in the PM_{10} data scatter plot (-1.8 µg/m³) and from the average value of the residuals (1.5 µg/m³).

B2.3 Site Bruehl

The Bruehl campaign, as known, has been carried out using PM_{10} sampling heads in compliance with DIN EN12341 Standard on the reference system; therefore, the descriptive analysis of the PM_{10} and $PM_{2.5}$ concentration values in comparison with the reference method (see graphs 23, 24, 25, 26 and table 5) makes it evident that:

1. the combined uncertainty level associated with the PM_{10} raw data of the candidates in comparison with the reference method is of the same order as the one associated with the $PM_{2.5}$ data (1.62 vs. 1.98 µg/m³);
2. the PM_{10} data dispersion is similar to the one relative to the $PM_{2.5}$ data;
3. the reference PM_{10} concentration values do not present statistically significant differences in comparison with the correspondent candidate values (21.6 vs. 20.8 µg/m³).

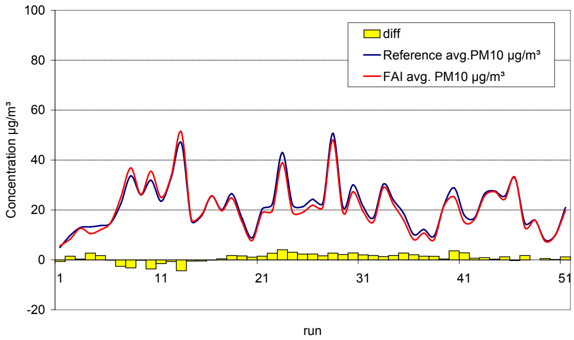


Figure 23: PM_{10} reference and candidates: temporal trend and differences

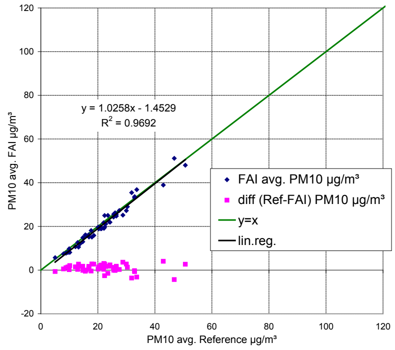


Figure 24: PM_{10} candidates and differences vs. reference

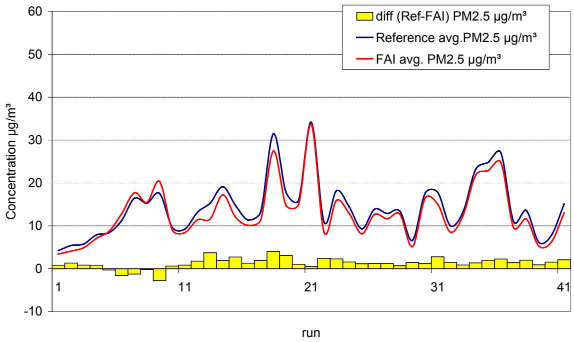


Figure 25: $PM_{2.5}$ reference and candidates: temporal trend and differences

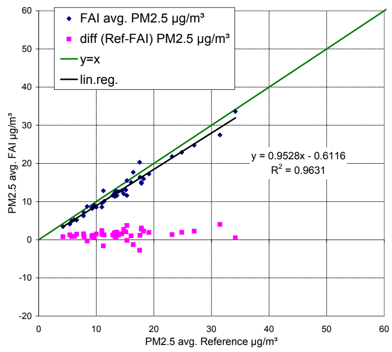


Figure 26: $PM_{2.5}$ candidates and differences vs. reference

Figure 27 represents the experimental results of the site Bruehl as expressed in (0.6).

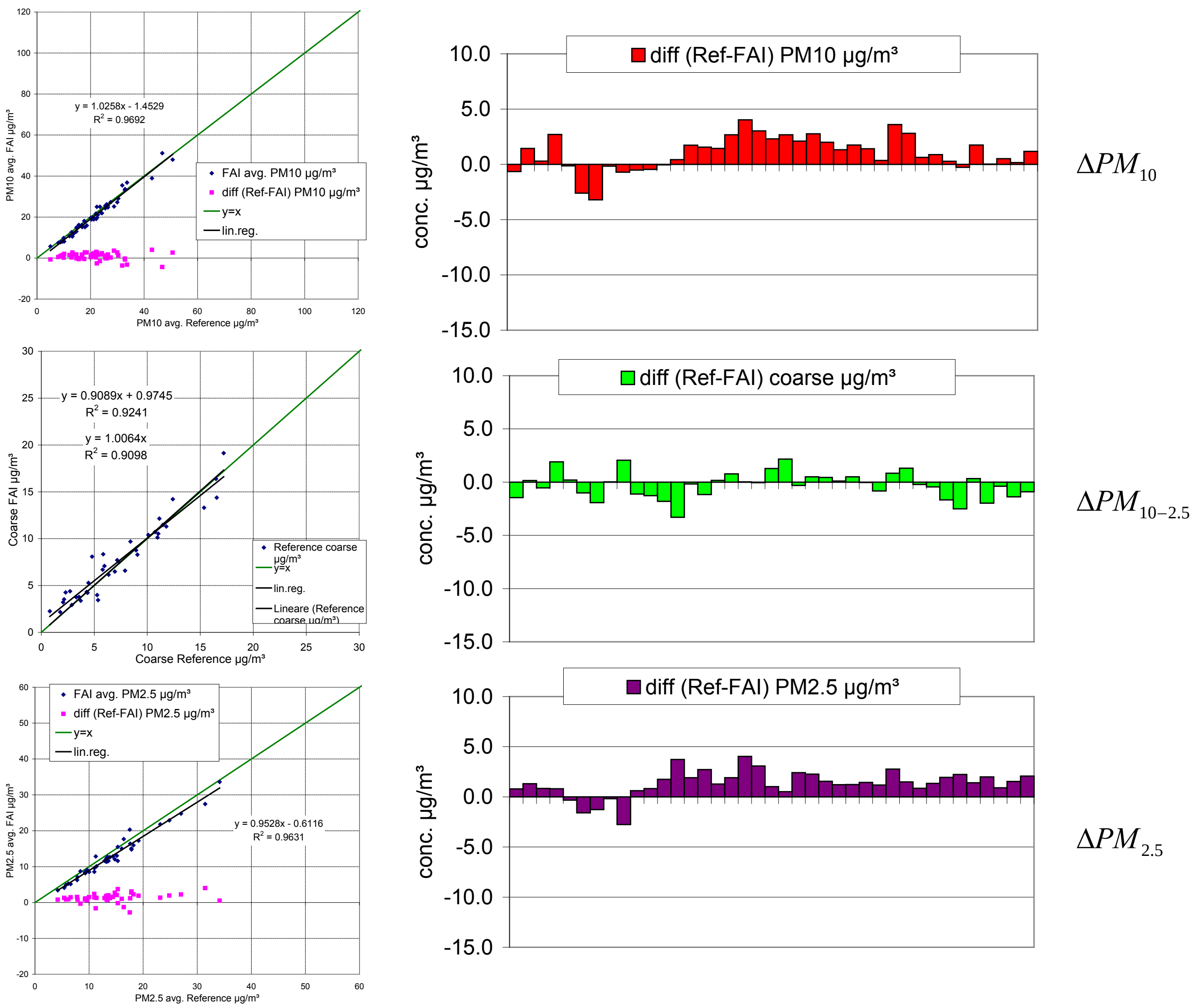


Figure 27

We observe that ΔPM_{10} does not present any functional connection with $\Delta PM_{10-2.5}$, while it has the same structure as the $\Delta PM_{2.5}$ data. Moreover, the scatter plot between the coarse data ($\Delta PM_{10-2.5}$) of the RM and of the CM points out their equivalence.

These results are those expected considering that for ΔPM_{10} and $\Delta PM_{2.5}$ we can write:

$$\Delta PM_{10} = \delta T_{10} + \delta L + \delta M_{\beta G} + \varepsilon + unknown \qquad (0.3)$$

$$\Delta PM_{2.5} = \qquad \delta L + \delta M_{\beta G} + \varepsilon + unknown \qquad (0.4)$$

We also observe that, in the Bruehl campaign, we have $(\delta T_{10})_i = 0$ (PM_{10} heads of the reference system and of the candidate are absolutely equivalent).

B2.4 Site Teddington

Before going on with the data analysis of the Teddington campaign, it's necessary to remember that PM_{10} and $PM_{2.5}$ EMFAB filters were used in spite of quartz fibre filters for the reference system in this case.

From a first descriptive analysis of the PM_{10} and $PM_{2.5}$ concentration values in comparison with the RM (see graphs 28, 29, 30, 31 and table 6) it's evident that:

1. the combined uncertainty level associated with the PM_{10} raw data of the candidates in comparison with the reference measurement is of the same order of magnitude as the one associated with the $PM_{2.5}$ data (1.45 and 1.41 µg/m³);
2. the PM_{10} data dispersion does not considerably differ from the one relative to the $PM_{2.5}$ data;

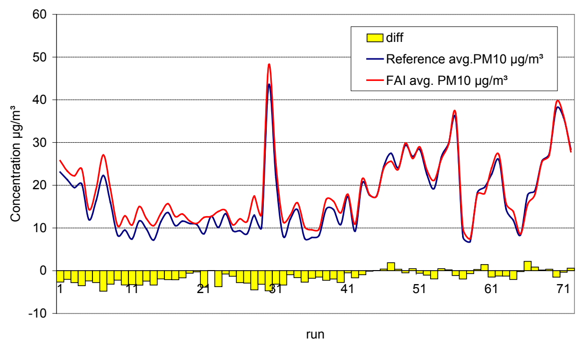


Figure 28: PM_{10} reference and candidates: temporal trend and differences

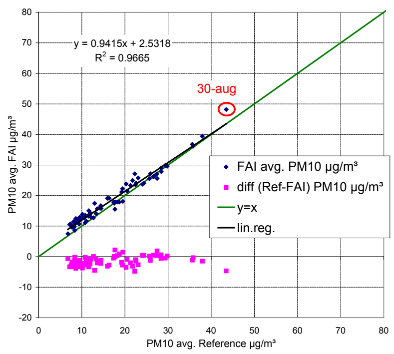


Figure 29: PM_{10} candidates and differences vs. reference

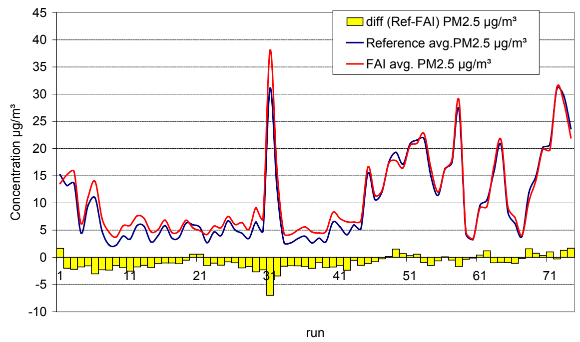


Figure 30: $PM_{2.5}$ reference and candidates: temporal trend and differences

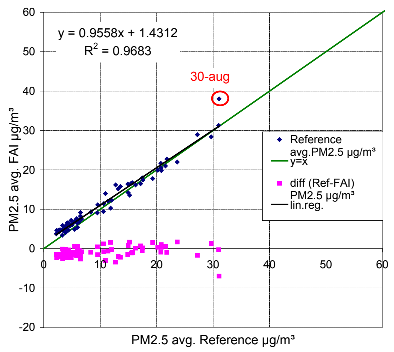


Figure 31: $PM_{2.5}$ candidates and differences vs. reference

The contribution of $(\delta T_{10})_i$ to the differences observed between the reference and the candidate PM_{10} does not appear in a quantitatively evident way.

Analyzing the data of the reference and candidate coarse fractions (Figure 32) and comparing the ΔPM_{10} and $\Delta PM_{2.5}$ data (Figure 33), we note that the bias connected with $(\delta T_{10})_i$ has been quantitatively evident from the beginning of the campaign until the early days of September 2008, while it has been irrelevant during the second period, with the exception of the last days (first week of November). These results can be explained in relation with the meteorological-climate trend during the measurement campaign performed from July 27th to November 6th, 2008. Indeed, following a first period typically characterized by dry conditions (more relevance of the coarse fraction contribution), a typically autumnal period occurred (wet conditions). The relevance of the $(\delta T_{10})_i$ bias, observed during the last period of the campaign, even though the meteorological-climate conditions were not favourable, is due to the fact that during this period some “firework” occurred. These “fireworks” determined an enrichment of the PM_{10} coarse fraction.

Moreover, observing the temporal trend of the ΔPM_{10} and $\Delta PM_{2.5}$ data, we note that the ΔPM_{10} difference is quantitatively represented by the $\Delta PM_{2.5}$ differences. Then, the term giving a contribution to the determination of the combined uncertainty value is δL (different physicco-chemical behaviour of the filtering media in the RM and in the CM). In particular, we observe that in dry conditions these differences are quantitatively appreciable, in opposition to what is happening in wet conditions.

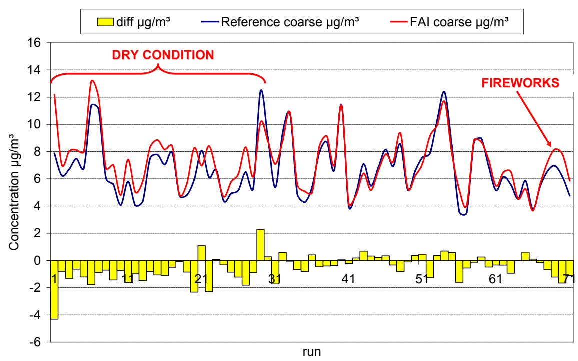


Figure 32

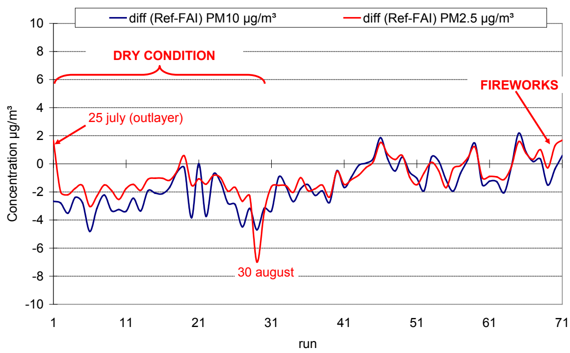


Figure 33

In conclusion we can state that in Teddington campaign the $(\delta T_{10})_i$ bias, even though functionally absolutely recognizable, does not significantly contribute to the combined uncertainty value and, for this reason, it is useless to correct the reference PM_{10} values.

C) Site Bruehl (Sampling head bias evaluation)

During the Koeln and Bonn campaigns it has been pointed out the presence of a bias in the reference PM_{10} data referable to differences in the granulometric cut between the PM_{10} heads of the reference and the candidate system. A geometric/dimensional check on the FAI PM_{10} sampling heads and on the PM_{10} heads used for the reference system highlighted that the nozzles used in the last ones were different from DIN EN12341 standard requirement. Since the noticed geometric differences could justify, in fluid-dynamic terms, even significant differences in the mass concentrations relative to the coarse fraction, TÜV and FAI did agree on the opportunity to perform a specific field test campaign aimed at confirming the hypothesis that the granulometric cut differences of the heads can produce quantitatively significant biases. Please find here below the results as temporal trend and scatter plot of the PM_{10}, $PM_{2.5}$ and $PM_{10-2.5}$ (coarse fraction) data.

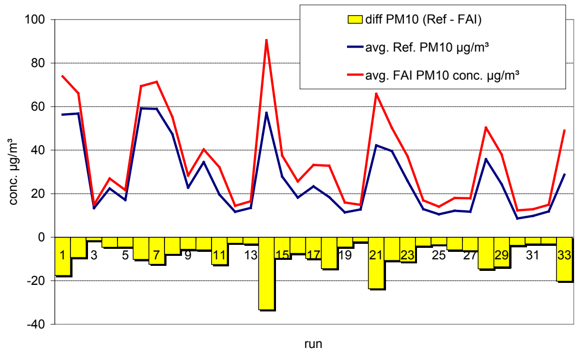


Figure 34: PM_{10} reference and candidates: temporal trend and differences

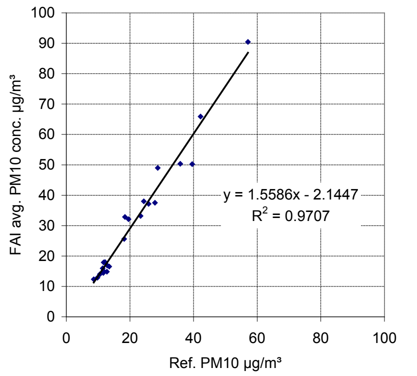


Figure 35: PM_{10} reference vs. candidates

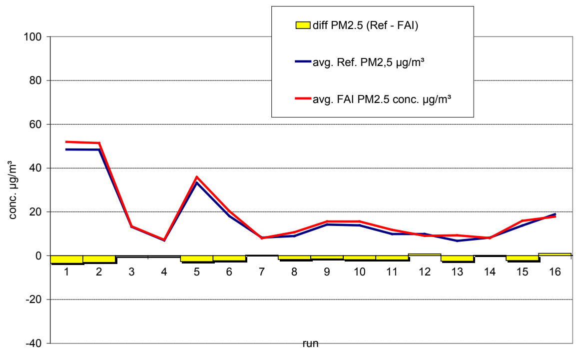


Figure 36: $PM_{2.5}$ reference and candidates: temporal trend and differences

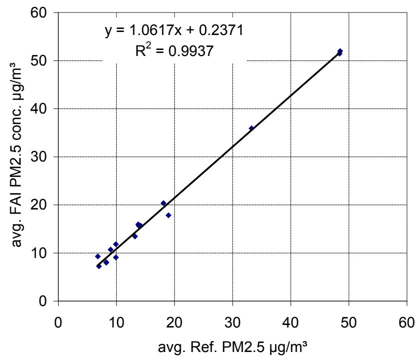


Figure 37: $PM_{2.5}$ reference vs. candidates

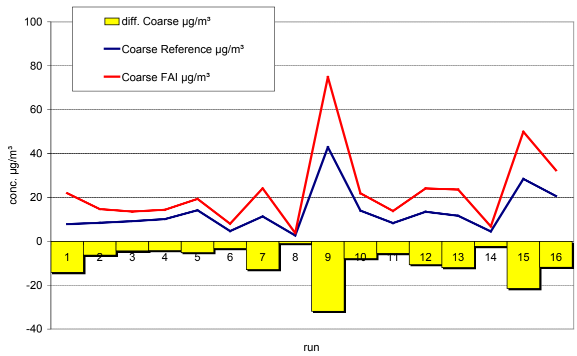


Figure 38: coarse particles reference and candidates: temporal trend and differences

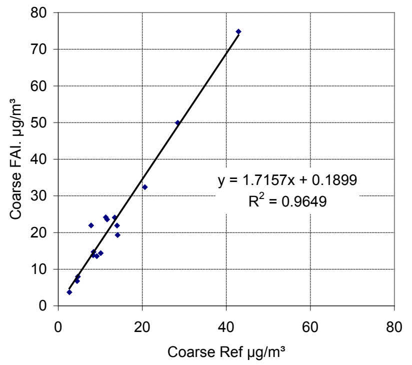


Figure 39: coarse particles reference vs. candidates

We note that:

1. the candidate PM_{10} values are considerably higher than the correspondent reference values (slope about 1.56), while the candidate $PM_{2.5}$ data are equivalent to those of the reference measurements;
2. the PM_{10} data dispersion is higher than the one relative to the $PM_{2.5}$ data;
3. The values of the coarse fraction calculated with the candidate system are over the 70% higher than the relative reference values.

In this case the "D" variable, defined in the text as:

$$\Delta PM_{10} - \Delta PM_{2.5} = D \rightarrow \delta T_{10} + \delta M_{\beta G} + \varepsilon + unknown$$

takes high values (see Figure 40 and 41) and it is hardly related with the values of the coarse fraction determined with the candidate systems.
Quantitatively we have that the average value of the FAI coarse is 22.9µg/m³, the reference one is 13.3µg/m³ and then the absolute "D" average value is a good 9.7µg/m³.

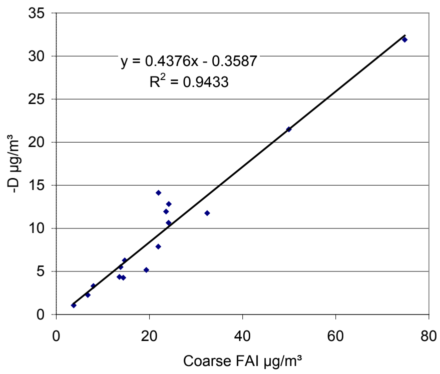


Figure 40

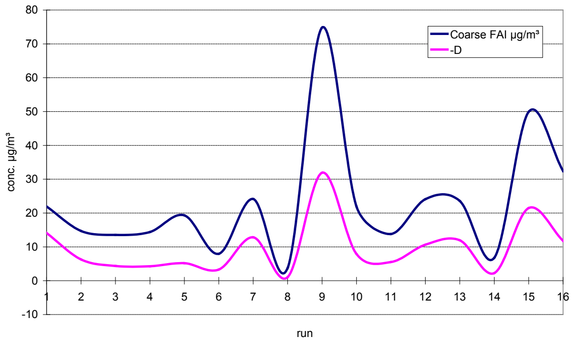


Figure 41

To conclude, the Bruehl test demonstrates that the difference of the PM_{10} head implemented in the reference system causes biases that completely alter the representativeness of the PM_{10} samples. These biases, in particular environmental conditions, can take quantitatively very high values.

D) Re-evaluation according to EN12341, 5.3.1 Equivalency of the sampling system

Re-evaluation of the PM_{10} data analogue to Section 6.1 5.3.1 Equivalency of the sampling system was based on the corrected reference data set of the Koeln and Bonn campaign.

The reference equivalency functions are within the limits of the respective acceptance range. Moreover, the variation coefficient R^2 of the determined reference equivalency functions within the respective concentration range is ≥ 0.95

Table 88 and Table 89 show the results of the regression analysis, graphically represented in Figure 91 to Figure 100. The two-sided acceptance range and the ideal curve y = x are shown in addition to the regression line of both candidates

Table 88: Results of the linear regression analysis (candidates SN 127 and SN 131, all sites)

SN 127	**No. of paired values N**	**Slope m**	**Ordinate intercept b**	**R²**
Koeln	98	1.04	-0.91	0.99
Bonn	62	1.01	-1.79	0.99
Teddington*	72	0.94	2.92	0.96
Bruehl*	51	1.03	-1.65	0.97
SN 131	**No. of paired values N**	**Slope m**	**Ordinate intercept b**	**R²**
Koeln	98	1.00	-0.22	0.99
Bonn	62	1.00	-1.70	0.99
Teddington*	72	0.96	2.39	0.96
Bruehl*	51	1.03	-1.54	0.97

* not corrected

Table 89: Results of the linear regression analysis, device SN 127 (SN 145) and SN 131 (SN 149) (total)

Device	**No. of paired values N**	**Slope m**	**Ordinate intercept b**	**R^2**
SN 127 (SN 145)	283	1.00	0.9	0.97
SN 131 (SN 149)	283	0.97	0.42	0.98

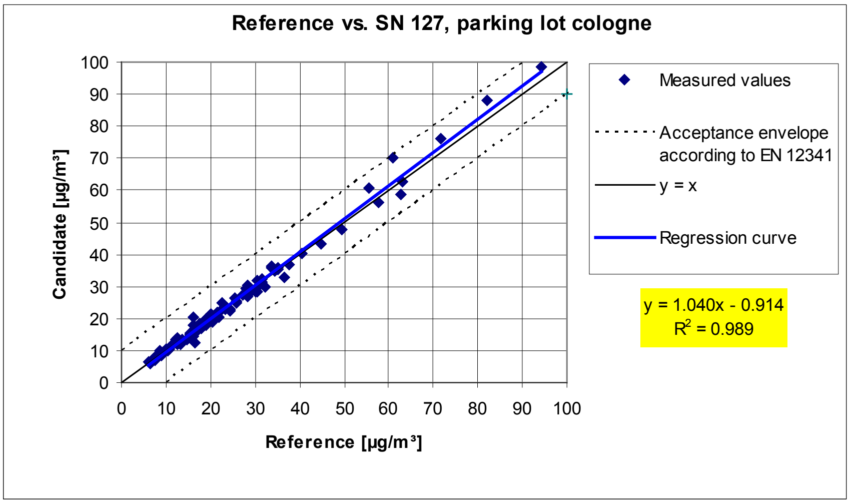


Figure 91: Reference equivalency function SN 127, PM_{10}, Site Koeln, Parking lot, reference correction

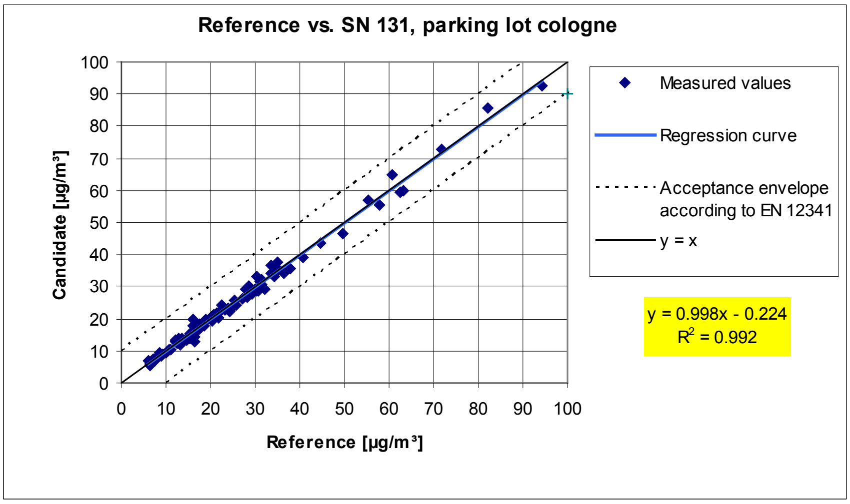


Figure 92: Reference equivalency function SN 131, PM_{10}, Site Koeln, Parking lot, reference correction

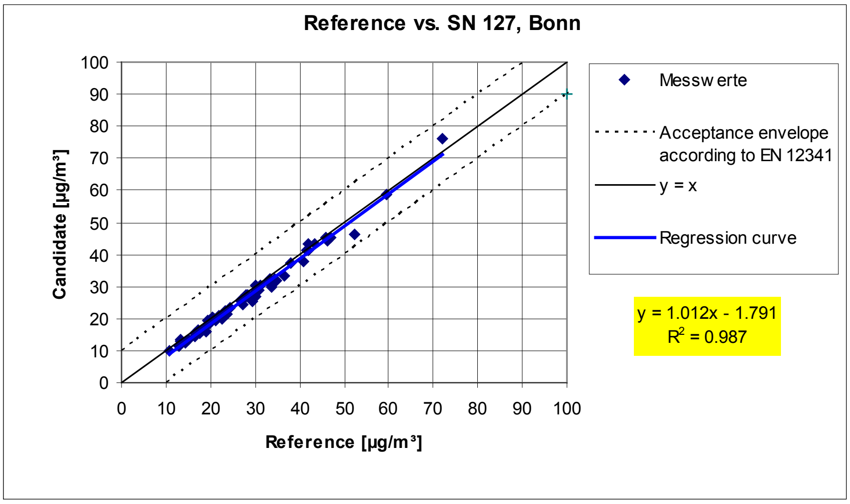


Figure 93: Reference equivalency function SN 127, PM_{10}, Site Bonn, Belderberg, reference correction

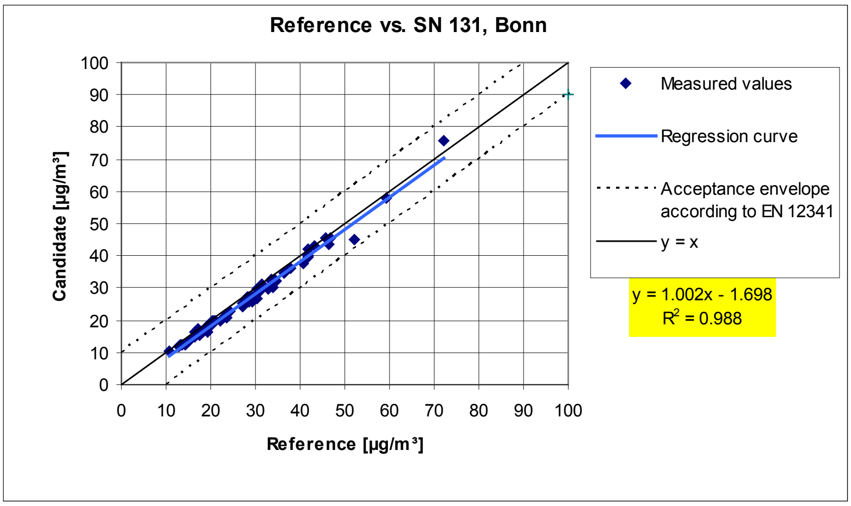


Figure 94: Reference equivalency function SN 131, PM_{10}, Site Bonn, Belderberg, reference correction

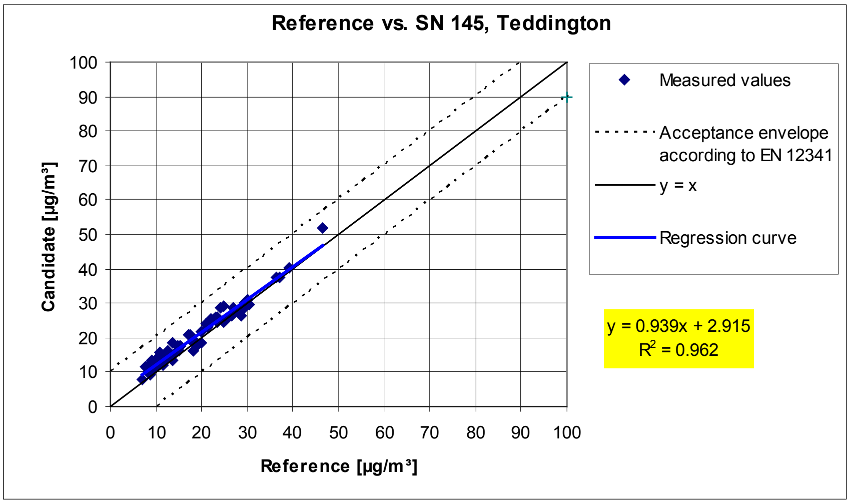


Figure 95: Reference equivalency function SN 145, PM_{10}, Site Teddington, no correction

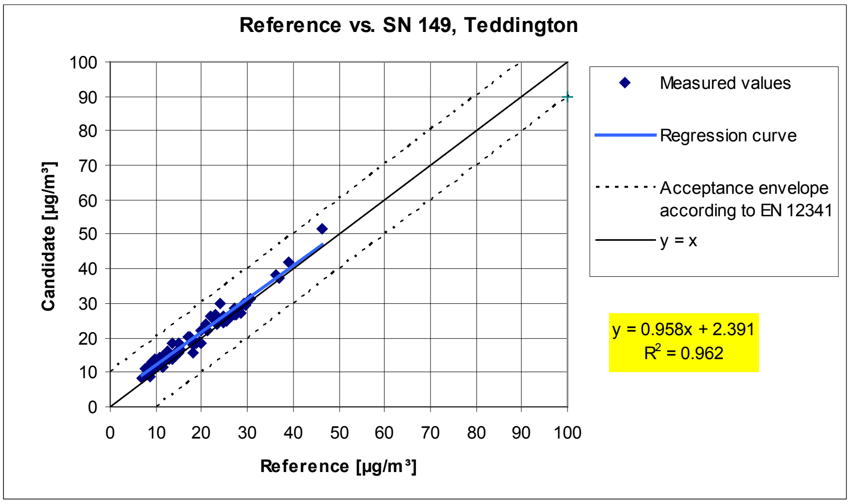


Figure 96: Reference equivalency function SN 149, PM_{10}, Site Teddington, no correction

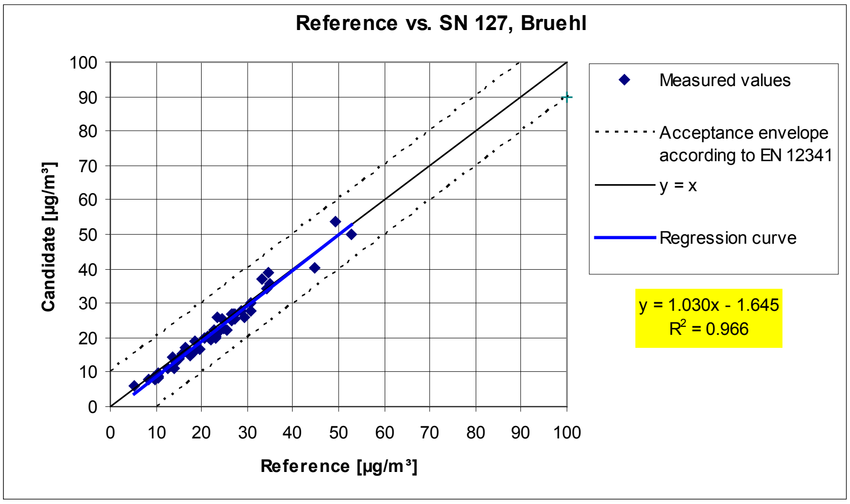


Figure 97: Reference equivalency function SN 127, PM_{10}, Site Bruehl, no correction

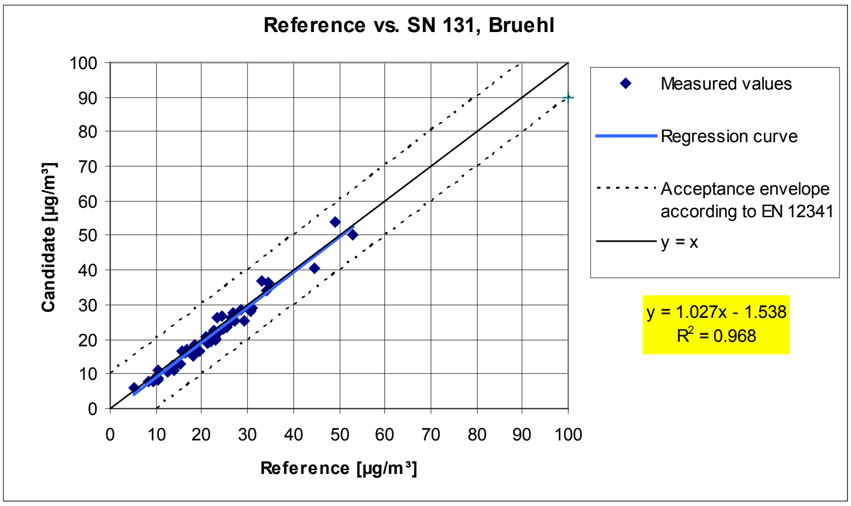


Figure 98: Reference equivalency function SN 131, PM_{10}, Site Bruehl, no correction

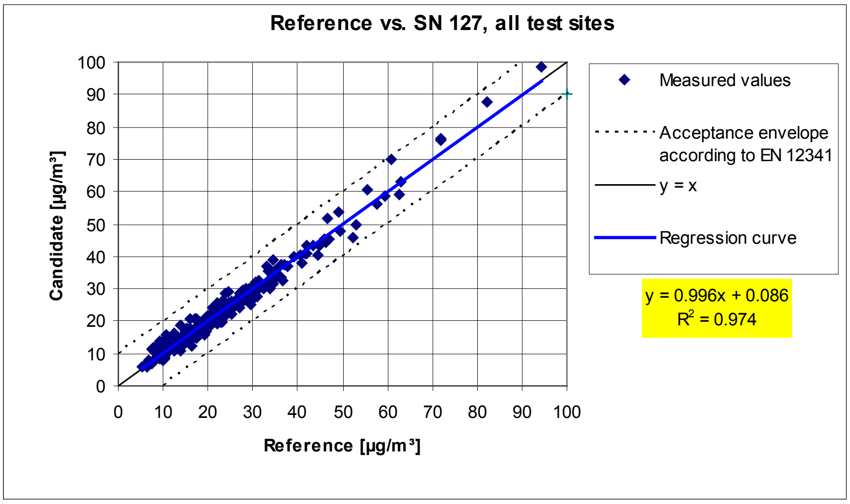


Figure 99: Reference equivalency function SN 127 (SN 145), PM_{10}, all sites, reference correction Koeln & Bonn

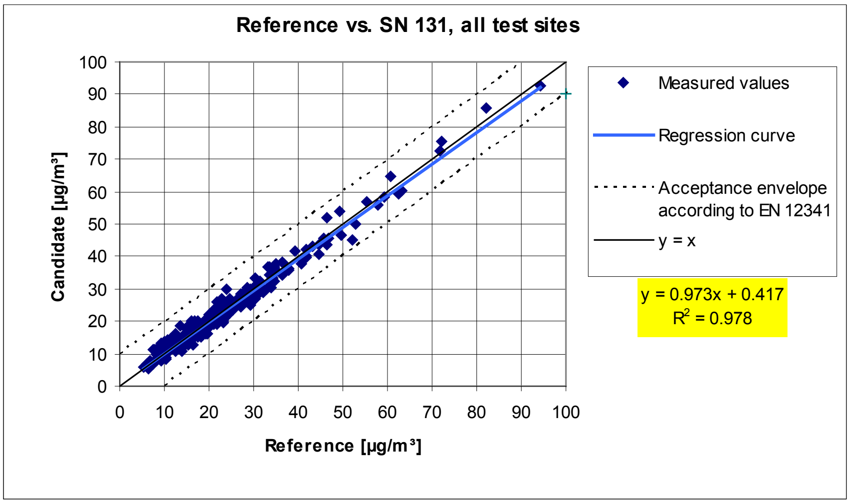


Figure 100: Reference equivalency function SN 131 (SN 149), PM_{10}, all sites, reference correction Koeln & Bonn

E) Re-evaluation according to Guide, 9.5.2.2-9.5.6 Calculation of the expanded uncertainty of the instruments

Re-evaluation of the PM_{10} data analogue to 7.1 Calculation of the expanded uncertainty of the instruments [9.5.2.2-9.5.6] was based on the corrected reference data set of the Koeln and Bonn campaign.

The determined uncertainties W_{CM} for all relevant data sets are below the expanded relative uncertainty W_{dqo} of 25%, as specified for particulate matter, without application of corrective factors.

A summarized description and evaluation of the expanded measurement uncertainties W_{CM} obtained during field test is given in Table 90. Table 91 to Table 102 show the results of evaluation for individual data sets. Graphical representations are given in Figure 101 to Figure 107.

Table 90: Summary and evaluation of the expanded measurement uncertainties W_{CM} from the field measurements, measured component PM_{10}, raw data

PM_{10} Site	Limit µg/m³	Slope b (µg/m³)/(µg/m³)	Ordinate intercept a µg/m³	u_{c_s} at the limit µg/m³	w_{CM} %	W_{CM} %	$W_{CM} \leq W_{dqo}$ (W_{dqo} = 25 %)
Koeln, Parking lot	50	1.02	-0.70	1.15	2.31	4.62	Yes
	40	1.02	-0.70	1.09	2.73	5.46	Yes
Bonn	50	1.01	-1.97	1.75	3.49	6.99	Yes
	40	1.01	-1.97	1.85	4.63	9.26	Yes
Teddington*	50	0.96	2.27	1.45	2.90	5.79	Yes
	40	0.96	2.27	1.54	3.86	7.71	Yes
Bruehl*	50	1.04	-1.82	1.62	3.24	6.48	Yes
	40	1.04	-1.82	1.59	3.98	7.97	Yes
All sites	50	1.00	-0.08	1.76	3.52	7.03	Yes
	40	1.00	-0.08	1.75	4.38	8.76	Yes
values ≥ 50 % DL (≥ 25 µg/m³)	50	1.06	-2.68	1.75	3.49	6.99	Yes
values ≥ 50 % AL (≥ 20 µg/m³)	40	1.04	-1.83	1.75	4.38	8.77	Yes

*not corrected

Table 91: Comparison between candidate and reference device, site Koeln, Parking lot, measured component PM_{10}, limit 50 µg/m³, reference correction

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	parking lot cologne	Limit value	50	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.02**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**-0.70**	**significant**		
Uncertainty of a	**0.28**			
Results of equivalence test				
Deviation at limit value	**0.42**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.15**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**2.31**	**%**		
Expanded uncertainty W_{CM}	**4.62**	**%**		
Status equivalence test	**passed**			

Table 92: Comparison between candidate and reference device, site Koeln, Parking lot, measured component PM_{10}, limit 40 µg/m³, reference correction

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	parking lot cologne	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.02**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**-0.70**	**significant**		
Uncertainty of a	**0.28**			
Results of equivalence test				
Deviation at limit value	**0.20**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.09**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**2.73**	**%**		
Expanded uncertainty W_{CM}	**5.46**	**%**		
Status equivalence test	**passed**			

Table 93: Comparison between candidate and reference device, site Bonn, Belderberg, measured component PM_{10}, limit 50 µg/m³, reference correction

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	Bonn	Limit value	50	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.01**	**not significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**-1.97**	**significant**		
Uncertainty of a	**0.42**			
Results of equivalence test				
Deviation at limit value	**-1.28**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.75**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**3.49**	**%**		
Expanded uncertainty W_{CM}	**6.99**	**%**		
Status equivalence test	**passed**			

Table 94: Comparison between candidate and reference device, site Bonn, Belderberg, measured component PM_{10}, limit 40 µg/m³, reference correction

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	Bonn	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.01**	**not significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**-1.97**	**significant**		
Uncertainty of a	**0.42**			
Results of equivalence test				
Deviation at limit value	**-1.42**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.85**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**4.63**	**%**		
Expanded uncertainty W_{CM}	**9.26**	**%**		
Status equivalence test	**passed**			

Table 95: Comparison between candidate and reference device, site Teddington, measured component PM_{10}, limit 50 µg/m³, no correction

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN145 & SN149	
Test site	Teddington	Limit value	50	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.96**	**significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**2.27**	**significant**		
Uncertainty of a	**0.40**			
Results of equivalence test				
Deviation at limit value	**0.11**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.45**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**2.90**	**%**		
Expanded uncertainty W_{CM}	**5.79**	**%**		
Status equivalence test	**passed**			

Table 96: Comparison between candidate and reference device, site Teddington, measured component PM_{10}, limit 40 µg/m³, no correction

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN145 & SN149	
Test site	Teddington	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**0.96**	**significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**2.27**	**significant**		
Uncertainty of a	**0.40**			
Results of equivalence test				
Deviation at limit value	**0.54**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.54**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**3.86**	**%**		
Expanded uncertainty W_{CM}	**7.71**	**%**		
Status equivalence test	**passed**			

Table 97: Comparison between candidate and reference device, site Bruehl, measured component PM_{10}, limit 50 µg/m³, no correction

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	Bruehl	Limit value	50	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.04**	**not significant**		
Uncertainty of b	**0.03**			
Ordinate intercept a	**-1.82**	**significant**		
Uncertainty of a	**0.60**			
Results of equivalence test				
Deviation at limit value	**0.32**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.62**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**3.24**	**%**		
Expanded uncertainty W_{CM}	**6.48**	**%**		
Status equivalence test	**passed**			

Table 98: Comparison between candidate and reference device, site Bruehl, measured component PM_{10}, limit 40 µg/m³, no correction

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	Bruehl	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.04**	**not significant**		
Uncertainty of b	**0.03**			
Ordinate intercept a	**-1.82**	**significant**		
Uncertainty of a	**0.60**			
Results of equivalence test				
Deviation at limit value	**-0.11**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.59**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**3.98**	**%**		
Expanded uncertainty W_{CM}	**7.97**	**%**		
Status equivalence test	**passed**			

Table 99: Comparison between candidate and reference device, all sites, measured component PM_{10}, limit 50 µg/m³, reference correction for Koeln & Bonn

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites	Limit value	50	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.00**	**not significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**-0.08**	**not significant**		
Uncertainty of a	**0.23**			
Results of equivalence test				
Deviation at limit value	**-0.28**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.76**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**3.52**	**%**		
Expanded uncertainty W_{CM}	**7.03**	**%**		
Status equivalence test	**passed**			

Table 100: Comparison between candidate and reference device, all sites, measured component PM_{10}, limit 40 µg/m³, reference correction for Koeln & Bonn

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.00**	**not significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**-0.08**	**not significant**		
Uncertainty of a	**0.23**			
Results of equivalence test				
Deviation at limit value	**-0.24**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.75**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**4.38**	**%**		
Expanded uncertainty W_{CM}	**8.76**	**%**		
Status equivalence test	**passed**			

Table 101: Comparison between candidate and reference device, all sites, values ≥ 50 % DL (≥ 25 µg/m³), measured component PM_{10}, limit 50 µg/m³, reference correction for Koeln & Bonn

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites, Ref.≥25µg/m³	Limit value	50	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.06**	**significant**		
Uncertainty of b	**0.02**			
Ordinate intercept a	**-2.68**	**significant**		
Uncertainty of a	**0.59**			
Results of equivalence test				
Deviation at limit value	**0.18**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.75**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**3.49**	**%**		
Expanded uncertainty W_{CM}	**6.99**	**%**		
Status equivalence test	**passed**			

Table 102: Comparison between candidate and reference device, all sites, values ≥ 50 % AL (≥ 20 µg/m³), measured component PM_{10}, limit 40 µg/m³, reference correction for Koeln & Bonn

Comparison candidate with reference according to Guidance "Demonstration of Equivalence Of Ambient Air Monitoring Methods"				
Candidate	SWAM5a	SN	SN127 & SN131	
Test site	all test sites, Ref.≥20µg/m³	Limit value	40	µg/m³
Status of measured values	raw data	Allowed uncertainty	25	%
Results of regression analysis				
Slope b	**1.04**	**significant**		
Uncertainty of b	**0.01**			
Ordinate intercept a	**-1.83**	**significant**		
Uncertainty of a	**0.45**			
Results of equivalence test				
Deviation at limit value	**-0.21**	**µg/m³**		
Uncertainty u_{c_s} at limit value	**1.75**	**µg/m³**		
Combined measurement uncertainty W_{CM}	**4.38**	**%**		
Expanded uncertainty W_{CM}	**8.77**	**%**		
Status equivalence test	**passed**			

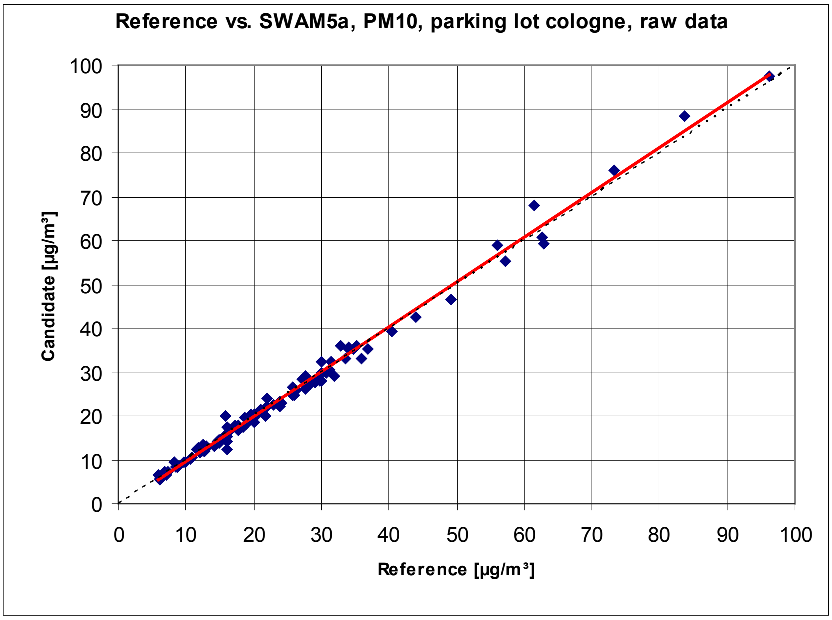


Figure 101: Reference vs. candidate, site Koeln, Parking lot, measured component PM_{10}, reference correction

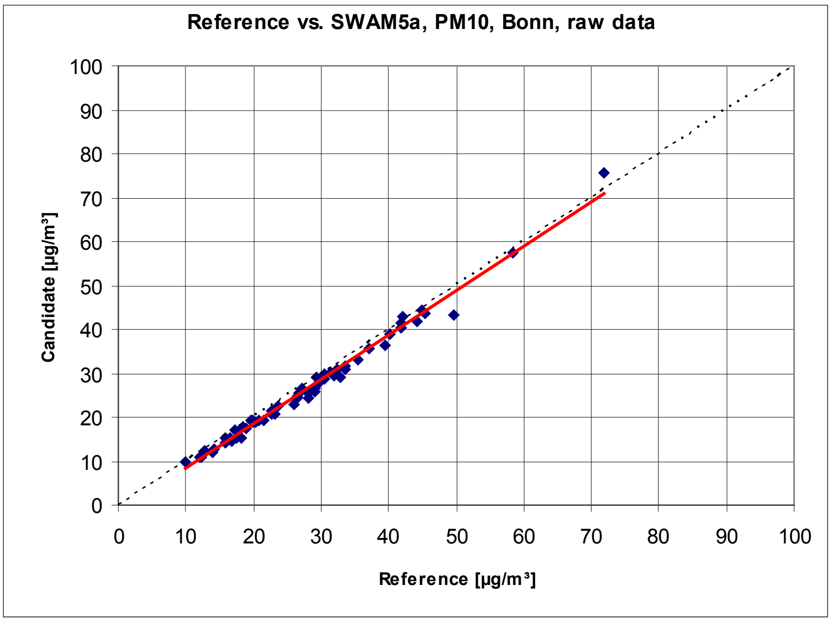


Figure 102: Reference vs. candidate, site Bonn, Belderberg, measured component PM_{10}, reference correction

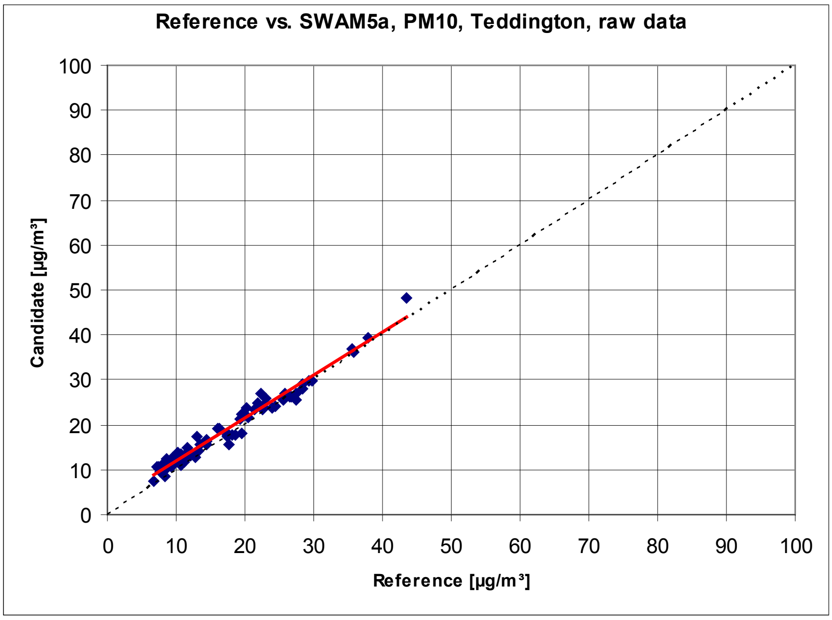


Figure 103: Reference vs. candidate, site Teddington, measured component PM_{10}, no correction

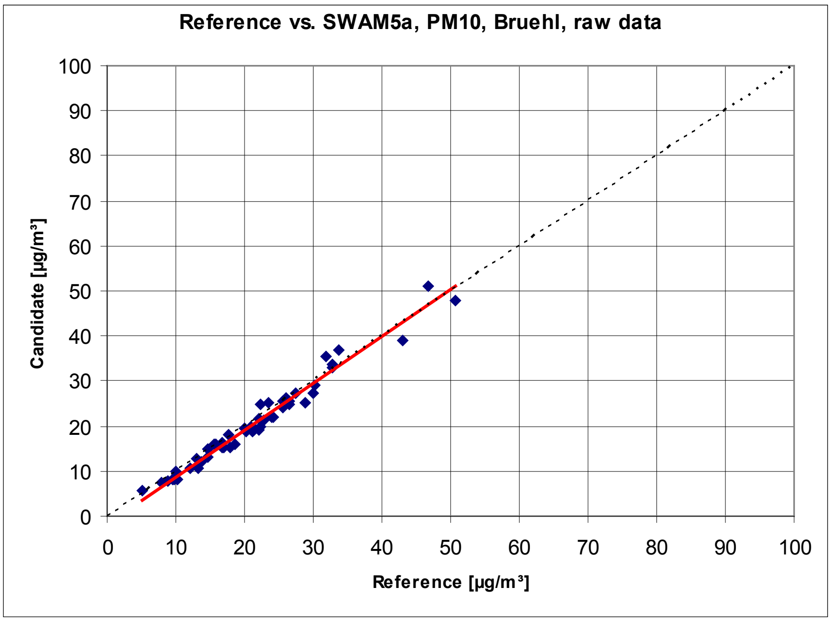


Figure 104: Reference vs. candidate, site Bruehl, measured component PM_{10}, no correction

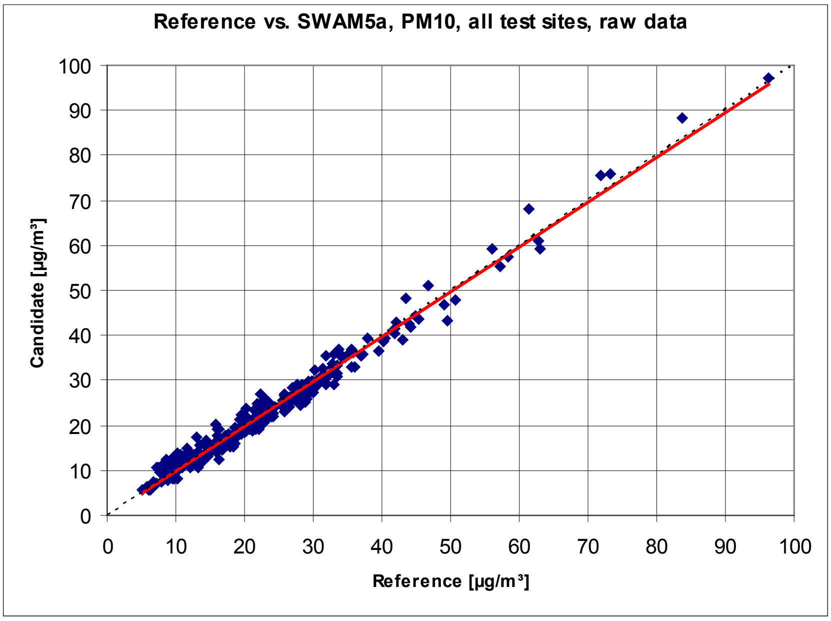


Figure 105: Reference vs. candidate, all sites, measured component PM_{10}, reference correction for Koeln & Bonn

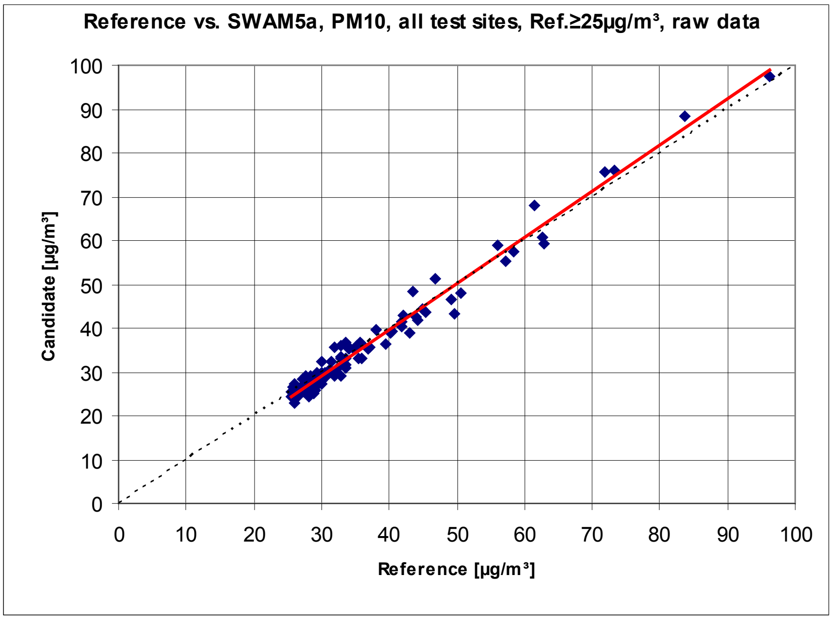


Figure 106: Reference vs. candidate, all sites, values ≥ 50 % DL (≥ 25 µg/m³), measured component PM_{10}, reference correction for Koeln & Bonn

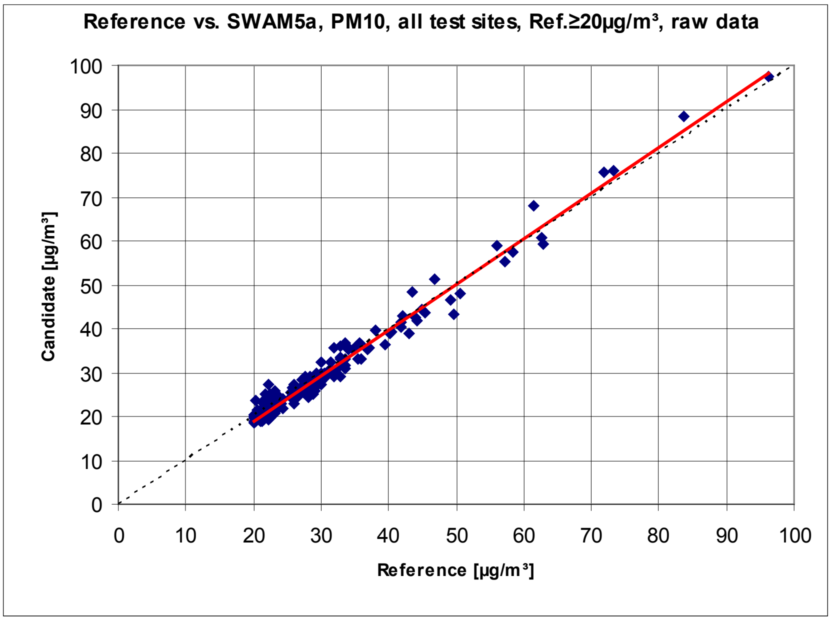


Figure 107: Reference vs. candidate, all sites, values ≥ 50 % AL (≥ 20 µg/m³), measured component PM_{10}, reference correction for Koeln & Bonn

F) Corrected reference data set for Koeln & Bonn

Annex | **Correction of the Cut-Size-Difference for Reference PM10** | **Page 1 of 6**

Manufacturer: FAI Instruments s.r.l.
Meas. Range: 0 to 200 µg/m³
Type: SWAM5a Dual Channel Monitor
Serial-No.: SN 127 & SN 131

Measured object: SPM PM 10
Measured values in µg/m³ (ambient and standard (i.N.))

$$PM^*_{10RMi} = PM_{10RMi} - \overline{\alpha}\left(PM_{10CMi} - PM_{2.5CMi}\right)$$

No.	Date	Test site	Ref. 1 PM10 [µg/m³]	Ref. 2 PM10 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref. 2 PM10 [µg/Nm³]	FAI PM10 [µg/m³]	FAI PM2,5 [µg/m³]	FAI PM10-PM2,5 [µg/m³]	$-\overline{\alpha}$	Ref. 1* PM10 [µg/m³]	Ref. 2* PM10 [µg/m³]	Ref. 1* PM10 [µg/Nm³]	Ref. 2* PM10 [µg/Nm³]
1	10/20/2007	Koeln,	18.0	20.2	18.2	20.5	20.9	16.1	4.8	0.32	19.5	21.7	19.7	22.0
2	10/21/2007	parking lot	18.1	19.8	18.3	20.2	20.2	16.4	3.8	0.32	19.3	21.0	19.5	21.4
3	10/22/2007		21.6	22.9	21.7	23.1				0.32				
4	10/23/2007		24.4	26.6	24.6	27.1				0.32				
5	10/24/2007		30.7	32.0	31.4	32.9	33.2	26.4	6.7	0.32	32.9	34.1	33.6	35.0
6	10/25/2007		26.7	28.3	27.5	29.2	28.1	22.8	5.3	0.32	28.4	30.0	29.2	30.9
7	10/26/2007		27.7	28.9	28.5	29.8	29.8	22.6	7.2	0.32	30.0	31.2	30.8	32.1
8	10/27/2007		33.9	35.9	34.6	36.9	35.4	29.2	6.2	0.32	35.9	37.9	36.6	38.8
9	10/28/2007		34.4	35.7	35.5	36.9				0.32				
10	10/29/2007									0.32				
11	10/30/2007									0.32				
12	10/31/2007		26.4	28.2	26.6	28.5	32.2	23.2	9.0	0.32	29.2	31.0	29.5	31.4
13	11/01/2007		29.1	31.3	29.6	32.1	35.8	27.2	8.6	0.32	31.8	34.1	32.4	34.8
14	11/02/2007		29.1	31.0	30.0	32.1	35.1	22.4	12.8	0.32	33.2	35.1	34.1	36.2
15	11/03/2007		23.7	23.8	24.5	24.7	28.3	18.0	10.3	0.32	27.0	27.1	27.8	28.0
16	11/04/2007		16.9	19.1	17.3	19.6	21.3	11.8	9.6	0.32	20.0	22.2	20.4	22.7
17	11/05/2007		18.4	18.9	18.9	19.5	23.8	13.6	10.3	0.32	21.7	22.2	22.2	22.7
18	11/06/2007		15.8	16.8	16.2	17.2	20.2	9.7	10.5	0.32	19.2	20.1	19.5	20.6
19	11/07/2007		23.1	23.0	23.8	23.8	29.2	14.6	14.6	0.32	27.8	27.6	28.5	28.5
20	11/08/2007		13.5	14.7	14.0	15.3	15.8	9.9	5.9	0.32	15.4	16.5	15.9	17.2
21	11/09/2007		10.0	10.6	10.3	10.9	13.5	6.9	6.7	0.32	12.2	12.7	12.4	13.0
22	11/10/2007		9.8	10.3	10.1	10.7	12.9	7.5	5.4	0.32	11.5	12.0	11.9	12.5
23	11/11/2007		6.3	7.8	6.4	8.1	9.4	5.6	3.9	0.32	7.5	9.0	7.7	9.3
24	11/12/2007		15.1	16.2	15.5	16.6	19.5	10.4	9.1	0.32	18.1	19.2	18.4	19.6
25	11/13/2007		15.8	15.7	16.2	16.2	17.7	13.3	4.4	0.32	17.2	17.1	17.6	17.6
26	11/14/2007		14.7	14.9	14.8	15.1	17.6	13.8	3.8	0.32	15.9	16.1	16.0	16.3
27	11/15/2007		22.4	25.8	22.4	25.9	24.8	19.6	5.2	0.32	24.1	27.4	24.1	27.5
28	11/16/2007		35.0	38.3	35.1	38.6	39.4	27.8	11.6	0.32	38.7	42.0	38.8	42.3
29	11/17/2007		55.7	60.5	55.9	61.0	60.9	46.3	14.5	0.32	60.3	65.1	60.6	65.7
30	11/18/2007		17.4	21.5	17.8	22.1	18.5	16.8	1.7	0.32	18.0	22.0	18.4	22.6

Annex **Correction of the Cut-Size-Difference for Reference PM10** **Page 2 of 6**

Manufacturer	FAI Instruments s.r.l.		
		Measured object	SPM PM 10
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ (ambient and standard (i.N.))
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		$PM^{*}_{10RMi} = PM_{10RMi} - \overline{\alpha}(PM_{10CMi} - PM_{2.5CMi})$

No.	Date	Test site	Ref. 1 PM10 [µg/m³]	Ref. 2 PM10 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref. 2 PM10 [µg/Nm³]	FAI PM10 [µg/m³]	FAI PM2,5 [µg/m³]	FAI PM10-PM2,5 [µg/m³]	$-\overline{\alpha}$	Ref. 1* PM10 [µg/m³]	Ref. 2* PM10 [µg/m³]	Ref. 1* PM10 [µg/Nm³]	Ref. 2* PM10 [µg/Nm³]
31	11/19/2007	Koeln,	24.5	28.3	25.1	29.0	26.2	22.3	3.9	0.32	25.8	29.5	26.3	30.2
32	11/20/2007	parking lot	22.5	27.5	23.4	28.6	25.8	21.9	3.9	0.32	23.8	28.8	24.6	29.9
33	11/21/2007		24.0	28.0	25.1	29.2	28.0	22.0	6.0	0.32	26.0	29.9	27.0	31.1
34	11/22/2007		26.2	29.5	27.4	30.9	29.9	23.3	6.6	0.32	28.3	31.7	29.5	33.0
35	11/23/2007		24.1	28.4	24.6	29.0	27.9	15.8	12.1	0.32	27.9	32.2	28.4	32.8
36	11/24/2007		23.8	28.2	24.2	28.7	28.1	16.1	12.0	0.32	27.6	32.0	28.0	32.5
37	11/25/2007		13.8	14.4	14.2	14.7	12.2	5.8	6.4	0.32	15.9	16.5	16.2	16.8
38	11/26/2007		15.3	15.4	15.5	15.6	17.6	8.2	9.4	0.32	18.3	18.4	18.5	18.6
39	11/27/2007		26.5	27.1	26.7	27.3	30.7	16.9	13.9	0.32	30.9	31.5	31.1	31.8
40	11/28/2007		26.4	26.2	26.7	26.6	27.8	19.2	8.6	0.32	29.1	28.9	29.5	29.3
41	11/29/2007		19.2	19.7	19.8	20.4	22.1	14.3	7.8	0.32	21.7	22.2	22.3	22.9
42	11/30/2007		14.0	13.8	14.6	14.3	15.3	8.3	7.0	0.32	16.3	16.0	16.9	16.6
43	12/01/2007		10.0	9.6	10.5	10.0	11.6	4.5	7.1	0.32	12.3	11.9	12.8	12.3
44	12/02/2007		6.0	5.7	6.4	6.1	7.2	2.7	4.5	0.32	7.5	7.1	7.9	7.5
45	12/03/2007		10.6	10.8	11.0	11.2	12.0	5.6	6.5	0.32	12.6	12.8	13.1	13.3
46	12/04/2007		13.2	13.9	13.6	14.4	16.9	8.3	8.6	0.32	16.0	16.7	16.4	17.2
47	12/05/2007		11.9	12.8	12.4	13.4	14.5	5.9	8.7	0.32	14.6	15.5	15.2	16.1
48	12/06/2007		5.8	7.6	6.2	8.0				0.32				
49	12/07/2007		13.3	13.4	13.9	14.0	16.4	7.1	9.3	0.32	16.2	16.3	16.9	17.0
50	12/08/2007		8.0	8.5	8.4	8.9	9.4	4.3	5.1	0.32	9.6	10.1	10.0	10.5
51	12/09/2007		5.6	5.9	5.9	6.3	7.1	3.8	3.3	0.32	6.6	7.0	7.0	7.3
52	12/10/2007		17.7	17.5	18.4	18.2	20.1	13.1	7.0	0.32	19.9	19.8	20.6	20.4
53	12/11/2007		13.2	13.3	13.4	13.5	20.1	11.8	8.3	0.32	15.8	15.9	16.0	16.2
54	12/12/2007		32.6	31.2	32.7	31.3	35.2	26.3	8.9	0.32	35.4	34.1	35.5	34.2
55	12/13/2007		18.9	17.8	18.8	17.8	20.3	15.1	5.3	0.32	20.6	19.5	20.5	19.5
56	12/14/2007		17.0	15.8	16.8	15.7	17.6	13.3	4.4	0.32	18.4	17.2	18.2	17.1
57	12/15/2007		17.2	16.2	16.9	15.9	17.7	14.7	3.0	0.32	18.1	17.1	17.9	16.9
58	12/16/2007		25.0	24.5	24.5	24.1	26.5	23.1	3.4	0.32	26.0	25.6	25.6	25.2
59	12/17/2007		31.1	31.0	30.6	30.4	35.5	25.8	9.7	0.32	34.2	34.1	33.7	33.5
60	12/18/2007		66.9	66.3	65.4	65.0	75.9	55.1	20.9	0.32	73.6	73.0	72.1	71.6

Annex **Correction of the Cut-Size-Difference for Reference PM10** **Page 3 of 6**

Manufacturer FAI Instruments s.r.l.

Meas. Range 0 to 200 µg/m³

Type SWAM5a Dual Channel Monitor

Serial-No. SN 127 & SN 131

Measured object SPM PM 10

Measured values in µg/m³ (ambient and standard (i.N.))

$$PM^*_{10RMi} = PM_{10RMi} - \overline{\alpha}\left(PM_{10CMi} - PM_{2.5CMi}\right)$$

No.	Date	Test site	Ref. 1 PM10 [µg/m³]	Ref. 2 PM10 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref. 2 PM10 [µg/Nm³]	FAI PM10 [µg/m³]	FAI PM2,5 [µg/m³]	FAI PM10-PM2,5 [µg/m³]	$-\overline{\alpha}$	Ref. 1* PM10 [µg/m³]	Ref. 2* PM10 [µg/m³]	Ref. 1* PM10 [µg/Nm³]	Ref. 2* PM10 [µg/Nm³]
61	12/19/2007	Koeln,	77.0	74.9	75.2	73.3	88.4	63.9	24.5	0.32	84.8	82.7	83.1	81.1
62	12/20/2007	parking lot	88.2	86.3	86.2	84.5	97.3	69.3	28.0	0.32	97.2	95.3	95.2	93.5
63	12/21/2007		53.5	54.2	53.1	53.8	59.0	52.6	6.5	0.32	55.6	56.3	55.2	55.9
64	12/22/2007		59.4	60.6	58.6	59.9	68.0	63.2	4.8	0.32	60.9	62.1	60.2	61.4
65	12/23/2007		58.6	59.2	58.2	58.8	59.3	46.6	12.7	0.32	62.7	63.3	62.2	62.9
66	12/24/2007		25.2	25.5	25.0	25.3	24.7	22.7	2.0	0.32	25.8	26.1	25.7	26.0
67	12/25/2007		30.3	30.6	30.2	30.6	32.5	29.2	3.3	0.32	31.3	31.7	31.3	31.7
68	12/26/2007		33.6	34.0	33.5	33.9	35.9	31.6	4.3	0.32	35.0	35.3	34.9	35.3
69	12/27/2007		12.3	12.7	12.4	12.7	12.6	10.8	1.9	0.32	12.9	13.3	13.0	13.3
70	12/28/2007		12.0	12.7	12.2	12.9	12.5	11.3	1.2	0.32	12.4	13.0	12.6	13.2
71	12/29/2007		8.9	10.0	9.2	10.3	10.2	6.9	3.3	0.32	10.0	11.1	10.2	11.3
72	12/30/2007		16.2	16.0	16.5	16.3	18.3	9.8	8.5	0.32	18.9	18.7	19.2	19.0
73	12/31/2007		46.0	45.6	46.4	46.0	46.7	36.3	10.4	0.32	49.4	48.9	49.7	49.3
74	01/01/2008		22.7	22.5	22.6	22.3	23.3	19.3	4.0	0.32	24.0	23.8	23.9	23.6
75	01/02/2008		19.4	19.3	19.5	19.4	20.1	17.1	3.0	0.32	20.3	20.3	20.4	20.4
76	01/03/2008		21.9	22.4	22.3	22.8	22.4	20.1	2.3	0.32	22.6	23.1	23.1	23.5
77	01/04/2008						26.4	22.9	3.5	0.32				
78	01/05/2008						11.3	6.5	4.8	0.32				
79	01/06/2008									0.32				
80	01/07/2008									0.32				
81	01/08/2008									0.32				
82	01/09/2008		12.4	13.4	12.7	13.8	14.7	7.7	7.0	0.32	14.7	15.7	15.0	16.0
83	01/10/2008		11.3	12.1	11.8	12.7	13.1	8.9	4.2	0.32	12.7	13.5	13.1	14.0
84	01/11/2008		7.5	8.3	8.0	8.9	8.5	6.0	2.6	0.32	8.4	9.2	8.8	9.7
85	01/12/2008		14.1	12.7	14.4	13.0	13.8	9.1	4.7	0.32	15.6	14.2	15.9	14.5
86	01/13/2008		16.2	16.6	16.6	17.0	16.8	12.9	3.9	0.32	17.5	17.8	17.8	18.2
87	01/14/2008		13.2	13.6	13.7	14.2	14.2	10.0	4.1	0.32	14.5	14.9	15.0	15.5
88	01/15/2008		7.0	5.8	7.4	6.2	6.6	4.7	1.9	0.32	7.6	6.4	8.0	6.8
89	01/16/2008		10.0	10.1	10.4	10.5	12.2	7.4	4.8	0.32	11.5	11.6	12.0	12.1
90	01/17/2008		12.3	11.7	12.9	12.2	12.9	6.0	6.9	0.32	14.5	13.9	15.1	14.4

Annex **Correction of the Cut-Size-Difference for Reference PM10** **Page 4 of 6**

Manufacturer FAI Instruments s.r.l.

Meas. Range 0 to 200 µg/m³
Type SWAM5a Dual Channel Monitor
Serial-No. SN 127 & SN 131

Measured object SPM PM 10
Measured values in µg/m³ (ambient and standard (i.N.))

$$PM^{*}_{10RMi} = PM_{10RMi} - \overline{\alpha}\left(PM_{10CMi} - PM_{2.5CMi}\right)$$

No.	Date	Test site	Ref. 1 PM10 [µg/m³]	Ref. 2 PM10 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref. 2 PM10 [µg/Nm³]	FAI PM10 [µg/m³]	FAI PM2,5 [µg/m³]	FAI PM10-PM2,5 [µg/m³]	$-\overline{\alpha}$	Ref. 1* PM10 [µg/m³]	Ref. 2* PM10 [µg/m³]	Ref. 1* PM10 [µg/Nm³]	Ref. 2* PM10 [µg/Nm³]
91	01/18/2008	Koeln,	12.0	11.8	12.5	12.3	14.4	5.0	9.5	0.32	15.0	14.8	15.5	15.4
92	01/19/2008	parking lot	5.6	4.4	5.9	4.6	6.4	3.9	2.6	0.32	6.4	5.3	6.7	5.5
93	01/20/2008		5.7	5.3	6.0	5.6	5.5	3.5	2.0	0.32	6.4	6.0	6.6	6.2
94	01/21/2008		8.5	8.4	8.9	8.7	9.4	5.5	4.0	0.32	9.8	9.6	10.2	10.0
95	01/22/2008		20.3	19.4	20.5	19.6	22.7	9.5	13.3	0.32	24.6	23.7	24.7	23.8
96	01/23/2008		20.6	20.0	20.9	20.3	22.1	10.7	11.4	0.32	24.2	23.6	24.5	23.9
97	01/24/2008		26.7	26.0	27.0	26.4	29.1	11.8	17.3	0.32	32.2	31.6	32.5	31.9
98	01/25/2008		18.3	18.0	18.5	18.3	20.0	9.1	10.9	0.32	21.8	21.5	22.0	21.7
99	01/26/2008		26.3	25.5	26.8	26.0	28.5	17.0	11.5	0.32	30.0	29.1	30.4	29.6
100	01/27/2008		31.6	30.3	32.1	30.8	33.0	17.2	15.8	0.32	36.6	35.4	37.1	35.9
101	01/28/2008		39.2	38.1	39.8	38.8	42.7	25.8	16.9	0.32	44.6	43.5	45.3	44.2
102	01/29/2008		51.0	50.8	51.4	51.3	55.4	35.3	20.1	0.32	57.4	57.2	57.9	57.7
103	01/30/2008		24.7	25.7	24.8	25.9	27.2	17.4	9.8	0.32	27.8	28.8	28.0	29.0
104	01/31/2008		7.7	7.7	7.9	8.0	8.2	5.6	2.7	0.32	8.6	8.6	8.8	8.8
105	02/01/2008		10.8	10.2	11.2	10.5	12.0	5.2	6.8	0.32	12.9	12.3	13.4	12.7
106	02/02/2008		13.4	14.2	13.6	14.3	14.2	6.9	7.3	0.32	15.8	16.5	15.9	16.6
107	02/03/2008		11.5	12.2	11.8	12.6	12.1	9.0	3.1	0.32	12.5	13.2	12.8	13.6
108	02/04/2008		9.7	10.4	10.0	10.7	10.6	7.9	2.7	0.32	10.6	11.3	10.8	11.6
109	02/05/2008		5.2	5.3	5.4	5.5	5.8	3.1	2.7	0.32	6.0	6.1	6.2	6.3
110	02/14/2008	Bonn	38.2	38.2	38.1	38.2	40.5	31.2	9.2	0.38	41.7	41.8	41.6	41.7
111	02/15/2008		15.0	15.5	14.8	15.3	17.1	11.7	5.4	0.38	17.1	17.6	16.8	17.3
112	02/16/2008		18.3	19.2	18.0	18.9	18.8	14.9	3.9	0.38	19.8	20.6	19.5	20.3
113	02/17/2008		37.7	37.4	37.5	37.2	42.8	30.7	12.0	0.38	42.3	42.0	42.0	41.8
114	02/18/2008		63.0	62.4	63.1	62.6	75.5	51.5	24.0	0.38	72.1	71.5	72.2	71.7
115	02/19/2008		52.0	51.9	53.0	53.0	57.3	40.6	16.7	0.38	58.4	58.3	59.4	59.3
116	02/20/2008		41.6	42.6	42.4	43.5	44.3	36.9	7.5	0.38	44.4	45.4	45.3	46.3
117	02/21/2008		39.9	39.5	41.3	41.0	43.7	28.7	15.0	0.38	45.6	45.2	47.0	46.7
118	02/22/2008		24.8	25.1	25.7	26.1	27.5	15.6	11.9	0.38	29.3	29.7	30.2	30.6
119	02/23/2008		27.4	27.2	28.2	28.1	29.8	21.5	8.4	0.38	30.5	30.4	31.4	31.3
120	02/24/2008		30.1	29.2	31.2	30.4	31.1	24.2	6.9	0.38	32.7	31.8	33.9	33.0

Annex **Correction of the Cut-Size-Difference for Reference PM10** **Page 5 of 6**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM 10
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ (ambient and standard (i.N.))
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		$PM^{*}_{10RMi} = PM_{10RMi} - \overline{\alpha}\left(PM_{10CMi} - PM_{2.5CMi}\right)$

No.	Date	Test site	Ref. 1 PM10 [µg/m³]	Ref. 2 PM10 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref. 2 PM10 [µg/Nm³]	FAI PM10 [µg/m³]	FAI PM2,5 [µg/m³]	FAI PM10-PM2,5 [µg/m³]	$-\overline{\alpha}$	Ref. 1* PM10 [µg/m³]	Ref. 2* PM10 [µg/m³]	Ref. 1* PM10 [µg/Nm³]	Ref. 2* PM10 [µg/Nm³]
121	02/25/2008	Bonn	24.1	24.6	25.3	25.8	26.1	18.5	7.7	0.38	27.0	27.5	28.2	28.7
122	02/26/2008		23.9	23.4	25.0	24.5	25.8	11.5	14.3	0.38	29.4	28.9	30.4	30.0
123	02/27/2008		27.6	27.8	28.4	28.7	29.2	15.3	13.8	0.38	32.8	33.0	33.7	34.0
124	02/28/2008		28.4	30.0	29.5	31.2	30.7	19.3	11.4	0.38	32.7	34.3	33.8	35.5
125	02/29/2008		14.7	14.0	15.6	14.8	14.6	8.4	6.2	0.38	17.1	16.4	18.0	17.2
126	03/01/2008		15.6	14.8	16.5	15.6	15.2	7.0	8.2	0.38	18.8	17.9	19.6	18.7
127	03/02/2008		23.3	23.1	24.4	24.3	24.3	11.1	13.2	0.38	28.3	28.1	29.4	29.3
128	03/03/2008		20.1	19.6	20.7	20.2	22.4	12.5	10.0	0.38	23.9	23.4	24.4	24.0
129	03/04/2008		22.2	22.2	22.4	22.4	25.3	13.2	12.1	0.38	26.8	26.8	27.0	27.0
130	03/05/2008		26.1	25.4	26.3	25.6	28.7	16.2	12.4	0.38	30.8	30.1	31.0	30.3
131	03/06/2008		30.0	30.2	30.9	31.1	33.0	18.8	14.2	0.38	35.4	35.6	36.3	36.5
132	03/07/2008		25.5	24.5	26.5	25.5	28.2	15.4	12.8	0.38	30.4	29.4	31.4	30.4
133	03/08/2008		20.7	20.1	21.7	21.1	20.7	14.5	6.2	0.38	23.1	22.4	24.0	23.4
134	03/09/2008		11.5	9.9	12.2	10.5	11.9	6.4	5.5	0.38	13.6	12.0	14.2	12.6
135	03/10/2008		8.6	7.6	9.2	8.1	9.6	4.5	5.1	0.38	10.5	9.5	11.1	10.1
136	03/11/2008		13.6	13.4	14.5	14.3	15.2	6.9	8.3	0.38	16.8	16.5	17.7	17.5
137	03/12/2008		19.1	19.2	19.9	20.0				0.38				
138	03/13/2008		16.5	16.9	17.2	17.7	19.0	10.5	8.5	0.38	19.7	20.1	20.5	20.9
139	03/14/2008						30.0	19.7	10.3	0.38				
140	03/15/2008		10.7	11.1	11.4	11.8	10.9	7.8	3.1	0.38	11.9	12.3	12.6	13.0
141	03/16/2008		16.9	18.4	17.7	19.2	18.8	11.6	7.1	0.38	19.6	21.1	20.4	21.9
142	03/17/2008		22.0	23.3	22.6	23.9	25.5	11.2	14.3	0.38	27.4	28.7	28.1	29.3
143	03/18/2008		21.6	22.0	22.3	22.6	24.2	12.1	12.1	0.38	26.2	26.6	26.9	27.2
144	03/19/2008		18.7	20.0	19.1	20.4	20.8	10.9	9.9	0.38	22.5	23.7	22.9	24.2
145	03/20/2008		10.3	10.8	10.8	11.4	11.1	6.6	4.5	0.38	12.0	12.5	12.5	13.1
146	03/21/2008						10.8	7.6	3.1	0.38				
147	03/22/2008		24.7	26.0	25.6	26.8	26.5	21.6	5.0	0.38	26.6	27.9	27.4	28.7
148	03/23/2008		19.8	21.1	20.4	21.7	21.3	15.1	6.2	0.38	22.2	23.4	22.8	24.1
149	03/24/2008		12.0	12.5	12.4	12.9	11.9	7.8	4.2	0.38	13.6	14.1	14.0	14.5
150	03/25/2008		16.6	16.7	17.0	17.1	17.4	11.6	5.8	0.38	18.8	18.9	19.2	19.3

Annex **Correction of the Cut-Size-Difference for Reference PM10** **Page 6 of 6**

Manufacturer	FAI Instruments s.r.l.	Measured object	SPM PM 10
Meas. Range	0 to 200 µg/m³		Measured values in µg/m³ (ambient and standard (i.N.))
Type	SWAM5a Dual Channel Monitor		
Serial-No.	SN 127 & SN 131		$PM^{*}_{10RMi} = PM_{10RMi} - \overline{\alpha}\left(PM_{10CMi} - PM_{2.5CMi}\right)$

No.	Date	Test site	Ref. 1 PM10 [µg/m³]	Ref. 2 PM10 [µg/m³]	Ref. 1 PM10 [µg/Nm³]	Ref. 2 PM10 [µg/Nm³]	FAI PM10 [µg/m³]	FAI PM2,5 [µg/m³]	FAI PM10-PM2,5 [µg/m³]	$-\overline{\alpha}$	Ref. 1* PM10 [µg/m³]	Ref. 2* PM10 [µg/m³]	Ref. 1* PM10 [µg/Nm³]	Ref. 2* PM10 [µg/Nm³]
151	03/26/2008	Bonn	22.2	22.6	23.1	23.5				0.38				
152	03/27/2008									0.38				
153	03/28/2008		12.8	13.2	13.4	13.8	14.1	6.5	7.5	0.38	15.6	16.0	16.2	16.7
154	03/29/2008		14.3	14.6	15.1	15.4	15.4	7.8	7.7	0.38	17.2	17.6	18.0	18.4
155	03/30/2008		15.0	15.3	15.9	16.2	17.9	9.6	8.3	0.38	18.2	18.4	19.1	19.3
156	03/31/2008		16.7	16.5	17.4	17.2	19.4	11.4	8.1	0.38	19.7	19.6	20.4	20.3
157	04/01/2008		25.0	25.4	26.0	26.5	29.3	11.8	17.5	0.38	31.6	32.1	32.7	33.2
158	04/02/2008		26.6	27.7	27.4	28.6	31.6	14.8	16.8	0.38	33.0	34.1	33.8	35.0
159	04/03/2008		30.9	31.5	31.6	32.3	35.8	20.2	15.5	0.38	36.8	37.4	37.5	38.2
160	04/04/2008		36.9	36.8	38.4	38.3	41.5	28.2	13.3	0.38	41.9	41.8	43.4	43.3
161	04/05/2008		14.4	13.9	14.9	14.5	15.4	11.1	4.3	0.38	16.0	15.5	16.6	16.1
162	04/06/2008		17.3	17.5	18.0	18.3	19.2	12.5	6.7	0.38	19.8	20.1	20.5	20.8
163	04/07/2008		26.3	26.7	27.1	27.6	29.0	21.6	7.4	0.38	29.1	29.5	29.9	30.4
164	04/08/2008		37.3	36.7	39.0	38.4	38.8	30.2	8.5	0.38	40.5	39.9	42.3	41.7
165	04/09/2008		40.8	39.9	42.9	42.1	41.8	31.5	10.3	0.38	44.7	43.8	46.8	46.0
166	04/10/2008		30.5	30.2	32.3	32.0				0.38				
167	04/11/2008		45.5	45.3	48.0	47.8	43.3	32.0	11.2	0.38	49.7	49.5	52.3	52.1
168	04/12/2008		12.6	12.1	13.3	12.7	12.7	7.7	5.1	0.38	14.5	14.0	15.2	14.6
169	04/13/2008		11.7	11.9	12.3	12.4	12.4	9.9	2.5	0.38	12.7	12.8	13.2	13.4
170	04/14/2008		36.2	36.0	37.4	37.2	36.5	27.3	9.1	0.38	39.7	39.5	40.9	40.7
171	04/15/2008		27.2	25.8	27.8	26.4	26.5	20.0	6.5	0.38	29.7	28.3	30.2	28.9
172	04/16/2008		25.6	24.7	26.4	25.5	26.3	17.0	9.3	0.38	29.1	28.2	29.9	29.0
173	04/17/2008		23.9	23.9	25.1	25.1	23.0	17.7	5.4	0.38	25.9	25.9	27.1	27.2
174	04/18/2008		25.0	24.0	26.6	25.6	24.7	19.7	5.1	0.38	26.9	26.0	28.5	27.5
175	04/19/2008		21.4	19.6	22.6	20.7	19.3	16.4	2.9	0.38	22.5	20.7	23.7	21.8
176	04/20/2008		19.7	18.8	21.0	20.0	19.2	15.2	4.0	0.38	21.2	20.3	22.5	21.5
177	04/21/2008		29.1	28.0	31.2	30.0	30.3	22.6	7.7	0.38	32.0	30.9	34.1	32.9

Annex 3

Filter weighing methodology

A) German sites (Koeln, Bonn and Bruehl)

A.1 Carrying out the weighing

All weightings are done in an air-conditioned weighing room. Ambient conditions are 20°C ±1°C and 50% ±5% rel. humidity, which conforms to the requirements of Standard DIN EN 14907.

The filters used in the field test are weighed manually. The filters (including control filters) are placed on sieves for the purpose of conditioning to avoid overlap.
The specifications for pre- and post-weighing are specified beforehand and conform to the Standard.

Before sampling = pre-weighing	After sampling = post-weighing
Conditioning 48 h + 2 h	Conditioning 48 h + 2 h
Filter weighing	Filter weighing
Re-conditioning 24 h +2 h	Re-conditioning 24 h + 2 h
Filter weighing and immediate packaging	Filter weighing

The balance is always kept ready for use. An internal calibration process is started prior to each weighing series. The standard weight of 200 mg is weighed as reference and the boundary conditions are noted if nothing out of ordinary results from the calibration process. Deviations to prior measurements conform to the Standard and do not exceed 20 µg (see Figure 108).
All six control filters are weighed afterwards and a warning is displayed for control filters with deviations > 40 µg during evaluation. These control filters are not used for post-weighing. Instead, the first three acceptable control filters are used while the others remain in the protective jar in order to replace a defective or deviating filter, if necessary. Figure 109 shows an exemplary process over a period of more than 4 months.

All filters which deviate more than 40 µg between the first and second weighing are excluded during the pre-weighing process. Filters which deviate more than 60 µg are not considered for evaluation after post-weighing, as conforming to standards.

Weighed filters are packed in separate polystyrene jars for transport and storage. These jars remain closed until the filter is placed in the filter holder. Virgin filters can be stored in the weighing room for up to 28 days before sampling. Another pre-weighing is carried out if this period is exceeded.

Sampled filters can be stored for not more than 15 days at a temperature of 23 °C or less. The filters are stored at 7°C in a refrigerator.

A2 Filter evaluation

The filters are evaluated with the help of a corrective term in order to minimize relative mass changes caused by the weighing room conditions.

Equation:

$$Dust = MF_{post} - (M_{Tara} \times (MKon_{post} / MKon_{pre})) \qquad (F1)$$

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

$MKon_{post}$ = average mass of the 3 control filters after 48 h and 72 h post-weighing

M_{Tara} = average mass of the filter after 48 h and 72 h pre-weighing

MF_{post} = average mass of the loaded filter after 48 h and 72 h post-weighing

Dust = corrected dust mass of the filter

This shows that the method becomes independent from weighing room conditions due to the corrective calculation. Influence due to the water content of the filter mass between virgin and loaded filter can be controlled and do not change the dust content of sampled filters. Hence, Point EN 14907 9.3.2.5 is fulfilled.

The exemplary course of the standard weight between November 2008 and February 2009 shows that the allowed deviation of not more than 20 µg on the previous measurement is not exceeded.

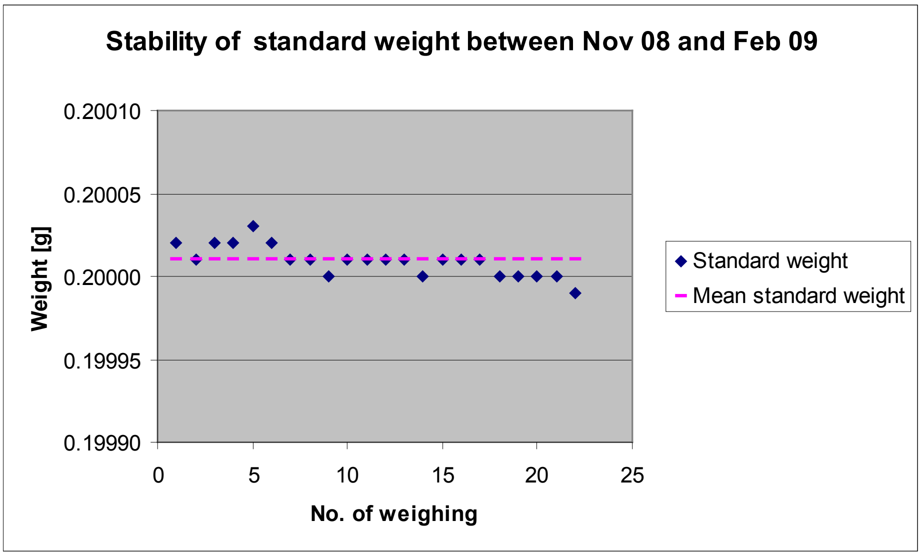


Figure 108: Stability of standard weight

Table 103: Stability standard weight

Date	Weighing No.	Standard weight	Deviation from prev. weighing
		g	µg
12.11.2008	1	0.20002	
13.11.2008	2	0.20001	-10
10.12.2008	3	0.20002	10
11.12.2008	4	0.20002	0
17.12.2008	5	0.20003	10
18.12.2008	6	0.20002	-10
07.01.2009	7	0.20001	-10
08.01.2009	8	0.20001	0
14.01.2009	9	0.20000	-10
15.01.2009	10	0.20001	10
21.01.2009	11	0.20001	0
22.01.2009	12	0.20001	0
29.01.2009	13	0.20001	0
30.01.2009	14	0.20000	-10
04.02.2008	15	0.20001	10
05.02.2009	16	0.20001	0
11.02.2009	17	0.20001	0
12.02.2009	18	0.20000	-10
18.02.2009	19	0.20000	0
19.02.2009	20	0.20000	0
26.02.2009	21	0.20000	0
27.02.2009	22	0.19999	-10

Highlighted yellow = average value

Highlighted green = lowest value

Highlighted blue = highest value

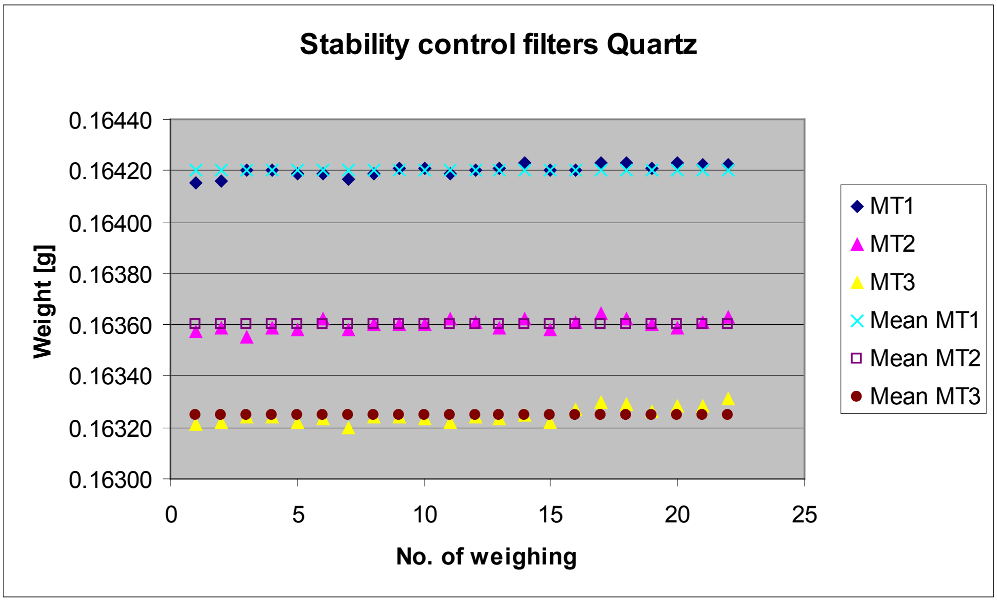


Figure 109: Stability of the control filters

Table 104: Stability of the control filters

Weighing No.	MT1 [g]	MT2 [g]	MT3 [g]
1	0.16415	0.16357	0.16321
2	0.16416	0.16359	0.16322
3	0.16420	0.16355	0.16324
4	0.16420	0.16359	0.16324
5	0.16419	0.16358	0.16322
6	0.16419	0.16362	0.16323
7	0.16417	0.16358	0.16320
8	0.16419	0.16360	0.16324
9	0.16421	0.16360	0.16324
10	0.16421	0.16360	0.16323
11	0.16419	0.16362	0.16322
12	0.16420	0.16361	0.16324
13	0.16421	0.16359	0.16323
14	0.16423	0.16362	0.16325
15	0.16420	0.16358	0.16322
16	0.16420	0.16361	0.16327
17	0.16423	0.16364	0.16330
18	0.16423	0.16362	0.16329
19	0.16421	0.16360	0.16326
20	0.16423	0.16359	0.16328
21	0.16422	0.16361	0.16328
22	0.16422	0.16363	0.16331
Average	0.16420	0.16360	0.16325
Standard deviation	2.19602E-05	2.1157E-05	3.0165E-05
Rel. standard deviation	0.013	0.013	0.018
Median	0.16420	0.16360	0.16324
Lowest value	0.16415	0.16355	0.16320
Highest value	0.16423	0.16364	0.16331

Highlighted yellow = average value

Highlighted green = lowest value

Highlighted blue = highest value

B) UK site (Teddington)

B.1 Implementation of Weighing Protocols

NPL were subcontracted to weigh filters manually for the field study. In line with EN14907 filters were kept in the weighing room for less than 28 days; the glove box used for weighing was maintained at (20 ± 1) °C and (50 ± 5) %; and filters were weighed twice before and after sampling. Table 105 summarises the conditioning and weighing timescales utilised:

Table 105: conditioning and weighing timescales

Pre Sampling	Post Sampling
Condition minimum of 48 hours Weigh Filters Condition 24 hours Weigh Filters	Condition 48 hours Weigh Filters Condition 24 hours Weigh Filters

At the start of each weighing session the balance was exercised to remove mechanical stiffness, and then calibrated. At the start and end of each batch of filters, a 50 and 200 mg check weight were weighed. In line with the recommendations of the UK PM Equivalence Report, filters were weighed relative to a 100 mg check weight, and not a tare filter, as the latter was shown to lose mass over time. Four filters were weighed between check weights, as the balance drift over time had been shown to be small.

The **Check weight Mass (CM)** of the filter was calculated for each weighing session using **E A.1** below:

$$CM = \frac{(m_{check,Beg} + m_{check,End})}{2} \quad \textbf{E A.1}$$

Where:

$M_{check,bef}$ = Mass of check weight weighed immediately prior to sample filter.

$M_{check,aft}$ = Mass of check weight weighed immediately after sample filter.

The **Relative Mass (RM)** of the filter was calculated for each weighing session using **E A.2** below:

$$RM = m_{filter} - CM \quad \textbf{E A.2}$$

Where:

m_{filter} = Mass of sample filter

Particulate Mass (PM) is calculated using the following equation in accordance with EN14907.

$$PM = \left(\frac{RM_{End1} + RM_{End2}}{2}\right) - \left(\frac{RM_{Beg1} + RM_{Beg2}}{2}\right) \quad \textbf{E A.3}$$

Where:

Pre1 denotes weighing session 1 prior to sampling

Pre2 denotes weighing session 2 prior to sampling

Post1 denotes weighing session 1 after sampling

Post2 denotes weighing session 2 after sampling

Pre Spread (S_{Pre}), Post Spread (S_{Post}) and Blank Spread (S_{Blank}) were calculated using the following equations:

$$S_{Pre} = RM_{Anf1} - RM_{Anf2}$$ **E A.4**

$$S_{Post} = RM_{End1} - RM_{End2}$$ **E A.5**

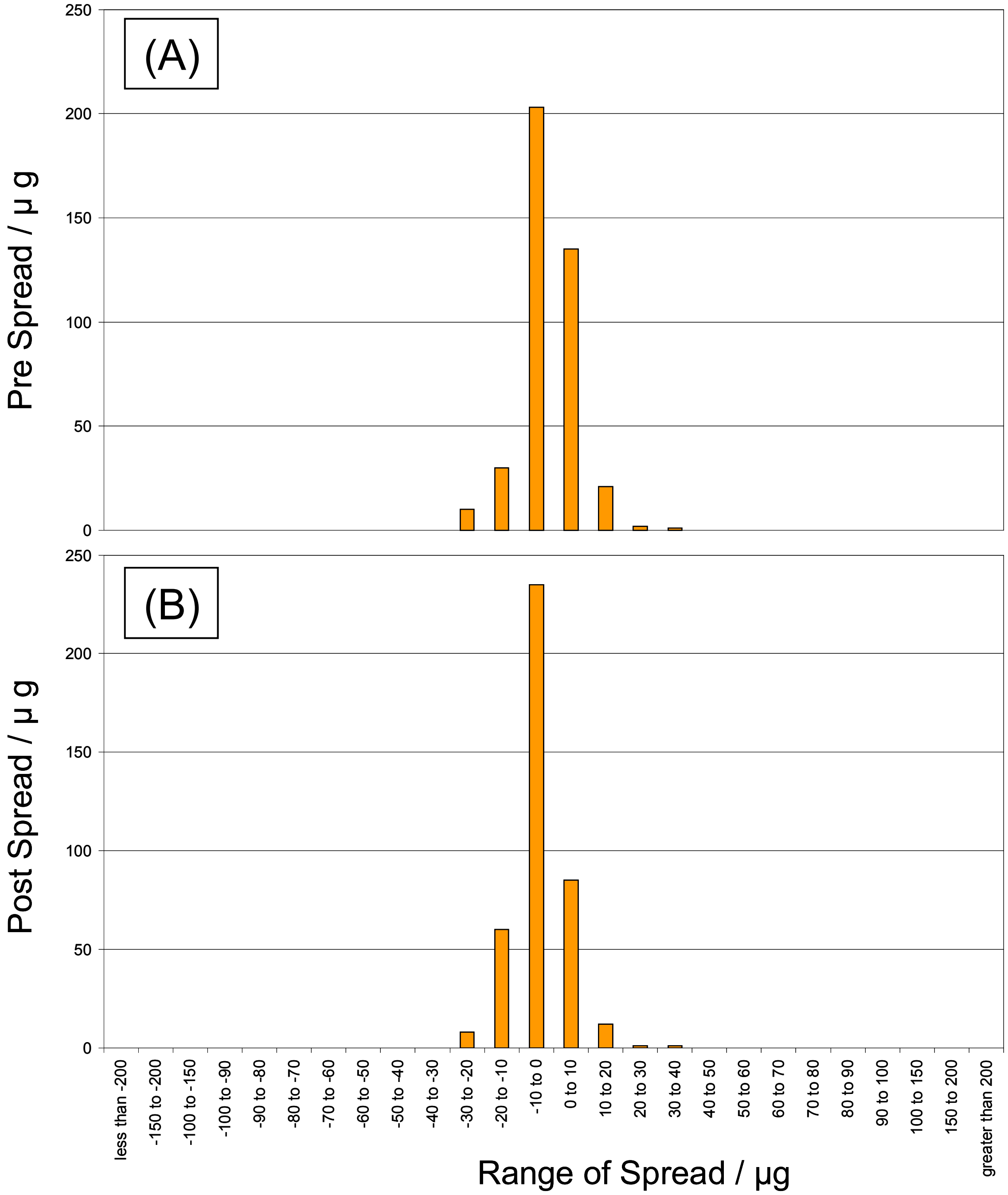
$$S_{Blank} = \left(\frac{CM_{End2} + CM_{End1}}{2} \right) - \left(\frac{CM_{Anf2} + CM_{Anf1}}{2} \right)$$ **E A.6**

As with the UK PM Equivalence Report [11], it was not possible to weigh all filters within the 15 day timeframe suggested in EN14907. However, as filters were removed immediately from the reference samplers and placed in the refrigerator, it was not necessary to determine if $T_{Ambient}$ exceeded 23 ºC. It is felt that as 15 days was impractical for a relatively small scale field study, it is less likely to be attainable if this methodology were adopted by a National or Regional network, and as such, the methodology employed herein is representative of how the reference samplers would be operated in practice.

B.2 Analysis of Protocols Employed

The distributions of pre and post weight for all Emfab filters weighed relative to the tare filter and checkweight are shown in Figure 110. If filters lose relative mass between weightings, then the distribution will be shifted to the right, whereas if there is a gain in the relative mass the distribution will shift to the left. EN14907 states that unsampled filters should be rejected if the difference between the masses of the two pre weightings is greater than 40 µg. Similarly, EN14907 states that sampled filters should be rejected if the difference between the masses of the two post weightings is greater than 60 µg. Filters were not rejected based on these criteria. The observed distributions of repeat mass measurements are considered unlikely to have had a significant effect on the results.

Figure 110: Distribution for Emfab filters of (**A**) Pre spread weighed relative to the checkweight and (**B**) Post spread weighed relative to the checkweight.



Annex 4

Manual

incl.

Manual SWAM5a (Rev22)

+

Manual „Test- and calibration procedures“ (Rev01)

DUAL CHANNEL MONITOR - SAMPLER OF ATMOSPHERIC PMx PARTICLES

swam 5a
DUAL CHANNEL MONITOR

USER MANUAL

May 2016 Edition – rev.24

TABLE OF CONTENTS

CHAPTER 1

1. GENERAL INFORMATION AND SAFETY WARNINGS

1.2 GENERAL INFORMATION

The instructions of this manual meet safety, installation, starting and maintenance requirements of the SWAM 5a Dual Channel Monitor instrument.

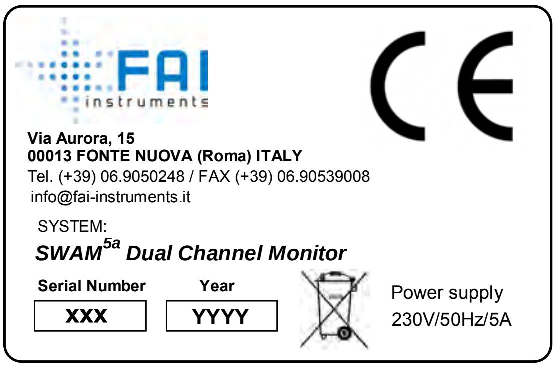
FAI Instruments s.r.l. reserves the right to modify the instrument described in this manual. Any update will be enclosed below or may be asked for straight the manufacturer.

This manual must be considered as integral part of the instrument. It must be always available for the interested personnel.

The operators in charge of the instrument installation, running and maintenance must read carefully this manual, in particular Chapter 1 about Safety.

1.2 EQUIPMENT AND MANUFACTURER IDENTIFICATION

The identification label is placed at the back of the instrument sampling unit:



Device category:	Instrument for the particulate matter monitoring	
Device identification:	***SWAM 5a Dual Channel Monitor***	
Liable manufacturer:	**FAI Instruments s.r.l.**	Via Aurora, 15 - 00013 FONTE NUOVA (Roma) Tel. (+39) 06.9050248 (+39) 06. 90532398 Fax (+39) 06. 90539008 info@fai-instruments.it

1.3 GUARANTEE

Fai Instruments s.r.l. products are guaranteed, if they are properly used, from engineering, manufacturing and material defects that make them unusable.

If no different written agreement is stipulated between Fai Instrument s.r.l. and the Buyer, the guarantee is valid for 1 (one) year as from the delivery date.

In case of failure during the guarantee period, FAI Instruments s.r.l. will pay guarantee, at his discretion, repairing or replacing at one's expense the defective parts. The guarantee doesn't cover for failures caused by accident, negligence, use of not original spare parts, improper use, installation or maintenance, repair attempts carried out by non authorized personnel, normal wear of parts or components, or by any other cause not imputable to Fai Instruments.

1.4 INSTRUCTIONS FOR TECHNICAL ASSISTANCE REQUEST

The Customer can always contact the manufacturer for any kind of information about use, maintenance, installation, etc.
The Customer is requested to put the questions clearly, referring to this manual and always pointing out the instrument model and serial number mentioned in the identification label.
The Technicians Qualified to carry out the assistance and the maintenance repairs are available at the telephone and fax number and at the email address of the manufacturer or of the authorized service center of the area.

1.5 INSTRUCTIONS FOR THE SPARE PARTS ORDER

The instrument may eventually need to have wearied or accidentally damaged parts replaced.

For this purpose the customer can order the spare parts for the components to be replaced, consulting the "Optional accessories and spare parts list" in Appendix 9.

Remember that only a Qualified Technician can carry out repairs. The Operator is authorized just to use the instrument and to carry out the routine preventive maintenance operations described in this manual.

1.6 SWAM 5a DUAL CHANNEL MONITOR CE CONFORMITY DECLARATION

CE CONFORMITY DECLARATION

The manufacturer:

FAI Instruments s.r.l.

Via Aurora, 15 - 00013 FONTE NUOVA (Roma)
Tel. (+39) 06.9050248 06.90532398
Fax (+39) 06.90539008

hereby declares that the instrument:

SAMPLER - MONITOR OF ATMOSPHERIC PMx PARTICLES
SWAM 5a Dual Channel Monitor

is in accordance with the following European directives, last amendments included

- directive 2014/35/UE about low-voltage electric material
- directive 2006/42/EC about safety of machinery
- directive 2014/30/UE about Electromagnetic Compatibility
- directive 2011/65/UE about RoHS

and that the following technical regulations have been applied:

Safety:

EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use

Electromagnetic Compatibility:

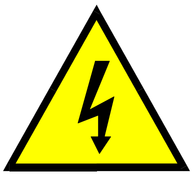
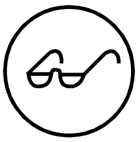
EN 61326-1	Emission and Immunity
EN 61000-3-2	Harmonics
EN 61000-3-3	Flicker

Person authorized to compile the technical file:
Alessandro Trapani
FAI Instruments s.r.l.
Via Aurora, 15 - 00013 FONTE NUOVA (Roma)

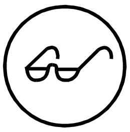
The managing director
Antonio Cesare Imperatore

1.7 SYMBOLS

In this manual the following symbols are used to draw reader's attention to danger signals.

	**Danger**	It marks a DANGER with even fatal accident risk for the user
	**High voltage**	It marks HIGH VOLTAGE elements. Touching them may be fatal. The inobservance of this warning may expose to electrocution risks.
	**Ionizing radiations**	It marks the presence of IONIZING RADIATIONS, which may cause health harms. The inobservance of this warning may expose to neoplasia risks.
	**Read carefully**	Read carefully the text marked by this symbol. The information marked by this symbol are very important for the perfect running of the instrument and for the operator's safety.
	**Warning**	This symbol is a warning: not observing it may cause instrument damages or it's incorrect running.

1.8 SAFETY WARNINGS



- ***SWAM 5a Dual Channel Monitor* is a sampling and mass measurement system of suspended particulate matter on filter membranes. The mass measurement is carried out using an internal low activity ß radiation source.**
- **This source does not represent a danger for the personnel.**
- **Anyway, appropriate safety signs, relevant to the presence of equipment containing ionizing radiation sources, must be stuck on, both inside and outside the installation room.**
- **Only authorized personnel can be admitted to the room where the system is running.**
- **Only trained personnel can use the instrument.**
- **Only trained and authorized technical personnel can carry out interventions inside the instrument.**

1.8.1 Specific information about ionizing radiations risk

SWAM 5a Dual Channel Monitor system contains a ^{14}C beta source, with 3.7 MBq (100 μCi) nominal activity.

The source is contained in an inaccessible mechanical block, integral with the instrument. Therefore outside the instrument just radiation dose-rates relative to natural background can be detected. Consequently, in normal operating conditions, there is no contamination risk.

So, according to the Italian current laws, the operators assigned to the instrument use are not classified as “exposed” and they don’t need medical controls.

Just in case of serious accidents such as fire, the risk of radioactive material dispersion in the environment is possible. An analytic evaluation, carried out in compliance with current regulations, for different and even pessimistic and improbable scenarios, leads to estimate dose values not remarkable for individuals or for the population.

Installing and removing the source from the instrument needs a specific procedure, requiring the removal of a mechanical block using an appropriately engineered tool. This operation must be always carried out by trained and authorized personnel with a fitting protection mean (IPM), such as rubber gloves of a fitting thickness and white coat.

The behavior rules and the procedure for the source handling are supplied together with the source itself.

1.9 SAFETY REGULATIONS

SWAM 5a Dual Channel Monitor system has been engineered in such a way to satisfy the requirements listed in the following European Directives and their subsequent modifications:

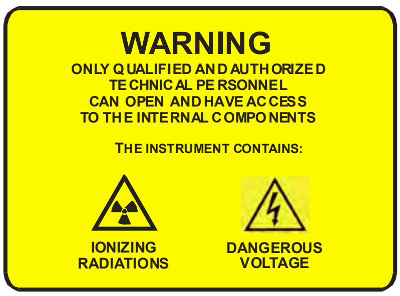
directive 2014/35/UE	low-voltage electric material
directive 2006/42/EC	safety of machinery
directive 2014/30/UE	Electromagnetic Compatibility
directive 2011/65/UE	RoHS

The equipment is in compliance with the following harmonized technical regulations:

EN 61010-1	Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use
EN 61326-1	Electromagnetic Compatibility (EMC) – Emission and Immunity
EN 61000-3-2	Harmonics
EN 61000-3-3	Flicker

1.10 SAFETY LABELS

At the back of the ***SWAM 5a Dual Channel Monitor*** system there are the following labels of danger warning:



Do not remove the warning labels. They must be kept in good conditions and if they are damaged or not readable they must be immediately replaced.

1.11 INTENDED USE OF THE INSTRUMENT

The instrument has been engineered for the following use:

- to sample in a sequential and automatic way the suspended particulate matter on filter membranes
- to carry out the mass measurement of the gathered particulate matter, using the β attenuation method

The instrument must be used in the following conditions:

- temperature and relative humidity values in compliance with the specified technical data
- not potentially explosive or at fire risk atmosphere.

The instrument must be used only for the operations and in the environmental conditions explicitly described in this manual: any other use is improper and prohibited.

1.12 PRESCRIBED USE

The instrument must be used as intended, only in perfect operating technical conditions and by qualified personnel in compliance with the current safety and accident prevention regulations.

This “User manual” is meant for the **Qualified User,** who must:

- verify the operating room and the relative arrangements suitability for the instrument installation/use
- know in detail all needed operations for the correct use and routine maintenance, all general safety rules and the warnings of this manual
- do not carry out instrument repairs

This "User manual" is also meant for the **Qualified Technician**, who will be able, following the detailed instructions received during an apposite training course, to perform:

- instrument maintenance repairs
- β source handling (installation, removal, storage, etc.)

If needed, for maintenance repairs call the **FAI Instruments s.r.l. Technical Assistance Service**, or one of its AUTHORIZED technical assistance service center, which can intervene with Specialized Technicians and with fitting tools and original spare parts.

1.13 STATE OF SUPPLY

If no different specification is present in the contract/order, the instrument is supplied in a standard commercial packaging and with the following configuration:

Posit.	DESCRIPTION	QUANTITY
1	User Manual	1
2	Monitor unit	1
3	Vacuum pump unit	2
5	Virgin filters Loader capacity: 35 filter cartridges - standard	1
6	Sampled filters Unloader capacity: 35 filter cartridges - standard	1
7	Filter cartridges *(β equivalent spot area 7.07 cm^2 - standard)*	40
8	Temperature probe	2
9	Power cord	1
10	Monitor-pump connection tie cable	2
11	Monitor-pump connection flexible pipe	2
12	Air compressor	1
13	Air compressor pipe	1
14	Kit no. 3 aluminum filter cartridges for spy filters, used by the instrument during the mass measurement procedure	1
15	“Ref 1” filter for beta test	1
16	“Ref 2” filter for beta test	1
17	Virgin filters insertion support	1

***NOTE*:**
The system is not supplied with the radioactive source installed. The source is usually supplied separately in compliance with specific contractual agreements and following the relative safety procedures for its handling, transportation and storage.

WARNING:
Holding the source imply particular law obligations to be accomplished in advance by the user.

The source installation and removal can be carried out only by qualified and expressly authorized personnel.

1.14 NOTES ON INSTALLATION AND TRANSPORT

1.14.1 Removal of the mass measurement system safety lock

Before switching on the instrument, it's necessary to remove the lock protecting the mass measurement system mechanics. Actually, in order to avoid possible damages during the transport and installation steps, the power supply connector of the measurement system is connected to the lock board (see figure B).

To remove the lock system, open the frontal panel of the instrument unscrewing the two screws placed on the panel sides (fig. A) and unplug the connector from the lock board (fig. B and C). Then plug the female connector on the male connector of the MOTEV board, marked by the string "Geiger" (fig. D). Close back the frontal panel of the instrument and re-screw the two side screws.

Fig. A

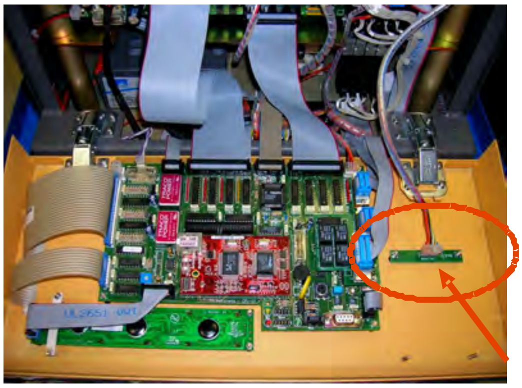


Fig. B

Fig. C

Fig. D

CHAPTER 2

2. INSTRUMENT DESCRIPTION

SWAM 5a Dual Channel Monitor is an automatic and sequential sampler of particulate matter on filter membranes. The system operates with two independent sampling lines. It has been engineered and manufactured as fundamental support to the studies aimed at the characterization of the air quality status connected with the particulate matter (PMx) pollution.
The mass measurement of the two drawn samples is performed contextually thanks to an innovative technique based on the β attenuation method. This technique allows to achieve a mass measurement data uncertainty of about 10 µg.
Therefore, SWAM 5a Dual Channel Monitor allows to monitor simultaneously and with a high quality standard the mass concentration temporal evolution of two airborne PMx fractions (for example PM_{10} and $PM_{2.5}$).
Moreover, the samples accumulation on filter membranes allow their chemical characterization.
The engineering and manufacturing characteristics of the instrument allow to perform metrological evaluations of particulate matter sampling and mass measurement systems (evaluation of the volatile compounds losses during the enrichment phase, evaluation of the equivalence of two different sampling inlets, evaluation of the biases associated with granulometric cut size variations of the fractionation device, evaluation of the mass measurement reproducibility, etc).

2.1 TECHNICAL SPECIFICATIONS

Operative interval of the mass thickness measurement	Total mass thickness (filtering medium + particulate matter film) up to 10 mg/cm²
Mass thickness measurement reproducibility	± 2 µg/cm²
Mass measurement reproducibility	± 10 µg; ± 15 µg; ± 23 µg respectively with sampling ß spot area 5.20; 7.07; 11.95 cm²
β source	^{14}C with 3.7MBeq (100µCi) nominal activity
Operating flow rate	Programmable in the range 0.8 – 2.5 m³/h
Flow rate measurement reproducibility	1% of the measured value
Flow rate measurement relative uncertainty	2% of the measured value
Flow rate control	Automatic, with regulation valve moved by a step motor. Stability in flow rate control better than the 1% of the required nominal value
Max allowed pressure drop	40 kPa For pressure drop values higher than 40 kPa the achievement of a 2.3 m³/h nominal flow rate is not guaranteed
Filters Loader/Unloader capacity	No. 35 filter cartridges (or 72 on demand)
Filter cartridges	Standard supply: for ∅ 47 mm filter membranes
I/O devices	RS232 interface for PC connection (equipped with 2 male DB9 connectors to be used in mutual exclusion). RS232 interface for Modem GSM/PSTN connection (equipped with 1 female DB9 connector).
Service compressed air	Operating pressure 200÷300 kPa (supplied by an auxiliary air compressor supplied with the instrument)
Power supply	230 V (± 10%) 50 Hz single-phase
Absorbed electric power	1200 W (max)
Power supply continuity in direct current	2 12 V 3.5 Ah floating batteries - Autonomy to complete mass measurements and filters movements
Air compressor unit	12 l/min at 300 kPa
Operating conditions inside the installation cabinet	Relative Humidity lower than 85% (with no condensate)
Storage conditions	Temperature within - 10 and + 55 °C Relative Humidity lower than 85% (with no condensate)
Dimensions(W x D x H) Sampling unit Vacuum pump unit Air compressor unit	 430 x 540 x 370 mm 200 x 320 x 200 mm 180 x 320 x 200 mm
Weights Sampling unit Vacuum pump unit Air compressor unit	 36 kg 10 kg 18 kg
Sampling inlets manufactured by FAI Instruments (on demand)	Sampling inlet for PM10 cut size (LVS-PM10 in compliance with the EN 1234-1 standard, nominal flow rate 2.3 m³/h) Sampling inlet for PM10 cut size LVS-PM10 with nominal flow rate 1 m³/h (equivalent to the LVS-PM10 model EN 1234-1) Sampling inlet for PM2.5 cut size (LVS-PM2.5 nominal flow rate 2.3 m³/h) Sampling inlet for PM2.5 cut size (LVS-PM2.5 model, nominal flow rate 1 m³/h) Sampling inlet for PM1 cut size (LVS-PM1 model, nominal flow rate 2.3 m³/h)

Outdoor cabinet (on demand)	**Modular outdoor cabinet** 3 functional modules: – Module 1 for the instrument housing – Module 2 for the air conditioning system housing – Module 3 for the pumps and the service air compressor housing (A 4th optional Module to house Water Chiller for the sampled filters cooling, can be installed) **Materials**: Structure : Laminar wood 3 layers, Internal insulating material : PE foam auto extinguishing fire Class 1 Sun protection: sections of epoxidic plates **Color**: Body: light grey RAL 7035, Sun protection: white **Dimensions and Weights:** Instrument module: 700 x 700 x 1000 mm 40 kg Air conditioner module: 700 x 700 x 350 mm 20 kg Pumps and service air compressor module: 700x700x350 mm 20 kg Stainless steel basement with adjustable feet: 700x700x250/300 mm 10 kg Roof: 900 x 1050 x 4 mm 5 kg TOTAL: 700 x 700 x 1950/2000 mm 95 kg

2.2 UNITS OF THE INSTRUMENTS

2.2.1 Sampling unit

This unit contains all the servomechanisms and the sampling and mass measurement devices. In the frontal part there is the control panel, at the instrument back there are the pneumatic and electric connections and the communication interfaces. On the instrument upper surface there are the filters Loader and Unloader housings and the sampling line connections.

Figures 2.1 and 2.2 show the frontal and the back view of the unit

figure 2.1

figure 2.2

2.2.2 Sampling inlets

The instrument samples the airborne particulate matter using sampling inlets with granulometric fractionation device.

The instrument can work simultaneously with two different sampling inlets (PTS, PM_{10}, $PM_{2.5}$, PM_1, etc.), as long as they have nominal flow rate values within the range 0.8 ÷ 2.5 m^3/h. The choice of the operating flow rate value depends on the characteristics of the used sampling inlet and on the desired granulometric cut size.

The list below shows some of the weatherproof sampling inlet models manufactured by FAI Instruments, that can be supplied together with the instrument:

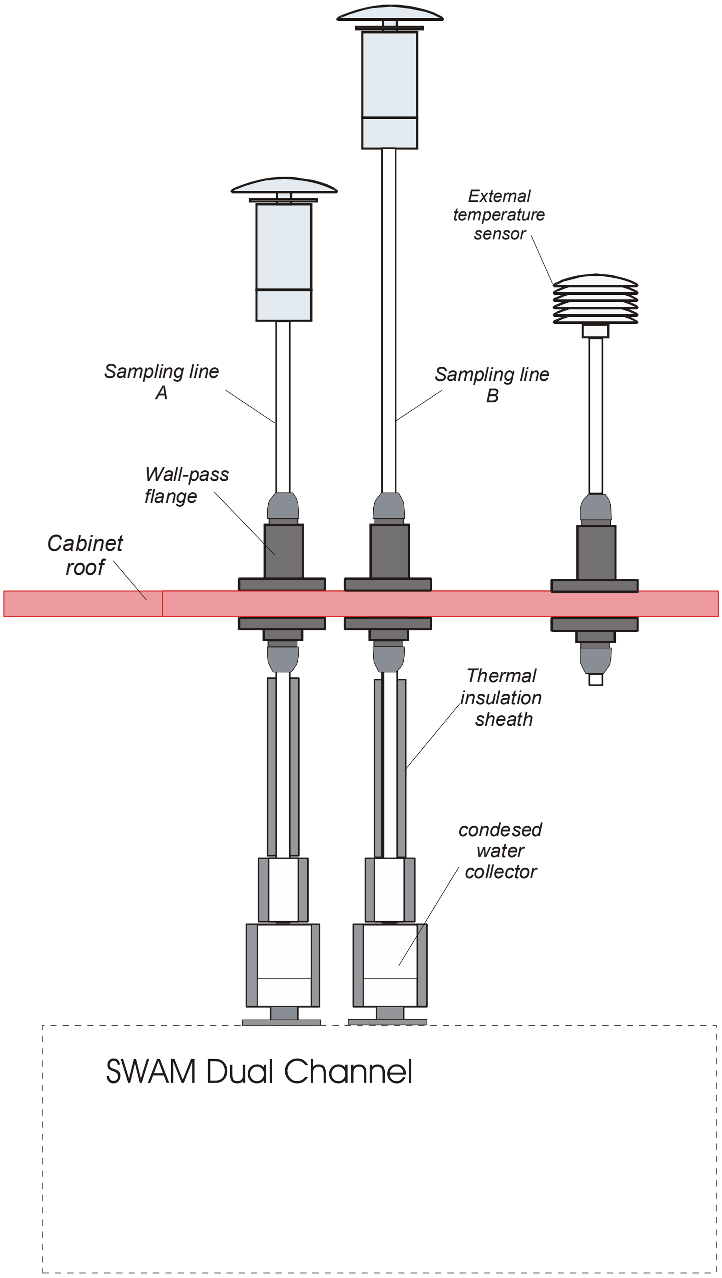
- PM_{10} cut size sampling inlet (***LVS-PM10 model* as required by the reference European standard EN1234.1** - Annex B1 - Design criteria for PM_{10} reference sampler - and by the Italian DM no. 60 of 02/02/2002, nominal flow rate 2.3 m^3/h)
- PM_{10} cut size sampling inlet LVS-PM10 model 1 m^3/h nominal flow rate (equivalent to the LVS-PM10 model EN 1234-1)
- $PM_{2.5}$ cut size sampling inlet (LVS-PM2.5 2.3 m^3/h nominal flow rate) in compliance with the EN 14907 standard
- $PM_{2.5}$ cut size sampling inlet (LVS-PM2.5 1 m^3/h nominal flow rate)
- PM_1 cut size sampling inlet (LVS-PM1 2.3 m^3/h nominal flow rate)

2.2.3 Sampling lines

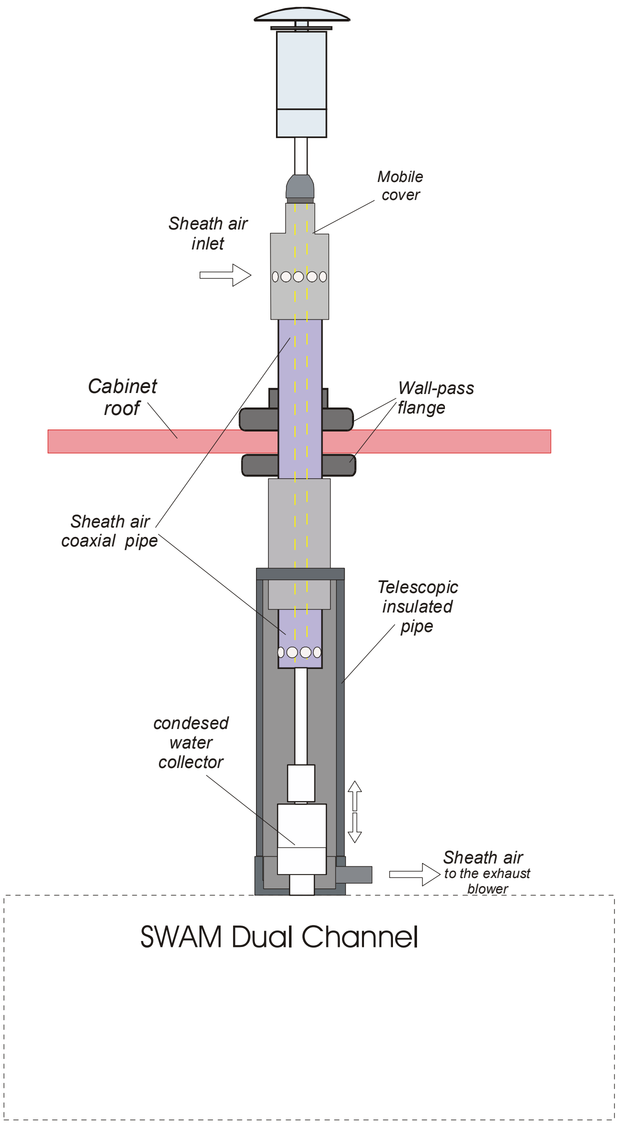
The accumulation on the filter membranes takes place with the transfer of the sample from the sampling inlet to the filter at a temperature value near the ambient one.

The instrument measures and stores the values of the main variables needed to describe the sampling phase, giving all needed information for the characterization of the sample transfer and of the sample accumulation on the filtering medium.

The instrument in basic configuration is equipped with the two sampling lines insulated inside the installation cabinet and both provided with a condensed water collector.



As an option, the instrument may be equipped with two sheath air coaxial pipes passed through by ambient air sucked by an exhaust blower, so as to guarantee a thermostatic effect on the sampling lines capable to maintain the air temperature on the filter membrane close to the value of the external temperature.



***NOTE**: For particular metrological needs and for studies on the particulate matter evaporation processes, the sampling lines can be equipped with accessory cooling or heating systems at controlled temperature.*

2.2.4 Vacuum pump units

The two vacuum pump units, placed below the sampling unit, suck up ambient air through the sampling inlets, the sampling lines and the two filter membranes.

These units are made up of a piston pump equipped with a ballast to equalize the on-line pressure fluctuations, with a silencer filter placed on the outlet and of an inlet filter.

The automatic regulation of the flow rate is carried out independently on the two sampling lines.

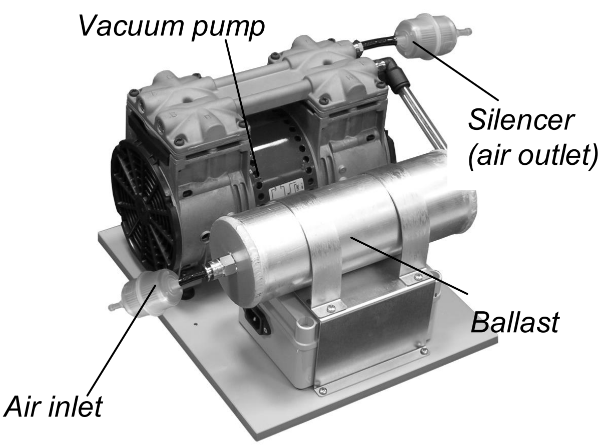


figure 2.3

NOTE: *The sampler can be also used with other types of vacuum pumps (for example with graphite vane pumps)*

2.2.5 Service air compressor unit

The instrument is equipped with a service air compressor able to supply compressed air (200÷300 kPa) used for the servomechanisms movements.

Note:
If the installation room is already equipped with a system able to supply compressed air (filtered and deumified), the air compressor is obviously not necessary.

figure 2.4

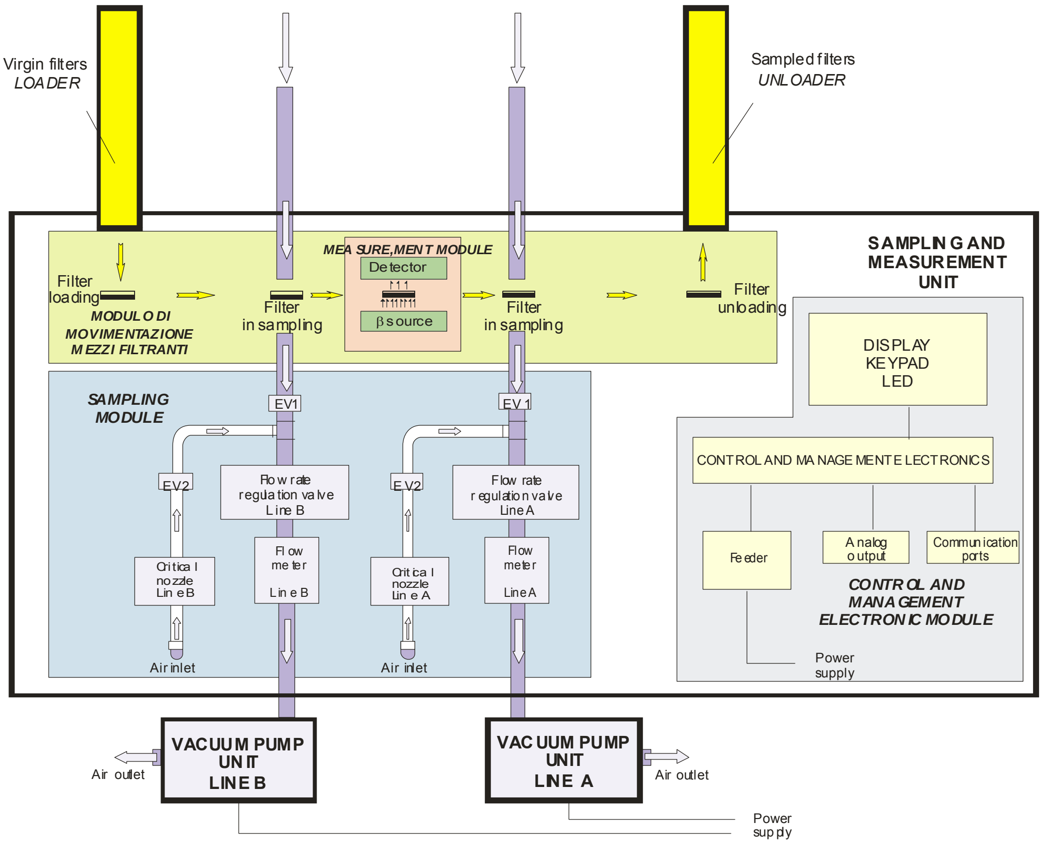
2.3 THE PNEUMATIC CIRCUIT

The sampling module uses two vacuum pumps allowing to achieve an operating flow rate value programmable in the range 0.5÷2.5 m^3/h. The flow rate regulation in real time is performed using a step motor moving the regulation valve.

Two solenoid valves placed on each sampling line allow to switch the pneumatic circuit from the sampling configuration to the Span test configuration (automatic check of the flow rate measurement system calibration, see paragraph 7.1.2) and to the Leak test configuration (automatic check of the pneumatic circuit seal, see paragraph 7.1.1).

The three possible pneumatic configurations are:

- **sampling**: EV1 open EV2 closed
- **Leak test**: EV1 closed EV2 closed
- **Span test**: EV1 closed EV2 open



The sampling flow rate measurement is based on the physical laws controlling the air mass transfer through a nozzle that in SWAM 5a Dual Channel Monitor is placed downstream the regulation valve.

By measuring the pressure value *"P_f"* downstream the nozzle, the nozzle pressure drop "*ΔP*" and the air temperature value *"T_a"* in the measurement area, it is possible to calculate the standard flow rate value "*Qs*" using the relation:

$$Qs = f(z)$$

where:

$$z = \sqrt{\frac{\Delta P \times (2P_p - \Delta P)}{T_m}}$$

In SWAM 5a Dual Channel Monitor the form of the function "*f(z)*" is approximated to a second-order polynomial in "*z*" whose coefficients are determined using a multipoint calibration procedure (see paragraph 2.4 "*Calibration of the flow rate regulation and measurement system*").

The figure below shows a scheme of the pneumatic circuit of a single pneumatic line.

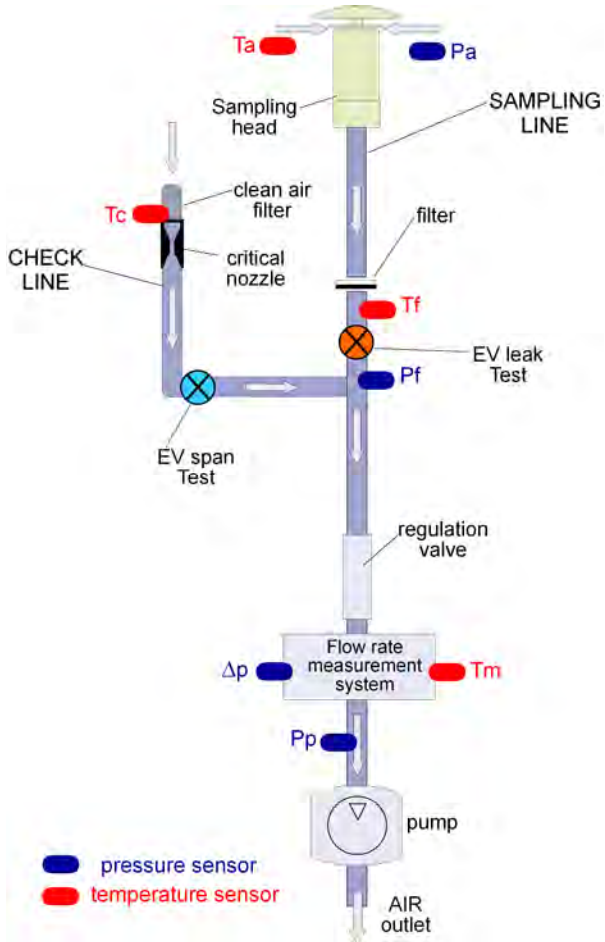


fig 2.5

<u>Sampling line:</u>

Pa: atmospheric pressure
Ta: air temperature
Tf: temperature in the accumulation area
Pf: pressure downstream the filter
ΔP: pressure drop at the measurement system nozzle
Pp: vacuum pump pressure

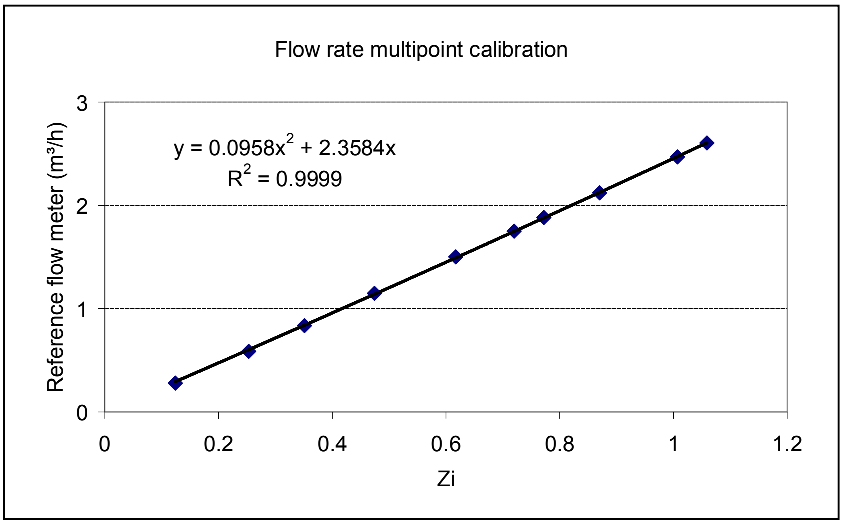
<u>Test Line:</u>

Tc: air temperature at nozzle inlet level

2.4 CALIBRATION OF THE FLOW RATE REGULATION AND MEASUREMENT SYSTEM AND QUALITY CONTROLS

The pneumatic system calibration is carried out during the general test and inspection, using instruments for the flow rate, volume, temperature and pressure measurement provided with traceability certificates as regards primary methods. In particular, the calibration procedure is based on a "*multipoint*" calibration approach within the operating flow rate range 0.5÷2.5 Nm³/h (T=273.1K; P=101.3kPa).

To each "z_i" value supplied by the instrument at a defined operating flow rate value the corresponding value of the reference standard flow rate is associated. So it is possible to calculate the coefficients *a, b, c* of a second-order relation in "*z*" $y=az^2+bz+c$ that describes at best the relation between "z" and the reference flow rate.



In operating conditions the guarantee of the correct implementation of the flow rate regulation and measurement procedure comes from the following quality controls (QC):

- **QC pneumatic circuit seal (Leak test):** at the beginning of every sampling cycle the instrument performs a procedure that, using the equation describing the equilibrium status of a perfect gas in a system at known volume, allows to check the pneumatic circuit seal downstream the filter membrane (see paragraph 7.1.1 "*Leak Test*"). The leak test results are stored in the *Buffer* data (see paragraphs 6.2.1 "*Buffer Data access by display*" and 6.3 "*Connection to an external PC and download of the data stored in the Buffer*") and if the specific leak exceeds the programmed limit values (Warning and Alarm) the relative messages are displayed.

- **QC flow rate measurement system (Span test):** at the beginning of every sampling cycle the instrument performs a procedure allowing to draw an ambient air flow that can be considered as a transferring standard, since it is generated using a convergent-divergent nozzle operating in critical pressure conditions (ISO 9300:2005). The mass flow rate value "Q_m" of this air flow comes from the relation

$$Q_m = \frac{C_d P_0 A C^*}{\sqrt{R_{gas} T_0}}$$

where P and T represent pressure and temperature values downstream the nozzle, C* the flow critical factor, A the nozzle area, R the gas constant and C_d the "discharge coefficient"

By the measurement of the atmospheric pressure and of the temperature downstream the nozzle and knowing the parameters characterizing it, it is possible to know the value of the mass flow going through the nozzle with a relative uncertainty of about 1%. The mass flow value going through the nozzle is compared with the value measured by the instrument. The instrument supplies the percentage deviation between the two values and stores this value in the Buffer Data. If the calculated percentage deviation value exceeds the programmed threshold values (Warning and Alarm) the relative messages are displayed (see paragraph 7.1.2 "*Span Test*").

- **QC Inlet flow rate stability:** the instrument performs an automatic control of the inlet flow rate value, regulating it so as to keep it constant with a relative precision lower then 1% of the nominal value. A quantitative estimation of the efficacy of this control is obtained with the calculation of the "*RSD*" variable. The value of this variable is calculated using the following expression:

$$RSD\% = \left(\sqrt{\frac{\sum (Q_i - Q)^2}{N-1}} \times \frac{1}{Q} \right) \times 100$$

where Qi is the measured flow rate and Q is the programmed flow rate.
The *RSD* value is available both during the sampling phase and in the relative buffer data.

- **QC filter pressure drop:** the instrument performs an automatic measurement of the filter pressure drop. The control of this parameter is fundamental to assure that the sampling takes place in optimal conditions. The filter pressure drop value gives, for example, information about a possible filter damage, about the possible condensation or about the achievement of the maximum load capacity of the filter membrane.

- **QC sensors:** the instrument performs some automatic quality controls aimed at checking the correct running of all the sensors. In particular it carries out a check of the pressure and temperature sensors verifying that, in operating conditions, the following relation is always respected: $P_{atmosphere} > P_{filter} > P_{pump}$ (see figure 2.5) (Warning 9, See Appendx 8), and checking the correct running of the temperature sensors (Warning 24, see Appendx 8).

2.5 MASS MEASUREMENT SYSTEM

In SWAM 5a Dual Channel Monitor the PMx mass measurement is based on the β attenuation technique. This technique has been implemented on the basis of an in-depth theoretical analysis of the interaction between β rays and matter that led to the formulation of a generalized parametric equation. This equation describes the connection between the attenuation of the β fluxes passing through the thin film and the mass thickness of this matter film (from the operative point of view, this implies that any type of filtering medium can be used with no need of instrumental recalibrations depending on the used filtering medium with mass thickness up to 9 mg/cm^2).
The used methodological approach allowed to refine the β measurement technique implemented in the instrument, so as to make it metrologically traceable.

2.5.1 Theoretic aspects

The estimation of the mass thickness x_p of a particulate matter film accumulated on a filtering medium with x_f mass thickness using the beta attenuation method is based on the correct quantification of the relative variation sustained by a flux of β electrons achieving an apposite detector, this film being present or absent. In purely formal terms, this can be expressed by the following functional scheme:

$$\ln \Phi_i - \ln \Phi_j \rightarrow \beta_{ij}\left[x_f^i,\ x_f^j + x_p\right] \qquad (1)$$

where β_{ij} is the operator describing the whole physico-mathematical relations that are basis for the beta attenuation technique and Φ_i and Φ_j are the beta fluxes measured during the respective measurement ith and jth sessions. The need to quantify the relative variations of the electron fluxes leads to the choice of the dimensionless variables

$$z^i = \ln\left(\frac{\Phi_0}{\Phi_i}\right),\ z^j = \ln\left(\frac{\Phi_0}{\Phi_j}\right) \qquad (2)$$

where Φ_0 is the beta electron flux when the mass thickness x_f interposed between source and detector is null.
Bear in mind that the correct implementation of the technique at issue calls for the study of the reversibility conditions of the relation (1), that is the possibility of estimating the mass thickness of the matter accumulated on a filter membrane knowing the variable $z^i(x_f)$ and $z^j(x_f + x_p)$ so as to make possible to write:

$$x_p \rightarrow \beta_{ij}^{-1}\left[z^i,\ z^j\right] \qquad (3)$$

In the ideal case, that is if $x_f^i = x_f^j$, if the thermo-dynamical conditions of the measurement chamber do not vary in the two measurement sessions, if the detector efficiency is constant, if the mass thickness x_p is quantitatively negligible compared to x_f, etc, the operator β_{ij} can be approximated by a function of the sole z variable. In order to determine its form, it's useful to start from the mathematic description of the beta attenuation process expressed by the differential relation:

$$dz = \mu(x)dx \qquad (4)$$

that once integrated assumes the form:

$$z = \beta(x) \qquad (5)$$

where $\mu(x)$ represents the mass absorption coefficient, function of the mass thickness value of the foil interposed between source and detector.
The main characteristics of the function $\mu(x)$ are that it is positive ($\mu(x) > 0\ \forall x$) and increasing monotone in x. These characteristics directly come from the physical laws controlling the beta rays interaction with matter. Indeed, it is sufficient to remember that $\mu \propto \frac{1}{E_{max}^{\alpha}}$ $(con\ \alpha > 0)$ and that when mass thickness value *x* increases, the electrons maximum energy E_{max} tends to decrease. Therefore, the (4) proves reversible and it is possible to write:

$$dx = \frac{1}{\mu(x)}dz = k(z)dz \qquad (6)$$

It follows that it's possible to go back to any finite variation *dx* of the mass thickness using the relation:

$$\Delta x = \int_{x_1}^{x_2} k(z)dz = g(z_2) - g(z_1) \quad con\ g(z) = \int k(z)dz + C \qquad (7).$$

Therefore, by comparing the relation (3) with the (7) one, comes that in an ideal model the function β_{ij}^{-1} corresponds to the function *g(z)*:

$$\beta_{ij}^{-1} \rightarrow g(z) \qquad (8)$$

This is the best approach to the experimental determination of the function *g(z)* and to the calibration of the mass measurement systems based on the beta attenuation technique. Indeed, once *n* mass thickness values x_i have been chosen in the operating interval of the beta measurement system, in principle the z_i correspondent values can be determined with a very high precision. By the research analysis of the function of maximum likelihood ratio, it is possible to get the best fit of the experimental data. The studies show that a homogeneous third-level polynomial relation in *z* is an optimal approximation of the experimental data (see the paragraph about Calibration).
If *g(z)* is known, it is possible to deduce the function *k(z)* and the correspondent values of the absorption coefficient $\mu(x)$.
These considerations can be extended to the real case, where it is necessary to generalize the relation (5) considering that in a real system air with density *ρ* interposes between source and detector and that the detector efficiency depends on other variables as for example the high voltage and the lifetime. For this reason the (5) must be rewrote in the form:

$$z = \beta(x, \rho, E(x,t)) \qquad (9)$$

The relative variation of the variable *z* between two measurement sessions, when we have a δx increase of the mass thickness *x* of the film interposed between source and detector, will be expressed with

$$\delta z = \left(\frac{\partial \beta}{\partial x} \delta x + \frac{\partial \beta}{\partial \rho} \delta \rho + \frac{\partial \beta}{\partial E} \delta E \right) \qquad (10)$$

The mass thickness variation δx ca be wrote as the sum of the mass thickness variation of the filtering medium δx_f and of the contribution of the particulate matter film accumulated on it x_p, $\delta x = \delta x_f + x_P$. It follows that the (10) can be rewrote as:

$$\delta z = \frac{\partial \beta}{\partial x} x_p + \left(\frac{\partial \beta}{\partial x} \delta x_f + \frac{\partial \beta}{\partial \rho} \delta \rho + \frac{\partial \beta}{\partial E} \delta E \right) \qquad (11)$$

The (11) explicitly highlights all the terms contributing in determining the relative variation in the beta flux values (variable *z*). The term $\frac{\partial \beta}{\partial x} x_p$ expresses the functional contribution associated with the presence of the particulate matter film accumulated on the filtering medium, while the term $\left(\frac{\partial \beta}{\partial x} \delta x_f + \frac{\partial \beta}{\partial \rho} \delta \rho + \frac{\partial \beta}{\partial E} \delta E \right)$ expresses the whole contributions determining the systematic fluctuations in the measured beta fluxes. These fluctuations can't be traced back to the presence of particulate matter mass accumulated on the filter (systematic biases). These contributions comes from:

- the variation of the filtering medium mass thickness
- air density fluctuations
- detector response efficiency fluctuations

By analysing the relation (11), we deduce that an accurate mass measurement using the beta technique can be performed only if the term $\left(\frac{\partial \beta}{\partial x} \delta x_f + \frac{\partial \beta}{\partial \rho} \delta \rho + \frac{\partial \beta}{\partial E} \delta E \right)$ is quantitatively negligible or if this term is quantified and then removed in the evaluation of δz.

In the real implementation of the beta technique it is actually impossible to completely remove the considered systematic biases and for this reason SWAM 5a Dual Channel Monitor implements a procedure based on the use of spy filters that allows to quantify and to remove these *biases*.

This is achieved thanks to the beta flux measurements on the spy filters F_s (of the same type of the operative filters F_r) carried out during the beta flux measurement phases on the operative filters F_r. Indeed, writing the (11) for a spy filter, we will have:

$$\delta z_{Fs} = \left(\frac{\partial \beta}{\partial x} \delta x_{Fs} + \frac{\partial \beta}{\partial \rho} \delta \rho + \frac{\partial \beta}{\partial E} \delta E \right) \qquad (12)$$

It is plain that if the spy filter and the operative filters have comparable mass thicknesses ($x_{Fr} \cong x_{Fs}$), the second term of (11) is quantitatively equivalent to δz_{Fs}. Comparing the (11) and the (12), we deduce that:

$$(\delta z)_{Fr} - (\delta z)_{Fs} \cong \left(\frac{\partial \beta}{\partial x} \right) \times x_P \qquad (13)$$

By remembering that:

$$\frac{\partial \beta}{\partial x} = \mu(x) = \frac{1}{k} \qquad (14)$$

we will get

$$x_p = k(z) \times \left[(\delta z)_{Fr} - (\delta z)_{Fs} \right] \qquad (15)$$

That represents the differential form of the relation describing the mass measurement implemented in SWAM Dual Channel.

2.5.2 Mass measurement procedure

Every i[th] measurement session, whether *blank* or *collect* measurement, is made up of a sequence of *n* beta flux measurement cycles. Every cycle is alternately performed on the operative filtering mediums F_{r1} and F_{r2} and on the spy filter F_s (see Appendix 11 "*Mass Measurement*"). The matrix describing the sequence of the measurements contained in the *n* measurement cycles is:

$$\begin{bmatrix} F_s^{11} & F_{r1}^{1} & F_s^{12} & F_{r2}^{1} & F_s^{13} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ F_s^{n1} & F_{r1}^{n} & F_s^{n2} & F_{r2}^{n} & F_s^{n3} \end{bmatrix} \text{ with } 4 \le n \le 6 \qquad (16)$$

Beta measurement times T_m relative to the single phases:

- 10 min for the operative filters F_r
- 5 min for the spy filters F_s

Number of measurement cycles *n*:

- n=4 for 8 hours long sampling cycles
- n=6 for 12 or more hours long sampling cycles

All the measured values of beta flux are correct in proportion to the dead time "τ" of the Geiger Muller, determined experimentally using a suitable procedure implemented in the instrument.
The measurement cycles are integrated with the estimate of the background noise (Φ_{dark}) and with the beta flux measurement when no filtering medium interposes between source and detector (Φ_0 "beta flux in air").
These ancillary measures function as important quality controls: the estimate of the *dark* (Φ_{dark}) allows to quantify the background noise, the measurement of the beta flux in air (Φ_0) allows to evaluate the stability of the Geiger Muller detector. Moreover, the value of Φ_0, determined in the *blank* session, allows to estimate the values of the dimensionless variables $z(x_{Fr})$ and $z(x_{Fs})$ and of the respective uncertainties, for the *blank* and the *collect* measurements.
Moreover, during the *collect* phase, it is necessary to consider that the measured values of the flux associated with the operative filters include the beta flux Φ_{nat} caused by the presence of natural radio nuclides in the sample (natural radioactivity associated with the Radon decay products). This contribution would cause negative *artifacts* in the sample mass estimate. Therefore, it is necessary to quantify it using the data relative to ancillary measures preceding and closing the *collect* measurement cycle. These measures are performed thanks to the presence of a mobile shield that, interposing between source and filtering medium, allows to find out the sole beta flux coming from the sample accumulated on it (figure 2.6).

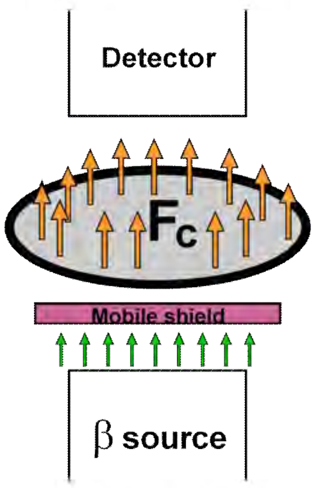


figure 2.6

The availability of a population of data Φ(x) relative to the operative filtering mediums Fr_1, Fr_2 and the 3*n* data relative to the spy filter (F_s) allow the estimate both of the expected values <Φ(x)> of the beta flux, using the calculation of the arithmetic mean of the values $\Phi(x_r)$, and of the uncertainty associated with them. With regard to the data of the fluxes measured during the *blank* phase, they must be corrected considering the background noise (dark):

$$\Phi^{b}_{corr}(x) = \Phi(x) - \Phi_{dark} \qquad (17)$$

In the *collect* measurements, the correct values of the beta flux are determined removing from the measured values the contribution of the natural radioactivity Φ_{nat}:

$$\Phi^{c}_{corr}(x) = \Phi(x) - \Phi_{nat} \qquad (18)$$

2.5.3 Sample mass calculation

If the variables *z(x)* are known, the corresponding values k_r and k_s can be determined using the relation representing the first derivative of the calibration function *g(z)*:

$$k(z) = 3az^2 + 2bz + c \qquad (19)$$

where *a, b* and *c* represent the coefficients of the third-level homogeneous polynomial that represent the function *g(z)* of the mass measurement system (see paragraph 2.6 “*Mass measurement system calibration*”).
The calculation of the mass m_p of the particulate matter sample accumulated on the filtering medium comes from the relation:

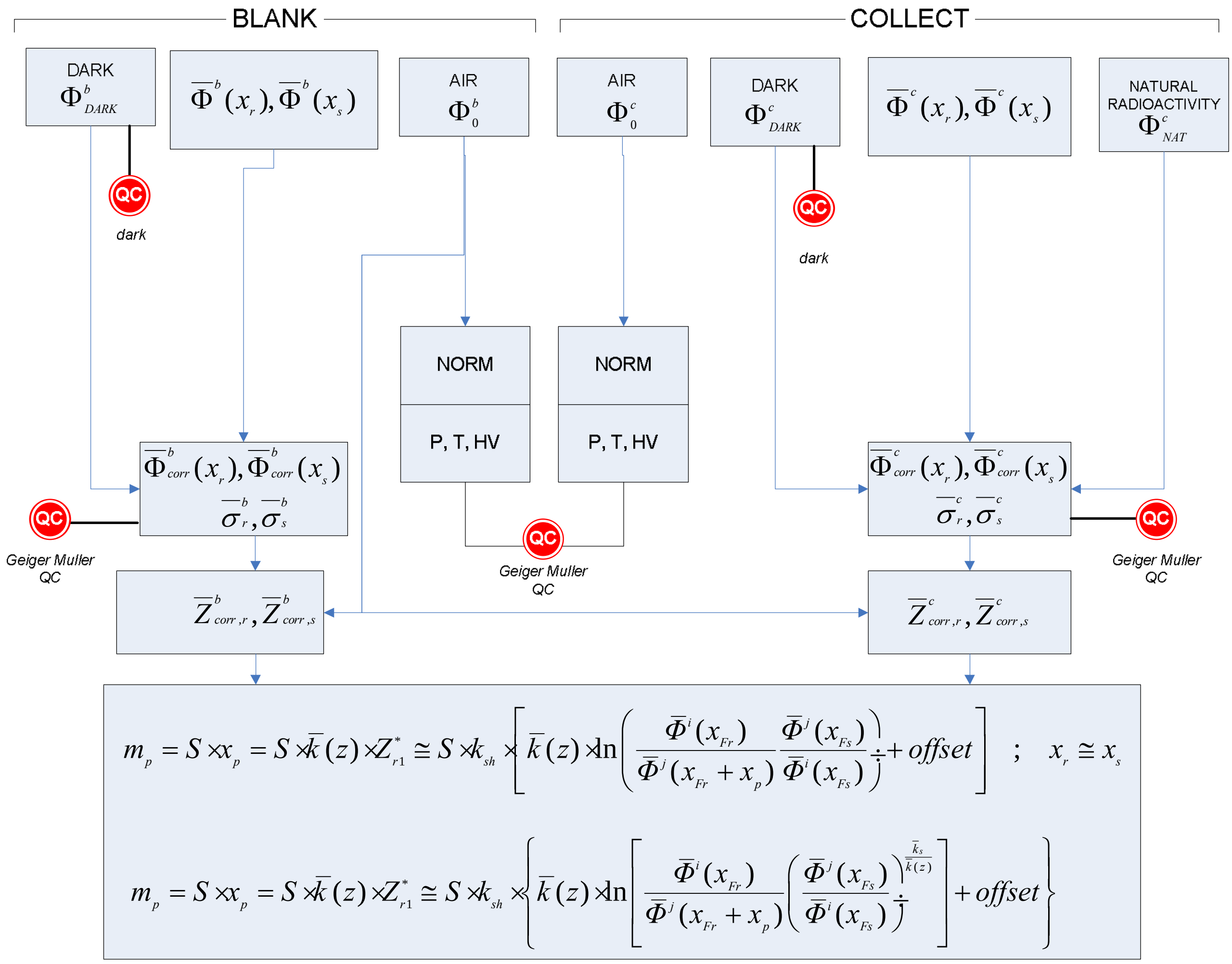
$$m_P = S \cdot x_p = S \cdot \bar{k}(z) \cdot Z^{*}_{r1} \cong S \cdot k_{sh} \cdot \left[\bar{k}(z) \cdot \ln\left(\frac{\bar{\Phi}^{i}(x_{Fr})}{\bar{\Phi}^{j}(x_{Fr}+x_p)} \frac{\bar{\Phi}^{j}(x_{Fs})}{\bar{\Phi}^{i}(x_{Fs})} \right) + offset \right] \qquad (20)$$

where *S* represents the area of the usable sampling surface and *k(z)* is the geometric mean between the values of k_r determined during the *blank* and *collect* sessions.

This relation is used if the mass thicknesses of the operative filtering mediums and of the spy filters satisfy the condition $x_{Fr} \cong x_{Fs}$. Anyway, if this condition is not verified, it is possible to obtain an excellent estimate of m_p using the relation:

$$m_P = S \cdot x_p = S \cdot \overline{k}(z) \cdot Z^*_{r1} \cong S \cdot k_{sh} \cdot \left\{ \overline{k}(z) \cdot \ln\left[\frac{\overline{\Phi}^i(x_{Fr})}{\overline{\Phi}^j(x_{Fr}+x_p)} \left(\frac{\overline{\Phi}^j(x_{Fs})}{\overline{\Phi}^i(x_{Fs})} \right)^{\frac{\overline{k}_s}{\overline{k}(z)}} \right] + offset \right\} \qquad (21)$$

The dimensionless parameter k_{sh} (equations 20 and 21) characterizes the uniformity level of the particulate matter sample distribution on the filtering medium. It takes a unit value if the sample surface distribution is homogeneous.
The "offset" term in the equations 20 and 21 is a term which takes into account the possible slight deformations that the filtering medium could undergo during the sampling process. The "offset" in ideal conditions takes a null value (see paragraph 7.7).



2.6 MASS MEASUREMENT SYSTEM CALIBRATION

The goal of the calibration procedure is the experimental determination of the function *g(z)* that in SWAM Dual Channel is obtained using a *multipoint* approach. The calibration range is within the mass thickness interval 0÷10 mg/cm². Using this procedure, to every nominal value "x_i" of the i[th] mass thickness the corresponding expected value $z_i = \ln\left(\frac{\Phi_0}{\Phi(x_i)}\right)$ is associated.

Once n mass thickness values x_i have been chosen within the operating interval of the beta measurement system, in principle the corresponding expected values of z_i can be determined with a very high precision. Using the maximum likelihood technique, it is possible to get the *best fit* of the experimental data (in the considered interval the function must result increasing monotone), for example using a third-level homogeneous polynomial whose coefficients will be the calibration parameters. Once he function *g(z)* has been determined, it is possible to obtain the function *k(z)* and then the corresponding values of the absorption coefficient $\mu(x)$. This methodological approach allows to minimize the uncertainty in the calibration coefficients determination.

2.6.1 Calibration procedure

The calibration procedure used during the final acceptance test allows to make quantitatively negligible all the uncertainties associated with the beta measurement reproducibility (Poisson statistics of the beta emission, reproducibility of the mechanical repositioning, detector efficiency fluctuations, density variations of the air interposed between source and detector).

In order to correctly determine the function *g(z)* it is necessary to verify that the detector response can be considered stable in time. For this sake, the instrument implements an automatic program allowing to perform a sequence of beta fluxes measurements both in air (A) and on six reference aluminum foils (F_i) with known mass thickness values.

$$\left.\begin{array}{llllll} F_{1,1}A & F_{2,1}A & F_{3,1}A & F_{4,1}A & F_{5,1}A & F_{6,1}A \\ F_{1,2}A & F_{2,2}A & F_{3,2}A & F_{4,2}A & F_{5,2}A & F_{6,2}A \\ F_{1,3}A & F_{2,3}A & F_{3,3}A & F_{4,3}A & F_{5,3}A & F_{6,3}A \\ \ldots\ldots\ldots\ldots & & & & & \end{array}\right\}$$

Measurement time F_i= 300sec.
Measurement time A= 150sec.

figure 2.7

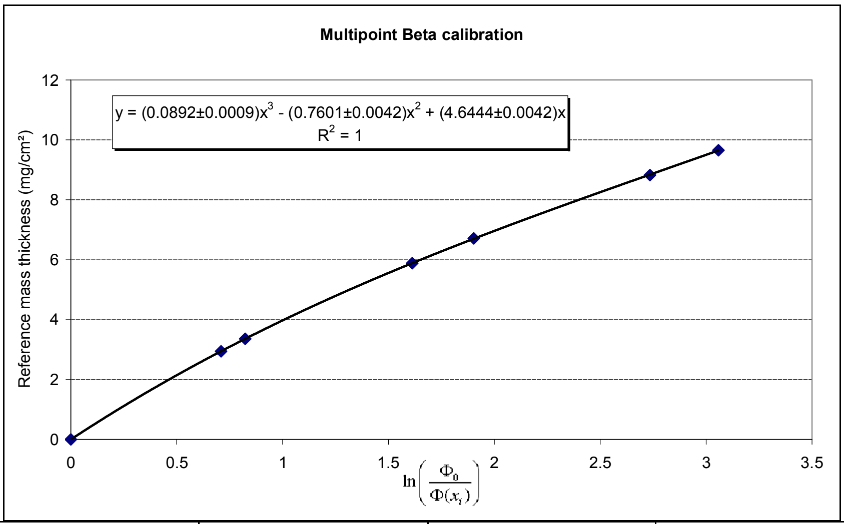
The mass thickness values usually used are such as to cover the range 0÷10 mg/cm² and they are shown in the table below (Tab. 1)

Reference mass thickness (mg/cm²)
2.963
3.405
5.926
6.810
8.889
9.773

Tab. 1

To every beta flux measurement the Geiger high voltage value is associated, besides the ancillary measures of temperature, pressure and humidity relative to the measurement area. The measurements sequence is repeated for at least 48 hours and, analyzing the collected data, it is possible to evaluate correctly the stability level of the Geiger detector response.
Once verified the Geiger detector stability, it is possible to go on with the beta measurement system calibration, determining the coefficients of the function *g(z)* by a sequence of measurements as the one shown in figure 2.7, with a minimum duration of 24 hours. Using this procedure allows to minimize the uncertainty associated with the expected values of the beta fluxes, that is with the corresponding values of *z* determined using the arithmetic means of the populations of every single measurement, so as to reduce the uncertainty intrinsically associated with the measurement method.

As an example, we show here below the results of a calibration performed during the last acceptance test: figure 2.8 shows the coefficients of the function $g = az^3 + bz^2 + cz$ determined using the maximum likelihood technique, while figure 2.9 shows the results of the analysis of linear regression between the values of the reference mass thicknesses and the values determined by SWAM 5a Dual Channel Monitor using the beta technique.



Coefficient	*a*	*b*	*c*
Value	0.0892	0.7601	4.6444
Uncertainty	0.0009	0.0042	0.0042

figure 2.8

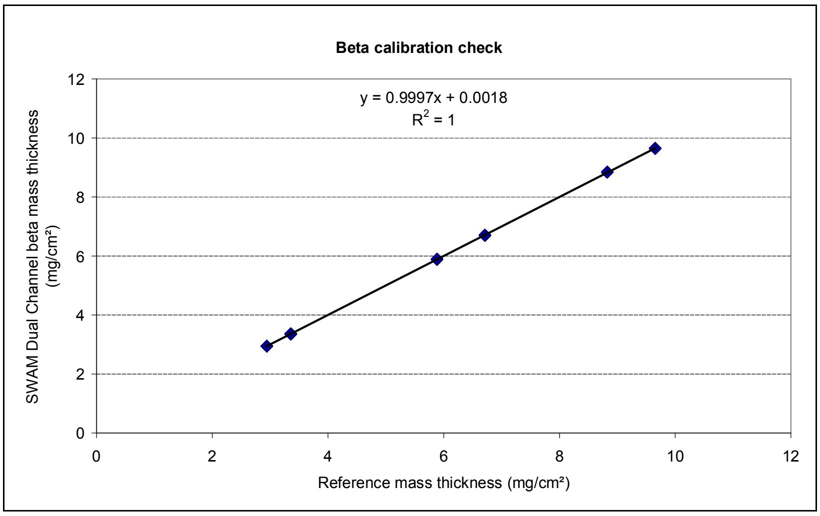


figure 2.9

2.6.2 Automatic calibration check and quality controls

In relation to the implementation level of the measurement technique, in the instrument **no periodical calibrations are needed** but when failures of the measurement system take place implying the replacement of one or more components (Geiger Muller detector and associated electronics). In operating conditions the correct implementation of the measurement procedure and the invariance of the calibration function are guaranteed by the implemented quality controls, that are in short:

- **QC background noise**: the background radioactivity counts are checked at the beginning of each measurement cycle and, if they are out of the predefined interval, the instrument signals it with the relative messages (Warning and Alarm).
- **QC short-term Geiger counter stability**: during the measurement of the β radiations flux passing through the filter, the congruence between the counts ratio and the Poisson statistics (radioactive decay) is checked. If the result of this comparison does not comply with the decay descriptive statistics, the instrument signals it with the relative messages (Warning and Alarm).
- **QC long-term Geiger counter stability**: in order to monitor the possible Geiger response creeps (not affecting mass measurement quality), the "Air counts" of two consecutive measurement cycles are compared. If the percentage difference between the Air counts measured value and the reference value is higher then the programmed limit value, the instrument generates the relative messages (Warning and Alarm).
- **QC Geiger counter high voltage**: the Geiger detector response quality is closely connected with the stability of its high voltage supply. The instrument feeder can supply a stabilized voltage within 1‰ of the average value. If the standard deviation of the Geiger high voltage value is higher then 2‰, the instrument generates the relative messages (Warning and Alarm).
- **QC mass measurement system calibration**: at the beginning of every operating cycle, an automatic procedure for the calibration check is performed using beta flux measurements in air (Φ_0) and using two reference aluminum foils (R_1, R_2) with known

mass thickness. After having calculated the mean values $\overline{\Phi}_0, \overline{\Phi}_{R1}, \overline{\Phi}_{R2}$, the instrument determines the mass thicknesses values "x_{mis}" of R_1 and R_2, using the calibration function:

$$x_{mis}(R1) = a\,z^3(R1) + b\,z^2(R1) + cz(R1)$$
$$x_{mis}(R2) = a\,z^3(R2) + b\,z^2(R2) + cz(R2)$$

By comparing the mass thickness values so determined with the corresponding nominal values, the instrument calculates the relative percentage deviation:

$$\frac{x_{mis}(R1) - x_{R1}}{x_{R1}}\%$$

$$\frac{x_{mis}(R2) - x_{R2}}{x_{R2}}\%$$

Considering that the whole length of the measurements of the beta fluxes through R_1 and R_2 for the calibration check is about 40 minutes, the value of the associated uncertainties will be higher than the values obtained during the last acceptance test.

2.7 QC AND INSTRUMENTAL FUNCTIONALITY:

2.7.1 Warning messages

SWAM 5a Dual Channel Monitor performs a complete automatic control of the sampling and measurement phases, giving in real time useful information for the characterization of the quality level of the supplied data of the instrumental functionality (see Appendix 8). If some parameters do not satisfy the quality standards or in case of situations that could affect the quality of sampling and measurement data, the instrument activates *Warning* messages.

The *Warnings* are signaled by a yellow led on the control panel, they are displayed in *Instrument Info* menu and, when provided for, stored in the *Buffer Data*. Some of them have also the function to inform the user and/or the maintenance engineer about the need of aimed controls (automatic indication of "*Warning*" causes).

2.7.2 Alarm messages

SWAM 5a Dual Channel Monitor automatically manages all those situations that prejudice its functionality or integrity. In these situations the instrument activates stop procedures, informing the user about the causes of it. These information are identified with Alarm messages (see Appendix 7) that are stored by the instrument and then available both in local (a red led on the control panel and displaying) and by remote.

If an Alarm message is displayed, please contact FAI Instruments s.r.l.

2.8 CONTROL ELECTRONICS, MANAGEMENT SOFTWARE AND INTERFACES

The sampler electronics has been engineered with two CPU's in master-slave architecture with different tasks. The *slave* CPU attends to the mechanical handlings and to the acquisition of digital and analog signals. The *master* CPU manages I/O, communications, operation timing, flow rate measurement and control, sample mass measurement, data storage tasks.

In the *master* CPU structure are stored all information about the sampling and mass measurement processes, the test logs, the alarm/warning and mechanical movements logs. This characteristic allows to carry out, by remote too, a continuous check on the mechanics operating conditions in order to find out possible failure causes. The local I/O are managed by LCD display, membrane keypad and status indicators (LED).

The management software is structured in tree menus and it allows:

- to access the sampling and measurement data of the processed filters
- to access the data of the sampling and measurement in progress
- to set the sampling and measurement parameters
- to use the tools for instrumental tests and for calibration

SWAM 5a Dual Channel Monitor is equipped with the following interfaces:

- Graphic "Display" interface: the display in the frontal control panel allows to read all the instrumental information and the Alarm and Warning messages
- RS-232 serial interface PC: allows the data interchange with a PC
- RS-232 serial interface Modem: allows the connection with a modem for the remote control of the instrument
- Analog interface

2.9 REMOTE CONTROL OF THE INSTRUMENT "GSM modem"

The instrument can be equipped with a GSM modem allowing the complete remote control (see paragraph 7.4 and Appendix B) and in particular it allows:

- to set the operating parameters
- to have continuous access to the sampling and measurement data (see paragraph 7.4 and Appendix 2)
- to check the mechanical functionality
- to read the system "trace files" (storage of all servomechanisms movements, of the tests, of all Alarm and Warning messages, etc.)
- to receive diagnostic SMS's automatically sent by the instrument (see paragraph 6.5)

NOTE: For the list of the optional accessories and of the main spare parts, see Appendx 9.

2.10 ANALOG DATA OUTPUT

An analog data output is placed on the back panel of the instrument, allowing the connection with a “traditional” acquisition system (for example *data logger*). For the connection it is necessary to use a cable with a 15 poles connector (see figure 2.10).
The signals distribution on the connector pins is the following one:

pin	Description
5	Ground
8	Analog signal proportional to the ***Concentration value measured on Line A*** varying between 0V and 5V (the 5V value corresponds by default to 200 $\mu g/m^3$) or *a negative concentration value*[1]
15	Analog signal proportional to the ***Concentration value measured on Line B*** varying between 0V and 5V (the 5V value corresponds by default to 200 $\mu g/m^3$) or *a negative concentration value*[1]
14	Analog signal proportional to the ***Service air pressure value*** varying between 0V and 5V (the 5V value corresponds to 500 kPa)
1-9	***ALARM*** signal NO contact
2-10	***WARNING*** signal NO contact (see Appendix 8 “*Warnings*”
3-11	***Data validation*** signal NO contact
4-12	***Available measure*** signal NO contact

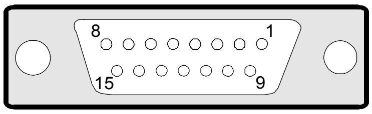


figure 2.10

[1] Starting from the firmware revision 04080166, the possible negative concentration values are represented in the buffer data of the instrument preceded by the minus sign, but they are associated, independently from their absolute value, to the emission of a fixed value of 5V from the correspondent analog output.

2.11 SEQUENTIALIZATION MECHANICS CHARACTERISTICS

In SWAM 5a Dual Channel Monitor both the project choices and the mechanical implementation have been directed towards the achievement of a very high reliability level of the mechanical movements. Besides, the used solutions allowed the complete elimination of the possibility of undesirable interruptions of any step of the sequentialization process.

The main mechanical movements (filters loading/unloading, filter placing in the accumulation area, etc.) are carried out by electropneumatic servomechanisms with a single degree of freedom, guaranteeing a very high repeatability. Besides, a set of quality controls on the mechanical movements times allows to objectively monitor and characterize the mechanical status as a whole, allowing an efficacious preventive diagnosis (see Appendix 7).

Finally, the use of electropneumatic actuators allows to achieve a considerable movements autonomy even in power down conditions.

2.12 INSTRUMENTAL MANAGEMENT IN POWER FAILURE CONDITIONS "*floating batteries*"

SWAM 5a Dual Channel Monitor has been engineered to overcome at its best all possible improper fluctuations of the power supply or its interruptions. So the instrument is practically immune from all the potential problems connected with the power supply. In fact, the instrument is equipped with two rechargeable floating batteries and it has a mechanical movement architecture (electro-pneumatic) such as to let it achieve any mechanical configuration even in power failure conditions.

In Power Failure conditions:

- the sampling processes in progress stops (vacuum pumps power failure)
- the instrument estimates the batteries charge status and the residual battery operation time
- if the residual battery operation time is long enough, the instrument completes the mass measurement cycles in progress
- by the analysis of the operating and programming status, SWAM 5a Dual Channel Monitor selects the best mechanical configuration to achieve in order to correctly restart the operating cycle at power restore
- once achieved the correct mechanical configuration, the instrument starts an auto-switch-off procedure (see paragraph 2.13) deactivating the control panel till power restoring

"Power failure" events are displayed with a *Warning* message and stored in the *Buffer Data* (Warning 28, see Appendix 8).

2.13 Self-Power-Down procedure

The way how the instrument automatically manages possible "power down" conditions depends on the operative conditions of the instrument when the self-power-down occurs, on the "power down" duration, on duration and mode of the programmed sampling and measurement cycles and on the sampled volume minimum value for the mass concentration data validation (Warning 23, Appendix 8). The table here below shows all possible operative conditions (marked with the variable PF) when a "power down" can occur:

PF = 0	Instrument in Ready Status
PF = 1	Instrument in Delay Status, loading the filters at the end of the starting procedure
PF = 2	Instrument in Delay Status, filters loading completed, instrument waiting for starting the Blank measurements on the first pair of operative filters.
PF = 3	Instrument in Delay Status, performing the Blank measurements on the first pair of operative filters
PF = 4	Instrument in Delay Status, Blank measurements on the first pair of filters completed, instrument waiting for starting the sampling cycle at the programmed date and time
PF = 5	Instrument in Sampling Status, Collect measurement on the sampled filters in progress
PF = 6	Instrument in Sampling Status, Blank measurement in progress
PF = 7	Instrument in Sampling Status and no mass measurements in progress
PF = 8	Instrument in Sampling Status, loading new virgin filters on the plate
PF = 9	The instrument stopped the sampling and measurement cycles due to a lack of new virgin filters

Here below a short list of the other variables used by the SWAM 5a Dual Channel Monitor software for the "power failures" management:

IR: difference between the power supply restore time and the expected time for the end of current Status (variable PF).
MV: minimum sampled volume value for the mass concentration data validation.
T: power supply restore time.
T0: first sampling cycle start time at the end of Delay Status.
Ts: start time of the sampling cycles following the first one.
Ta: end time of the sampling cycle in progress.
Iy: sampling cycle duration.
Ir: remaining time, $Ir = (Ta - T)$.
Id: Blank measurements duration in Delay Status.
IB: Blank measurements duration in Sampling Status.
IC: Collect measurements duration.
IS: fraction of time to be subtracted from the sampling and measurement cycle following the one when the power failure occurred, so that the sampler volume in the following cycle is ≥ MV.

"Power down" management depending on the PF variable value:

PF value	Operations performed at power supply restoration
0	The instrument goes back to Status Ready
1	The Restart procedure is performed (see note 1)
2	• If $(T+Id)>(Ta+IS)$: the sampling cycle start date and time are moved to multiples of *Iy*. • If $(T+Id)\le(Ta+IS)$: the instrument goes back to Delay Status and performs the Blank measurements (see note 2).
3	• If $(T+Id)>(Ta+IS)$: the sampling cycle start date and time are moved to multiples of *Iy* and the Blank measurements are repeated. • If $(T+Id)\le(Ta+IS)$: the instrument goes back to Delay Satus and repeats the Blank measurements. (see note 2)
4	• If $T>(Ta+IS)$: the sampling cycle start date and time are moved to multiples of *Iy*. • If $T\le(Ta+IS)$: the instrument goes back to Delay Status and then starti the sampling process (see note 2).
5	• If $(T+IC+IB)>(Ta+IS)$: the Restart procedure is performed • If $(T+IC+IB)\le(Ta+IS)$: the Collect measurements are repeated (see note 2)
6	• If $(T+IB)>(Ta+IS)$: the Restart procedure is performed • If $(T+IB)\le(Ta+IS)$: the Blank measurements are repeated (see note 2)
7	• If $T>(Ta+IS)$: the Restart procedure is performed • If $T\le(Ta+IS)$: the sampling process starts again
8	The Restart procedure is performed (see note 1)
9	The instrument completes the unloading of the filters present on the plate.

NOTE 1: Restart procedure
All filters on the plate are unloaded (keeping the insertion order), the sampling cycle start date and time are moved to multiples of *Iy* till the condition $(T+Id)<T0$ comes true, the instrument enters Delay Status and loads new virgin filters on the plate.

NOTE 2:
If a fraction of time "*IS*" is subtracted from the following sampling cycle, a percentage of the effective sampling time compared with the programmed time higher then 100% could be displayed in the Buffer Data records corresponding to those when the self-power-down occurred (see Appendix 1). Therefore, the sampling duration of the following cycle will be lower then the programmed duration, but anyway such as to guarantee the mass concentration data validity compared with the sampled volume (Warning 23).

CHAPTER 3

3. OPERATING MODES

The instrument has two operating modes selectable by the operator, *Monitor Mode* and *Reference Mode*.

3.1 "MONITOR MODE"

The *Monitor Mode* allows the particulate matter sampling and mass measurement on two independent lines. Therefore, this mode allows to draw simultaneously two PMx samples (replicated or representative of two different granulometric fractions) and to measure the relative mass concentration value using the instrument as two "*co-located samplers*". So it is possible, for example, to determine simultaneously the PM_{10} and $PM_{2.5}$ ($PM_{2.5}$ and PM_1, etc.) concentrations. Moreover, this configuration allows to perform particularly interesting metrological evaluations as for example:

- the evaluation of the volatile material losses thanks to the possibility of heating or cooling the two sampling lines (in this case it is necessary to order the accessory heating or cooling systems for the lines)
- the evaluation of the performances of two different sampling inlets

Moreover, the instrument allows to use a single line too (A or B) for drawing the sample of particulate matter. Appendix 10 shows some possible configurations. To start the instrument in *Monitor Mode* see paragraph 5.8.1 "*Sampling start in Monitor Mode*"

NOTE: In *Monitor Mode* we recommend to use on the two lines the same type of filtering medium, so as to get optimal performances in mass measurement.

3.2 "REFERENCE MODE"

In *Reference Mode* the instrument is used as high quality standard reference single-channel monitor. In this mode one sampling line is used for the PMx sample accumulation and mass measurement, while the other line is equipped with an absolute filter for the particulate matter (accessory supply) in order to have a membrane that will serve as "field blank" (metrological significance in gravimetric mass determination and in chemical speciation). Therefore, during the mass measurement phase, besides the data relative to the "spy filter", also the data relative to the field blank are available. Using these data for the sample mass calculation procedure will allow a further improvement of the measure quality level.

The operator can choose the line to be used for the sample accumulation and, consequently, the line to be equipped with the absolute filter.
Using SWAM 5a Dual Channel Monitor in *Reference Mode* it is possible to choose three different configurations:

1. Reference Mode Normal
2. Reference Mode Split "Constant Flow Rate"
3. Reference Mode Split "Constant Stokes Number"

To start the instrument in *Reference Mode* see paragraphs 5.8.2

3.2.1 Reference Mode Normal

This mode can be used only if the instrument is assembled with two independent sampling lines (two sampling inlets). Both lines work at the same constant volumetric flow rate. The line not used for the sample accumulation must be equipped with an accessory absolute filter for particulate matter (not included in the standard supply of the instrument)

$$Q_{inletA} = Q_{inletB} = constant$$

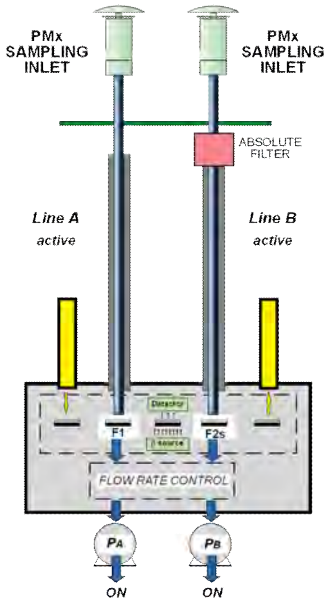


figure 3.1

3.2.2 Reference Mode Split "constant flow rate"

This configuration can be used only if the instrument is assembled with a single sampling inlet. Downstream the sampling inlet the sucked air flow, passing through a plenum chamber (not included in the standard supply – see Appendix 9), is split between the two sampling lines.
In this configuration both lines work at constant volumetric flow rate and the values of the two flow rates are such as their sum is equivalent to the nominal flow rate of the sampling inlet. The line not used for the sample accumulation must be equipped with the absolute filter.
It is necessary to set only the operating flow rate of the accumulation line and the inlet flow rate at sampling inlet level (sampling inlet nominal flow rate). The flow rate value of the line equipped with the absolute filter will be automatically calculated by the instrument (see paragraph 5.8.3 "*Sampling start in Reference Mode Split Constant flow rate*") so as to meet the following condition:

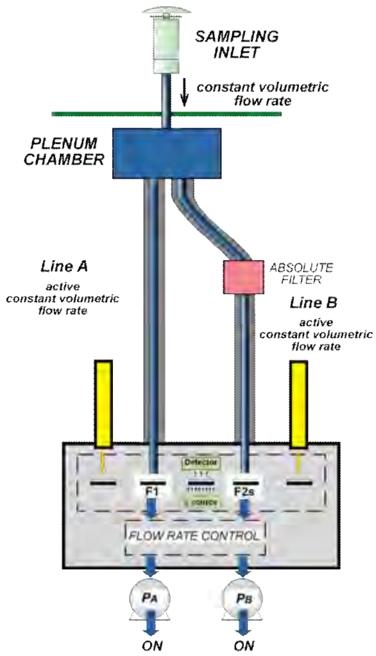


figure 3.2

$$Q_{inlet} = Q_{nominal\ inlet} = Q_A + Q_B$$
Q_A= constant volumetric flow rate
Q_B= balance flow rate (volumetric constant)

3.2.3 Reference Mode Split "constant Stokes number"

In order to get a granulometrically representative sample using the accumulation methods, the granulometric cut size at sampling inlet level must be constant. It is common knowledge that the penetration efficiency of a particle with aerodynamic diameter "d_a" through an impactor is function of a single dimensionless variable named Stokes number. The relation between the value of this variable and the value of the aerodynamic diameter ($d_a = \sqrt{\rho_p} \times d_p$) comes from:

$$Stk = \frac{4 \times Q_{nozzle} \times d_a^2 \times C_c}{9 \times \pi \times \eta \times d^3{}_{nozzle}}$$

where: C_c is the Cunningham's correction factor, Q_{nozzle} is the operating volumetric flow rate of a single nozzle, η is the air viscosity, *Stk* is the Stokes number, d_{nozzle} is the diameter of a nozzle.

It follows that in order to get an invariant cut diameter "d_{50}" (aerodynamic diameter with 50% penetration efficiency) the ratio Q_{inlet}/η must be constant.

Sampling at constant volumetric flow rate, representing the classic operating mode, can assure a nearly constant granulometric cut size only in case of negligible air viscosity variations during the sampling.

On the other hand, in accumulation methods the magnitude to be measured is represented by the average concentration "$\overline{C}$" of the particulate matter mass in an observation time "T" and it is expressed by the relation

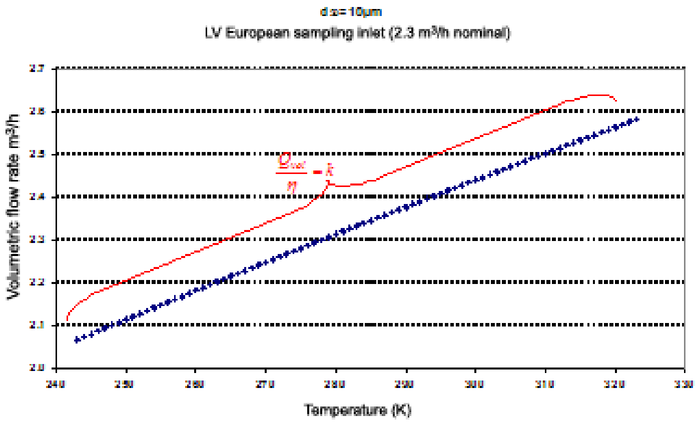
$$\overline{C} = \frac{1}{T}\int_0^T C(t)dt$$

in the accumulation methods the estimation of the average concentration is performed using the value "C*", defined as the ratio between the accumulated sample mass and the sampled volume.

$$C^* = \frac{Mass}{Volume} = \frac{\int_0^T C(t) \times Q(t)dt}{\int_0^T Q(t)dt}$$

"$\overline{C}$" and "C*" coincide only if the sample accumulation on the filter is carried out at constant volumetric flow rate.

The "*Reference Mode Split constant Stokes number*" mode allows to get both the sample granulometric representativeness (constant Stokes) and the accumulation at constant volumetric flow rate. In fact, the air sample is drawn using a single sampling inlet at a flow rate value such as to guarantee an invariant granulometric cut size.



Downstream the sampling inlet, the sample is split between Line A operating at constant volumetric flow rate “QA” and Line B operating at a flow rate value “QB” (balance flow rate) so as to guarantee that the ratio between the inlet flow rate and the ambient air viscosity is constant and equivalent to the nominal value assuring the desired granulometric cut size.

The sampling lines configuration in “*Reference Mode Split constant Stokes number*” mode is shown in figure 3.3.

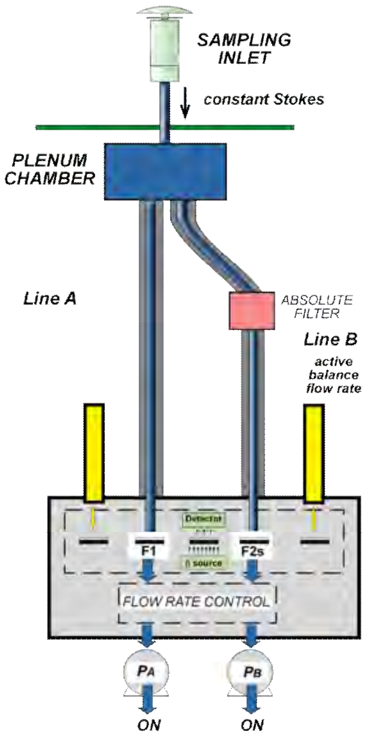


figure 3.3

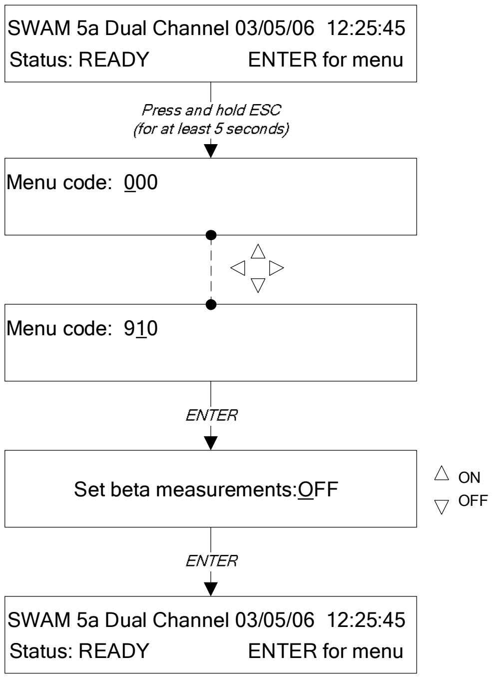
$Q_{inlet} = Q_{constant\ Stokes} = Q_A + Q_B$

Q_A = constant volumetric flow rate
Q_B = balance flow rate

3.3 "SAMPLER" MODE WITH MASS MEASUREMENT DISABLED

SWAM 5a Dual Channel Monitor may be used as a simple sampler too, disabling the mass measurement. For this operation follow the procedure below:

- With the instrument in READY Status, press and hold for at least 5 seconds the ESC button to have access to the *Menu code* (access to support *tools*).
- Select the *code 910* using the Select buttons and press ENTER to have access to the tool allowing to activate or deactivate the mass measurement
- Using the YES/NO buttons, select "ON" to activate the measurement or "OFF" to deactivate it and press ENTER to confirm your choice.



CHAPTER 4

4. FILTER MEMBRANES MANAGEMENT

SWAM 5a Dual Channel Monitor can manage automatically and in continuous the virgin filters loading steps and the steps of sampling, mass measurement and unloading of the sampled filters. At the end of every sampling and measurement cycle the sampled filters are immediately moved to the Unloader and they are available for the operator. The maximum autonomy of the instrument without adding new virgin filters is 35 filters if the instrument is equipped with the standard virgin filters Loader and sampled filters Unloader (the autonomy can reach 72 filters if the instrument is equipped with oader and Unloader with capacity 72 filter cartridges – optional accessories, see Appendix 9).

It is possible to add new virgin filters and to remove the sampled ones in any moment without interfering with the instrumental operating cycle.

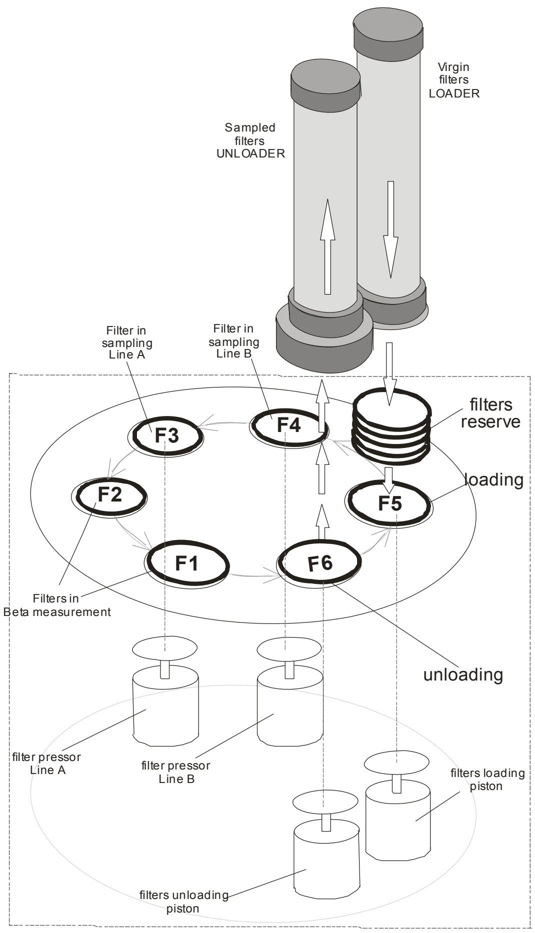
The constituent elements of the filter membranes management module are:

- filter cartridges
- virgin filters Loader
- sampled filters Unloader

4.1 FILTERS MOVEMENT MODULE

The module is made up of:

- **rotating plate** allowing to place the 6 filter membranes “F”, the 3 spy filters “S” and the 2 reference aluminum foils “R” (see figure 4.1). On the plate there is also a hole “A” for the measurement of the air ß flux. The plate is moved by a step-motor controlled by the management electronics.
- **virgin filters reserve**: an area inside the instrument, placed between the plate and the Loader bottom, that can contain till 6 filter membranes.
- **electro-pneumatic pistons** for filters loading and unloading
- **electro-pneumatic filter-presser pistons** for the operative positioning of the filters on the sampling line
- **sensors for plate positioning**
- **sensors for filter presence** (allowing to check that the filter has been loaded)
- **sensors for mass measuring system positioning**



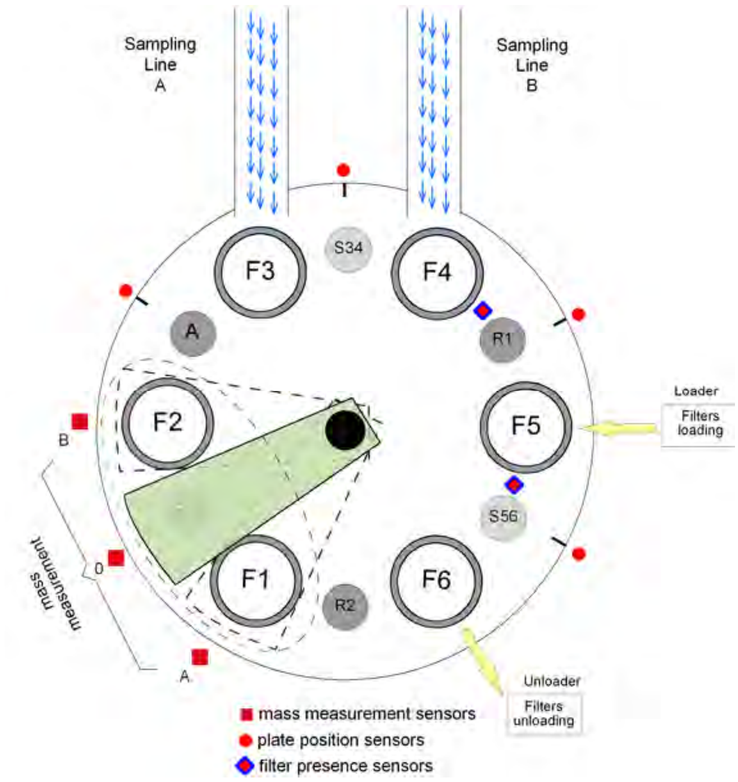


figure 4.1

The schemes here below show a synthesis of the filtering mediums movements.
The movement operations in case of instrumental start-up are preceded by an initialization phase made of:

- insertion of the filter membranes in the Loader (at least no. 8 filters, see paragraph 4.8)
- insertion and lockage of the Loader in the instrument
- automatic filling of the virgin filters reserve; when the Loader is connected to the instrument, the contained filters lift down, so that the first 6 filters fill the reserve (see figure 4.1a).

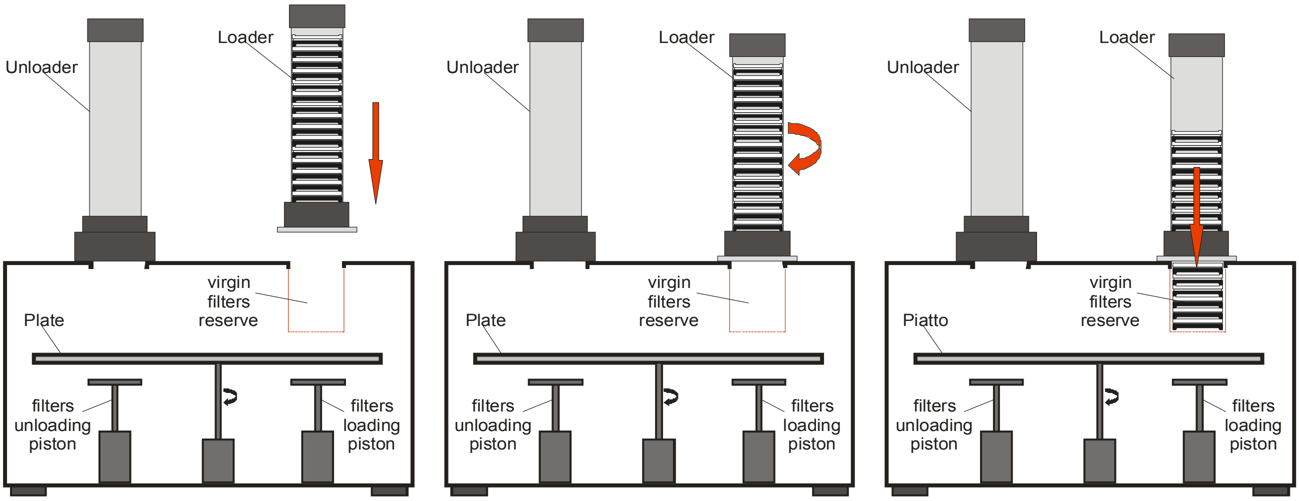


fig. 4.1a

After this step, it's possible to program the sampling cycles (see paragraph 5.8).
After the programming step, the instrument moves in sequence from the reserve to the plate the six filter membranes of the reserve. While each membrane is moved to the plate, the pile of filters above lift down. In this condition six filters are on the plate and the other filters (at least 2) are in the reserve-Loader system.
After the filters loading phase, the instrument performs the Blank measurements on the membranes that will be used in the 2 first sampling cycles (see Appendix 12). At the programmed date and time the instrument starts the sampling process and performs the Blank measurement on those membranes that will be used in the third cycle.
At sampling end, the instrument performs the Collect measurements on those membranes used in the first cycle and simultaneously starts the sampling process on the next membranes.
At the end of the Collect measurements, the sampled filters will be moved to the Unloader and as many virgin filters will be moved from the reserve to the plate to replace the previous ones.
The instrument repeats the whole set of operations (see Appendix 12) of sampled filters unloading, virgin filters loading, Blank measurement, sampling and Collect measurement till virgin filters are present in the reserve. If no virgin filters are in the reserve, the instrument does not perform the loading procedure, letting empty the plate positions corresponding to the last unloaded filters. In this condition the instrument starts a procedure (Ending see paragraph 5.9.2) allowing to go on with the sampling cycles using just the filters on the plate (2 cycles).
At the end of this procedure the instrument goes back to Ready Status (see par. 5.3) and it's ready for a new programming procedure.

<u>To use the instrument as monitor in continuous (main application) it's absolutely necessary to avoid that the reserve is empty when new virgin filters are loaded on the plate (see par. 4.6), so that the instrument does not start the Ending procedure. Indeed, during the Ending procedure that's no way to avoid the automatic stop of the sampling and measurement cycles.</u>

4.2 "COMPLETE FILTER" COMPOSITION

A complete filter is made up of a filter membrane placed in a filter cartridge made up of two circular discs pressure coupling and keeping inside the filter membrane.
Figure 4.2 shows the complete filter composition.

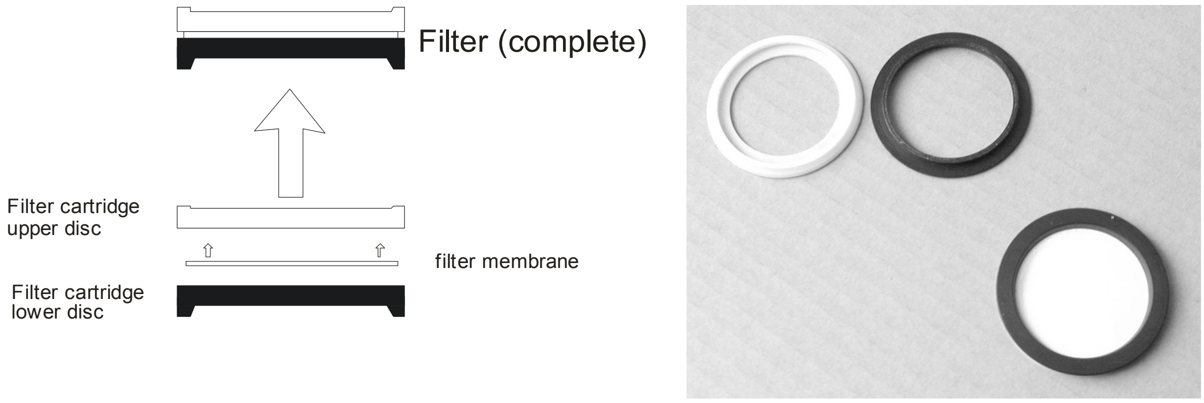


fig. 4.2

4.3 FILTERING MEDIUM CHOICE

The methods for the choice of the filtering medium (Teflon, glass fiber, quartz fiber, etc.) to be used in SWAM 5a Dual Channel Monitor are based on the optimization of the β mass measurement performances, on the choice of the sampling operating conditions and on the possible need of sample chemical speciation. While there's no bond for the mass thickness of the used filtering mediums, as long as they are in the range 0÷9 mg/cm².

As regards the mass β measurement optimization, the decisive factor for the choice of the filtering medium is the one connected with its structural homogeneity (the mass thickness value must be homogeneous in all the points of the filtering medium section passed through by the beta flux). Moreover, the filtering medium homogeneity is essential to guarantee a uniform deposition of the particulate matter film.

The other factors determining the filter choice are: the sampling operating conditions, the expected PMx average concentrations, the fluid-dynamic impedance of the filtering medium and its chemico-physical characteristics.

Guidelines

a. ***SWAM 5a Dual Channel Monitor is used just for the mass concentration measurement (monitoring networks, etc.) at 2.3 m³/h operating flow rate.***

In these conditions we recommend the use of glass fiber filters. For example the "Whatman Schleicher & Schuell GF10 Ø 47mm" or, anyway, glass fiber filters with equivalent homogeneity characteristics. We recommend the use of these filters, since they have:

- a suitable separation efficiency
- a low load drop in normal operating conditions
- a high load capacity
- a low higroscopicity level
- a suitable structural homogeneity
- a good mechanical resistance
- low costs

b. ***SWAM 5a Dual Channel Monitor is used both for the mass concentration measurement and for drawing samples to be used for the particulate matter chemical speciation.***

In this case, the filtering medium choice must be the best compromise between analytical needs, mass measurement quality, sampling operating conditions and management costs.

PTFE filters

If the analytical needs (ionic characterization, metals in traces, etc.) need the use of PTFE filters, we recommend the "PALL Life Sciences Teflo™ Ø 47mm 1µm" or filters with equivalent characteristics. Indeed, this type of filter has a high structural homogeneity. We advise against the use of PTFE filters with porosity higher then 1 µm, due to the presence of evident inhomogeneity. The use of this kind of filters requires a careful choice of the operating fluid dynamic conditions, since they has some limit due to:

- high load drop on the filtering medium in standard operating conditions
- low load capacity of particulate matter accumulative in optimal operating conditions
- possible obstruction of the filter porous structure in high relative humidity conditions, due to the hydrophobic properties of the medium

Therefore, the accumulation flow rates on each single line must be kept at quite low values (for example 1 m³/h) and the sampling cycles length must be chosen depending on the expected particulate matter average concentration values during the period under examination and depending on the site climatic conditions.
In these operating conditions the attainable quality level in PMx mass concentration measurement, is equivalent or higher than the one attainable using glass fiber filters at 2.3 m³/h operating flow rate.

Quartz fiber filters

If, for analytical needs (organic and inorganic carbon, etc), quartz fiber filters are needed, please remember that they have some structural limits. In particular, they have a lower homogeneity in comparison with the glass fiber filters and with the PTFE filters, a low mechanical resistance and a high higroscopicity level, that in particular RH conditions (values near to saturation or extremely low values) could determine some positive or negative biases in the determination of the particulate matter mass concentration values.
SWAM 5a Dual Channel, thanks to the “spy filters” technique, allows to get mass concentration data of a good quality level, provided that you choose filters with a high structural homogeneity as, for example, the “Whatman Schleicher & Schuell QF20 Ø 47mm” filters. In particular, using the “Reference Mode” (see paragraph 3.2I), we achieve the higher quality standard of the mass concentration data, thanks to the presence of the field blank (dynamic spy filter).

Given the importance of the used filter type for the quality of the instrumental performances, if you choose filters different from the recommended ones, please contact FAI Instruments srl.

4.4 FILTER CARTRIDGE CHOICE (β equivalent spot area)

The mass measurement performed using the ß attenuation method is based on the determination of the mass surface density. This one, with the same quantity of sampled particulate matter, is in inverse relation to the usable enrichment surface. In the specific case of SWAM 5a Dual Channel, the usable measurement surface is about 2 cm^2.

For this reason SWAM 5a Dual Channel Monitor can use filter cartridges with *β equivalent spot area* going from 11.95 cm^2 to 5.20 cm^2 with 2.3 m^3/h operating flow rate and from 11.95 to 2.54 cm^2 with 1 m^3/h operating flow rate. The possibility of choosing different *ß equivalent spot areas* allows to optimize the ratio signal/noise, depending on the expected concentration levels in the sampling site, on the considered season, on the impedance and on the load capacity of the used filtering medium.

Just as an indication, for glass or quartz fiber filters, having a quite low fluid-dynamic impedance and a load capacity high enough, you had better use, if possible (see Table 1), reduced *β equivalent spot areas*.

If, for analytical needs, you want to use Teflon filters with 1µm porosity, you must use filter cartridges having 11.95cm² *β equivalent spot area*.

NOTE: At instrument start, it is necessary to set the usable sampling and measurement surface (β *equivalent spot area*) of the used filter cartridge type (see paragraph 5.5).

Filter	Sampling flow rate [m^3]	Expected maximum concentration [$\mu g/Nm^3$]	*ß equivalent spot area* [cm^2]
Glass fiber	1	< 80	2.54
	2.3	< 80	5.20
	2.3	80 ÷ 150	7.07
	2.3	> 150	11.95
Quartz fiber	1	< 80	2.54
	2.3	< 80	5.20
	2.3	80 ÷ 150	7.07
	2.3	> 150	11.95
Teflon	1	--	11.95

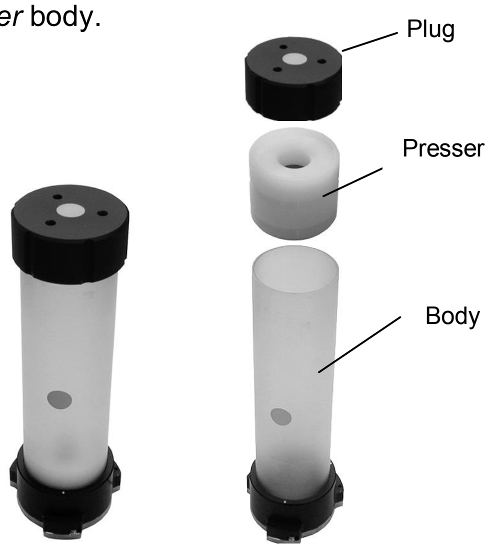
Table 1

The data shown in the table above refer to 24 hours long sampling cycles.

4.5 FILTERS LOADER AND UNLOADER COMPOSITION

Virgin filters Loader

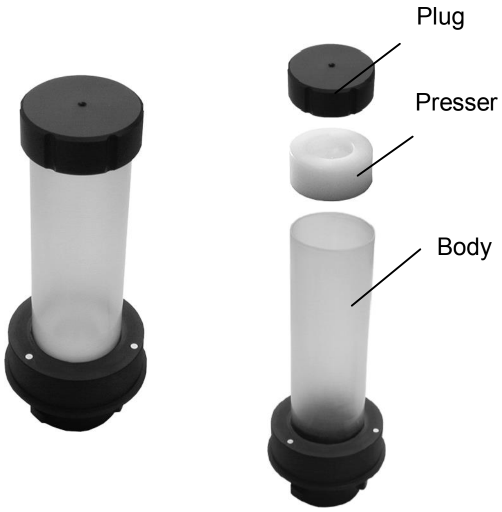
The *Loader* is made up of a white semitransparent cylindrical body, of a white plastic presser placed inside the Loader and of a black plug marked by a yellow circle corresponding to the yellow circle on the *Loader* body.



NOTE:
The presser must be placed inside the Loader with the hollow surface turned upwards. Actually it contains a magnet that starts a reed-relay signaling the virgin filters lack in the Loader.

Sampled filters unloader

The Unloader is made up of a white semitransparent cylindrical body, of a white plastic presser and of a black plug.



NOTE:
The presser must be placed inside the Unloader with the hollow surface turned upwards.

WARNING: **do not exchange the two black Loader and Unloader plugs.**

4.6 REMARKS ON THE INSTRUMENTAL AUTONOMY

In order to determine the autonomy of the instrument cycles it's necessary to remember that:

- the rotating plate inside the instrument (see par. 4.1) has 6 housings
- the internal reserve of the instrument (see par. 4.1) contains 6 filters
- at first start the instrument draw 10 filters from the Loader, loading 6 of them on the rotating plate and 4 of them in the internal reserve (see Appendix 12)
- adding new virgin filters without stopping the sampling and measurement cycles it's possible till the instrument enters the Ending Status (see par. 5.9.2)
- the maximum Loader and Unloader capacity is 35 filters for the standard Loader/Unloader supply or 72 filters for the special Loader/Unloader supplied on demand (see Appendix 9)
- in Monitor A&B and in Reference Mode 2 filters are used for each sampling and measurement cycle (see Appendix 12)
- in Monitor A or Monitor B Mode 1 filter is used for each sampling and measurement cycle. At first start 3 of the 6 filters loaded un the plate are not used for the samplings and they will serve as additional spy filters (see Appendix 12). Those filters will be unloaded at the end of the Ending procedure (see par. 5.9.2) or if the sampling cycles are stopped (Abort, see par. 5.9.1).

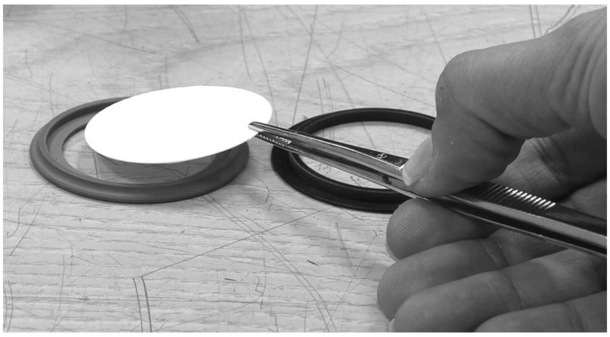
In order to prevent the filling of the Unloader, remove the unloaded filters before going on with the addition of new virgin filters and add as many filters so that the total number of filters (loader, reserve, plate) does not exceed the maximum capacity of the used Unloader

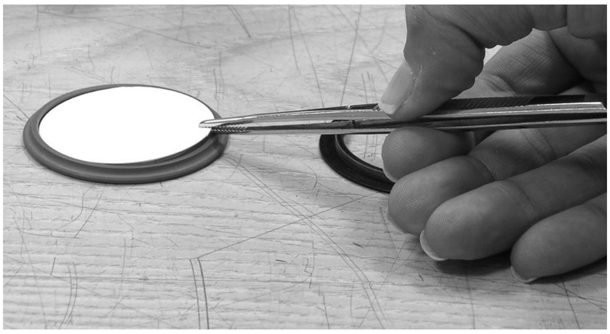
The table below shows the instrumental autonomy depending on the programmed operating mode:

Mode	Number of loader filters	**Autonomy expressed in days, before entering in reserve (see note 1)**
Monitor A&B	36	**14**
	72	**32**
Monitor A	36	**28**
	72	**64**
Reference mode	36	**14**
	72	**32**

4.7 INSERTION OF THE FILTER MEMBRANES IN THE FILTER CARTIDGES

The filter membrane must be inserted in the apposite housing of the upper disc.





Once the filter membrane has been inserted, put the lower disc of the filter cartridge on the upper one, as shown in figures 4.2a and 4.2b. Then press with the fingers all long the circumference till the two discs are completely pressure coupled.

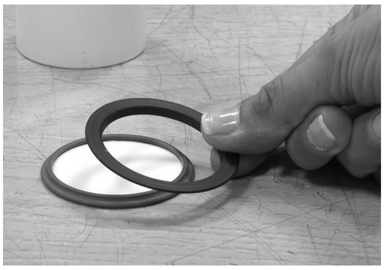


figure 4.2a

figure 4.2b

figure 4.2c

Once coupled the two discs, the lower part of the complete filter is hollow (see figure 4.2d). Inserting the filters inside the virgin filters Loader, make sure that each filter cartridge has the hollow part turned downwards (see paragraph 4.6 “Virgin filters loader filling”).

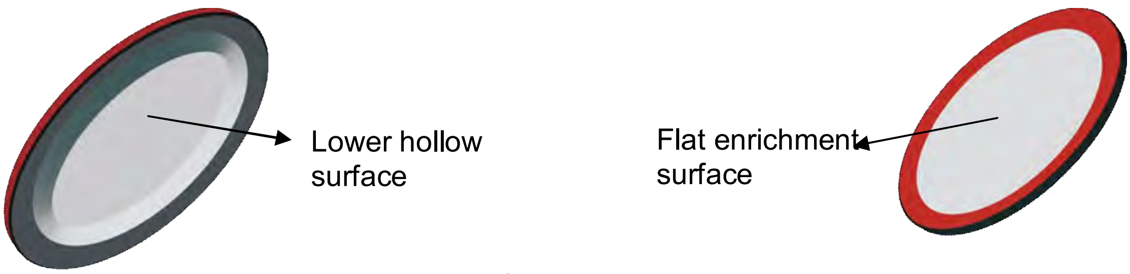


figure 4.2d

figure 4.2e

The colour of the filter cartridge discs is not relevant for their correct positioning inside the Loader. FAI Instruments supplies filter cartridges with different colour couplings (white-black, white-white, etc).
The fundamental element for the correct positioning of the filter cartridges is the surface shape. The complete filter must be inserted inside the Loader with the hollow part turned downwards, since the hollow shape of the lower disc corresponds to the upper surface of the loading and unloading pistons and with the filter pressers (see paragraph 4.1 and 4.8).

4.8 INSERTION OF THE FILTER MEMBRANES IN THE "LOADER"

In order to insert virgin filters in the Loader (not interchangeable with the sampled filters *Unloader*), disconnect the Loader turning it anticlockwise and make sure that each filter cartridge gets in the lower part of the *Loader* with the hollow part turned downwards. It's important to respect the filter insertion direction, considering that they will be loaded depending on their starting position inside the Loader. In all operative modes – except for Monitor Mode Line A and Monitor Mode Line B - the filter insertion sequence must be the one shown in figure 4.3 (filter A – filter B)

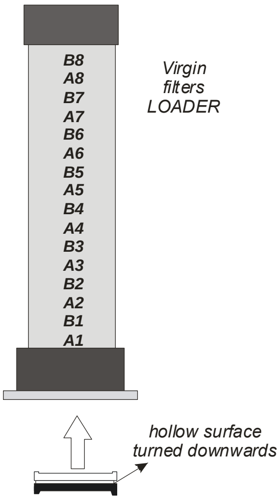


figure *4.3*

In *Monitor Mode Line A* and *Monitor Mode Line B* the filter insertion sequence must be the one shown in figure 4.4. The three first filters loaded on the plate won't be used in accumulation phases and they will serve as additional "spy filters". All the filters next loaded will be used for the samples accumulation.

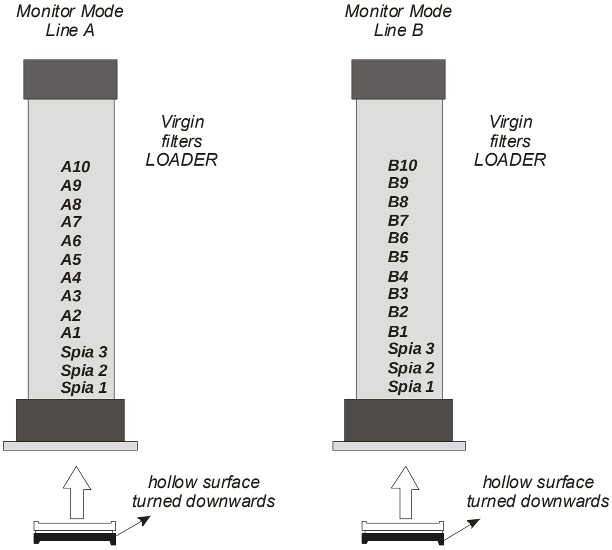


figure *4.4*

For the filters insertion in the *Loader* use the apposite accessory (figure 4.5A), supplied with the instrument. Rest the filter cartridges on it with the hollow part turned downwards and make lift the Loader on it as shown in figure 4.5B.

figure *4.5A*

figure *4.5B*

If the *Loader* is not empty and you want to add new virgin filters respecting the order of the filters already inside the Loader, we suggest to use the apposite accessory (figure 4.5C, not included in the standard supply of the instrument) and follow this procedure:

1- assemble the accessory for the filters unlocking putting the ring (b) on the accessory for the filters insertion (a)
2- insert the *Loader* on it
3- rotate the *Loader* clockwise stopping the unlocking ring (b) with a hand
4- lift the *Loader* paying attention to keep the filters pile
5- get out the presser (c) and add the new virgin filters to the pile
6- before loading the filters in the Loader, insert back the presser in it with the hollow part turned upwards

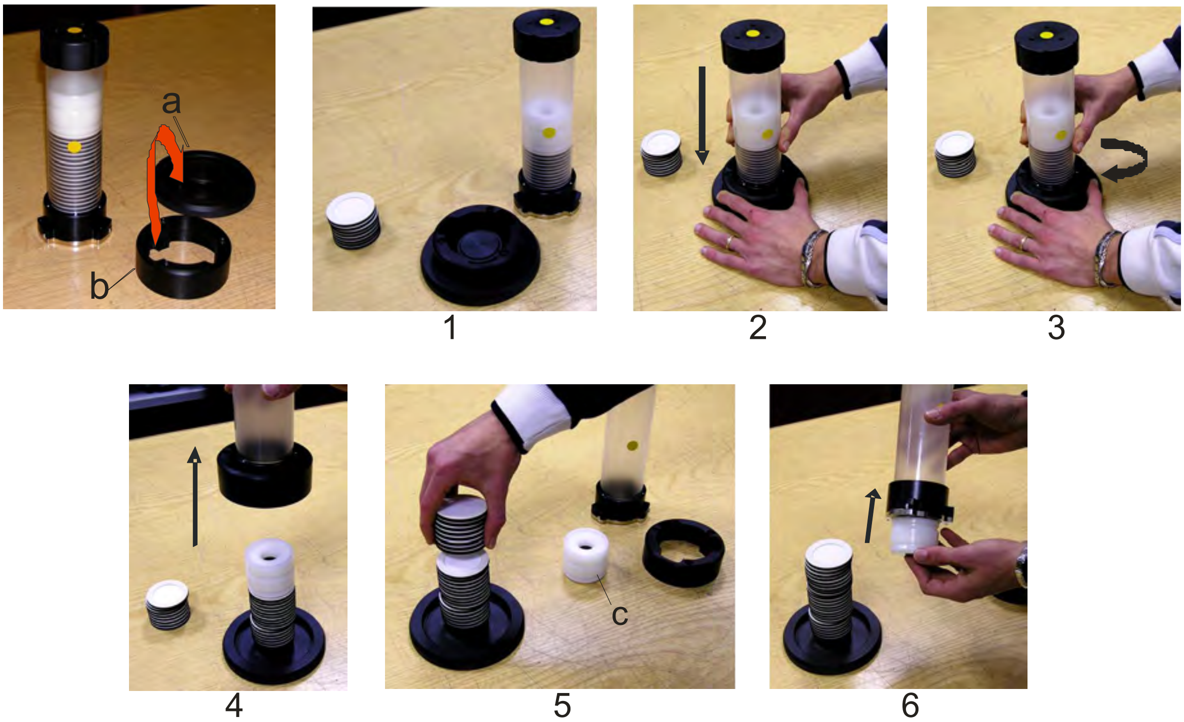


figure 4.5C

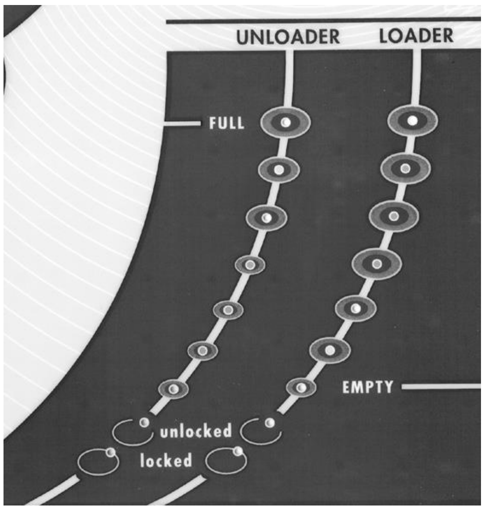
It is possible to add new virgin filter in the *Loader* even during the sampling without stopping the cycle.

In order to start the sampling and measurement cycles insert at least 8 virgin filters in the Loader.

After having loaded the virgin filters, to insert the Loader in the apposite seat (the right one looking the front of the instrument) rotate it clockwise with a resolute movement, till you'll listen the click of the mechanical block

This operation opens the Loader filters lock system, making the filters go down to the sampling unit.

On the LOADER control panel the green led *locked* lights up and simultaneously the red led *unlocked* turns off. In these conditions the *EMPTY* led is off and the green led, signaling the filters presence in the *Loader*, flashes to point out that the filters have been loaded.



The yellow led on the Loader control panel signals that the filters are running out. When the Loader is empty, the red led *EMPTY* lights up.

4.9 FILTER MEMBRANES REMOVAL FROM THE UNLOADER

At the end of every sampling and measurement cycle the instrument will immediately move the processed filters to the Unloader. The filters inside the Unloader will have, depending on the used sampling mode, the order shown in figure 4.5D.
In *Monitor Mode Line A* and in *Monitor Mode Line B* the three spy filters are unloaded only at the end of the *Ending* phase (see par. 5.9.2) or at the end of the *Abort* procedure (see par. 5.9.1)

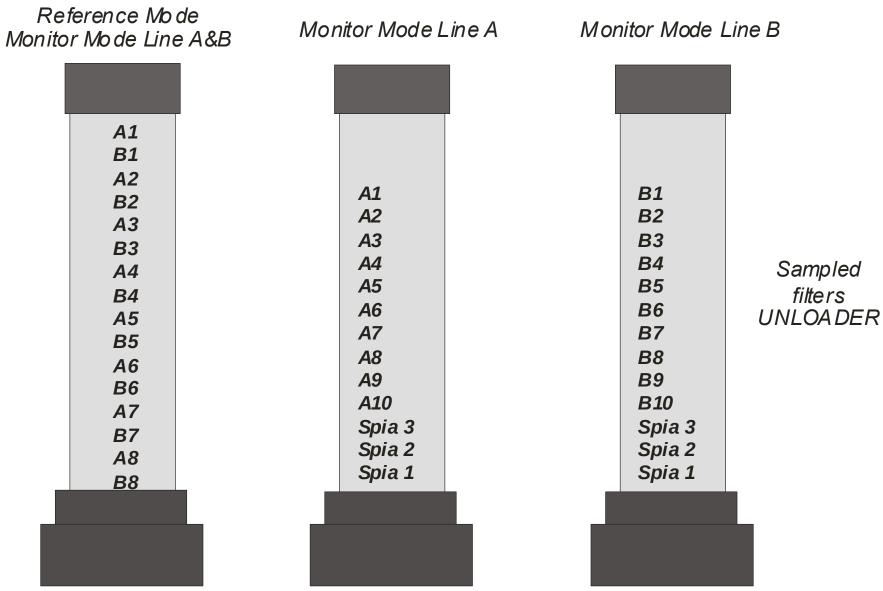


figure *4.5D*

At every virgin filters loading, in order to avoid the *Unloader* overload, all the filters already sampled must be unloaded.

In order to draw out the filters from the sampled filters *Unloader* follow the steps below:

- disconnect the *Unloader* turning it anticlockwise
- quickly overturn the Unloader (figure 4.6A)
- keep it in vertical upside down position and put it on a surface (figure 4.6B)
- delicately take the pipe off the plug and lift it taking care of keeping the filters pile (figure 4.6C)

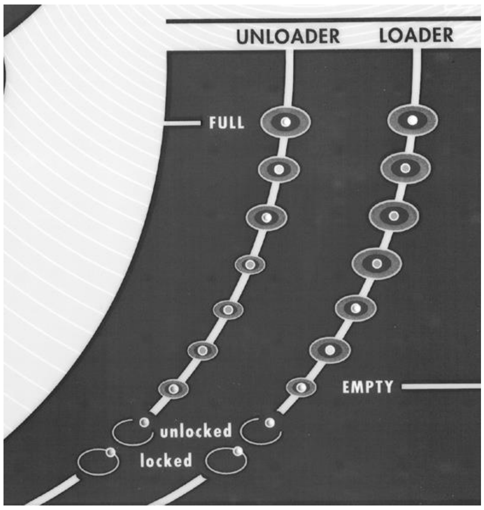
figure *4.6A*

figure *4.6B*

figure *4.6C*

Before inserting again the sampled filters *Unloader* in the apposite seat, make sure that the presser has been correctly inserted (see figure 4.6).

To insert the sampled filters *Unloader* in the apposite seat (the left one looking the front of the instrument) turn it clockwise till you'll listen the click of the mechanical block.
On the UNLOADER control panel the green led *locked* will light up and simultaneously the red led *unlocked* will turn off. The UNLOADER control panel shows the progressive Unloader filling till the achievement of the maximum capacity, that makes the red led FULL light up.



Removing for over 10 seconds the sampled filters Unloader, the sampler assumes that all filters have been unloaded from the Unloader and then, after its readjustment, it considers it empty.

4.9.1 Removal of the membranes from the filter cartridge

To quickly and easily open the filter cartridges we recommend the use of the apposite tool made by FAI Instruments (figure 4.7, accessory not included in the standard supply of the instrument – see the optional accessories and spare parts list in Appendix 9).

Putting a complete filter in the apposite housing and pushing the lever, the two discs of the filter cartridge uncouple.

figure *4.7*

To remove the filter membrane from the filter cartridge:

Insert the filter cartridge in the apposite housing **with the sampled surface of the filter turned downwards.**

figure *4.8*

Press resolutely the levers so that the two discs uncouple.

figure *4.9*

Remove the upper disc

figure *4.10*

Using a tweezers, draw the filter membrane out of the filter cartridge, as shown in figure 4.11 and 4.12.

figure 4.11

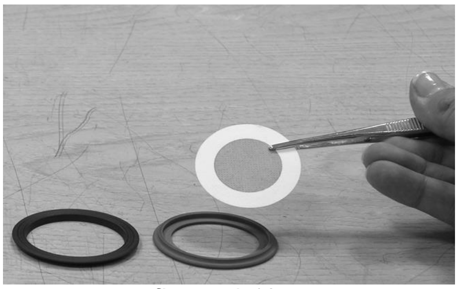
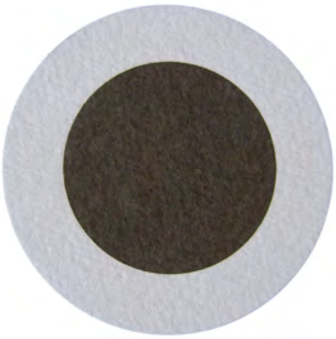


figure 4.12

NOTE:
The sample image on the filter must be homogeneous and the outline of the sampling surface must be well-defined (see figure 4.13, example of a 7.07cm² β spot area).
If the sample image has clear inhomogeneities, due for example to the presence of condensation water (see figure 4.14), drain the condensation collection system (see par. 8.1.2).

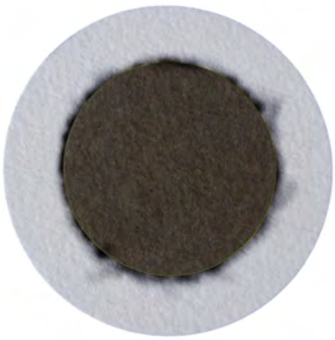
If the outlines of the sampling surface are not well-defined (see figure 4.15), there could be problems connected to the seal of the filter cartridge-filter presser system: in this case, please contact FAI Instruments srl.

In both cases (figures 4.14 and 4.15) the mass concentration data referred to the filter must be considered invalid.



4.13

4.14



4.15

4.10 AUTOMATIC CONTROLS ON THE FILTER MEMBRANES LOADING

If a filter cartridge has been inserted in the Loader upside-down or without filter membrane by mistake, the instrument operates as follows, depending on the programmed operating mode (see chapter 3):

- In "Monitor Mode Line A" and in "Monitor Mode Line B" the upside-down or without membrane filter cartridge will be unloaded and it will be replaced by a new virgin membrane (the following one in the reserve).
- In the other Modes, where both the lines are active, the pair of filters containing the upside-down (or without membrane) filter cartridge will be replaced. The unloaded pair will be replaced by the following one in the reserve.

In both cases this event will be stored in the Buffer Data and it will be signalled by a Warning message (Warning 10, see Appendix 8).

CHAPTER 5

5. SAMPLING CYCLES

5.1 INSTRUMENT- OPERATOR INTERFACE

ENTER	*It allows the data entry and/or the functions start*
ESC	*It allows to go back to the previous menu, till the first one and to cancel numeric input*
YES / NO	They allow whether or not to accept the proposed options, or to select values
SELECT	It allows to scroll the menu
ESC + NO	Pressing the two buttons at the same time allows to RESET the instrument

5.2 CONTROLS AND INDICATORS

STATUS	*Green LED (OK) - no anomalies* *Yellow LED (Warning) - alert/warning situations* *Red LED (Alarm) - instrument malfunction*
SERVICE AIR	*Yellow LED (Over pressure) – service compressed air overpressure* *Green LED (OK)* – optimum service compressed air pressure *Red LED (Low pressure) - service compressed air pressure value too low*
BATTERY LEVEL	*Green LED (OK) – live battery* *Red LED (Low)* – flat battery
LOADER	*Yellow LED – almost empty virgin filters Loader* *Flashing Green LED–it marks that virgin filters have been loaded* *Green LED – full virgin filters Loader* *Green LED (locked) – filters Loader correctly connected* *Red LED (unlocked) – filters Loader not connected* *Red LED (FULL) – full sampled filters Unloader*
UNLOADER	*Yellow LED – almost full sampled filters Unloader* *Green LED – the sampled filter Unloader is empty or it can admit filters* *Green LED (locked) – filters Unloader correctly connected* *Red LED (unlocked) – filters Unloader not connected*
PNEUMATIC MODULE	*Green LED –Pneumatic module correctly connected* *Red LED – Pneumatic module not connected*
PUMP A	*Green LED – vacuum pump Line A on*
PUMP B	*Green LED – vacuum pump Line B on*

5.3 OPERATING STATUS

STATUS: READY	*The instrument is ready to start a sampling and measurement cycle.* *It's possible to read data, to set instrumental and sampling parameters, to carry out tests and checks.*
STATUS: DELAY	*The instrument has been programmed (start) and it will start the sampling and measurement process at the programmed date and time. It is possible to read data and to modify some instrumental parameters. If needed, you can stop the starting procedure.*
STATUS: SAMPLING	*The instrument is sampling and measuring. It is possible to read data and information relative to the sampling and to the mass measurement. If needed, you can stop the sampling sequence.*
STATUS: ENDING	*No filters in the Loader and in the reserve for the continuation of the programmed cycles, the sampling and the measurement processes go on till the last filter on the plate*
STATUS: ALARM	*The instrumental functionality has been compromised by an anomaly that caused the interruption of the sampling and measurement cycles. After having removed the anomaly causes, reset the instrument pressing simultaneously the two buttons ESC + NO [▾]. So the instrument will go back to the Ready status.*
STATUS: TEST	*The instrument is performing the automatic tests on the servomechanisms and sensors functionality, on the pneumatic circuit and on the mass measurement system.*

5.3.1 Instrument in sampling

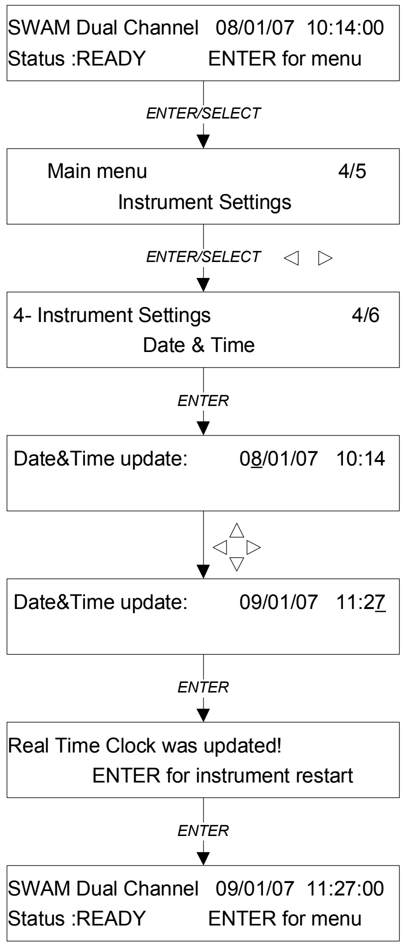
The instrument works in subsequent **cycles**. The duration of one cycle corresponds to the duration of the sampling process carried out on each filter membrane (*timing*: 8-12-24-48-72-96-120-144-168 hours).

The particulate matter samples are accumulated on the membranes and the mass measurement process will be carried out on them. During each membrane pair measurement, the following membrane pair is in sampling.

5.4 DATE AND TIME SETTING

Before starting the sampling and measurement cycles, it could be necessary to update date and time of the instrument. To set date and time follow the procedure below:

1. With the instrument in READY Status, press ENTER to have access to the main menu.
2. Using the Select button, select the “Instrument Settings” menu and press ENTER to access.
3. Using the Select button, select the “Date & Time” menu and press ENTER.
4. Using the Select buttons, move the cursor to the number to be modified (to modify one number of the date use the YES/NO buttons).
5. Once correct date and time have been programmed, press ENTER.
6. Press ENTER again to confirm the date and time update and wait till the display will show again the main window.



Note: the date and time update can be performed only when the instrument is in READY Status.

5.5 SAMPLING AND MEASUREMENT PARAMETERS SETTING (Instrument Setting)

Before starting the sampling cycles it is necessary to set the parameters relative to the sampling and mass measurement operating conditions. The programmable parameters accessible from the *Instrument Setting* menu (see figure 5.1) are:

sampling parameters of the single sampling line A and/or B

- Sampling operating flow rate in m^3/h (range 0.8÷2.5 m^3/h).
- Minimum value of the percentage ratio "$Q_{operative}/Q_{nominal}$ %" between operating and nominal flow rate.
  For example, setting to 90 this value, with a sampling nominal flow rate equal to 2.3 m^3/h and an operating flow rate lower than 2.07 m^3/h, the display and the Buffer Data show a Warning message (Warning 6, see Appendix 8).
- Minimum and maximum filter pressure drop in kPa (range 0÷60 kPa). The achievement of the load drop lower or upper limits during the sampling process is displayed and stored in the *Buffer Data* by Warning messages (Warnings 4,5,7,8 – see Appendix 8). Anyway, in order to preserve the integrity of the filter-presser porous septum, the instrument automatically stops the suction pumps if the filter pressure drop is lower than 4 kPa at a flow rate value of 2,3 m^3/h. A correct choice of the limit values to be programmed must be based on the analysis of previous field data. Usually, in order to program the load drop maximum value it is necessary to keep in mind that its value depends on the concentration levels, on the meteoclimatic sampling conditions, on the filtering medium type and on the used *ß equivalent spot area*.
- Useful sampling and measurement surface, depending on the filter cartridge type used on the sampling line (see paragraph 4.4).

instrumental parameters common to the two sampling lines

- Temperature value used for the standard volume calculation (range: 248.0÷323.0 K default value: 273.0 K).
- Pressure value used for the standard volume calculation (range: 80.0÷104.0 kPa default value: 101.3 kPa).
- Temperature value used for the impactor dimensioning to get the wanted nominal cut diameter "*Split temperature reference*" (range: 100.0÷333.0 K). The exact setting of this value is fundamental when using SWAM 5a Dual Channel Monitor in "Reference mode Split Constant Stokes Number" mode. Using standard sampling inlets manufactured by FAI Instruments S.r.l., it is necessary to set the "Split Temperature Reference" at 293 K. While using different sampling inlets, to know the correct value ton be programmed, please contact the manufacturer.

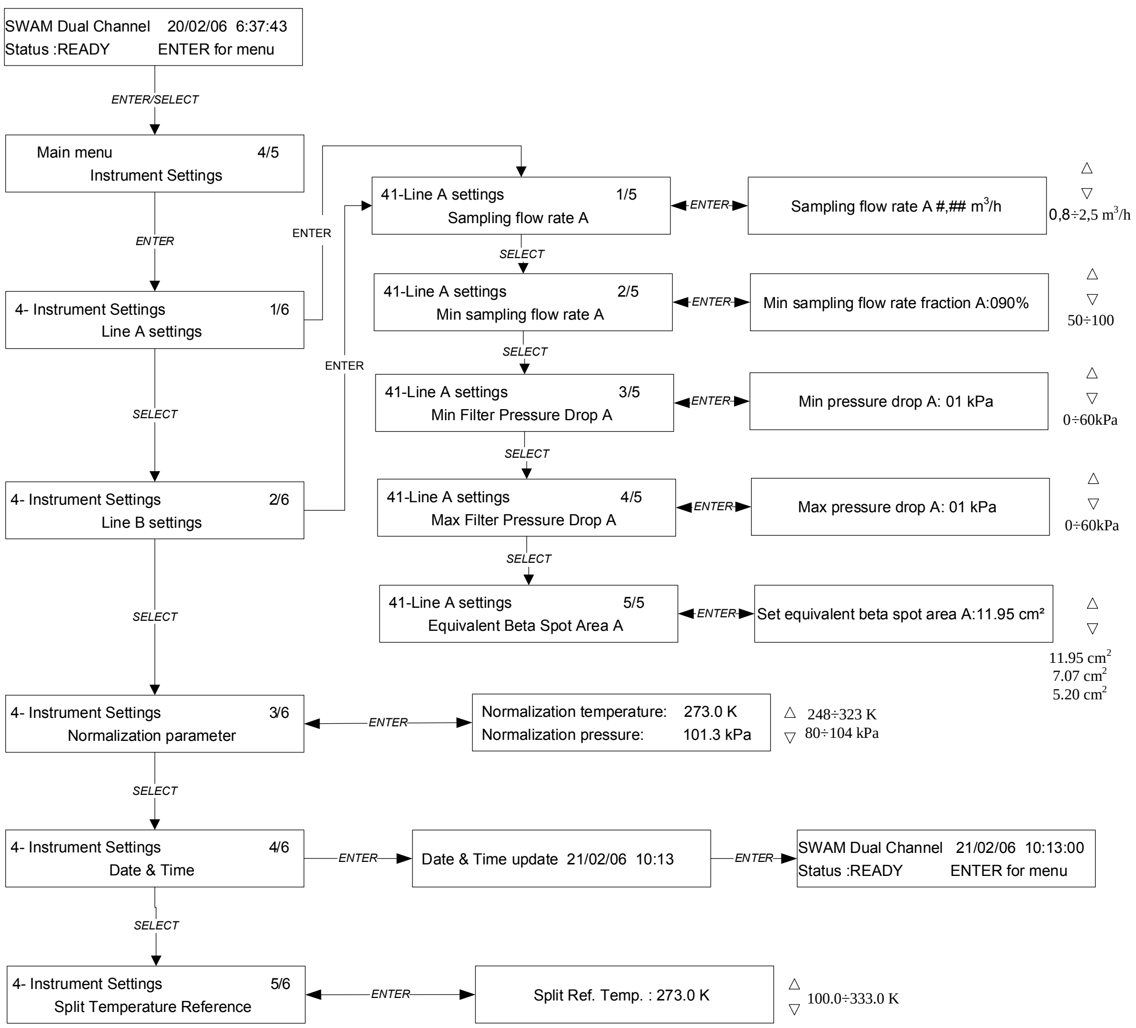


figure 5.1

If a sensor for the temperature measurement is disconnected or malfunctioning, the instrument will use 293 K as default value (Warning 24, see Appendix 8).
If you need to modify this temperature value, please contact FAI Instruments s.r.l.

To display the default value, see Appendix 2.

To enable the SMS messaging service (see par. 6.5), set the "User" and "Operator" telephone numbers before starting the sampling and measurement cycles.

5.6 INSERTION OR REPLACEMENT OF THE REFERENCE ALUMINUM FOILS

Before starting the sampling and measurement cycles, it is necessary to make sure that the two aluminum reference membranes R1 and R2, with known surface mass density, are inside the instrument. If R1 and R2 are not inside the instrument or if you need to replace them, follow the procedure below:

1. With the instrument in READY Status, press and hold for at least 5 seconds the ESC button to have access to the *Menu code* (access to support tools)
2. Using the SELECT buttons select the cose *920* and press ENTER to have access to the tool for the R1 and R2 membranes insertion or removal
3. Disconnect the sampled filters Unloader to have access to the reference membranes housings on the plate
4. Using the YES/NO buttons, select the code of the reference membrane that you want to insert or remove (R1 or R2) and press ENTER. The housing, on the rotating plate, of the selected filter cartridge will automatically move to the position corresponding to the Unloader insertion opening. Using the SELECT buttons it is possible to make just little plate clockwise or anticlockwise movements (The *Center* indicator can have values between “<5” and “5>”).
5. Insert or remove the filter cartridge containing the reference membrane, using the apposite accessory (see figures 5.3, 5.4, 5.5 – accessory not included in the standard supply of the instrument. For the optional accessories and spare parts list see Appendix 9)
6. Repeat the steps 4 and 5 of the procedure for the insertion or the removal of the second membrane.
7. Press ESC to go back to the main window.

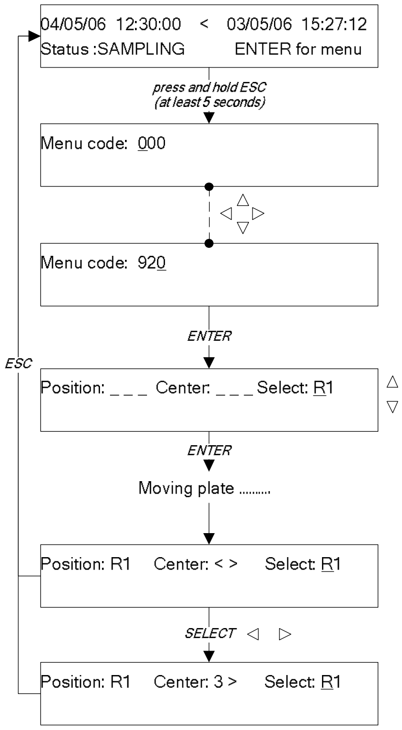


figure 5.2

figure 5.3

figure 5.4

figure 5.5

5.7 SPY FILTERS ASSEMBLING AND INSERTION

Before starting the sampling and measurement cycles, it is necessary to make sure that the three spy filters S12 S34 S56, used by the instrument during the mass measurement procedure, are inside the instrument (see paragraph 2.5.2 “*Mass measurement procedure*”). These filters must be of the same type of the filters used for the sampling. If it’s not possible to place the fitting membrane inside the metallic filter cartridges, do not insert any spy filter. The instrument will automatically manage this condition. For assembling and inserting the spy filters see the following procedures:

Spy filters assembling

To assemble the spy filters, use the apposite accessory kit (figure 5.6, not included in the standard supply of the instrument) and follow this procedure:

Step 1: lay down the filter membrane from which you want to get the spy filter on the white colored rest and press it using the apposite dinking die

Step 2: extract the obtained membrane with reduced diameter and insert it inside the aluminum filter cartridge

Step 3: close the filter cartridge using the clamping key

Step 4: using the tweezers, seize the spy filter and insert it inside the instrument

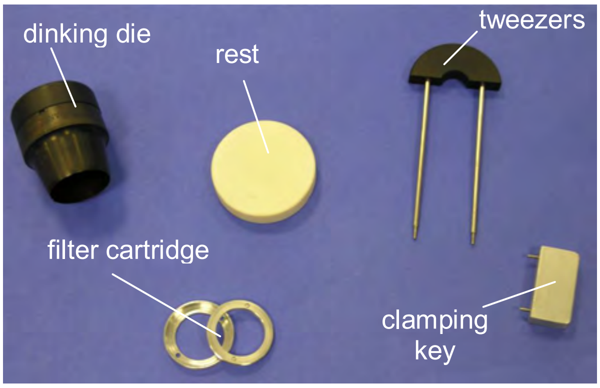


figure 5.6


step 1


step 2


step 3


step 4

Spy filter insertion and removal

1. With the instrument in READY Status, press and hold for at least 5 seconds the ESC button to have access to the *Menu code* (access to support tools)

2. Using the SELECT buttons, select the code *920* and press ENTER to have access to the tool for the S12 S34 S56 membranes insertion or removal

3. Disconnect the sampled filters Unloader to have access to the spy filters housings on the plate

4. Using the YES/NO buttons, select the code of the spy filter that you want to insert or remove (S12 – S34 – S56) and press ENTER. The housing, on the rotating plate, relative to the selected filter cartridge will automatically move to the position corresponding to the Unloader insertion opening. Using the SELECT buttons, it is possible to make little plate clockwise or anticlockwise movements (the *Center* indicator can have values between “<5” and “5>”).

5. Insert or remove the filter cartridge containing the spy filter, using the apposite tweezers (see figure 5.8)

6. Repeat the steps 4 and 5 of the procedure for the insertion or the removal of the other two membranes

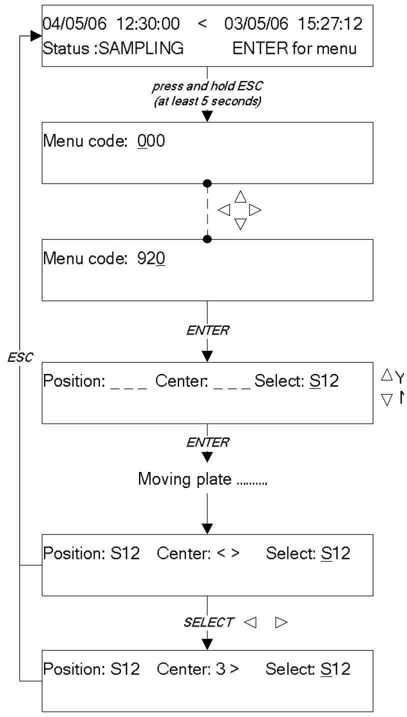


figure *5.7*

7. Press ESC to go back to the main window

figure 5.8

5.8 SAMPLING START

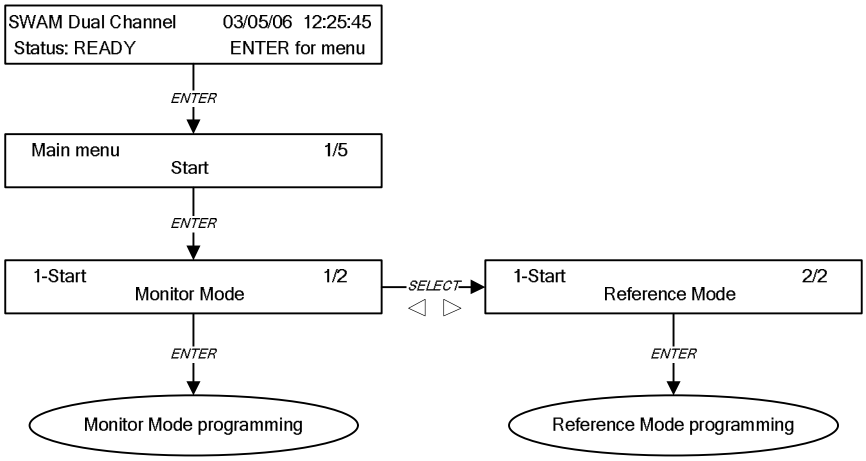
Before starting the sampling process, depending on the selected operating sampling mode (see paragraph 3 "*Description of the operating modes*"), it is necessary to:

- make sure that all the instrument units have been correctly connected
- insert the Unloader in the apposite housing and make sure that it is correctly locked (see paragraph 4.9 "*Filter membranes unloading*")
- switch on the instrument moving the general power switch to ON position
- check that the green status led on the frontal panel are on (STATUS – SERVICE AIR – BATTERY LEVEL)
- check that no filter is inside the Unloader and if some filter are present, remove them and lock back the Unloader in its housing
- make sure that the reference aluminum foils and the spy filters have been inserted inside the instrument (see paragraphs 5.6 "*Insertion or replacement* of the reference aluminum foils" and 5.7 "*Spy filters assembling and insertion*")
- check that the filters have been correctly inserted inside the Loader (see paragraph 4.8)
- insert the Loader in the apposite housing and make sure that it is correctly locked (see paragraph 4.6 "*Insertion of the filter membranes in the Loader*")
- Set the sampling and measurement parameters (see paragraph 5.5 "*Sampling and measurement parameters setting – Instrument Setting*")

NOTE: If the programmed *β equivalent spot area* is different from the one of the used filter cartridges, SWAM 5a Dual Channel Monitor will anyway perform the programmed sampling and measurement cycles, but the final mass calculus will be incorrect since the instrument will use a useful sampling area value different from the real one (see paragraph 2.5.3 "*Sample mass calculation*")

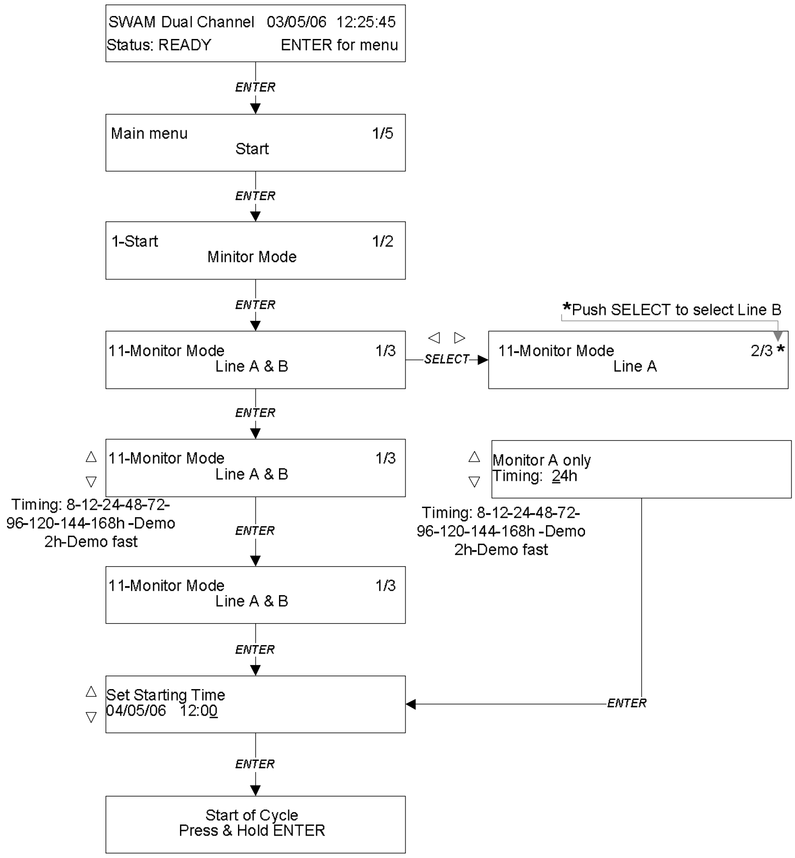
We describe here below the programming procedures to be used to start the sampling process depending on the selected operating mode: *Monitor Mode* or *Reference Mode* (see paragraph 5.8 "*Sampling Start*").

The selection of the sampling operating mode must be carried out starting from *Start* menu.



5.8.1 Sampling start in “Monitor Mode”

To start the instrument in Monitor Mode:



1 From the main window, with the instrument in READY Status, press ENTER to have access to the *Start* menu

2 from *Start* menu press ENTER to have access to the submenu and select the *Monitor Mode* pressing ENTER

3 using the SELECT buttons, select the option *LineA&B* if you want to use both he lines, or select the option *LineA* or *LineB* if you want to accumulate the sample on a single filter membrane (A or B respectively) and press ENTER to confirm your choice

4 using the YES/NO buttons, st the sampling *Timing* and press ENTER to confirm

5 set the sampling start date and time using the SELECT buttons (the display will show the first possible sampling start time) and press ENTER to confirm

6 press and hold for a few seconds ENTER in order to complete the starting procedure

5.8.2 Sampling start in "Reference Mode Normal"

To start the instrument in *Reference Mode Normal*:

1 From the main window, with the instrument in READY Status, press ENTER to have access to the *Start* menu

2 from *Start* menu press ENTER to have access to the submenu. Using the SELECT buttons, select the *Monitor Mode* and press ENTER to confirm

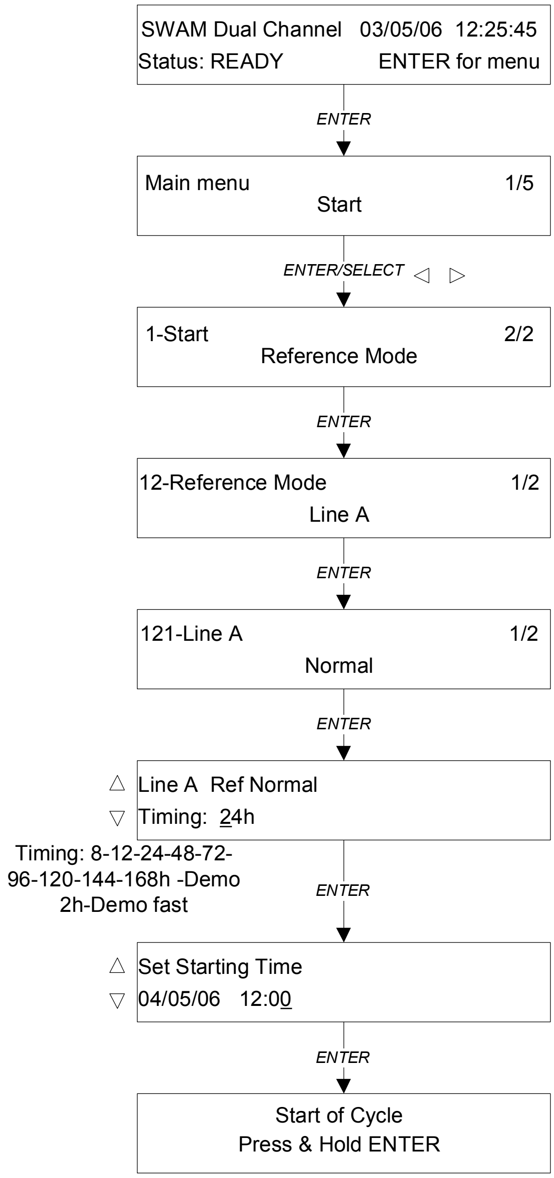
3 using the SELECT buttons, select the Line to be used for the sample accumulation (*Line A* or *Line B*) and press ENTER to confirm your choice

4 press ENTER to select the sampling *Normal* mode (available modes Normal and Split)

5 with the YES/NO buttons set the sampling *Timing* and press ENTER to confirm

6 set sampling start date and time using the SELECT buttons (the display will show the first possible sampling start time) and press ENTER to confirm

7 press and hold for a few seconds the ENTER buttons to complete the starting procedure



5.8.3 Sampling start in “Reference Mode Split Constant flow rate”

To start the instrument in *Reference Mode Split “Constant flow rate”*:

1. From the main window, with the instrument in READY Status, press ENTER to have access to the *Start* menu
2. from *Start* menu press ENTER to have access to the submenu. Using the SELECT buttons, select the *Reference Mode* and press ENTER to confirm
3. using the SELECT buttons, select the Line to be used for the sample accumulation (*Line A* or *Line B*) and press ENTER to confirm your choice
4. to select the *Split* mode (available modes Normal and Split), press SELECT and then ENTER to confirm your choice
5. to select the “Constant Flow Rate” option (alternative to “Constant Stokes number”), press ENTER
6. using the YES/NO buttons, set the flow rate value of the accumulation line and press ENTER to confirm
7. using the YES/NO buttons, set the sampling *Timing* and press ENTER to confirm
8. set the sampling start date and time using the SELECT buttons (the display will show the first possible sampling start time) and press ENTER to confirm
9. press and hold for a few seconds the ENTER buttons to complete the starting procedure

SWAM Dual Channel 03/05/06 12:25:45
Status: READY ENTER for menu

↓ ENTER

Main menu 1/5
Start

↓ ENTER/SELECT ◁ ▷

1-Start 2/2
Reference Mode

↓ ENTER

12-Reference Mode 1/2
Line A

↓ ENTER/SELECT ◁ ▷

121-Line A 2/2
Split

↓ ENTER

Flow adj mode: Cons flow rate

↓ ENTER

△▽ Acc. flow rate A :1.84 m³/h

↓ ENTER

△ Line A ref split
▽ Timing: 24h

Timing: 8-12-24-48-72-96-120-144-168h -Demo 2h-Demo fast

↓ ENTER

△ Set Starting Time
▽ 04/05/06 12:00

↓ ENTER

Start of Cycle
Press & Hold ENTER

5.8.4 Sampling start in "Reference Mode Split Constant Stokes number"

To start the instrument in Reference Mode Split Constant Stokes number:

1 From the main window, with the instrument in READY Status, press ENTER to have access to the *Start* menu

2 from *Start* menu press ENTER to have access to the submenu. Using the SELECT buttons, select the *Reference Mode* and press ENTER to confirm

3 using the SELECT buttons, select the Line to be used for the sample accumulation (*Line A* or *Line B*) and press ENTER to confirm your choice

4 to select the *Split* mode (available modes Normal and Split), press the SELECT button and then ENTER to confirm your choice

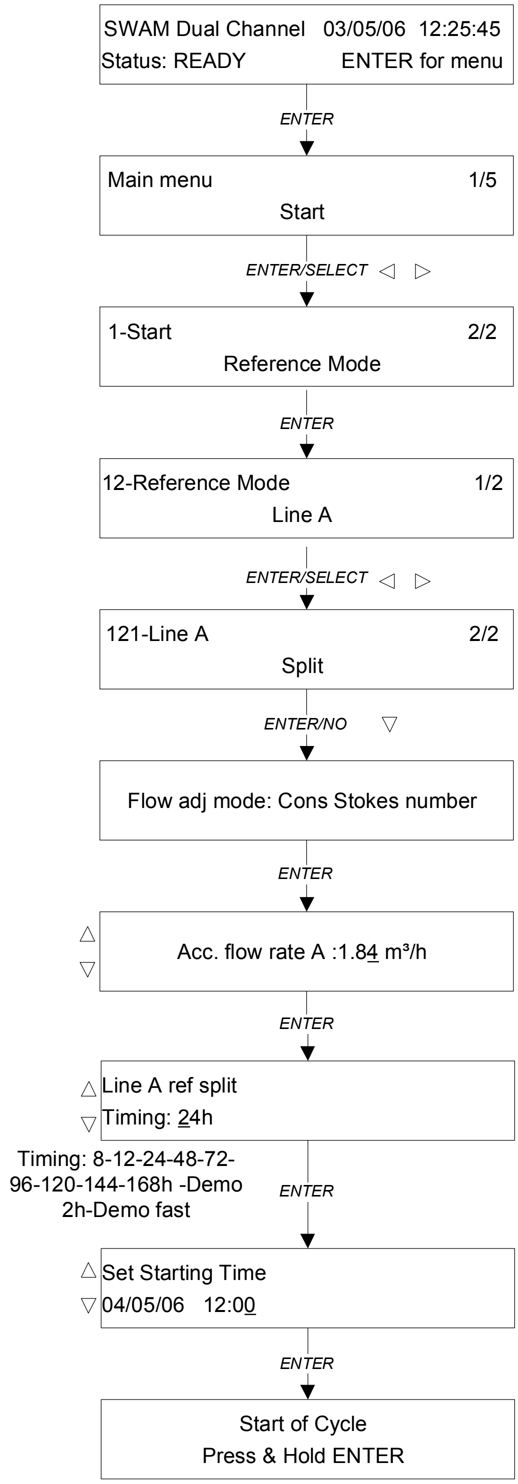
5 to select the "Constant Stokes number" option (alternative to "Constant flow rate"), press SELECT and confirm your choice pressing ENTER

6 using the YES/NO buttons, set the flow rate value of the accumulation line and press ENTER to confirm

7 using the YES/NO buttons, set the sampling *Timing* and press ENTER to confirm

8 set the sampling start date and time using the SELECT buttons (the display will show the first possible sampling start time) and press ENTER to confirm

9 press and hold for a few seconds the ENTER buttons to complete the starting procedure

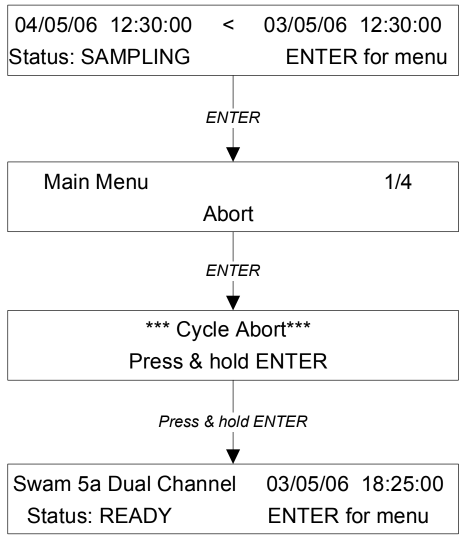


5.9 SAMPLING STOP

5.9.1 Manual interruption using the Abort procedure

To stop the sampling and measurement cycles, select *Abort* from the main menu and press and hold for a few seconds the ENTER button.
The instrument stops the sampling in process and unloads the filters from the plate. If you want to remove the filters in the reserve and in the Loader too, use the *Unloading* procedure (see paragraph 5.10 "*Filters removal – Unloading procedure*").

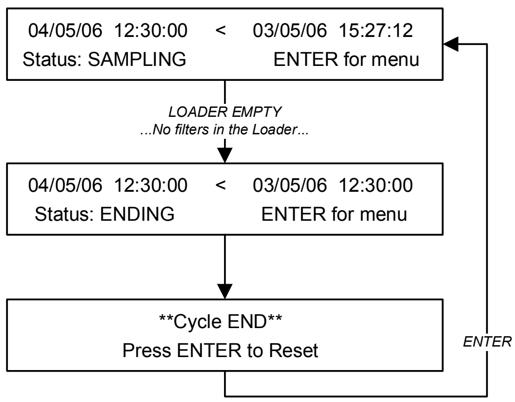
Note:
A Warning message is displayed (Warning 21, see Appendix 8) in the Buffer record relative to the stopped sampling and measurement cycle.



5.9.2 Automatic interruption of the sampling cycles due to lack of filters "ENDING"

If during the sampling and measurement cycles the virgin filters in the Loader and in the reserve run out (Loader EMPTY), the instrument will pass automatically to the ENDING Status.
The sampling and measurement processes will go on for all the filters on the plate. After the last filer the instrument will stop.
Then it will be necessary to insert new virgin filters in the Loader and to repeat the sampling start procedure.

<u>**Note**</u>**:**
The access to Ending Status prevents from loading new virgin filters on the plate



5.10 FILTERS REMOVAL “Unloading” procedure

In order to remove all the filters inside the instrument (from the rotating plate, from the reserve and from the Loader), use the “***Filters unloading*** ” procedure available in the *“Instrument tools / Mechanics direct control*” menu (see figure 5.9).

In this case, the order of the unloaded filters won’t respect the Loader filling order.

SWAM Dual Channel 03/05/06 12:25:45
Status: READY ENTER for menu

ENTER/SELECT ◁ ▷

Main menu 5/5
Instrument Tools

ENTER/SELECT ◁ ▷

5-Instrument tools 2/4
Mechanics Direct Control

ENTER

52-Mechanics Direct Control 1/9
Filters Unloading

ENTER

Press ENTER to Start

ENTER

Unloading………..

figure *5.9*

5.11 “RESET” PROCEDURE

If a “reset” of the instrument is needed, press simultaneously for at least 3 seconds ESC and NO buttons on the frontal control panel. At the end of the reset procedure the instrument enters Ready Status.

figure 5.10

CHAPTER 6

6. SAMPLING AND MEASUREMENT DATA

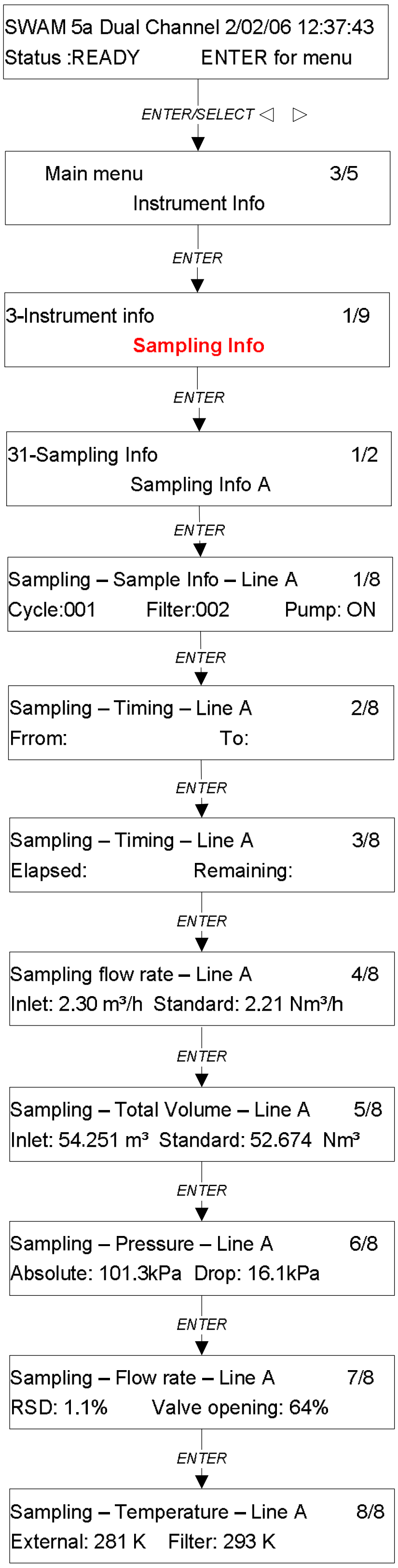
6.1 AVAILABLE INFORMATION DURING THE SAMPLING PROCESS (Instrument Info)

During the sampling and measurement cycles, the following information are available, from the *Instrument Info* menu:

- *Sampling Info* information about the sampling cycle in process
- *Beta Info* information about the mass measurement
- *Test Info* information about pneumatic tests, mass measurement system and power supply system
- *Program Info* information about the programmed sampling and measurement cycles
- *System Info* information about the instrument and the general working condition
- *Warnings Info* information about possible Warning messages
- *OPC Info* information about the optional unit “Optical Particle Counter”
- *About* information about the instrumental management software
- *GSM signal* information about the GSM modem

The schemes in the following pages show the structure of the main submenus of the *Instrument Info* item

6.1.1 Sampling Info



Available information about the sampling in progress:

Sample Info
- Cycle: number of the cycle in progress
- Filter: number of the filter in sampling
- Pump: vacuum pump status (On/Off)

Timing
- From: sampling start date and time
- To: sampling end date and time
- Elapsed: elapsed time
- Remaining: remaining time

Sampling flow rate
- Inlet: inlet operating flow rate
- Standard: operating flow rate brought back to the programmed standard conditions (default value: 273.1 K and 101.3 kPa)

Total Volume
- Inlet: total sampled volume
- Standard: total sampled volume brought back to the programmed standard conditions (default value: 273.1 K and 101.3 kPa)

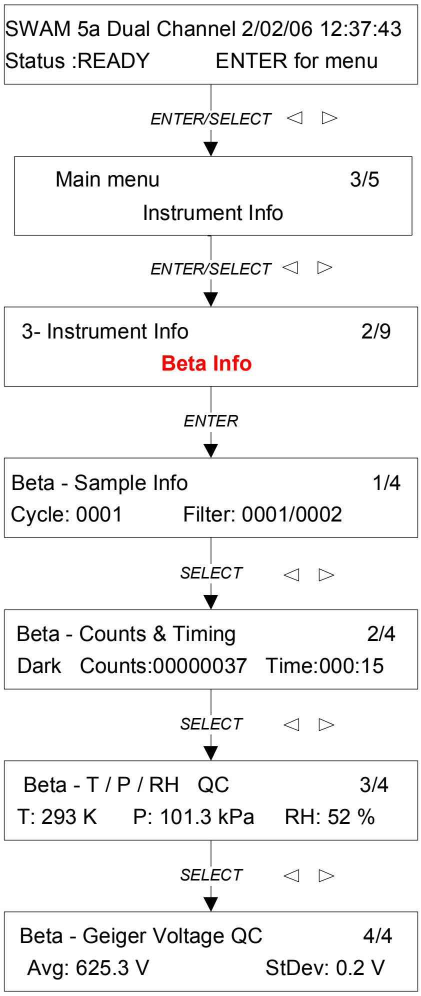
Pressure
- Absolute: atmospheric pressure value
- Drop: filtering medium pressure drop

Sampling flow rate
- RSD: variabile describing the inlet flow rate stability
- Valve opening: opening percentage of the regulation valve

Temperature
- External: external temperature value
- Filter: temperature value in the accumulation area

Note 1: if, due to a power down during the blank measurement step, the sampling didn't stop at the programmed date and time, the string "*over time*" is displayed instead of the remaining time.

6.1.2 Beta Info



Available information about the mass measurement in progress. If the instrument is not performing any measurement process, some information won't be available.

Sample Info

- Cycle: number of the cycle in progress
- Filter: identification number of the filters in measurement
  (for example 0001/0002 = filters 1 and 2)

Counts & Timing

- Counts: instantaneous value of the counts per minute
- Time: remaining measurement time

None= no filters in measurement
Dark= background noise measurement
Air= "air" counts measurement
CountA= measurement filter A position
Ref= spy filter measurement
CountB= measurement filter B position

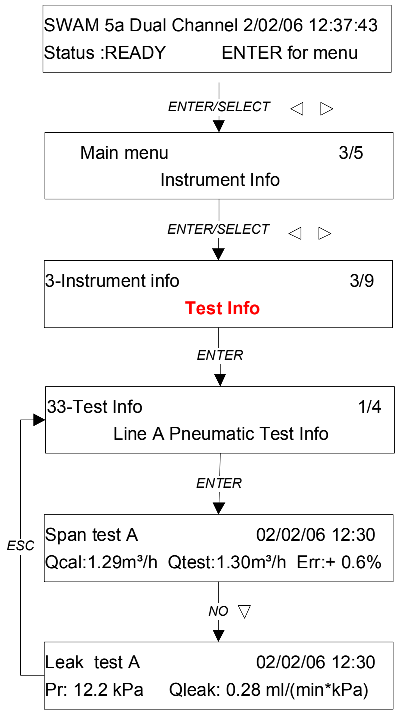
Beta – T/P/RH QC

- T: temperature in the measurement area
- P: pressure in the measurement area
- RH: relative humidity inside the instrument

Beta – Geiger Voltage QC

- Avg: average value of the Geiger detector high voltage
- StDev: associated standard deviation of the power supply high voltage measurements

6.1.3 Test Info



Information available in SAMPLING Status about the automatic tests performed by the instrument

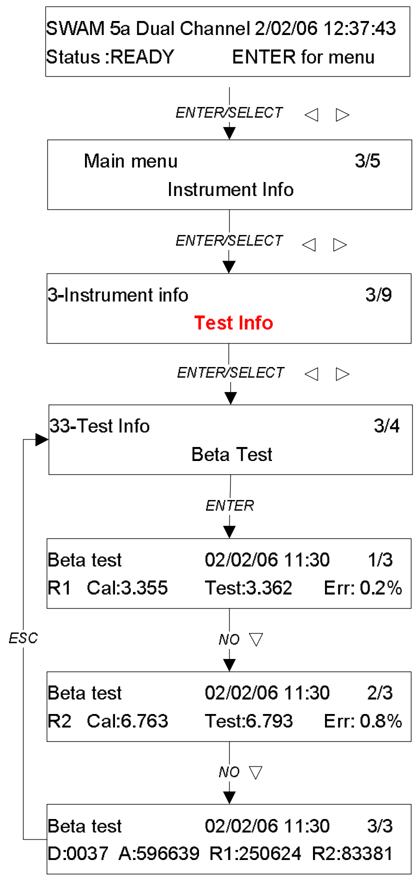
Line A/B pneumatic test Info: indicates the sampling line the tests refer to (see paragraphs 7.1.1 and 7.1.2)

Span test A/B:

- Test date and time
- Qcal: reference flow rate value
- Qtest: measured flow rate value
- Err: percentage deviation

Leak test A/B:

- Test date and time
- Pr: residual pressure
- Qleak: specific leak

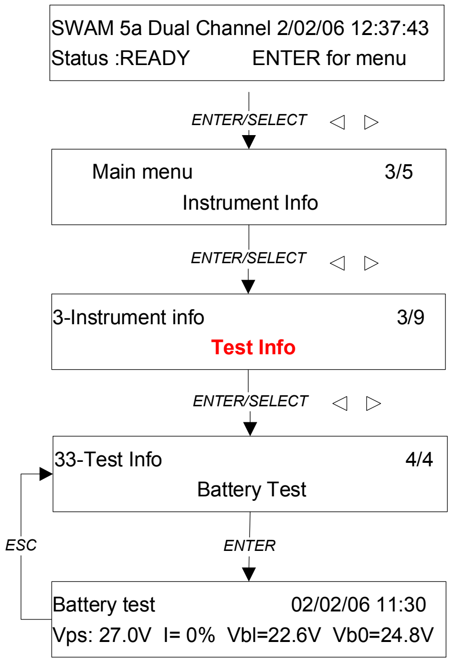


Information available in SAMPLING Status about the automatic tests performed by the instrument

Beta test: contains information about the automatic test of the mass measurement system calibration check (see paragraph 7.2.2)

Beta test:

- Test date and time
- R1: number of the reference aluminium foil that the data refer to
  - Cal: nominal value of the mass surface density
  - Test: mass surface density value measured during the test
  - Err: percentage deviation between the two values
- R2: number of the reference aluminium foil that the data refer to
  - Cal: nominal value of the mass surface density
  - Test: mass surface density value measured during the test
  - Err: percentage deviation between the two values
- D: background radioactivity counts
- A: “air” counts
- R1: membrane R1 counts
- R2: membrane R2 counts

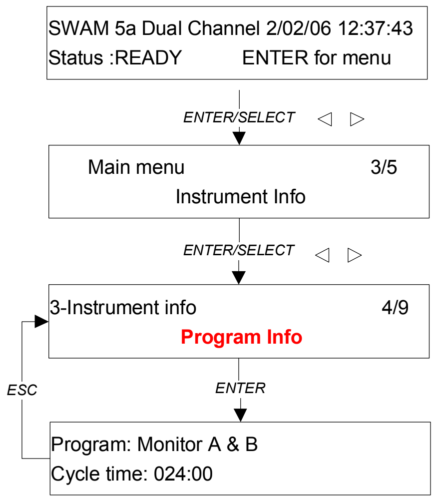


Information available in SAMPLING Status about the automatic tests performed by the instrument

Battery test: contains information concerning the automatic test of the floating batteries status check (see paragraph 7.3)

- Test date and time
- Vps: internal instrumental working high voltage
- I: battery charging rate
- Vbl: load battery voltage
- Vb0: no-load battery volatge

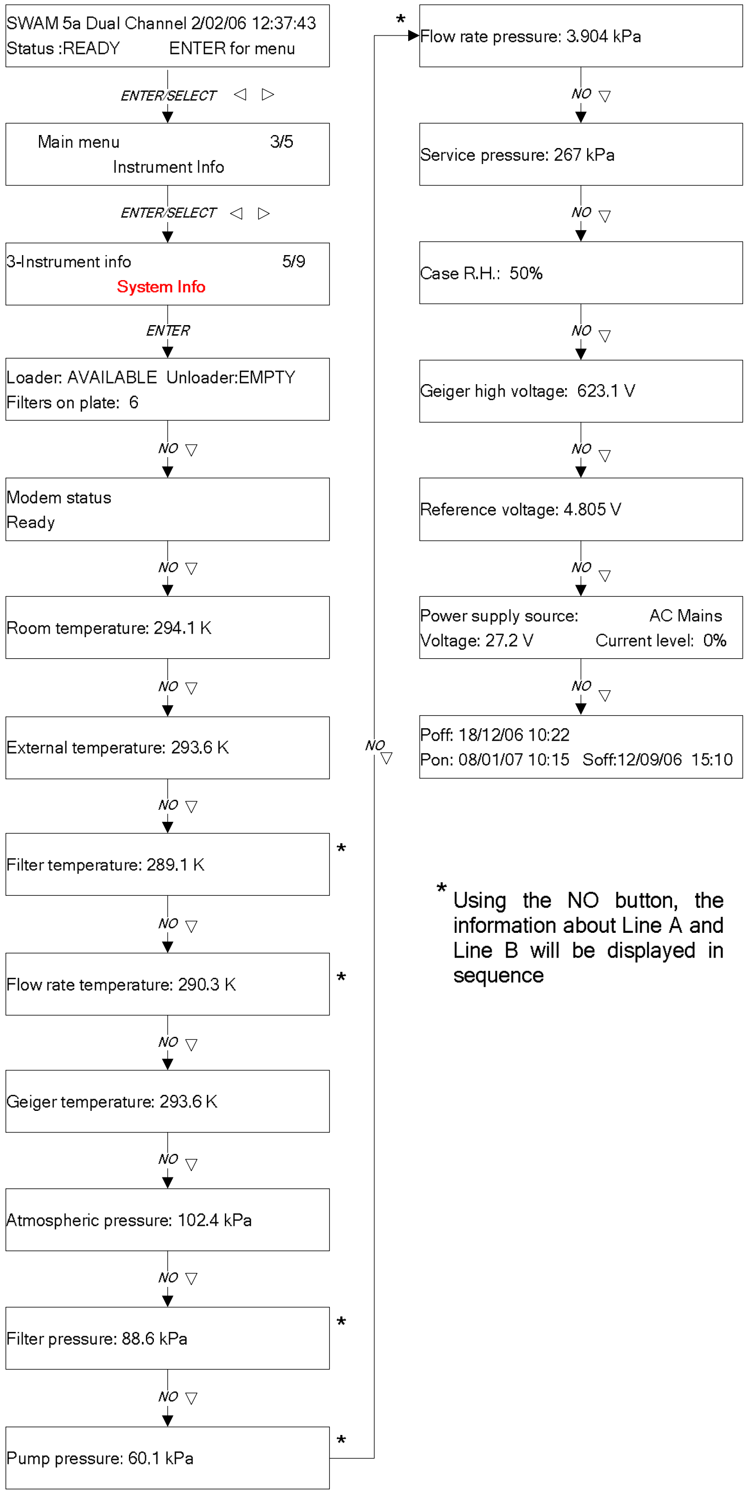
6.1.4 Program Info



Information available in SAMPLING Status about the programmed sampling and measurement cycles

- Program: programmed operating mode
- Cycle time: sampling and measurement cycle duration

6.1.5 System Info

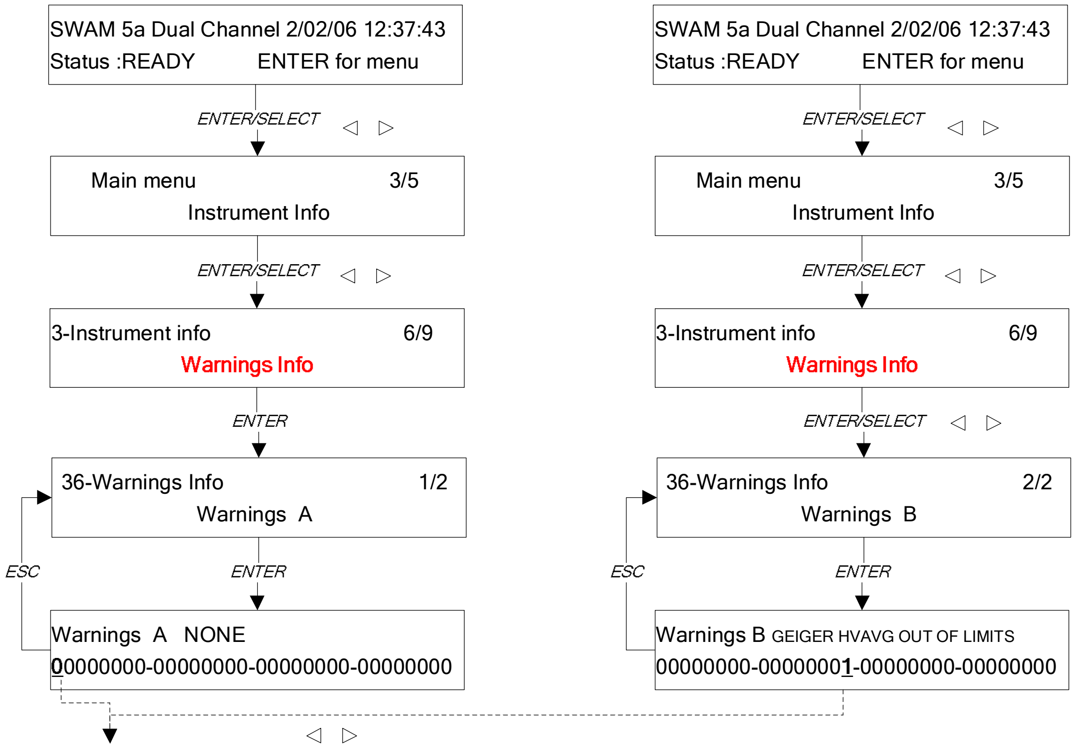


Available information in *SAMPLING Status*

- Loader: virgin filters Loader status
- Unloader: sampled filters Unloader status
- Filters on plate: number of filters on the plate
- Modem status: GSM modem status
  - Ready
  - Not ready
- Room temp.: cabinet temperature
- External temp.: external temperature
- Filter temp.: temperature of the A or B accumulation area
- Flow rate temp.: temperature of the sampled air flow line A or B
- Geiger temp.: Geiger detector temperature
- Atmospheric press.: atmospheric pressure
- Filter press.: Pressure value in the A or B accumulation area
- Pump press.: vacuum pump A or B pressure
- Flow rate press.: pressure of the sampled air flow line A or B
- Service press.: service pressure
- Case RH: relative humidity inside the instrument
- Geiger high voltage: Geiger detector high voltage value
- Reference voltage: reference internal voltage
- Power supply source:
  - AC Mains = supply mains
  - DC Battery = battery operated working
- Poff: power supply off
- Pon: power supply reset
- Soff: auto-switch-off due to exhausted batteries
- Son: switch on after an auto-switch-off

6.1.6 Warnings Info

Information available in *SAMPLING* Status about the Warnings associated with the two sampling lines (for the Warning messages interpretation, see Appendix 8):



Using the SELECT buttons, it is possible to move the cursor alonge the Warnings string. Positioning the cursor on an active bit of the string, the word NONE will be replaced by the Warning corresponding to the selcted bit

<u>Appendix 5</u> shows the complete structure of the "Instrument Info" menu

6.2 INFORMATION STORED IN THE BUFFER DATA

At the end of each sampling and measurement cycle, all the information useful for its complete characterization are stored in the Buffer Data of the instrument. The Buffer is structured in records identified by a progressive number from 000 up to 720 (maximum capacity); each record contains the sampling and measurement data relative to one sampling line.

Note: The *Buffer* has a cyclical structure. Therefore, once achieved the maximum capacity (720 records), the records are overwritten starting from number 0.

Here below you can find a synthetic list of the information contained in each record stored in the Buffer (fro the complete list of the fields and of their format, see Appendix 1):

General information

- Identification number of the record
- Date and time of the sampling cycle start and end
- Sampling cycle identification number
- Sampling line that the information contained in the record refers to

Pneumatic and instrumental information relative to the single sampling and measurement cycle

- Possible "Power Down" duration (time of battery operated working due to Power Down, see Appendix 13)

  In case of Power Down the instrument activates a Warning message (Warning 29). During the battery operated working, the suction pumps are not working. Therefore, the effective sampling duration will be lower than the programmed one.

- Result of the automatic test of the pneumatic circuit seal "Automatic Leak Test" performed at the beginning of the sampling cycle (see paragraph 7.1.1)

  If the test results are out of the programmed limit [5 ml/(min*kPa)], a Warning message will be displayed (Warning 12, Appendix 8)

- Result of the automatic test on the operating flow rate measurement system calibration "Automatic Span Test" performed at the beginning of the sampling cycle (see paragraph 7.1.2)

  If the test results are out of the programmed limit [± 4%], a Warning message will be displayed (Warning 13, Appendix 8)

- Value of the total sampled volume and of the total normalized volume at the standard programmed conditions (default: 273.1 K and 101.3 kPa)

  The temperature and pressure values used by the instrument to define the standard conditions can be programmed by the operator before starting the sampling and measurement cycles (see paragraph 5.5)

- Percentage of the effective sampling time compared with the programmed one

  The effective sampling duration compared with the programmed one is useful for the determination of the representativeness of the particulate matter sample accumulated on the filtering medium. If this duration is lower than the programmed one, a Warning message will be displayed (Warning 23, Appendix 8)

- External temperature values during the sampling process (minimum, average and maximum value)
- Temperature values near the accumulation area (minimum, average and maximum value)

  The availability of the minimum, average, maximum temperature values in the sample accumulation area is helpful for the evaluation of the sample representativeness and of the possible losses of volatile materials.

- Atmospheric pressure values (minimum, average and maximum value)
- Value of the “RDS” variable, describing the stability of the flow rate value at sampling head inlet level (see paragraph 2.4)
- Starting, final and maximum value of the filter medium load drop (see paragraphs 2.4 and 5.5)
- Maximum difference between the external temperature and the temperature in the sample accumulation area
- Date and time of the maximum detected temperature difference
- Duration of the period when the temperature difference exceeded the value 5 K
- Average value of the difference between the external temperature and the temperature in the accumulation area

Mass measurement information about the single sampling and measurement cycle

- Value of the background noise “Dark”

  If the value of the ß electrons flux measured by the Geiger Muller detector with shielded source is out of the interval 1÷150 counts per minute (see paragraph 2.6.2), a Warning message will be displayed (Warning 19, Appendix 8)

- “Air counts” value (see paragraph 2.6.2)

  The measurement of the ß electrons flux when no filtering medium interposes between source and detector gives information useful for the determination of possible slow creeps in the Geiger Muller response

- Value of the ß electrons flux through the spy filter, measured in the *Blank* session, and associated standard deviation
- Value of the ß electrons flux through the virgin filter during the *Blank* session

  This value must be between 20000 cpm and the value of the “air counts” (Warning 17, Appendix 8)

- Temperature, pressure and relative humidity in the measurement area, during the *Blank* session
- Geiger Muller high voltage value (see paragraph 2.6.2)

  As security for a correct detector functionality, this value must be in the range 610 V ÷ 640 V and the associated standard deviation must be lower than 1 V (Warnings 15 and 16, Appendix 8)

- Value of the ß electrons flux associated with the presence of natural radionuclides in the particulate matter sample accumulated on the filter

- Value of the ß electrons flux through the spy filter, measured in the *Collect* session, and associated standard deviation
- Value of the ß electrons flux measured through the sampled filter during the *Collect* session
- Temperature, pressure and relative humidity in the measurement area, during the *Collect* session
- Geiger Muller high voltage value (see paragraph 2.6.2)
- Value of the sample mass and associated uncertainty
- Value of the concentration in standard and current conditions

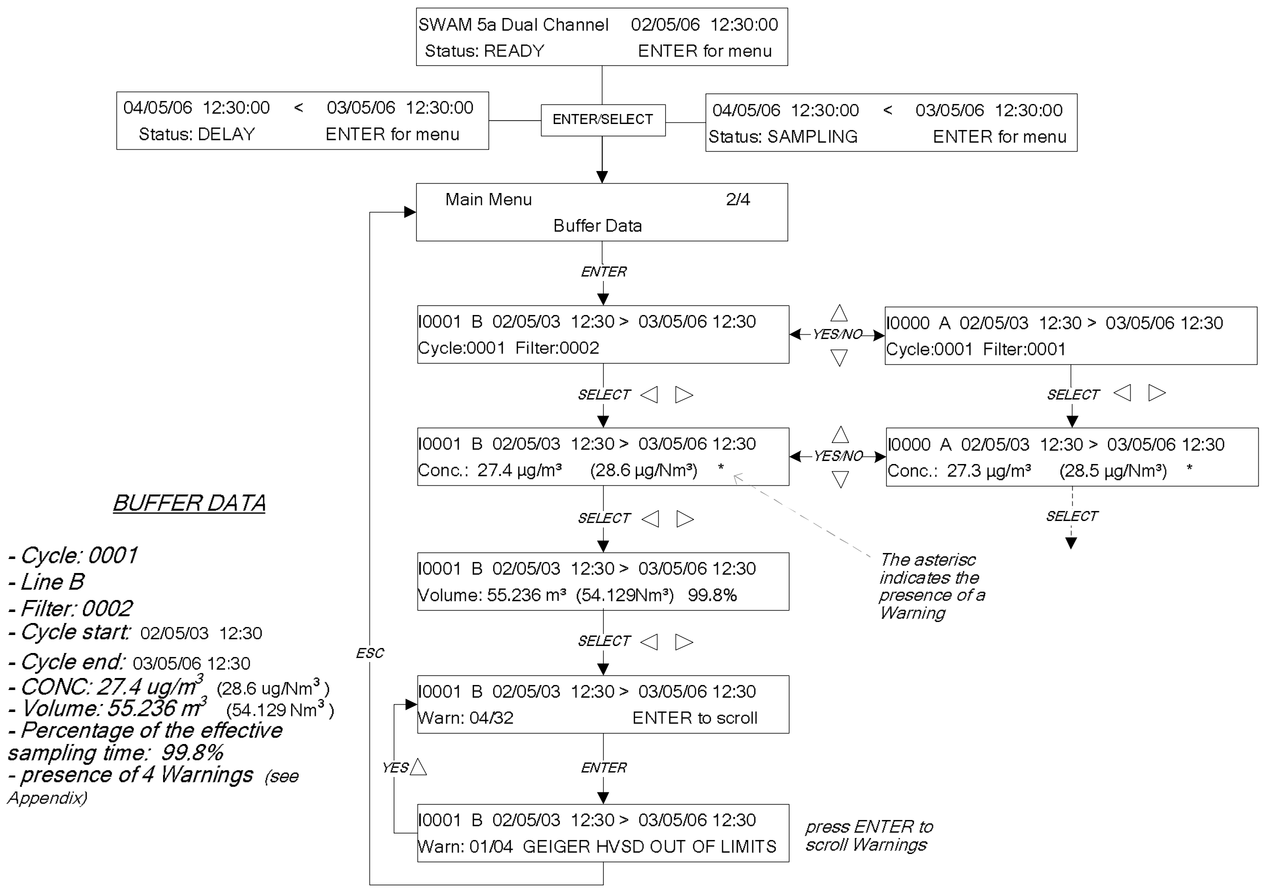
Information about the quality controls

- Warnings relative to the sampling and measurement cycle

6.2.1 Access to the Buffer Data from display

The main information contained in the Buffer Data are also readable on the display of the instrument.

The scheme here below shows how to have access to the information contained in the Buffer Data starting from any of the three Status *READY, DELAY* and *SAMPLING*.
From this menu you can automatically see the information relative to the last stored record (in the example I0001).
To scroll the information of each single record use the “Select” buttons. To change the displayed record use the “YES/NO” buttons.



6.3 CONNECTION TO AN EXTERNAL PC AND BUFFER DATA DOWNLOAD

The instrument can be controlled in all its functions by an external PC. To connect a PC to the instrument the 9 poles connector placed on the instrument back and a cable for RS232 serial port must be used.

Using an external PC, it is also possible to display the *Buffer Data* content and to download data to a file using the following procedure:

1. Connect the instrument to the PC via RS232 serial port
2. Start on the PC a serial communication software (for ex. Windows Hyperterminal)
3. Make sure that the software has the following configuration:
   - emulation ANSI
   - port speed 19200 Baud
   - data bit 8
   - parity None
   - stop bit 1
   - flow control None
4. Make sure that the communication software is running
5. Type the command **42xxx**, where xxx [0÷720] is the record sequential storage code of the sampling and measurement cycles and press *Enter.* The response will be the sequence of the Buffer data corresponding to the requested record preceded by = and separated by a comma (see the example below)

Note: The Buffer has a cyclical structure, therefore once achieved its maximum capacity (720 records) the records are overwrote starting from number 0.

Other useful commands:

40	Information about the older record	Index, Cycle, Filter, Check, ecc.
41	Information about the newer record	Index, Cycle, Filter, Check, ecc.

Appendix 2 shows the complete list of the PC commands

EXAMPLE: Command: 42002

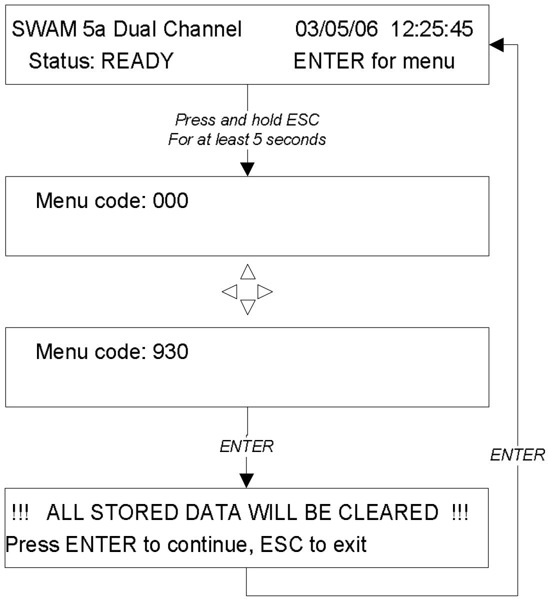
Response:
=0002,27/01/200612.00,28/01/200612.00,2,3,A,0.00,0.58,0.2,26.63,25.778,96.7,279.8,281.8,283.5,287.8,288.6,291.8,100.9,101.3,101.2,0.4,18,20.1,21,9.3,27/01/200617.24,011:33,6.8,24,721565,114860,152,104547,294.7,100.9,624.7,26,141,114181,179,100992,293.7,101.3,624.6,41,440,0,16.5,17,00000000

See ***Appendix 1*** *Buffer Data Structure*

6.4 BUFFER DATA ZERO SETTING

To delete all the data stored in the Buffer Data (in any instrumental Status), press and hold for at least 5 seconds the ESC button to have access to *Menu Code* (access to the support tools). Select code *930* using the SELECT buttons and press ENTER to delete the *Buffer Data* content.

NOTE: after this procedure it will be no more possible to recover information about the sampling and measurement cycles stored in the Buffer.



6.5 SMS MESSAGING SERVICE

SWAM 5a Dual Channel Monitor is equipped with a “Short Message System” service allowing to receive on your mobile phone real-time information about the instrumental operating condition and about the measured concentration values. The table below lists all the information sent to two different telephone numbers “*Operator*” and “*User*”:

Information sent to the “*Operatorôs*” cell number	Information sent to the “*Userôs*” cell umber
• Instrument ID and serial number • SMS sending date and time • ALARM messages causing the sampling and measurement cycles stop (see Appendix 7) • Loader in reserve (less than 6 filters left) • Full *Unloader*	• Instrument ID and serial number • SMS sending date and time • Measured concentration values (µg/m³) on both the sampling lines • Warnings messages (8 hexadecimal ciphers) see Appendix 8

To set the two telephone numbers that will receive the SMS messages follow the procedures below:

- *“Operator’s” telephone number setting*
  - In “Status READY”, from the main menu enter the *Instrument Settings / SMS Cell Number’s* menu
  - select *Operator’s Cell Number*
  - using SELECT buttons type the telephone number complete with international code (for example +39 ##########)
  - press ENTER to confirm or press simultaneously the two SELECT buttons to delete the typed number
- *“User’s” telephone number setting*
  - In “Status READY”, from the main menu enter the *Instrument Settings / SMS Cell Number’s* menu
  - select *User’s Cell Number*
  - using the SELECT buttons type the telephone number complete with international code (for example +39 ##########)

- press ENTER to confirm or press simultaneously the two SELECT buttons to delete the typed number

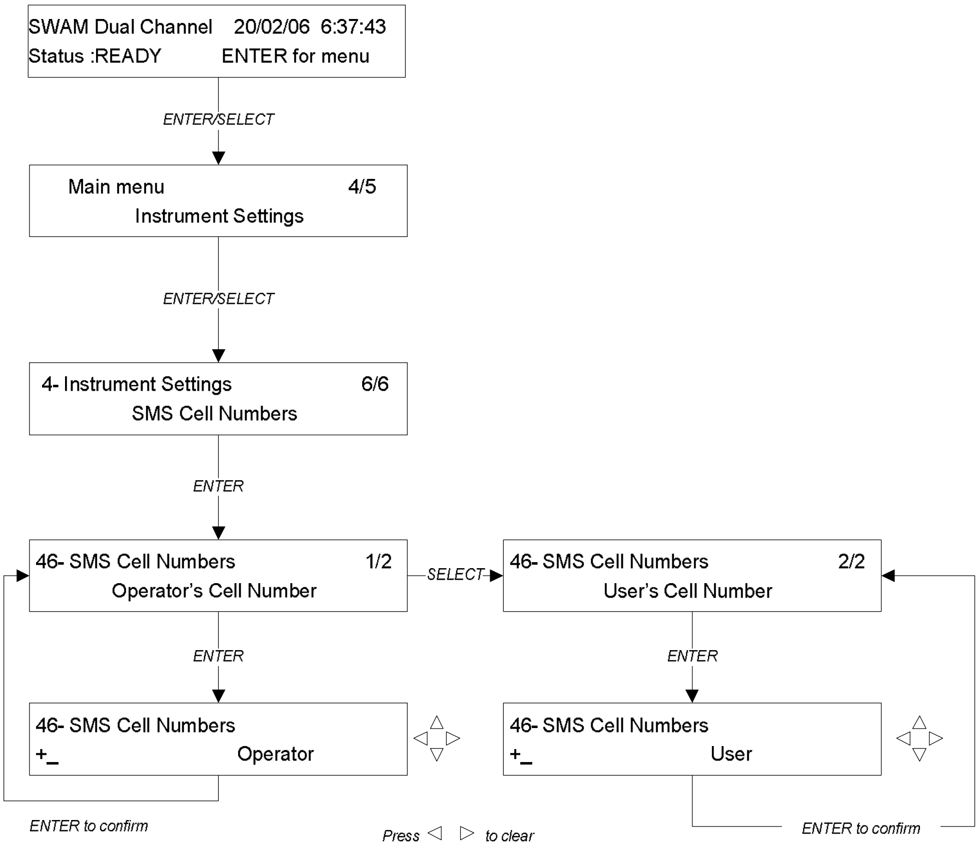


figure 6.2

To enable the SMS messaging service, set the "User" and "Operator" telephone numbers before starting the sampling and measurement cycles.

CHAPTER 7

7. TESTS AND QUALITY CONTROLS

The instrument implements tests and quality controls in order to guarantee high quality standards sampling and measuring data.

The available tests concern the pneumatic system, the mass measurement system, the power supply system, the GSM modem and they can be performed both automatically by the instrument or manually by the operator.
The quality controls automatically performed by the instrument concern the sensors, the mechanics, the flow rate measurement and control system, the mass measurement system, the instrumental power supply and the filter membranes management. The figure 7.1 shows a sampling and measurement cycle with the main quality controls.

Both the quality controls and the tests can generate *Warning* and *Alarm* messages that are displayed and stored in the *Buffer Data* of the instrument.

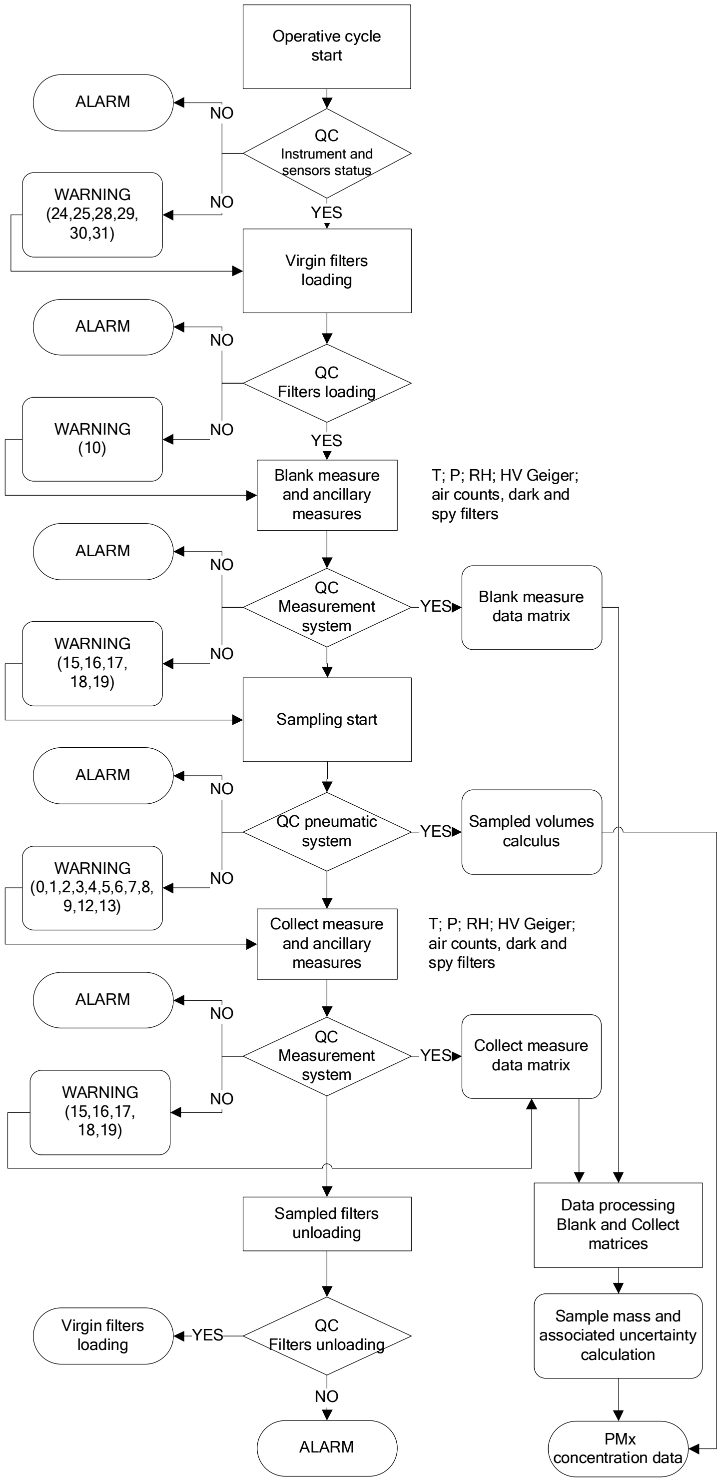


figure *7.1*

7.1 CALIBRATION AND PNEUMATIC CIRCUIT SEAL CONTROL

Following the procedures described below, from the *Instrument Tools* menu it is possible to check both the pneumatic circuit seal (*Leak Test*) and the calibration of the operating flow rate regulation system (*Span Test*).

7.1.1 Leak test

Two different types of pneumatic circuit seal check are possible: *Auto Leak Test* and *Manual Leak Test*. The *Auto Leak Test* allows to check the pneumatic circuit seal downstream the accumulation section (a solenoid valve closes the pneumatic circuit to perform the Leak Test). The *Manual Leak Test* allows to check the seal of the pneumatic circuit as a whole (here included the sampling line) or of parts of it (using the accessory tools for the instrumental tests not included in the standard supply of the instrument – see Appendix 9).

To determine the extent of the possible losses an equation is used, describing the equilibrium status of a perfect gas in a system with known volume. The sequence of the operations performed by the instrument is:

- Leak solenoid valve closing (only in *Auto Leak Test*) – see figure 7.2
- Blind filter loading (only in *Manual Leak Test*), see figure 7.3
- Complete filter loading (only in *Manual Leak Test* all along the whole sampling line), see figure 7.4
- Vacuum pump switching on till the achievement of the minimum inline pressure "P_r" (residual pressure)
- Vacuum pump switching off; the inline pressure value "$P_l(t)$" will tend to increase depending on the extent of the possible losses
- Using the perfect gases equation, the instrument determines the mass loss by the relation:

$$\frac{dn}{dt} = \frac{V}{RT} \times \frac{dP}{dt}$$

the value of this loss, expressed in ml/min in standard conditions (T=273.1 K P=101.3 kPa), is determined when the pneumatic circuit pressure is equivalent to the residual pressure. In operating conditions the pneumatic circuit pressure is very higher then the residual pressure. Therefore, the mass flow value associated with the loss is proportionally lower and can be calculated using the relation:

$$Q_{leak}^{op} = Q_{leak}^{r} \times \left(\frac{P_a - P_l}{P_a - P_r} \right) = \left(\frac{Q_{leak}^{r}}{P_a - P_r} \right) \times (P_a - P_l)$$

Considering the pneumatic circuit type of the instrument, it is possible to assume that the mass loss is proportional to the pressure difference between ambient and pneumatic circuit. Once the atmospheric pressure values and the inline pressure values are known, it is possible to calculate the loss value in operating conditions knowing the value of the term $\left(\frac{Q_{leak}^{r}}{P_a - P_r} \right)$. For this reason at the end of the test the instrument gives the value of this term (specific leak), indicated simply as "Q_{leak}" and expressed in ml/(min*kPa).

For example, assuming: Q_{leak} = 0.57 *ml/min·kPa* ; P_a=101.5 kPa; P_l=93.1kPa; $Q_{leak}^{op} = 4.79$ ml/min

Figures 7.2, 7.3 and 7.4 show Leak Test types implemented in the instrument:

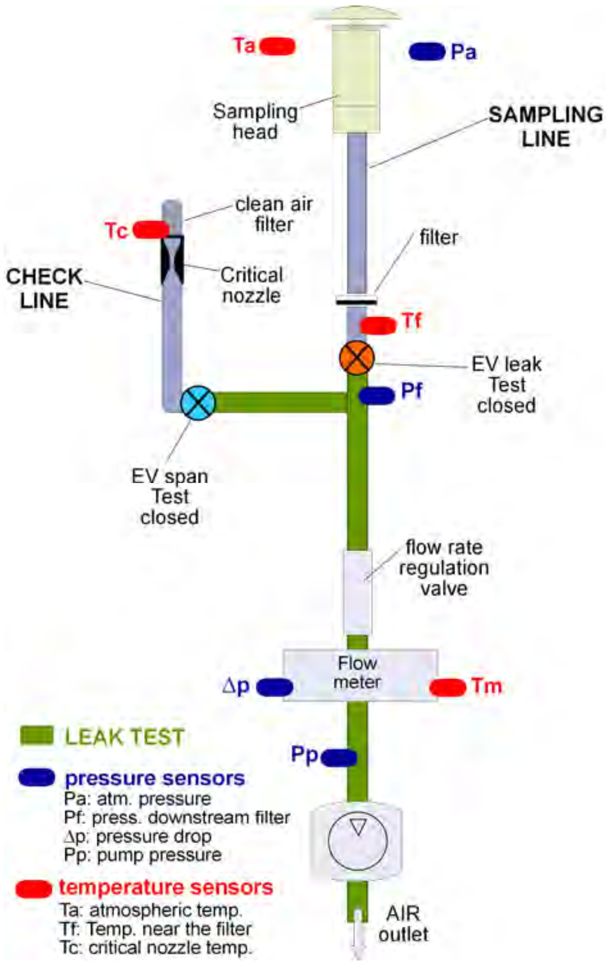


figure 7.2

Auto Leak Test

It allows to check the pneumatic circuit seal downstream the accumulation area

Configuration:

- EV leak: closed
- EV: span closed

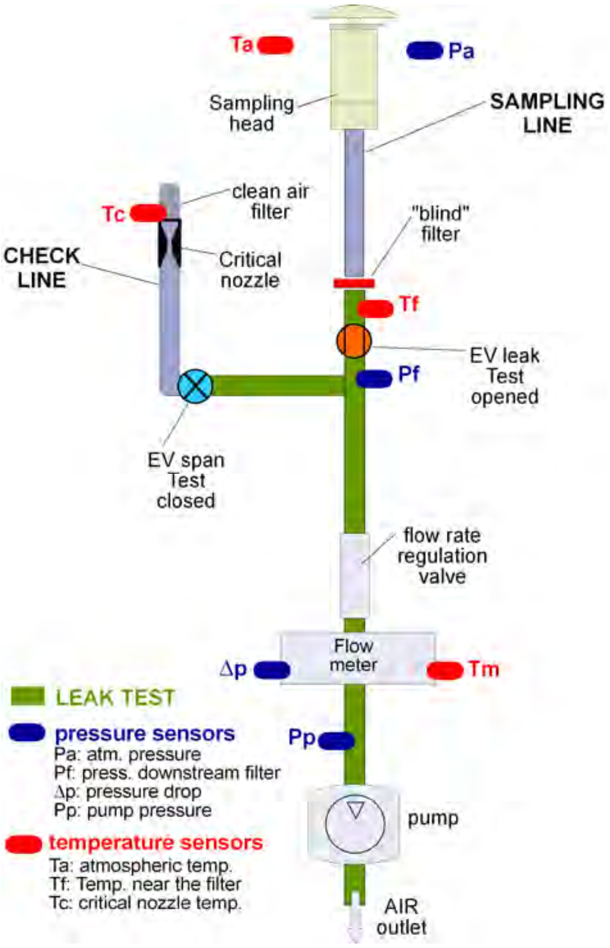


figure 7.3

Manual Leak Test
with ñblindò filter cartridge

It allows to check the pneumatic circuit seal between the vacuum pump and the accumulation area, allowing to check the filter presser seal too (see paragraph 4.1)

Configuration:

- EV leak: open
- EV: span closed
- Blind filter

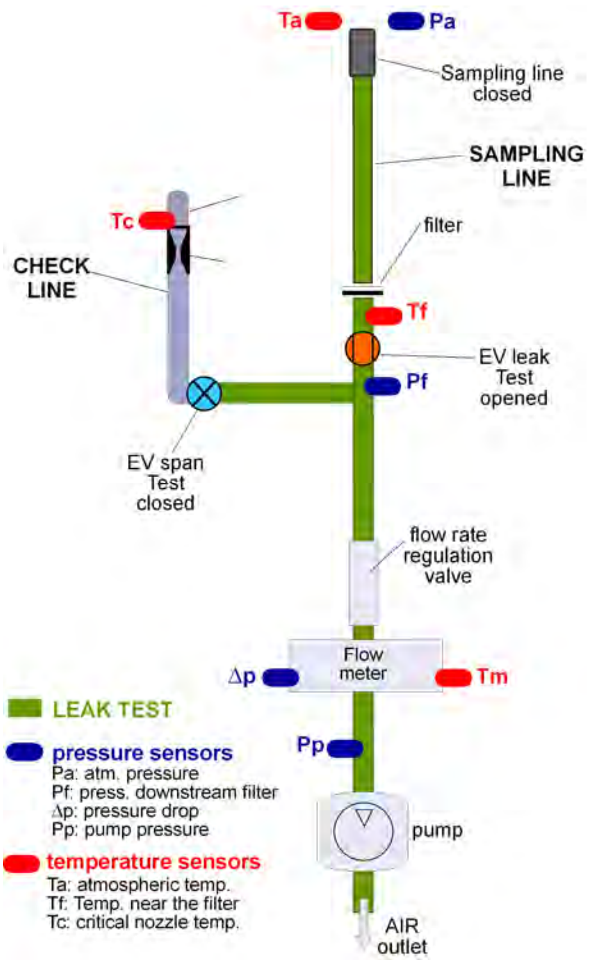


figure 7.4

Manual Leak Test
Sampling line

It allows to check the seal of the whole pneumatic circuit, allowing to check the correct coupling filter presser-external sampling line too

Configuration:

- EV leak: open
- EV: span closed
- "Operative" filter
- Accessory for closing the line

Auto Leak Test Line A/B starting procedure

To start the test (see figure 7.5):

1. from the READY status press ENTER and then SELECT to display the "Instrument Tools" window.
2. press ENTER to have access to the "Instrument Tools" menu
3. press ENTER to select the "Test" menu
4. using the SELECT buttons, select the line of the pneumatic circuit to be tested
   Line A pneumatic test
   Line B pneumatic test
5. Press ENTER to confirm your choice
6. press ENTER to start the test

At the end of the test the instrument automatically displays the values of the residual pressure "P_r" [kPa] and of the specific leak "Q_{leak}" [ml/(min*kPa)]

If the specific leak value is higher than 5 ml/(min*kPa), a Warning message is automatically displayed (Warning 12, see Appendix 8), if it is higher than 10 ml/(min*kPa), an Alarm message is automatically displayed.

***NOTE*:**
In operating conditions this test is automatically carried out by the instrument at the beginning of every sampling cycle and the results are stored in the *Buffer Data* (see paragraph 6 "*Sampling and measurement data*") and available in the *Instrument Info* menu.

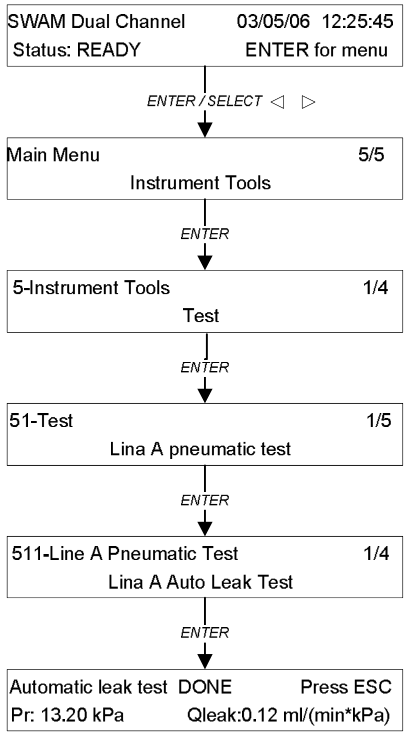


figure *7.5*

Manual Leak Test Line A/B starting procedure

Before starting the procedure, when the instrument is in READY Status, it is necessary to perform the Unloading procedure (see paragraph 5.10) in order to make sure that no filter is present inside the instrument.

To start the test (see fig. 7.6):

1. from READY Status press ENTER and then SELECT to have access to the "*Instrument Tools*" window
2. press ENTER to have access to the "Instrument Tools" menu
3. press ENTER to select the "Test" menu
4. using the SELECT buttons, it's possible to select the line of the pneumatic circuit to be tested
   Line A pneumatic test
   Line B pneumatic test
5. press ENTER to confirm your choice
6. press SELECT to select "Line A Manual Leak Test" and press ENTER to confirm
7. unlock the virgin filters Loader and put the blind filter cartridge in it (accessory not included in the standard supply of the instrument, see fig. 7.6a) with the allow surface turned downwards
8. lock the loader back
9. press ENTER to start the test
   the values of the residual pressure "P_r" [kPa] and of the specific leak "Q_{leak}" [ml/(min*kPa)] will be displayed
10. press ENTER to stop the test

If you want to check the seal of all the pneumatic system, here included the pneumatic stretch containing the filtering medium, follow the procedure in figure 7.6 replacing the "blind filter cartridge" with a "complete filter" (of the same type as the filters used for the sampling) and closing the sampling line inlet with the suitable plug for leak test (not included in the standard supply of the instrument - figures 7.6b, 7.6c). In this case it's necessary to remember that the pneumatic circuit volume value used by the instrument (1,3 liters) for the leak calculation is lower than the real one (it changes depending on the pneumatic configuration of the instrument on the sampling site).

If the specific leak value is higher then 15 ml/(min*kPa), a Warning message is automatically displayed (Warning 12, see Appendix 8, if this value is higher then 30 ml/(min*kPa), an Alarm message is automatically displayed.

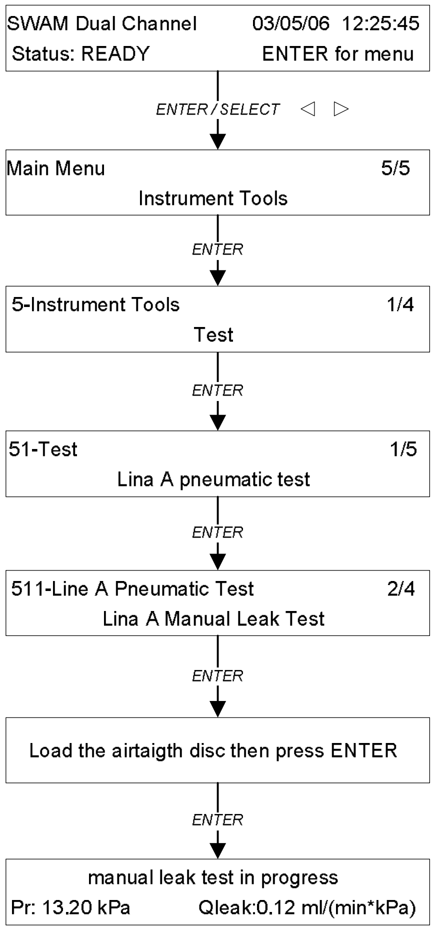


figure *7.6*

fig. 7.6a

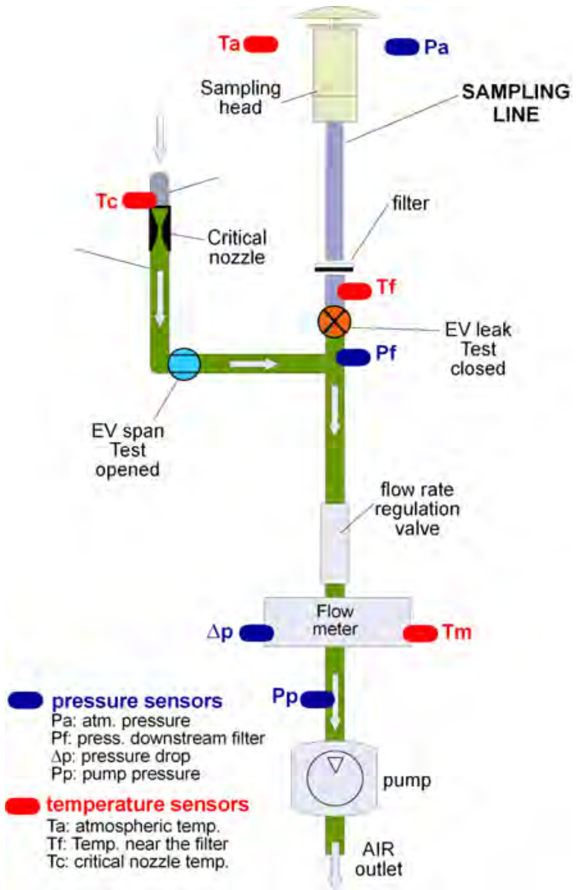
fig. 7.6b

fig. 7.6c

7.1.2 Span test

In the instrument two different procedures are possible for the uncertainty control of the operating flow rate measurement: an automatic procedure (*Auto Span Test*) and a manual procedure (*Manual Span Test*).

The automatic sequence of the operations performed by the instrument to carry out the *Auto Span Test* (see paragraph 2.4) is:



- Span solenoid valve opening and closing of the leak valve
- suction pump switching on.
- automatic check of the achievement of the critical pressure conditions, by comparing the measured values od the pressure downstream "Pf" and upstream "Pa" the nozzle (see note 1)
- displaying and storage of the reference flow rate value "Q_{cal}" expressed in Nm³/h at the programmed temperature and pressure conditions
- displaying and storage of the flow rate values "Q_{test}" (expressed in Nm³/h) determined by the flow rate measurement system
- calculation and displaying of the percentage deviation "*ERR%*" between the values "Q_{cal}" and "Q_{test}".

NOTE: to preserve the Test line from the air flow impurities, inside the pneumatic module of the instrument there is a clean air filter placed upstream the critical nozzle.

The *Manual Span Test* allows to perform the flow rate measurement system calibration and check. To perform this test it is necessary a flow meter to be used as reference secondary transfer standard. Acting on the flow rate regulation valve, it is possible to choose any operating condition. Per every chosen operating condition, it is possible to associate to the reference flow rate value both the corresponding value of the "z" variable (see paragraph 2.4 "*Calibration of the flow rate regulation and measurement system*") and the flow rate value measured by the instrument (calibration check).

Auto Span Test starting procedure

1. With the instrument in READY Status press ENTER and than SELECT till the “Instrument Tools” menu will be displayed. Than press ENTER
2. press ENTER to have access to the “Test” menu
3. using the SELECT buttons it’s possible to select the pneumatic circuit line to be tested

   Line A pneumatic test
   Line B pneumatic test

4. press ENTER to confirm your choice
5. Using the SELECT button, select “Line A Auto Span Test” or “Line B Auto Span Test” and press ENTER to start the test

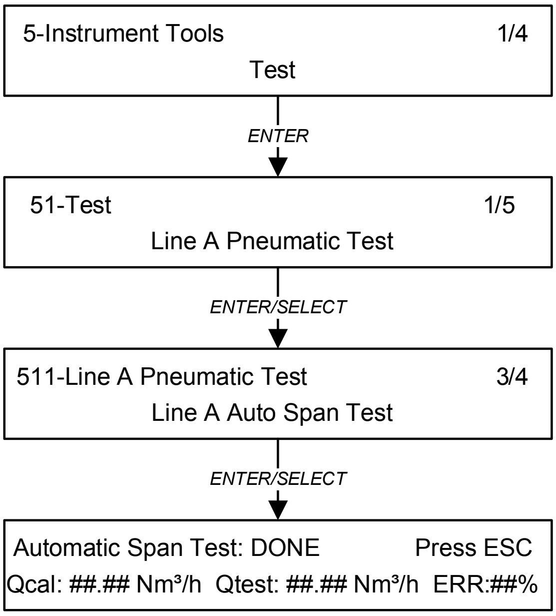


figure 7.7

The display will show the values of “Q_{test}”, “Q_{cal}” and the percentage deviation “*ERR%*”

If the percentage deviation from the starting calibration value is out of the interval ± 4%, a Warning message is automatically displayed (Warning 13, see Appendix 8), while if the percentage deviation is out of the interval ± 10%, an Alarm message is automatically displayed.

NOTE 1:
in operating conditions this test is automatically performed at the beginning of each sampling cycle and the result is stored in the *Buffer Data*.

NOTE 2:
the displaying of Err:+99.9% indicates that the nozzle “critical conditions” have not been achieved. This implies that the test is not performed.

__Manual Span Test starting procedure for the pneumatic calibration check__

For this procedure it is necessary to disconnect the instrument from the sampling line, in order to insert the flowmeter using the adapter for flow rate calibration (not included in the standard supply of the instrument).

Before starting the test it is necessary to:

- make sure that there are no filters inside the instrument and inside the Loader (see *Unloading procedure*, paragraph 5.10)
- connect the reference instrument to the sampler using the adapter, so that the same air flow passes through both instruments.

If you want to connect e flow meter at the sampling line top, please remember that the volumetric flow rate Qi value appearing on the display during the test refers to the temperature conditions inside the installation room. These conditions do not necessarily correspond to the external conditions. Therefore, we recommend to use standard flow rate Qs values for the test.

To connect the flow meter with the instrument, uncouple the sampling inlet from the sampling line and use the apposite adapter for external flow rate calibration (accessory not included in the standard supply of the instrument).



The manual test can be started from the display in READY status using the *Instrument Tools / Test* menu and following the procedure below:

1. With the instrument in READY Status, press ENTER and then SELECT till the “Instrument Tools” menu will be displayed. Then press ENTER
2. press ENTER to have access to the “Test” menu
3. Use the SELECT buttons to select the pneumatic circuit line to be calibrated

   Line A pneumatic test
   Line B pneumatic test

4. press ENTER to confirm your choice
5. use the SELECT buttons to select “Line A Manual Span Test” or “Line B Manual Span Test” and press ENTER
6. insert a complete filter in the Loader and press ENTER to complete the loading process
7. start the pump pressing ENTER button
8. Adjust the valve opening till the flow rate value displayed by the reference instrument will stabilize at the desired value $Q_{i\ ref}$. To achieve the desired flow rate value, use the selection buttons: with the right “SELECT” button you’ll set the ***St*** parameter, with the “YES” and “NO” buttons you’ll set the flow rate value adjusting the valve opening.

   St: H *(high) /* ***M*** *(mid) /* ***L*** *(low), show the wideness of the regulation intervals by which it is possible to achieve the desired flow rate value*

   V*: shows the regulation valve position compared with the zero position*

   Qs*: shows the flow rate value measured by the instrument in standard conditions*

   Qi*: shows the inlet volumetric flow rate value calculated using the temperature value measured by the instrument inside the installation room*

9. Repeat this operation for at least three different points of the valve regulation scale (we suggest to cover all the valve range)

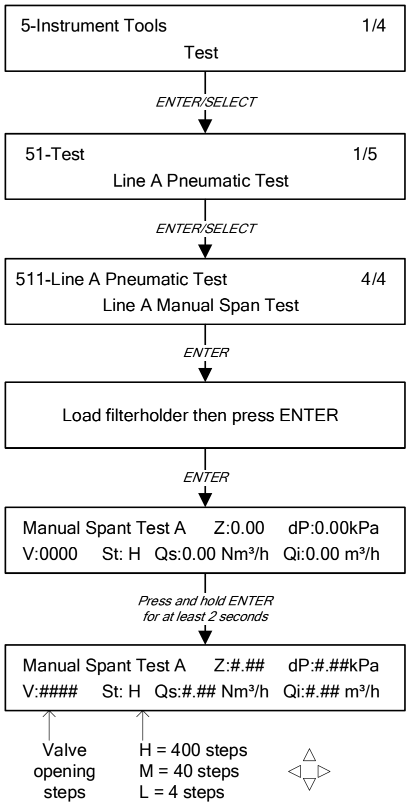


figure *7.8*

Press ESC to stop the test

7.2 MASS MEASUREMENT SYSTEM CALIBRATION CHECK (Beta Span Test)

In relation to the implementation level of the measurement technique in the instrument **<u>no periodical calibrations are needed</u>** but in case of measurement system failures requiring the replacement of one ore more components (Geiger-Muller detector and associated electronics).

Therefore, usually the calibration function determined during the final acceptance test keeps its validity during all the GM detector life.
In operating conditions the correct implementation of the measurement procedure and the calibration function invariance are guaranteed by the implemented quality controls (see paragraph 2.6.2 "*Automatic calibration check and quality controls*").

Anyway the instrument can automatically perform a ß calibration check (*Beta span test*) by measuring alternately the ß flux in air and the ß flux passing through the reference aluminum membranes. The mass thickness values of the two membranes, calculated during the test, are compared with the nominal values assocated with them. The test gives the calculated mass thickness values and the percentage deviations from the respective nominal values.

7.2.1 Starting the test (STATUS: Sampling)

At the beginning of every operating cycle the instrument automatically performs the *beta span test* (see paragraph 2.6.2 "*Automatic check of the calibration and quality controls*")
Anyway it is possible to perform the *beta span test* even during the normal sampling and measurement cycles, without stopping the operating cycles. Following the procedure described below, it is possible to choose whether at the beginning of the following mass measurement cycle the instrument must perform or not the *beta span test*.

- With the instrument in SAMPLING Status, press and hold for at least 5 seconds the ESC button to have access to the *Menu code* (access to support *tools*).
- Select the *951 code* using the Select buttons and press ENTER to have access to the tool allowing to activate or deactivate the beta span test performing at the beginning of the following sampling.
- Using the YES/NO buttons, select "ON" to activate the test or "OFF" to deactivate it and press ENTER to confirm the choice. **Choosing "ON", the *beta span test* will be performed <u>only</u> at the beginning of the sampling cycle following the sampling in process.**

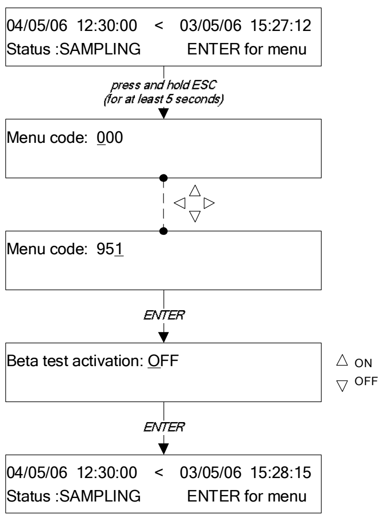


figure 7.9

NOTE: the test ask for 40 minutes that will be detracted from the programmed sampling time (*timing*) for the cycle in progress

7.2.2 Starting the test (STATUS: Ready)

Before performing the test, make sure that the reference membranes have been inserted as required in the starting setup of the instrument (see paragraph 5.6 "Insertion or replacement of the reference aluminium foils").

To start the test:

1. with the instrument in READY Status, press ENTER and then SELECT till the "Instrument Tools" menu will be displayed
2. press ENTER to have access to the menu
3. press ENTER and then SELECT till the "Beta Span Test" menu will be displayed
4. press ENTER to start the test

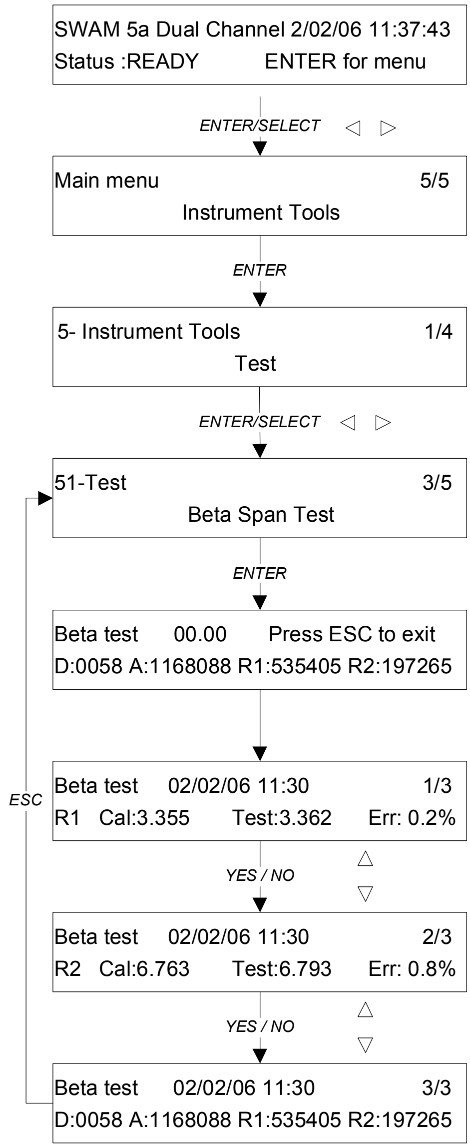
At the beginning of the test the display shows the counts relative to the background radioactivity (D), the air (A), the reference membranes Ra and R2.

At the end of the test, the following parameters will be displayed for both the reference membranes:

Cal: *value of the mass surface density of the reference membrane (mg/cm²)*

Test: *value of the mass surface density of the membrane estimated by the instrument (mg/cm²)*

Err: *percentage error*



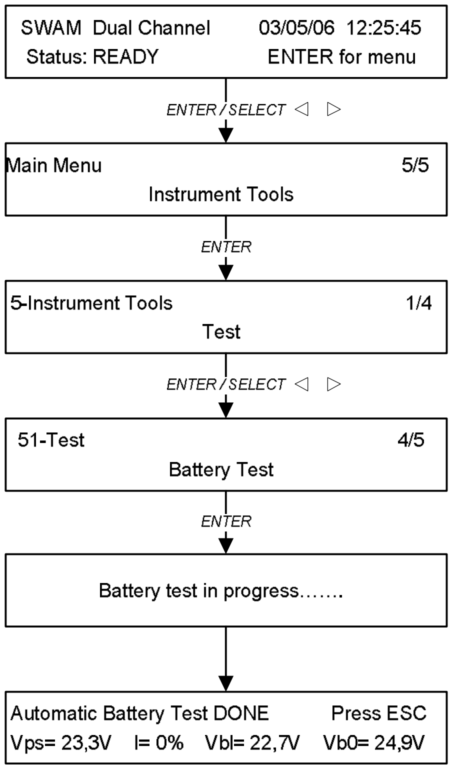
NOTE: during the test, the effective value of the counts measured by the Geiger Muller is displayed. At the end of the test, the correct counts for the G.M. dead time are stored and displayed. The value of the used dead time is the one given by the G.M. producer (since the calibration function is empiric, effective values of dead time different from the one given by the producer do not affect the mass measurement quality).

If the percentage deviation (Err) between the surface mass density nominal and measured value of one or both the reference membranes is out of the interval ± 5%, a Warning message is automatically activated (Warning 14, see Appendix 8).

7.3 BATTERY TEST

To check the floating batteries charge status follow this procedure:

1. with the instrument in READY Status, press ENTER and then SELECT till the "Instrument Tools" menu will be displayed
2. press ENTER to have access to the menu
3. press ENTER and then SELECT till the "Battery Test" menu will be displayed
4. press ENTER to start the test



The display shows the values of the following parameters:

Vps: *shows the instrument internal operating voltage*

I: *shows the battery charging current*

Vbl: *shows the "Load" battery voltage*

Vb0: *shows the "No-load" battery voltage*

If the instrument won't get over the test (the battery charge is insufficient to guarantee the instrument running), the red led *"Battery Level Low"* and the yellow led "*Warning*" will light up on the frontal control panel.

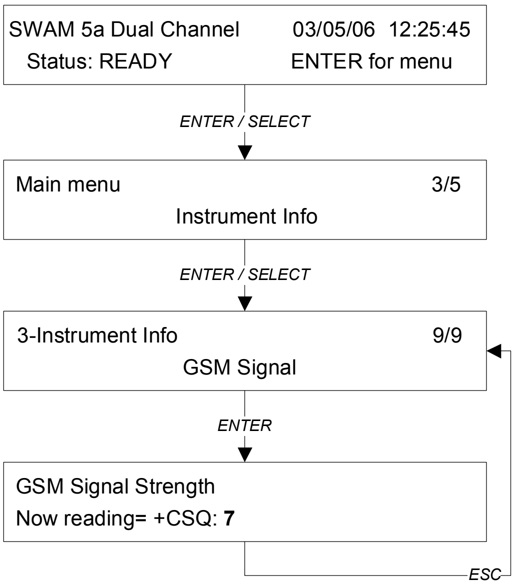
NOTE:

The instrument is also able to perform automatically the battery high voltage test during the sampling and measurement cycles.

If the battery high voltage is too low and unable to guarantee the instrument working, a Warning message will be displayed and stored in the Buffer Data (Warning 28, see Appendix 8).

7.4 MODEM SIGNAL

The instrument can be equipped with a modem (PSTN, ISDN, GSM, GPRS), allowing a complete instrumental remote control and in particular:



- set the operative parameters
- have access to the sampling and measurement data
- check the mechanical functionality
- have access to the “trace files”
- receive diagnostic SMS’s sent automatically by the instrument

For the connection with the modem a cable for RS232 serial port suitable for the 9 poles connector [**Modem**] placed on the instrument back must be used.

It is possible a direct check on the display of the signal intensity value detected by the modem:

1. with the instrument in READY Status, press ENTER and then SELECT till the “Instrument Info” menu will be displayed.
2. press ENTER to have access to the menu
3. press SELECT till the “GSM Signal” will be displayed
4. press ENTER to start the test

The signal intensity value is displayed and updated once a second and a sound is sent:

- signal between 0-10 (insufficient signal)
- signal between 10- 98 (operative range)
- signal 99 (no signal)

NOTE: We recommend to place the GSM modem so as to get a signal > 15

7.5 SMS TEST

The *SMS Test* allows to check the correct working of the SMS messaging service that sends messages to the Operator's and User's mobile numbers, previously programmed (see paragraph 6.6 "*SMS Messaging Service*").
To perform the test follow the procedure below:

7. From the main menu, in READY Status, press ENTER and select the Instrument Tools menu, using the SELECT buttons
8. press ENTER to have access to the *Test* menu
9. press ENTER again and select the *SMS Test* menu, using the SELECT buttons
10. press ENTER and, using the SELCT buttons, select the user that you want the instrument send the messages to (Operator or User). Press ENTER again to confirm your choice.

If the user does not receive the SMS message, check that:

- *the GSM modem is correctly installed (see paragraph 7.4)*
- *the Modem Test gives correct result*
- *the GSM cards contracts (modem and operator) did not expire*

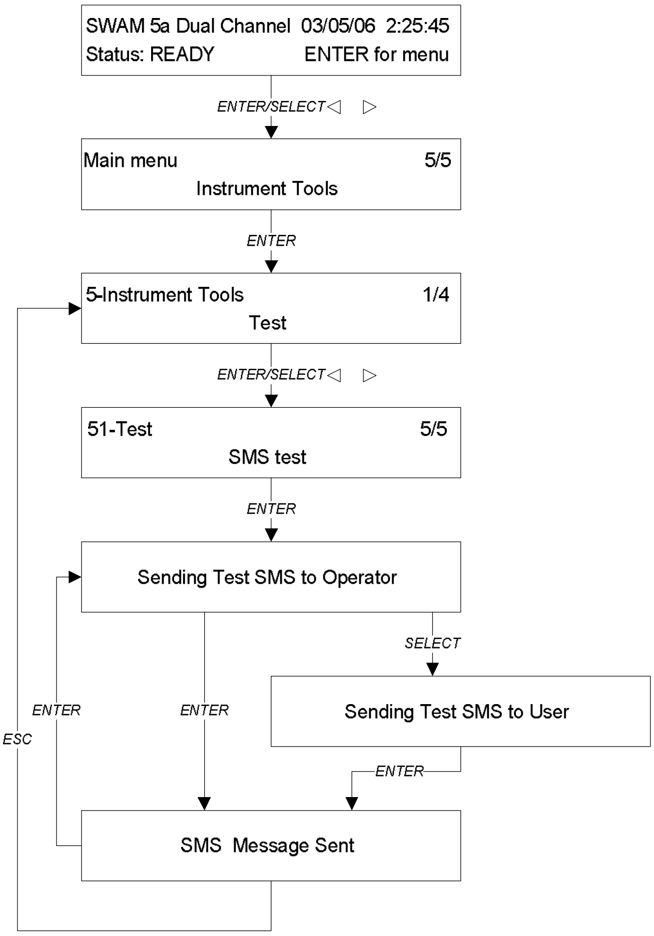


figure *7.10*

7.6 FULL MECHANICS TEST

The *Full Mechanics Test* allows to check the functionality of all the servomechanisms involved in the operating cycles of the instrument.
So that the test is significant, make sure that at least one filter is inside the Loader. To start the test respect the procedure shown in figure 7.11.
After having selected the *Full Mech Test* (see figure 7.11), it is possible to choose wether or not to send the test results to an external PC connected by RS232 serial port (*Monitor on Serial Ext? YES or NO*).
The test goes on till all the filters inside the Loader have been unloaded. Anyway, it is possible to stop the test pressing ESC.
If the test gives correct results, **Err:00** appears on the display. If during the test anomalous working conditions are detected, the corresponding error messages will be displayed, allowing to identify the involved servomechanism and the anomaly too.

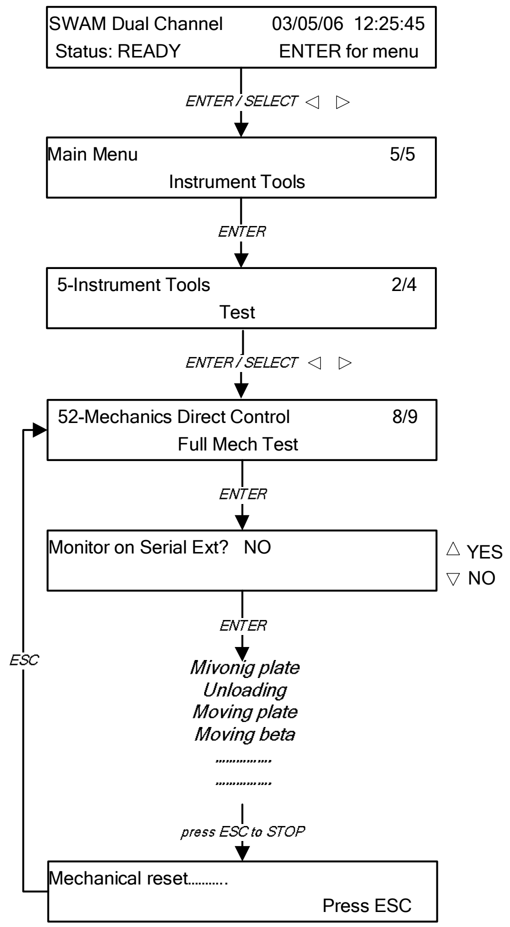


figure 7.11

7.7 ZERO TEST: offset check

The zero test can be carried out in order to verify the mass measurement system response when the particulate matter present on the sample is removed from the sampling flow.
In those conditions the measured mass and consequently the relative “expected” concentration value is equal to zero.

1. Connect the absolute filters kit (Fig. 7.12 – item not included in the standard supply, see <u>Appendix 9</u>) to the sampling lines instead of the sampling heads, using the adapter “*a*” (fig. 7.13). Another possibility is to connect the absolute filters directly to the instrument using the adapter “*b*”(Fig.7.14).

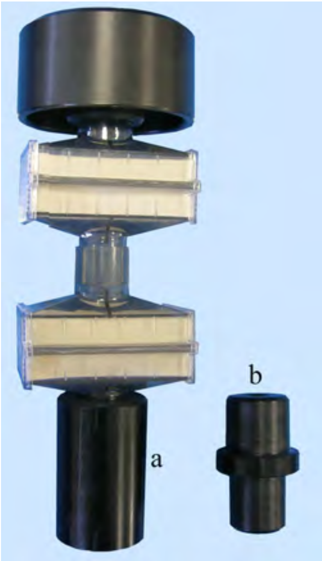


Fig. 7.12

Fig.7.13

Fig.7.14

2. Assemble and load into the instrument a suitable number of filters, using filter membranes of the same type as those that will be used for the sampling and “Beta equivalent spot areas” of 5.20 cm², 7.07 cm² or 11.95 cm².

3. Start the instrument in “Monitor Mode Line A&B” and set a 12 hours long “Timing”

4. At the end of the programmed sampling cycles, download the “Buffer Data” (see Appendices 1 and 2).

5. The mass and concentration values determined during the test, together with the current volume data, are listed in the columns 47, 49 and 19 of the Buffer Data (see Appendix 1)

   The obtained experimental mass and concentration values are expected to be scattered around the zero value and therefore to take both negative and positive values

7.7.1 Interpretation of the zero test data

The obtained mass and concentration experimental data are expected to be scattered around the zero value and to have both negative and positive values. The instrument does not directly displays the negative mass and/or concentration values.

The negative mass values are stored as values complementary to 65536 (16^4), while the corresponding concentration values are set equal to zero.
For example, a measured mass value equal to -19 µg is stored in the buffer as 65517 [65517 – 65539 = -19].

In order to calculate the corresponding concentration value it's enough to divide the mass value by the corresponding sampled volume.
For example:
mass = -19 µg volume = 54,955 m^3
concentration = -19 / 54,955 = - 0.3 µg/ m^3

The table here below shows some data set from the buffer of one of the two lines of the instrument:

Inlet volume [m³]	Buffer mass [µg]	Buffer concentration [µg/m³]	Measured mass [µg]	Measured concentration [µg/m³]
54,955	65517	0	-19	-0,3
54,710	65533	0	-3	-0,1
54,646	65534	0	-2	0,0
54,626	3	0	3	0,1
54,646	21	0,3	21	0,4
54,648	4	0	4	0,1
54,665	13	0,2	13	0,2
54,681	65511	0	-25	-0,5
54,656	3	0	3	0,1
54,687	65522	0	-14	-0,3
54,602	13	0,2	13	0,2
54,657	8	0,1	8	0,1
54,584	16	0,3	16	0,3
54,617	65524	0	-12	-0,2
54,598	16	0,2	16	0,3
54,611	13	0,2	13	0,2
54,670	65526	0	-10	-0,2
54,593	6	0,1	6	0,1
54,699	65532	0	-4	-0,1
54,643	9	0,1	9	0,2
54,649	65529	0	-7	-0,1
average mass value [µg]			1,381	
Std [µg]			12,527	

The result of the zero test will be expressed by an average mass value in µg and by the relative standard deviation.

CHAPTER 8

8. MAINTENANCE

8.1 ROUTINE PREVENTIVE MAINTENANCE

To preventive maintenance belongs the routine system management, including cleaning operations on the instrument and all the checks that the operators will perform during the normal instrumental operating cycle.

The recommended checks and preventive maintenance interventions are listed in the table below:

Intervention type	Recurrence
Sampling inlet cleaning and greasing	fortnightly / monthly
Sampling line draining	three-monthly
Sampling line inspection	three-monthly
Oil level and service air compressor filter inspection	six-monthly
Subject to wear vacuum pump components replacement, using the maintenance kit (not supplied with the instrument)	yearly

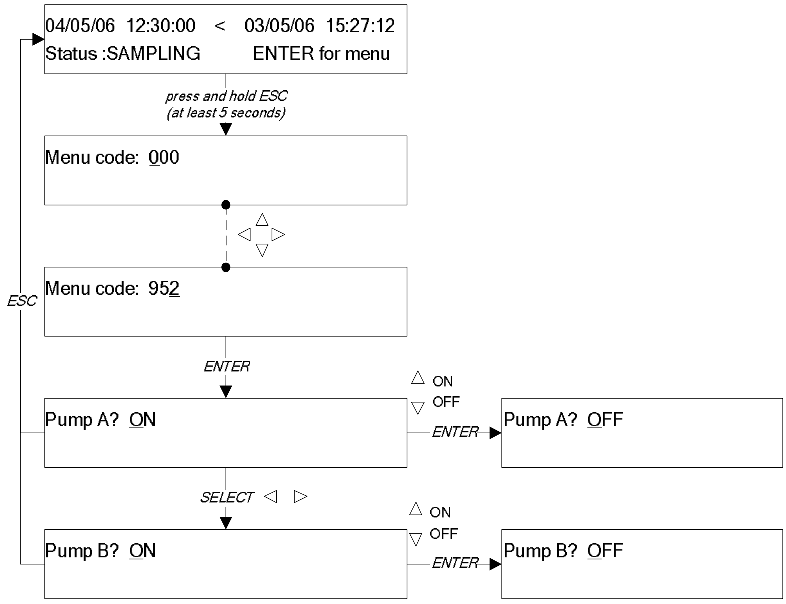
The instrumental operating conditions may be very different in time. Therefore we recommend to carry out the interventions at intervals suitable to the real use conditions, considering the recurrences of the table above as an indicative reference.

8.1.1 Sampling inlet clearing

The sampling inlets cleaning can be performed when the instrument is in Ready, Sampling or Ending Status. If the instrument is in Sampling or Ending Status it's necessary to switch off the vacuum pumps before removing the sampling inlet from the sampling line.

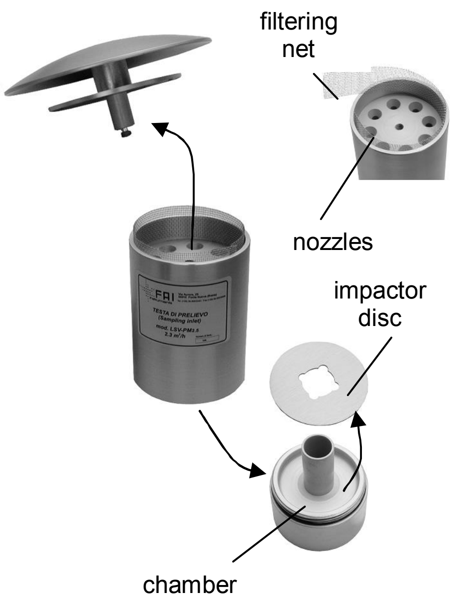
To switch off the pumps follow the procedure here below:

- From the main window press and hold the ESC button for at least 5 seconds to have access to the *Menu code* (access to support *tools*)
- Select the *952* code using the Select buttons and press ENTER to have access to the *tool* of pumps control.
- Select the pump you want to switch off using the Select buttons.
- Press NO to select OFF
- Press ENTER to confirm the switching off of the pump



After having switched the pump off, it's possible to go on with the removal and the cleaning of the relative sampling head:

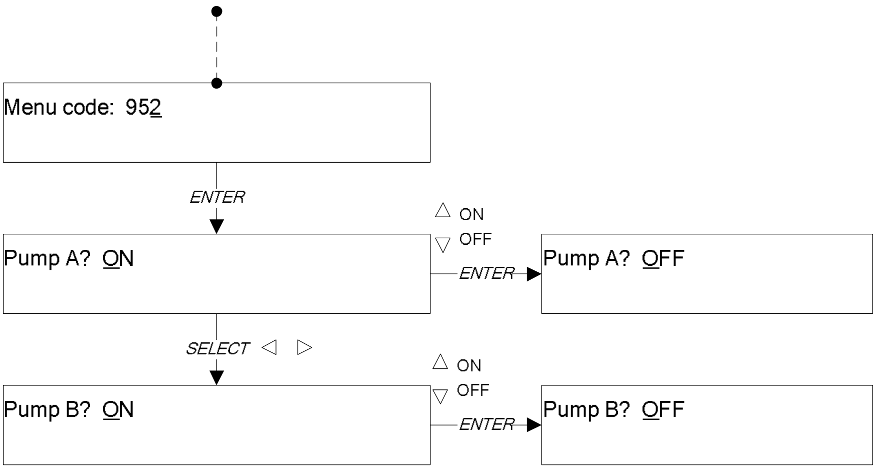
- remove the sampling inlet tacking it off the sampling line
- disassemble the sampling inlet
- accurately remove the dust deposits from the impactor disk and the condensation accumulated in the chamber below
- clean all the components using water and a light detergent
- dry with a clean cloth and blow compressed air through the nozzles
- apply again a veil of grease on the impactor disk
- remove from the filtering net insects or vegetable deposits
- check and if needed replace the two fixing o-rings for the coupling sampling inlet-sampling line and grease them
- reassemble the sampling inlet



NOTE: The cleaning interventions must be performed at least monthly, a correct intervention plan must anyway consider the expected concentration levels and the granulometric cut size of the used sampling inlet.

After having reassembled the sampling head, use the *tool* for the pumps control to switch on again the pumps.

- Select the pump you want to switch on using the Select buttons.
- Press YES to select ON.
- Press ENTER to confirm the switching on of the pump.



NOTE: At the beginning of every sampling and measurement cycle and after having unloaded the sampled filters (at the end of the collect mass measurement session), the suction pumps are automatically activated.

8.1.2 Condensation drainage from the sampling line

Three-monthly, and in particular in environmental conditions producing a high condensation amount, we recommend to drain the condensation from the sampling lines as follows:

- put a little container near the drain plug
- remove the drain plug
- drain the condensation accumulated
- put the plug back in its place

fig. 8.1

fig. 8.2

8.1.3 Sampling line inspection

Three-monthly we recommend to check the sampling line conditions as follows:

- switch off the instrument
- remove the insulating thermic protection sleeve and disconnect the sampling unit from the sampling line, operating on the ball joint
- remove possible insects or vegetable deposits from the filtering net placed on the sampling line, under the air intake protective sleeve
- make sure that there are no water infiltrations in the sampling line and in particular in the sampler, caused by condensation phenomena
- dry and remove possible deposits from the surfaces
- check, grease and, if needed, replace the two fixing o-rings of the sleeve on which the ball joint is placed
- connect again the sampling unit with the sampling line and insert the thermic protection sleeve

In case of water infiltrations inside the sampler, ask for an urgent intervention of the FAI Instruments Technical Assistance.

8.1.4 Service air compressor check

Six-monthly it's necessary to check and control the service air compressor and in particular:

- check the oil level and, if needed, top it up
- check the condition of the sampler air feeder flexible pipe
- check the air filter and, if needed, clean it

To avoid oil losses, during the compressor maintenance do not tip it or turn it upside down.

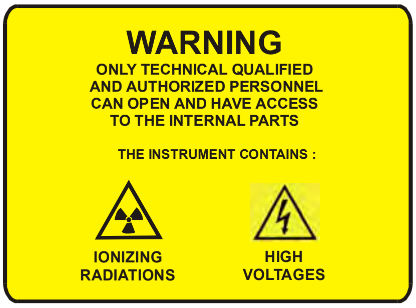
8.1.5 Vacuum pumps maintenance

Yearly it's necessary to replace the vacuum pump parts subject to wear, using the spare parts kit recommended by the pump manufacturer (see Appendix 9 "Optional accessories and spare parts list").

Carefully follow the instructions supplied by the pump manufacturer.

8.2 REPAIRS

With repairs we mean the interventions needed to go back to the normal instrument running conditions after failures or after long inactivity periods.



WARNING:

Only technical qualified and authorized personnel can open the instrument and have access to its internal parts.

The instrument contains dangerous high voltages and a radioactive source.

Maintenance repairs can be carried out only by:

- **Qualified Technicians** who can carry out instrument maintenance repairs on the basis of detailed technical instructions received during apposite training course
- **FAI Instruments s.r.l. Technical Assistance Service**
- **Authorized technical assistance center**

Instrumental modifications and transformations are prohibited. In case of modifications and transformations the user must take full responsibility for all possible resulting consequences.
In case of modifications, we recommend to contact the manufacturer in order to keep the guarantee validity.

8.3 STORAGE AND DISPOSAL

In case of an instrumental temporary storage, deactivate the system and stick on it suitable “OUT OF SERVICE MATERIAL” marks / labels.

The instrument, if possible in its original packaging, must be stored indoors, in horizontal position, no other weights must rest on it.

The storage temperature must be kept in the range - 10 and + 55 °C in order to avoid damages to the parts in synthetic material and to the electronics.
The storage relative humidity values must be such as to avoid condensation phenomena.

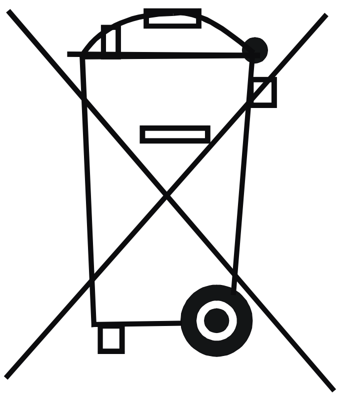
At the end of the instrumental operating life, it’s necessary to get rid of it **without causing dangers for people and without damaging the environment**.

In case of instrumental final dismantling, disassemble it selecting the materials depending on their type. The main components that can be disassembled are:

- Ionizing radiations source
- Various metallic materials (aluminum, carbon and stainless steel, copper)
- Plastic materials (PVC, Polyethylene, ABS, Nylon, Teflon)
- Electric and electronic components (metals and parts in synthetic material)
- Elastomers (Viton, Rubber)
- Pb batteries

	***Warning**: The radioactive source must be disassembled by qualified and authorized personnel, its storage or disposal must be performed in accordance with the enforceable specific safety regulations.*

The wreckage must be committed to specialized firms, depending on its type and dangerousness, in conformity with current regulations. If possible, the material must be recycled.



APPENDICES

Appendix 1	Buffer Data structure	List of the sampling and measurement data contained in the Buffer
Appendix 2	Pc commands list (RS232)	How to manage the instrument by an external PC for the sampling cycles programming and the data enquiry and download.
Appendix 3	Menu structure	Structure of the instrument menu
Appendix 4	Instrument Settings	How to set the sampling and measurement parameters
Appendix 5	Instrument Info	List of the available information
Appendix 6	Test and “QC” (Instrument Tools)	List of the automatic and manual tests
Appendix 7	ALARM messages codes	How to interpret the Alarm messages codes
Appendix 8	WARNING messages codes	How to interpret the Warning messages codes
Appendix 9	Optional accessories and spare parts	List of the optional accessories not included in the standard supply of the instrument and of the main spare parts
Appendix 10	Sampling lines configurations	Some examples
Appendix 11	Mass measurement	Information about the mass measurement module and on the measurement sequences
Appendix 12	Sequentialization operative steps	Information about the filters loading-sequentialization system and about the sampling cycles

APPENDIX 1: Buffer Data structure

The table below shows the structure of the data stored in the Buffer Data of the instrument

Abbrev.	Description	Format	Unit
Record	Record number (internal reference progressive no.)	####	
Sampling start	Sampling start date/time	##/##/## ##:##	dd/mm/yy hh:mm
Sampling end	Sampling end date/time	##/##/## ##:##	dd/mm/yy hh:mm
Cycle	Cycle progressive number	####	
Filter	Filter progressive number	####	
Line	Sampling Line	A or B	
Power down	Duration of the power down relative to the cycle (battery operating)	##.##	hours:min
Leak test[ml/(min*kPa)]	Leak test result	##.##	ml/(min kPa)
Span test[%]	Span test result	##.#	%
Inlet volume[m^3]	Total sampled volume	###.###	m^3
Standard Volume[Nm^3]	Total sampled volume in standard conditions(default:273.1K;101.3kPa)	###.###	Nm^3
Sampling time ratio [%]	Percentage of the real sampling time compared with the programmed time	###.#	%
Min.Ext.Temp.[K]	Minimum external temperature during the sampling process	###.#	K
Avg.Ext.Temp.[K]	Average external temperature during the sampling process	###.#	K
Max.Ext.Temp.[K]	Maximum external temperature during the sampling process	###.#	K
Min.Filter Temp.[K]	Minimum temperature in the accumulation area during the sampling process	###.#	K
Avg.Filter Temp.[K]	Average temperature in the accumulation area during the sampling process	###.#	K
Max.Filter Temp.[K]	Maximum temperature in the accumulation area during the sampling process	###.#	K
Min.Atm.Press.[kPa]	Minimum atmospheric pressure	###.#	kPa
Avg.Atm.Press.[kPa]	Average atmospheric pressure	###.#	kPa
Max.Atm.Press.[kPa]	Maximum atmospheric pressure	###.#	kPa
RSD[%]	*RSD* variable value (see paragraph 2.4)	##.#	%
Initial Press.Drop[kPa]	Initial filter pressure drop	##.#	kPa
Final Press.Drop[kPa]	Final filter pressure drop	##.#	kPa

Max.Press.Drop[kPa]	Maximum filter pressure drop	##.#	kPa
max.DT[K]	Maximum difference between the external temperature and the temperature in the accumulation area(Maximum ΔT value)	± ###.#	K
max.DT Time	Maximum ΔT date and time	##/##/## ##:##	dd/mm/yy hh:mm
DT>5 K Time	Required time so that max ΔT exceeds the threshold value of 5K	###:##	hhh:mm
Avg.DT[K]	Average ΔT value during the sampling process	##.#	K
Dark[counts/min]	ß flux Background radioactivity	####	Count/min
Air[counts/min]	ß flux in Air	#########	Count/min
Spy Blank[counts/min]	β flux spy filters S12/S34/S56 during the ***blank*** measurement session	#########	Count/min
Spy Blank SD[counts/min]	Standard deviation β flux spy filters S12/S34/S56	######	Count/min
Blank[counts/min]	β flux Blank filter	#########	Count/min
Temp.Blank[K]	Temperature of the blank filter measurement area	###.#	K
Press.Blank[kPa]	Pressure of the blank filter measurement area	###.#	kPa
Geiger HV Blank[V]	Geiger high voltage during the ***blank*** measurement session	###.#	V
RH Blank[%]	RH during the ***blank*** measurement session	###	%
Nat.Rad.[counts/min]	β flux Natural radioactivity	#####	Count/min
Spy Collect[counts/min]	β flux spy filters S12/S34/S56 during the ***collect*** measurement session	#########	Count/min
Spy Collect SD[counts/min]	Standard deviation β flux spy filters S12/S34/S56	######	Count/min
Collect[counts/min]	β flux sampled filter	#########	Count/min
Temp. Collect[K]	Temperature of the sampled filter measurement area	###.#	K
Press. Collect [kPa]	Pressure of the sampled filter measurement area	###.#	kPa
Geiger HV Collect[V]	Geiger high voltage during the ***collect*** measurement session	###.#	V
RH Collect[%]	RH during the ***collect*** measurement session	###	%
Mass[ug]	Sample mass	+/-#######	µg
Mass Error[ug]	Mass calculation error	###	µg
Conc.[ug/m^3]	Concentration	+/-####.#	µg/m³
Standard Conc.[ug/Nm^3]	Concentration in standard conditions	+/-####.#	µg/Nm³
Warnings	Warning bits	########	

APPENDIX 2: PC commands list (RS232)

A command is made up only of ASCII characters, so as to allow an easy access to information and functionalities of the instrument by a PC equipped with a RS232 serial interface and with a common terminal emulation software.
The connection settings are:

- Speed: 19200 baud
- Parity: none
- Data bit: 8
- Stop bit:1
- Flow control: none

The commands have the following sintax:

<command code>[<spcifiers>]<CR>

where:

<command code>, is a couple of numeric characters in ASCII format within the interval [00÷99].
<specifiers>, are one ore more optional ASCII characters that specify the given command.
<CR> (ASCII 13), is the terminator of every command/response given/received from/by the instrument.

As a response to every given command, the instrument sends at least one character, following the table below and then, if expected, the response to the command.

Response	Meaning
<	Command length lower than 3 bytes (command+CR)
?	Command out of the interval 00 ÷ 99
*****	Not implemented command
#	Command length not corresponding to the expected one
=	Command recognized and executed

If the command ask for a response, the instrument sends:

=<response>

The ***<response>*** may be one ore more lines long. Every line ends with the character ***<CR>*** :

<line-1><CR>[<line-2><CR><line-3><CR>é .<line-N><CR>]

Every ***<line-i>*** is made up of one or more fields separated by a comma (ASCII 44):

<field-1>[,< field -2>,< field -3>,é .,< field -N>]

Every ***< field -i>*** is made up of a sequence of ASCII characters:

< ASCII characters sequence that cannot contain commas>

The non-integer numeric data are represented using a full stop (ASCII 46) as separator between integer and decimal part.
If a given command requires for functional parameters to be sent, the response will be:

=? **-** If the parameters are incorrect
=! **-** If the parameters have been accepted

The table below lists all commands available for the user and their description. Please notice that the "#" symbol represents a numeric ASCII character within the interval [0 ÷ 9].

NOTE 1: The elements inside square brackets represent optional data in the command/response.

COMMAND	DESCRIPTION	RESPONSE		
050	Calibration parameters reading	=14/06/07,14/06/07,001,0127,101.5,4.213,2.220, 0.003,0.1605,2.413,-0.001, 0.1636, 0,2080,0.001000,2.220, 0.003,-0.028000,2.413,-0.001,0.092000, -0.880800,5.413100,3.405000,6.810000, 160000, 1600,1.007,1.007, 1.000,1.000, 0.000, 5, 2.8,0.100, 0.28, 10, 10		
		##/##/##	Calibration date	14/06/07
		##/##/##	Update date	14/06/07
		###	Update number	1
		####	Serial number of the instrument	127
		###.#	Atmospheric Pressure kPa	101.5
		##.###	Reference high voltage of the Atmospheric Pressure (V)	4.213
		##.###	Service info (Flow rate A)	2.22
		###.###	Service info (Flow rate A)	0.003
		##.####	Auto Span Test Constant line A	0.1605
		##.###	Service info (Flow rate B)	2.413
		###.###	Service info (Flow rate B)	-0.001
		##.####	Auto Span Test Constant line B	0.1636
		####	Offset reset regulation valve of the flow rate A (calibration constant)	0
		####	Offset reset regulation valve of the flow rate B (calibration constant)	2080
		#.######	Coefficient "a" of the calibration equation of Line A flow rate measurement system	0.001
		##.###	Coefficient "b" of the calibration equation of Line A flow rate measurement system	2.22
		###.###	Coefficient "c" of the calibration equation of Line A flow rate measurement system	0.003
		#.######	Coefficient "a" of the calibration equation of Line B flow rate measurement system	-0.028
		##.###	Coefficient "b" of the calibration equation of Line B flow rate measurement system	2.413
		###.###	Coefficient "c" of the calibration equation of Line B flow rate measurement system	-0.001
		#.######	Coefficient "a" of the calibration equation of the mass measurement system	0.092
		#.######	Coefficient "b" of the calibration equation of the mass measurement system	-0.8808
		#.######	Coefficient "c" of the calibration equation of the mass measurement system	5.4131
		#.#####	Mass surface density of the R1 reference membrane (mg/cm²)	3.405

		#.#####	Mass surface density of the R2 reference membrane (mg/cm²)	6.81
		#######	OPC higher limit channel 1	160000
		#######	OPC higher limit channel 2	1600
		##.###	OPCset.Kf	1.007
		##.###	OPCset.Kc	1.007
		###.###	OPC K equivalent concentration "fine faction"	1
		###.###	OPC K equivalent concentration "coarse faction"	1
		###.###	OPC K equivalent concentration	0
		##	OPC average Time (m)	5
		###.#	OPC flow rate l/min	2.8
		#.##	OPC dilution (1÷0.03)	0.1
		###.##	OPCSet.LitMin	0.28
		####	OPC zero limit fine	10
		####	OPC zero limit coarse	10
051	System parameters reading	=SYS:1500.0,35, 0.0033,-0.0100, 0.0006,00,00,00,00,00,00,00,00, 00,00,00,00,00,00,00,00,1.000000,0.000000,1505914,200,750,ID,33333,33334,DOMAIN,HOST,293.0, +39000000000, +39000000000, +39000000000, 5.20, 5.20, 7.07,11.95,1,0,6,25,35, 1.3,1.3,0,200,22.0, 1.000000,0.000000, 200,577142.87,0, 4.0		
		#####.#	Constant of the flow rate regulation valve	1500
		##	Geiger Muller Tau (µs)	35
		###.####	Temperature constant "Air counts"	0.0033
		###.####	Pressure constant "Air counts"	-0.01
		###.####	Constant of the Geiger Muller high voltage "Air counts"	0.0006
		##	DAS Analogic	0
		##	DAS Analogic	0
		##	DAS Analogic	0
		##	DAS Analogic	0
		##	DAS Digital	0
		##	DAS Digital	0
		##	DAS Digital	0
		##	DAS Digital	0
		##	service	0
		##	service	0
		##	service	0
		##	service	0
		##	service	0
		##	service	0
		##	service	0
		##	service	0
		#.######	K shape line A	1
		#.######	Mass measurement offset line A	0
		########	Reference value "Air counts"	1505914
		###	DAC Full Scale line A	200
		###	Minimum sampler volume in ‰ for the mass concentration data validation	750
		##	Instrument ID	ID
		#####	TCP Port	33333
		#####	UDP Port	33334
		Domain	Domain	DOMAIN
		Host	Host	HOST

		###.#	Temperature value with sensor non connected (K)	293
		+########## ##	Service telephone number	+3900000000
		+########### ##	Operator telephone number	+39000000000
		+########### ##	User telephone number	+39000000000
		##.##	Beta spot area fast (cm²)	5.2
		##.##	Beta equivalent spot area index 0 (cm²)	5.2
		##.##	Beta equivalent spot area index 1 (cm²)	7.07
		##.##	Beta equivalent spot area index 2 (cm²)	11.95
		#	Beta measurement	1
		#	Enabling flag of data transmission via serial port or modem 0=off, 1=on serial, 2=on modem.	0
		###	Loader filters riserve capacity	6
		###	Unloader reserve limit	25
		###	Unloader maximum capacity	35
		###.#	Auto leak test Volume (l)	1.3
		###.#	Manual leak test Volume (l)	1.3
		#	Enabling flag "Beta span test" 0=off 1=on (see par. 7.2.1)	0
		#####	Consecutive rows transmission delay on the serial port (ms)	200
		##.#	Auxiliary battery minimum voltage (V)	22
		#.######	K shape line B	1
		#.######	Mass measurement offset line B	0
		####	DACFull scale line B	200
		#######.##	OPC DACFull scale	577142.9
		#	Modem Hand Shake	0
		###.#	Load drop minimum limit (kPa) in the pneumatic circuit before the automatic switch-off of the suction pump	4
052	Setting parameters reading	=SET: 2.30, 90, 0, 0,0,273.1,101.3,2.30, 90, 0, 0,0,273.1,101.3,21/09/07 22:00,008:00,000:00,000:00,0,0,0,1.84,273.0,01		
		##.##	Flow rate line A (m³/h)	2.3
		###	Percentage minimum flow rate line A	90
		##	Minimum pressure drop line A (kPa) 0=disabled	0
		##	Max pressure drop line A (kPa) 0= disabled	0
		#	Flow rate regulation mode 0= Constant volumetric flow rate 1= Constant Stokes number	0
		###.#	Normalization temperature (K)	273.1
		###.#	Normalization pressure (kPa)	101.3
		##.##	Flow rate line B (m³/h)	2.3
		###	Percentage min flow rate line B	90
		##	Min pressure drop line B (kPa) 0= disabled	0
		##	Max pressure drop line B (kPa) 0= disabled	0
		#	Flow rate regulation mode	0
		###.#	Normalization temperature (K)	273.1

		###.#	Normalization pressure (kPa)	101.3
		##/##/## ##:##	Date and time cycle start (dd/mm/yy hh:mm)	21/09/07 22.00
		###:##	Sampling duration (hhh:mm)	008:00
		###:##	service	000:00
		###:##	service	000:00
		#	Enabling flag Unloader temperature measurement (1=on 0=off)	0
		#	Index beta equivalent spot area line A 0= 5.20cm² 1= 7.07cm² 2= 11.95cm²	0
		#	Index beta equivalent spot area line B 0= 5.20cm² 1= 7.07cm² 2= 11.95cm²	0
		##.##	Accumulation flow rate in split mode	1.84
		###.#	Reference temperature sampling inlets (K)	273
		##	Programmed sampling mode **= None, 01=Monitor Mode A & B, 02=Monitor Mode Line A, 03=Monitor Mode Line B, 04=Reference Mode Line A Normal, 05=Reference Mode Line A Split, 06=Reference Mode Line B Normal, 07=Reference Mode Line B Split.	01
055	Programming parameters	27/11/08 00:00,008:00:00,28/11/08 08:00,28/11/08 16:00,28/11/08 16:00		
		##/##/## ##:##	Starting date and time of the sampling cycles	=27/11/08 00:00
		###:##:##	Sampling cycle duration	008:00:00
		##/##/## ##:##	Starting date and time of the sampling in process	28/11/2008 8.00
		##/##/## ##:##	Ending date and time of the sampling in process	28/11/2008 16.00
		##/##/## ##:##	Reference date and time for the interruption of the sampling in process	28/11/2008 16.00
06	Date and Time	=22/03/06 15:05:54		
07	Information about the software release	=04-06.01.18-30.02.00		
12	Display	=22/03/06 18:45 ← 22/03/06 15:06:03 Status: SAMPLING ENTER for menu		
13	Main physical magnitudes values	= 98.87,302.89,302.45,203.8,281.20, 26.6,4.7766,304.98,624.1		
		###.##	Atmospheric pressure (kPa)	98.87
		###.##	Room temperature (K)	302.89
		###.##	External temperature (K)	302.45
		###.#	Service pressure (kPa)	203.8
		###.##	Air fan temperature (K)	281.2
		###.#	Cabinet Relative Humidity (%)	26.6
		#.####	Sensors reference voltage (V)	4.7766
		###.##	Beta Measurement block temperature (K)	304.98

		###.#	Geiger high voltage (V)	624.1
14	Line A physical magnitudes values	=303.26,303.52, 84.27,14.59,3.8128, 55.89		
		###.##	Filter A temperature (K)	303.26
		###.##	Flow temperature line A (K)	303.52
		###.##	Pressure filter A (kPa)	84.27
		###.##	Pressure drop filter A (kPa)	14.59
		#.####	Flow pressure Line A (kPa)	3.8128
		###.##	Pressure vacuum pump A (kPa)	55.89
16###	Direct access to the submenus			
	Status READY	###	menu	
		11	Monitor Mode	
		111		Line A & B
		112		Line A
		113		Line B
		12	Reference Mode	
		121		Line A
		122		Line B
		31	Sampling Info	
		311		Sampling Info A
		312		Sampling Info B
		32	Beta Info	
		33	Test info	
		331		Line A Pneumatic Test Info
		332		Line B Pneumatic Test Info
		333		Beta Test
		334		Battery Test
		34	Program Info	
		35	System Info	
		36	Warnings Info	
		361		Warnings A
		362		Warnings B
		37	OPC Info	
		38	About	
		39	GSM Signal	
		41	Line A Settings	
		411		Sampling Flow Rate A
		412		Min Sampling Flow Rate A
		413		Min Filter Pressure Drop A
		414		Max Filter Pressure Drop A
		415		Equivalent Beta Spot Area
		42	Line B Settings	
		421		Sampling Flow Rate B
		422		Min Sampling Flow Rate B
		423		Min Filter Pressure Drop B
		424		Max Filter Pressure Drop B
		425		Equivalent Beta Spot Area
		43	Normalization Parameter	

		44	Date & Time	
		45	Split Temperature Reference	
		46	SMS Cell Numbers	
		461		Operator's Cell Number
		462		User's Cell Number
		51	Test	
		511		Line A Pneumatic Test
		512		Line B Pneumatic Test
		513		Beta Span Test
		514		Battery Test
		515		SMS Test
		52	Mechanics Direct Control	
		521		Filters Unloading
		522		Loader Device
		523		Unloader Device
		524		Line A Filter Pressing Device
		525		Line B Filter Pressing Device
		526		Beta Device
		527		Motorized Wheel
		528		Full Mech Test
		529		Mech Recover
		53	Signals Direct Control	
		531		ADC Converter
		532		Digital Readings
		533		Digital Settings
		534		DAC Test
	Status DELAY e SAMPLING	31	Sampling Info	
		311		Sampling Info A
		312		Sampling Info B
		32	Beta Info	
		33	Test info	
		331		Line A Pneumatic Test Info
		332		Line B Pneumatic Test Info
		333		Beta Test
		334		Battery Test
		34	Program Info	
		35	System Info	
		36	Warnings Info	
		361		Warnings A
		362		Warnings B
		37	OPC Info	
		38	About	
		39	GSM Signal	
		41	Line A Settings	
		411		Sampling Flow Rate A
		412		Min Sampling Flow Rate A
		413		Min Filter Pressure Drop A
		414		Max Filter Pressure Drop A
		415		Equivalent Beta Spot Area

		42	Line B Settings	
		421		Sampling Flow Rate B
		422		Min Sampling Flow Rate B
		423		Min Filter Pressure Drop B
		424		Max Filter Pressure Drop B
		425		Equivalent Beta Spot Area
		43	Normalization Parameter	
19	Line B physical magnitudes values	=303.29,304.32, 84.98,13.89,3.8776, 55.26		
		###.##	Filter B temperature (K)	303.26
		###.##	Flow temperature line B (K)	303.52
		###.##	Pressure filter B (kPa)	84.27
		###.##	Pressure drop filter B (kPa)	14.59
		#.####	Flow pressure Line B (kPa)	3.8128
		###.##	Pressure vacuum pump B (kPa)	55.89
21x	Information associated with the 6 filters on the plate	=0016,0031,0023,1168198,0206185,8466,0219174,301.96,100.89,623.09, 0.5, 32.6,0x00000000		
		To select the position of the plate corresponding to the filter about which you want to get the available information, use the following commands:		
		21A to select the filter below the *Loader* **21B** to select the filter on Line B **21C** to select the filter on Line A **21D** to select the filter in the B mass measurement area **21E** to select the filter in the A mass measurement area **21F** to select the filter below the *Unloader*		
		210 to select the filter placed in the 0 position of the plate **211** to select the filter placed in the 1 position of the plate **212** to select the filter placed in the 2 position of the plate **213** to select the filter placed in the 3 position of the plate **214** to select the filter placed in the 4 position of the plate **215** to select the filter placed in the 5 position of the plate		
		####	Cycle number	0016
		####	Filter number	0031
		####	Background radioactivity counts	0023
		#######	Air counts	1168198
		#######	Counts corresponding spy filter	0206185
		####	Spy filter counts St. Dev.	8466
		#######	Blank measurement counts	0219174
		###.##	Average temperature value (K) in the mass measurement area	301.96
		###.##	Average pressure value (kPa) in the mass measurement area	100.89
		###.##	Geiger supply average voltage value (V)	623.09
		##.#	Geiger supply voltage St. Dev.	0.5
		###.#	Relative humidity mean value (%) in the mass measurement area	32.6
		(Hex)	32 Warning bits	0x00000000

22	Information about the operative flow rate regulation system	=0,0,A1,2.300,2.306,07528,0,0,10,75,1,B1,2.300,2.331,07671,0,0,10,75,1		
		#	Flag valve enabling: 0= valve disabled 1= valve enabled	0
		#	Flag valve selection: 0= valve A 1= valve B	0
		##	Flag Line A pump enabling: 0= pump on 1= pump off	A1
		#.###	Programmed flow rate Line A (m^3/h)	2.3
		#.###	Inlet flow arte Line A (m^3/h)	2.306
		#####	Valve regulation step Line A (0-16000)	7528
		#	Flag flow rate regulation: 0= regulation deactivated 1= regulation active	0
		#	Counter Line A flow rate regulation (sec.) 0-5	0
		##	Counter activation of Line A flow rate regulation (if =0 regulation active)	10
		##	Flow rate regulation mode: 75= regulation coarse adjustment 25= regulation fine adjustment	75
		#	Flag Line A flow rate reaching: 0= flow rate not reached 1= flow rate reached	1
		##	Flag Line B pump enabling: 0= pump on 1= pump off	B1
		#.###	Programmed flow rate Line B (m^3/h)	2.3
		#.###	Inlet flow arte Line B (m^3/h)	2.331
		#####	Valve regulation step Line B (0-16000)	7671
		#	Flag flow rate regulation: 0= regulation deactivated 1= regulation active	0
		#	Counter Line B flow rate regulation (sec.) 0-5	0
		##	Counter activation of Line B flow rate regulation (if =0 regulation active)	10
		##	Flow rate regulation mode: 75= regulation coarse adjustment 25= regulation fine adjustment	75
		#	Flag Line B flow rate reaching: 0= flow rate not reached 1= flow rate reached	1
23	Temperature values Line A	=301.75,302.35,302.55,302.70,302.99,303.39		
		###.##	Minimum external temperature (K)	301.75
		###.##	Average external temperature (K)	302.35
		###.##	Maximum external temperature (K)	302.55
		###.##	Minimum filter temperature (K)	302.7
		###.##	Average filter temperature (K)	302.99
		###.##	Maximum filter temperature (K)	303.39

24	Temperature values Line B	=301.75,302.35,302.55,302.76,303.05,303.33		
		###.##	Minimum external temperature (K)	301.75
		###.##	Average external temperature (K)	302.35
		###.##	Maximum external temperature (K)	302.55
		###.##	Minimum filter temperature (K)	302.7
		###.##	Average filter temperature (K)	302.99
		###.##	Maximum filter temperature (K)	303.39
25	Pneumatic magnitudes reading	=0054,0106,2.300,2.300,2.295,2.168, 25.1690, 23.9331,08921,1,0,10, 0.3,1,0054,0107,2.300,2.300,2.299,2.171, 25.1838, 23.9460,08624,1,0,10, 0.2,1,1.840,0.000		
		####	Sampling cycle line A	54
		####	Filter line A	106
		##.###	Programmed flow rate line A (m³/h)	2.3
		##.###	Regulation flow rate line A (m³/h)	2.3
		##.###	Inlet flow rate line A (m³/h)	2.295
		##.###	Standard flow rate line A (Nm³/h)	2.168
		####.####	Inlet volume line A (m³)	25.169
		####.####	Standard volume line A (Nm³)	23.9331
		#####	Valve A position (step)	8921
		#	Enabling flag of the valve A regulation 0=regulation off 1=regulation on	1
		#	Service (timer valve A regulation delay)	0
		##	Service (parameter for the calculation of the RSD variable line A)	10
		##.#	RSD variable line A	0.3
		#	Enabling flag of the RSD variable calculation line A 0=disabled 1=enabled	1
		####	Sampling cycle line B	54
		####	Filter linea B	107
		##.###	Programmed flow rate line B (m³/h)	2.3
		##.###	Regulation flow rate line B (m³/h)	2.3
		##.###	Inlet flow rate line B (m³/h)	2.299
		##.###	Standard flow rate line B (Nm³/h)	2.171
		####.####	Inlet volume line B (m³)	25.1838
		####.####	Standard volume line B (Nm³)	23.946
		#####	Valve B position (step)	8624
		#	Enabling flag of the valve B regulation 0=regulation off 1=regulation on	1
		#	Service (timer valve B regulation delay)	0
		##	Service (parameter for the calculation of the RSD variable line B)	10
		##.#	RSD variable line B	0.2
		#	Enabling flag of the RSD variable calculation line A 0=disabled 1=enabled	1
		##.###	Accumulation flow rate in split mode (m³/h)	1.84
		##.###	Sampling inlet nominal flow rate in Split mode(m³/h)	0

26	Status reading	=3,0x00000000,0x00000000,06,02,6		
		#	Sampling status 0 = Initialization 1 = Status Ready 2 = Status Delay 3 = Status Sampling 4 = Status Test 5 = Status Ending 6 = Status Alarm 7 = End of cycle	3
		(Hex)	32 bit Warnings A	0x00000000
		(Hex)	32 bit Warnings B	0x00000000
		##	Filters in the Loader	6
		##	Filters in the Unloader	2
		#	Filters on the plate	6
281	Information about mass measurement	=0001,0001/0002,1,00000106,000:12		
		####	Mass measurement cycle	0001
		#### / ####	Numbers of the filters of Lines A/B under measurement	0001/0002
		#	Identification number of the mass measurement phase in process: 0 = none 1 = dark 2 = spy filter 3 = filter Line A 4 = filter Line B 5 = radioactivity filter Line A 6 = radioactivity filter Line B 7 = β test	1
		########	Number of counts in the measurement in process	00000106
		###:##	Remaining measurement time [mmm:ss]	000:12
30	Pressure values Line A	= 98.82, 98.96, 99.23,14.69,		
		###.##	Minimum absolute pressure (kPa)	98.82
		###.##	Average absolute pressure (kPa)	98.96
		###.##	Maximum absolute pressure (kPa)	99.23
		##.##	Maximum load drop (kPa)	14.69
35	Pressure values Line B	= 98.82, 98.96, 99.23,14.06,		
		###.##	Minimum absolute pressure (kPa)	98.82
		###.##	Average absolute pressure (kPa)	98.96
		###.##	Maximum absolute pressure (kPa)	99.23
		##.##	Maximum load drop (kPa)	14.06
40	Information about the older record	=0000,0001,0001,A,21/03/06,18:45,22/03/06,02:45		
		####	Cycle	0
		####	Filter	1
		####	Check	1
		#	Line	A
		##/##/## ##:##	Sampling start	21/03/0618:45
		##/##/## ##:##	Sampling end	22/03/06 2:45

41	Information about the newer record	=0001,0001,0002,B,21/03/06,18:45,22/03/06,02:45		
		####	Cycle	1
		####	Filter	1
		####	Check	2
		#	Line	B
		##/##/## ##:##	Sampling start	21/03/0618:45
		##/##/## ##:##	Sampling end	22/03/06 2:45
42	Buffer Data maximum size	=720,0032		
		####	Maximum number of record recordable in the Buffer Data	720
		####	Service info	0032
42xxxx	Record content (xxx=000÷720)	=0000,21/03/0618:45,22/03/0602:45,0001,0001,A,00:00,00.28,+00.1,018.129,016.175,098.1,299.5,301.0,301.6,301.0,302.0,302.3,099.4,099.6,099.8,00.4,14.4,14.2,14.5,001.9,21/03/0618:52,000:00,+01.0,0038,1328788,0195050,0225,0253359,303.5,099.8,624.2,028,0034,0195620,0148,0253442,303.3,099.2,624.2,026,00072,0017,0003.9,0004.4,00000000		
		See Appendix 1 “Buffer Data structure”		
44	Beta calibration	Download of the data relative to the last performed calibration (available only at the end of the mass measurement system calibration and anyway till the next instrument restart)		
46xxx	Mass measurement data relative to the records (xxx=000÷720)	=0000,15/11/08 00:00,15/11/08 08:00,0001,0001,A,0019,0873350, 0125863,0122,0114649,00250,298.8,100.7,624.3,036,0098,0125932,0262, 0112204,00305,300.7,101.1,624.2,033, 304,0020, 16.8, 17.5,10000000		
		####	Record number (internal reference progressive number)	0
		##/##/#### ##.##	Sampling starting date and time	15/11/2008 0.00
		##/##/#### ##.##	Sampling ending date and time	15/11/2008 8.00
		####	Cycle progressive number	1
		####	Filter progressive number	1
		#	Sampling line	A
		####	Background radioactivity β flux	19
		#########	B flux in air	873350
		#########	B flux spy filters S12/S34/S56 during the blank measurement session	125863
		######	β flux standard deviation spy filters S12/S34/S56	122
		#########	B flux blank filter	114649
		######	β flux standard deviation blank filter	250
		###.#	Temperature blank filter measurement area	298.8
		###.#	Pressure blank filter measurement area	100.7
		###.#	Geiger Muller counter high voltage during the blank measurement session	624.3
		###	Relative humidity during the blank measurement session	36
		#####	Natural radioactivity β flux	98
		#########	B flux spy filters S12/S34/S56 during the collect measurement session	125932
		######	β flux standard deviation spy filters S12/S34/S56	262
		#########	β flux sampled filter	112204
		######	β flux standard deviation sampled filter	305

		###.#	Temperature sampled filter measurement area	300.7
		###.#	Pressure sampled filter measurement area	101.1
		###.#	Geiger Muller counter high voltage during the collect measurement session	624.2
		###	Umidità Relativa durante la sessione di misura collect	33
		#######	Sample mass	304
		###	Error in mass calculation	20
		####.#	Concentration	16.8
		####.#	Concentration in standard conditions	17.5
		########	WARNINGS Bit	10000000
70x	Beta Span Test	**x=1** to enable the “beta test” at the beginning of the following cycle **x=0** to disable the “beta test” at the beginning of the following cycle (see paragraph 7.2.1)		

Note: The RS232 command list refers to the software versions higher than the 04080163

APPENDIX 3: Menu Structure

READY STATUS:	*The instrument is ready to start a sampling cycle. Before starting the sampling process it's possible to read data and information, to set new parameters, to carry out tests and quality controls.*
1 "Start"	11 "Monitor Mode" 111 "Line A & B" 112 "Line A" 113 "Line B" 12 "Reference Mode" 121 "Line A" 122 "Line B"
2 "Buffer data"	
3 "Instrument Info"	31 "Sampling Info " 311 "Sampling Info A" 312 "Sampling Info B" 32 "Beta Info " 33 "Test info" 331 "Line A Pneumatic Test Info" 332 "Line B Pneumatic Test Info" 333 "Beta Test " 334 "Battery Test " 34 "Program Info" 35 "System Info" 36 "Warnings Info" 361 "Warnings A" 361 "Warnings B" 37 "OPC Info" 38. "About" 39 "GSM Signal"
4 "Instrument Settings"	41 "Line A Settings" 411 "Sampling Flow Rate A" 412 "Min Sampling Flow Rate A" 413 "Min Filter Pressure Drop A" 414 "Max Filter Pressure Drop A" 415 "Equivalent Beta Spot Area" 42 "Line B Settings" 421 "Sampling Flow Rate B" 422 "Min Sampling Flow Rate B" 423 "Min Filter Pressure Drop B" 424 "Max Filter Pressure Drop B" 425 "Equivalent Beta Spot Area" 43 "Normalization Parameter 44 "Date & Time" 45 "Split Temperature Reference" 46 "SMS Cell Numbers" 461 "Operator's Cell Number" 462 "User's Cell Number"

5 "Instrument Tools"	51 Test 511 “Line A Pneumatic Test” 512 “Line B Pneumatic Test” 513 “Beta Span Test” 514 “Battery Test” 515 “SMS Test” 52 “Mechanics Direct Control” 521 “Filters Unloading” 522 “Loader Device” 523 “Unloader Device” 524 “Line A Filter Pressing Device” 525 “Line B Filter Pressing Device” 526 “Beta Device” 527 “Motorized Wheel” 528 “Full Mech Test” 529 “Mech Recover” 53 “Signals Direct Control” 531 “ADC Converter” 532 “Digital Readings” 533 “Digital Settings” 534 “DAC Test” 54 “Firmware Upgrade”

DELAY STATUS:	*The instrument has been programmed (start) and it’s waiting for starting the sampling process at the programmed date and time. In the meantime it is possible to read data and information and to modify some parameters.* *If needed, it is possible to go back to READY status selecting Abort from the main menu.*
1 "Abort"	
2 "Buffer data"	
3 "Instrument Info"	31 "Sampling Info " 311 “Sampling Info A” 312 “Sampling Info B” 32 "Beta Info " 33 "Test info" 331 "Line A Pneumatic Test Info" 332 “Line B Pneumatic Test Info" 333 "Beta Test " 334 "Battery Test " 34 "Program Info" 35 "System Info" 36 "Warnings Info" 361 “Warnings A” 361 “Warnings B” 37 "OPC Info" 38. “About” 39 “GSM Signal”
4 "Instrument Settings"	41 “Line A Settings” 411 “Sampling Flow Rate A” 412 “Min Sampling Flow Rate A” 413 “Min Filter Pressure Drop A” 414 “Max Filter Pressure Drop A” 415 “Equivalent Beta Spot Area” 42 “Line B Settings” 421 “Sampling Flow Rate B” 422 “Min Sampling Flow Rate B”

	423 “Min Filter Pressure Drop B” 424 “Max Filter Pressure Drop B” 425 “Equivalent Beta Spot Area” 43 “Normalization Parameter

SAMPLING STATUS:	*The instrument is sampling. It’s possible to read data and information and to modify some sampling parameters. If needed, you can stop the sampling sequence (Abort).*
1 " Abort"	
2 "Buffer data"	
3 "Instrument Info"	31 "Sampling Info " 311 “Sampling Info A” 312 “Sampling Info B” 32 "Beta Info " 33 "Test info" 331 "Line A Pneumatic Test Info" 332 “Line B Pneumatic Test Info" 333 "Beta Test " 334 "Battery Test " 34 "Program Info" 35 "System Info" 36 "Warnings Info" 361 “Warnings A” 361 “Warnings B” 37 "OPC Info" 38. “About” 39 “GSM Signal”
4 "Instrument Settings"	41 “Line A Settings” 411 “Sampling Flow Rate A” 412 “Min Sampling Flow Rate A” 413 “Min Filter Pressure Drop A” 414 “Max Filter Pressure Drop A” 415 “Equivalent Beta Spot Area” 42 “Line B Settings” 421 “Sampling Flow Rate B” 422 “Min Sampling Flow Rate B” 423 “Min Filter Pressure Drop B” 424 “Max Filter Pressure Drop B” 425 “Equivalent Beta Spot Area” 43 “Normalization Parameter

APPENDIX 4: Instrument Settings

Line A & B setting				
	Sampling Flow rate Sampling operating flow rate	#.#	0.8-2.5	m^3/h
	Min Sampling Flow Rate Minimum value of the operating flow rate expressed in percentage of the programmed flow rate value. If the deviation between operating and programmed flow rate exceeds this minimum value, a Warning message will be displayed (Warning 6)	###.#		%
	Min Filter pressure drop Low limit of the filter pressure drop: if the filter pressure drop is lower then the programmed limit, a Warning message will be displayed (Warning 7). This threshold is useful for the quality control on the seal of the filter-filter presser system and on the filtering medium integrity.	##.#	0-60	kPa
	Max filter pressure drop High limit of the filter pressure drop. If the filter pressure drop is higher then the programmed limit, a Warning message will be displayed (Warning 5). Setting this threshold allows the user to check that during all the sampling phase the particulate matter accumulation on the filtering medium occurs with no extraordinary events that could affect the sample representativeness (for example, presence of condensate water on the filtering medium).	##.#	0-60	kPa
	Beta Equivalent Spot Area Usable sampling and measurement area	##.##	2.54 / 5.20 / 7.07 / 11.95	cm^2
Normalization Parameter				
	Normalization Temperature Temperature value used for the calculation of the standard volume (by default programmed at 273.1K)	###.#		K
	Normalization Pressure Pressure value used for the calculation of the standard volume (by default programmed at 101.3 kPa)	###.#		kPa

Date & Time	Date and Time setting			
Split Reference Temperature				
	Split Ref.Temp. temperature value used for the impactor dimensioning to obtain the desired nominal cut diameter	###.#		K
SMS Cell numbers				
	Operator's cell number	+#############		
	User's cell number	+#############		

APPENDIX 5: Instrument Info

Menu		Abbreviation	Description	Format	Unit
SAMPLING INFO A /B	1/9				
Sampling–Sample Info		Cycle	Cycle progressive number	####	
		Filter	Filter progressive number	####	
		Pump	Pump status	ON/OFF	
Sampling–Timing		From/ To	sampling start/end date/time	##/##/## ##:##	dd/mm/yy hh:mm
		Elapsed/ Remaining	Remaining time	###/##	hhh/mm
Sampling–Flow rate		Inlet	Inlet air flow	#.##	m^3/h
		Standard	Standard air flow at 273.1K and 101,3 kPa (default settings)	#.##	Nm^3/h
Sampling–Total Volume		Inlet	Current inlet volume	###.###	m^3
		Standard	Standard volume at 273.1K and 101,3 kPa	###.###	Nm^3
Sampling–Pressure		Absolute	Atmospheric pressure	###.#	kPa
		Drop	Pressure drop	##.#	kPa
Sampling–Flow rate control		RSD	RSD variable	###.#	%
		Valve opening	Opening percentage of the flow rate regulation valve	###.#	%
Sampling Temperature		External	External temperature	###.#	K
		Filter	In sampling filter temperature	###.#	K
BETA INFO	2/9				
		Cycle	Cycle	####	
		Filter	Filter	####/####	
Beta counts & timing		Counts	Beta counts	########	
		Time	Remaining time	###:##	mmm:ss
Beta T/P/RH QC		T	Measurement block temperature	###.#	K
		P	Measurement block pressure	###.#	kPa
		RH	Relative Humidity	###.#	%
Beta Geiger voltage QC		Avg.	Mean value of the G.M. high voltage during the measurement	###.#	V
		St.Dev	Standard Deviation	###.#	V
TEST INFO	3/9				
Pneumatic Test Info Line A/B					
Span Test			Test date and time		
		Qcal	Calibration flow rate value	#.##	m^3/h
		Qtest	Flow rate value coming from the test	#.##	m^3/h
		Err	Percentage Error	± ###.#	%
Leak Test			Test date and time		
		Pr	Residual pressure	###.#	kPa
		Qleak	Specific leak	##.##	ml/min*kPa
Beta Test					
			Test date and time		
		R1/R2	Membrane R1		
		Cal	Reference value	#.###	mg/cm²
		Test	Measured value	#.###	mg/cm²
		ERR	Percentage error	###.#	%

			Test date and time		
		D	Dark counts	#####	counts/min
		A	Air counts	########	counts/min
		R1	R1 counts	########	counts/min
		R2	R2 counts	########	counts/min
Battery test					
			Test date and time		
		Vps	Internal reference voltage	##.#	V
		I	Charging battery current	###	%
		VBL	“Load” battery voltage	##.#	V
		VBO	“No-load” battery voltage	##.#	V
PROGRAM INFO	4/9				
		Program:	Selected mode		
		Cycle time:		###:##	hhh:mm
SYSTEM INFO	5/9				
		Loader: Unloader: Filters on plate:	loader status unloader status Filters on the plate		
		Modem status	GSM modem status		Ready/Not ready
		Room temperature:	Cabinet temperature	###.#	K
		External temperature	External temperature	###.#	K
		Filter temperature (A/B)	Filter temperature	###.#	K
		Flow rate temperature (A/B)	Air flow temperature	###.#	K
		Geiger Temperature	Measurement block temperature	###.#	K
		Atmospheric pressure	Atmospheric pressure	###.#	kPa
		Filter pressure (A/B)	Pressure near the filter	###.#	kPa
		Pump pressure (A/B)	Vacuum pump pressure	###.#	kPa
		Flow rate pressure (A/B)	Air flow pressure	###.#	kPa
		Service pressure	Service compressed air pressure	###	kPa
		Case RH	Relative Humidity inside the instrument	###	%
		Geiger high Voltage	Power supply voltage	#.###	V
		Reference Voltage	Reference voltage	#.###	V
		Power Supply source	Power Supply source		AC mains/ DC Battery
		Voltage	Internal voltage	###.#	V
		Current level	Current level	###	%
		Unloader temperature	Unloader internal temperature	###.#	K
		POff POn SOff Son	Power Off Power On Auto-switch-off Switch on after the Auto-switch-off		Date and Time

WARNINGS INFO	6/9				
Warning a /B		Warnings A /B:	NONE 00000000-00000000- 00000000-00000000 (see Appendix)		
OPC INFO	7/9				
		OPC- Size concentration (AVG 1 min)	Fine and Coarse fractions concentration (average 1 minute)		
		OPC- Equivalent mass conc. Trend (AVG 60 min)	Equivalent mass concentration trend		
		OPC- Equivalent mass conc. (AVG 1 min)	Equivalent mass concentration		
		OPC- Size concentration (AVG 1 min)	Fine and Coarse fractions concentration (average 1 minute)		
ABOUT	8/9				
			FAI Instruments s.r.l.		
		Rel	release	##-##.##.##-##.##.##	
		SN	Instrument serial number	####	
GSM Signal	9/9		GSM Modem signal (if present)		

APPENDIX 6: Instrument Tools

5 "Instrument Tools"	
51 "Test"	
511 "Line A Pneumatic Test"	Pneumatic Test Line A
512 "Line B Pneumatic Test"	Pneumatic Test Line B
513 "Beta span test"	Mass measurement system calibration check
514 "Battery test"	Battery test
515 "SMS test"	SMS sending test
5 "Instrument Tools"	
51 "Test"	
511 "Line A Pneumatic Test"	Pneumatic Test Line A
512 "Line B Pneumatic Test"	Pneumatic Test Line B
513 "Beta span test"	Mass measurement system calibration check
514 "Battery test"	Battery test
515 "SMS test"	SMS sending test
52 "Mechanics direct control"	Direct mechanical handlings
521 "Filters unloading"	Filters unloading
522 "Loader device"	*Service tool*
523 "Unloader device"	*Service tool*
524 "Line A filter pressing device"	*Service tool*
525 "Line B filter pressing device"	*Service tool*
526 "Beta device"	*Service tool*
527 "Motorized wheel"	*Service tool*
528 "Full mech test"	Servomechanisms test
529 "Mech recover"	*Service tool*
53 "Signals direct control"	Signals direct control
531 "ADC Converter"	*Service tool*
532 "Digital readings"	*Service tool*
533 "Digital settings"	*Service tool*
534 “DAC Test”	*Service tool*
54 “Firmware upgrade”	*Service tool*

APPENDIX 7: ALARMS

To the “ALARM” category belong those situations that prejudice the instrumental functionality, causing the sampling stop. If the instrument stops the running due to a failure, the display will show a message specifying the type of the anomaly in the following form:

*** SYSTEM ALARM***	DATA	ORA
20 FILTER	ERROR 2	

If the Alarm message is about the “plate”, the following codes will be added to the error message:

- “128” if a reading error of the sensors occurs
- “16” if a repositioning attempt occurs
- “144” if both the preceding conditions occur

The table below shows a legend to interpret the alarm codes

SYSTEM ALARM	ERROR
System alarm 10: PLATE Plate movement	1= Communication timeout 2= Invalid required position 3= Final position different from the wanted one 4= Position code not identified 5= Starting code not left after a prearranged steps number 6= Code not achieved within a prearranged steps number 7= Code reading error 8= Deceleration not performed within a prearranged steps number 9= Position not achieved within a prearranged steps number 10= Movement hampered by an incorrect cylinder position
System alarm 20: FILTER (loader) Filter loading	1= Communication timeout (*) 2= Insufficient service pressure 3= Starting cylinder position RUN (*) 4= Starting cylinder position UP (*) 5= Unlocked Loader (*) 6= Filter not ready (*) 7= Plate in wrong position 8= Uphill movement timeout 9= Downhill movement timeout 10= Second attempt cylinder up effected (*) 11= Second attempt cylinder down effected (*) 12= Filter not loaded at the end of the attempts (*) 13=Loader empty (reserve on) (*) 14=Loader empty (reserve off) (*)
System alarm 31 : FILTER A UP Cylinder Up positioning Line A	1= Communication timeout (*) 2= Service pressure lower than 140 kPa 3= Filter presser piston already moving (*) 4= Filter presser piston already UP (*) 6= Piston blocked in DOWN position 7= Plate in wrong position 8= Piston uphill movement timeout (*) 10= Second attempt piston up effected (*)

(*) Alarm messages displayed only in the system LOG and available just for the Technical Assistance Service

SYSTEM ALARM	ERROR
System alarm 32: FILTER A DOWN Cylinder Down positioning Line A	1= Communication timeout (*) 2= Service pressure lower than 140 kPa 3= Filter presser piston already moving (*) 5= Filter presser piston already DOWN (*) 6= Piston blocked in UP position 7= Plate in wrong position 9= Piston downhill movement timeout (*) 11= Second attempt piston down effected (*)
System alarm 34: FILTER B UP Cylinder Up positioning Line B	1= Communication timeout (*) 2= Service pressure lower than 140 kPa 3= Filter presser piston already moving (*) 4= Filter presser piston already UP (*) 6= Piston blocked in DOWN position 7= Plate in wrong position 8= Piston uphill movement timeout (*) 10= Second attempt piston up effected (*)
System alarm 35: FILTER B DOWN Cylinder Down positioning Line B	1= Communication timeout (*) 2= service pressure lower than 140 kPa 3= Filter presser piston already moving (*) 5= Filter presser piston already DOWN (*) 6= Piston blocked in UP position 7= Plate in wrong position 9= Piston downhill movement timeout (*) 11= Second attempt piston down effected (*)
System alarm 50: UNLOADER Filter unloading	1= Communication timeout (*) 2= service pressure lower than 140 kPa 3= Filter unloading piston already moving(*) 4= Filters unloading piston already UP (*) 6= The sampled filters Unloader is not correctly locked (*) 7= Plate in wrong position 8= piston Uphill movement timeout 9= piston Downhill movement timeout 10= Second attempt cylinder up effected (*) 11= Second attempt cylinder down effected (*)
System alarm 70: VALVE A Regulation valve Line A	1= Communication timeout during the reset process 2= valve limit switch closed 5= first reset attempt effected 6= second reset attempt effected
System alarm 71: VALVE B Regulation valve Line B	1= Communication timeout during the reset process 2= valve limit switch closed 5= first reset attempt effected 6= second reset attempt effected
System alarm 80: ADC ADC converter	9= Sensors reference voltage out of the limit 4.62-4.98 Volt (in 10 consecutive readings)
System alarm 92: LEAKTEST A LeakTest Line A	1= Leak exceeding the allowed limit
System alarm 93: LEAKTEST B LeakTest Line B	1= Leak exceeding the allowed limit
System alarm 94: MANUAL LEAKTEST A Manual LeakTest Line A	1= Leak exceeding the allowed limit
System alarm 95: MANUAL LEAKTEST B Manual LeakTest Line B	1= Leak exceeding the allowed limit

System alarm 96: SPANTEST A SpanTest Line A	2= Deviation exceeding the allowed limit
System alarm 97: SPANTEST B SpanTest Line B	2= Deviation exceeding the allowed limit
System alarm 63: BETA MOVE Beta measurement system movement	1=Communication timeout 2=Position sensors reading invalid 3=Beta position sensors reading invalid 4=Arrival position identification code invalid 5=Wrong position (*) 6=Final position not achieved 7=Blocked in starting position 8=Shield movement end position not achieved
System alarm 64: BETA RESET Beta measurement system movement	3=Reset attempts maximum number exceeded
System alarm 100: SLAVE Master-slave communication	1= Number of consecutive failed communications exceeding the allowed limit

(*) Alarm messages displayed only in the system LOG and available just for the Technical Assistance Service

APPENDIX 8: WARNINGS

To the **“WARNING”** category belong those situations when some parameters do not satisfy the applied quality standards. This condition does not imply the interruption of the normal sampling and measurement operations, but it can affect data quality. The Warnings have the function to inform the user and/or the maintenance engineer about the need of aimed controls (automatic indication of “Warning” causes). They are signaled by a yellow led on the control panel, they are displayed in the *Instrument Info* menu and stored in the *Buffer data*.

The WARNING message appearing in the ñBuffer dataò is made up of 8 hexadecimal figures.
Every figure represents 4 bits (0=0000 ï F=1111), therefore 8*4bit= 32bit. The bit presentation order, from left to right, goes from the most significant (bit31) to the least significant one (bit0).

Hex-Bit conversion:

0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**A**	**B**	**C**	**D**	**E**	**F**
0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
0	0	0	0	1	1	1	1	0	0	0	0	1	1	1	1
0	0	1	1	0	0	1	1	0	0	1	1	0	0	1	1
0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1

To identify the codes relative to instrument running anomalous situations use the table below

Figure	**Weight**	**Bit**	**Status**	
1	8	**31**	Service air pressure higher than 300 kPa	SERVICE PRESSURE OVER
	4	**30**	Service air pressure lower than 140 kPa [≤ 100 kPa → Alarm]	SERVICE PRESSURE LOW
	2	**29**	Power down condition – battery running	POWER DOWN CONDITION
	1	**28**	Low auxiliary battery voltage (*Battery Test*, default 22V)	LOW BATTERY VOLTAGE
2	8	**27**	Not implemented	
	4	**26**	Optical Particle Counter Alarm	OPC ALARM
	2	**25**	Internal cooling fan failure	INTERNAL FAN FAILURE
	1	**24**	Temperature sensors failure. The instrument uses the default value 293 K (programmable value) if the temperature sensors are incorrectly connected or malfunctioning (see paragraph 5.5).	TEMPERATURE SENSOR FAILURE
3	8	**23**	Invalid data. This Warning is activated if one of the Warnings 16-17 is active or if the real sampling time percentage is lower than the programmed value (default: 75%).	QC: CHECK DATA
	4	**22**	Long Term Geiger Instability. The percentage difference between the air counts value and the reference value is higher than the programmed limit value.	GEIGER ZERO DRIFT
	2	**21**	The sampling and measurement cycle has been stopped by the operator	CYCLE ABORT
	1	**20**	Not implemented	
4	8	**19**	The measured value of the background noise is out of the interval 1÷150 cpm	DARK COUNTS OUT OF LIMITS

	4	**18**	Short Term Geiger Instability During the measurement of the β rays flux the instrument noticed a contradiction between the measured counts ratio and the Poisson statistics, describing the radioactive decay.	GEIGER INSTABILITY
	2	**17**	The measured value of the Blank counts is out of the interval between 20.000 cpm and the counts of the beta flux in air	BLANK COUNTS OUT OF LIMITS
	1	**16**	The Geiger detector high voltage is out of the interval 610÷640 Volt	GEIGER H.V. OUT OF LIMITS
5	8	**15**	During the mass measurement cycle, the standard deviation value of the Geiger detector high voltage is higher than 1 Volt	GEIGER HV SD OUT OF LIMIT
	4	**14**	In the “Beta Auto Span Test” the percentage deviation between the nominal and the measured value of one or both the reference membranes is out of the interval ± 5%	BETA TEST OUT OF LIMIT
	2	**13**	In the “Pneumatic Auto Span Test” performed at the beginning of the sampling process, the percentage deviation from the starting calibration value is out of the interval ± 4% [± 10% →Alarm]	SPAN TEST OUT OF LIMITS
	1	**12**	In the “Pneumatic Auto Leak Test” performed at the beginning of the sampling process, the specific leak is higher than 5 ml/(min*kPa) [10 ml/(min*kPa) →Alarm] In the “Pneumatic Manual Leak Test” performed by the operator, the specific leak is higher than 15 ml/(min*kPa) [30 ml/(min*kPa) →Alarm]	LEAK TEST OUT OF LIMITS
6	8	**11**	Not implemented	
	4	**10**	Upside-down filter cartridge event. During the filters loading, the instrument noticed an upside-down filter cartridge. The pair of filters containing the upside-down filter cartridge has been discarded and replaced with the following pair.	UPSIDE-DOWN FILTER
	2	**9**	Pressure sensors malfunction. The condition P(pump)<P(line)<P(atmospheric) is not respected	PRESSURE SENSOR FAILURE
	1	**8**	Achieved the maximum filter pressure drop limit (60 kPa)	MAX PRESSURE DROP LIMIT
7	8	**7**	Achieved the minimum filter pressure drop limit (2 kPa at 2.3m³/h)	MIN PRESSURE DROP LIMIT
	4	**6**	Achieved the minimum flow rate limit (value programmed by the operator)	MIN SET FLOW RATE LIMIT
	2	**5**	Achieved the maximum filter pressure drop limit programmed by the operator	MAX SET PRESSURE DROP LIMIT
	1	**4**	Achieved the minimum filter pressure drop limit programmed by the operator	MIN SET PRESSURE DROP LIMIT
8	8	**3**	Instability of the value of the differential pressure transducers offset. During the transducers offset control, the difference between the two consecutive readings (2 second long intervals) is higher than 5 mV	OFFSET INSTABILITY
	4	**2**	Calibration constants of the pressure sensors out of the range (the pressure transducer offset is out of the interval 0.2÷0.6 Volt or the constant is out of the interval 120÷135)	PRESSURE SENSORS CALIBRATION
	2	**1**	Achieved the high limit of the sampling flow rate regulation valve	VALVE HIGH LIMIT
	1	**0**	Achieved the low limit of the sampling flow rate regulation valve	VALVE LOW LIMIT

EXAMPLES:

Warning message	Figure/Weight	Bit	Status
0 0 0 8 0 0 0 0	4^{th} figure = 8	19	DARK counts out of the interval 1-150 cpm
0 0 0 0 0 0 2 0	7^{th} figure = 2	5	Achieved the maximum pressure drop programmed by the user
0 4 0 0 0 0 0 1	2^{nd} figure = 4	30	Service pressure “LOW” (< 140 KPa)
	8^{th} figure = 1	0	Valve low limit achieved
0 0 0 0 0 0 5 0	7^{th} figure = 5 = 4 + 1	6	Flow rate low limit achieved
		4	Achieved the minimum pressure drop programmed by the user

APPENDIX 9: Optional accessories and main spare parts

Description	Code
OPTIONAL ACCESSORIES	
"Blind" filter for Leak test	RACPFLEAK
Plug for Leak test	RACTPLEAK
Adapter for internal flow rate measurer	RACADMP
Adapter for external flow rate measurer	RACADMP-EXT
Clamping key for locking the aluminum filter cartridges containing the reference membranes.	RACKEY
Tweezers for insertion/removal reference membrane filter cartridges	RACPZ
Dinking die for reference membranes cutting	RACFUST
Filter cartridges β *equivalent spot area 11.95* cm^2	RSWPFB1195 RSWPFR1195
Filter cartridges β *equivalent spot area 7.07* cm^2	RSWPFB707 RSWPFR707
Filter cartridges β *equivalent spot area 5.20* cm^2	RSWPFB520 RSWPFR520
Virgin filters Loader capacity 72 filter cartridges	RSWCAR72
Sampled filters Unloader capacity 72 filter cartridges	RSWSCAR72
Auxiliary tool for the virgin filters insertion inside the Loader. (Preservation of the filter insertion order)	RACAUXFV
Tool for pressure-coupled filter cartridges opening	RACAPPF
GSM Modem for the remote connection to the instrument, complete with power supply, antenna and connection cable.	MDMGSM
Remote management software *Dr-FAI-Manager*	DRFMNGR
Plenum chamber for the distribution of the particulate matter sample on two sampling lines downstream a single sampling head, complete with connectors	CDC-DCHY
Kit no. 2 absolute filters for Zero Test – Offset check	ZEROFLT
SET 6 aluminum reference membranes for mass measurement check/calibration	RACREFSET
Sampling inlet PM10 Nominal flow rate: 2.3 m^3/h In compliance with the EN 1234-1 standard	LVS-PM10
Sampling inlet PM10 Nominal flow rate: 1 m^3/h European design	LVSPM10-1M3
Sampling inlet PM2.5 Nominal flow rate: 2.3 m^3/h In compliance with the EN 14907 standard	LVS-PM2.5
Sampling inlet PM2,5 Nominal flow rate: 1 m^3/h European design	LVSPM2.5-1M3
Sampling inlet PM2.5 with rotary impactor Nominal flow rate: 2.3 m^3/h In compliance with the EN 14907 standard	LVS-PM2.5-ROT
Sampling inlet PM10 with rotary impactor Nominal flow rate: 2.3 m^3/h In compliance with the EN 12341 standard	LVS-PM10-ROT
PM1 2.3 m^3/h sampling inlet	LVSPM1
TSP sampling inlet	LVS-PTS
MAIN SPARE PARTS	
Fuses Kit	RDCELKF
Vacuum pump maintenance Kit	RSWKTPMP
O-ring for sampling heads	RTSSOR1
Air compressor oil 1/2 L pack	CMP-SIL-OIL

APPENDIX 10: Sampling lines configurations (some application examples)

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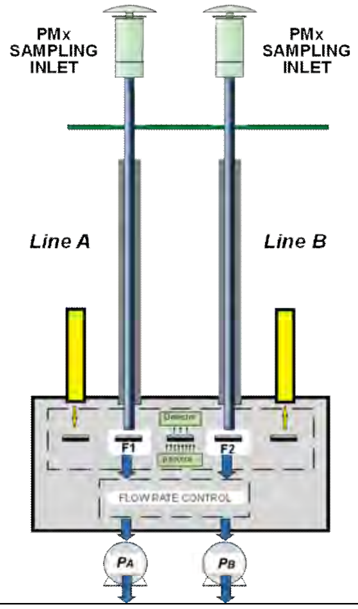
<td>
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EXAMPLE CONFIGURATION 1

Simultaneous drawing of PMx samples using the instrument as two "*co-located*" samplers

- two PMx samples available with different granulometric cut size (for example PM_{10} and $PM_{2,5}$)
- replicated samples available (use of the two lines the same or different types of filtering mediums, depending on the analytical needs)
- metrological studies, as for example the check of the equivalence of two sampling inlets

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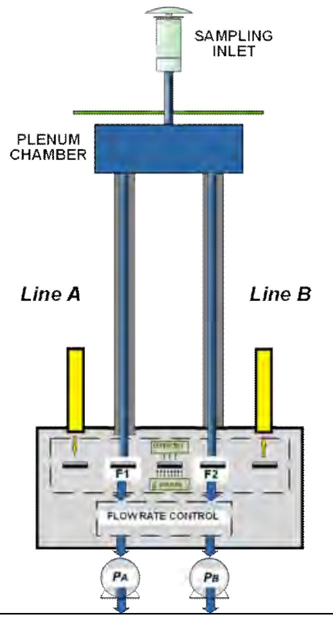
<td>
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EXAMPLE CONFIGURATION 2

Simultaneous PMx samples enrichment on two filtering mediums using a single sampling inlet

- replicated samples available (samples absolutely equivalent as regards the granulometric representativeness)
- optimal configuration for the use of an EU Low Volume 2.3m³/h sampling inlet contextually with the particulate matter enrichment on filtering mediums with a high specific impedance (for example Teflon 1µm for the particulate matter chemical speciation)

for example:

- *Line A Quartz filter* Q_A*=1.3 m³/h*
- *Line B Teflon filter* Q_B*=1 m³/h*

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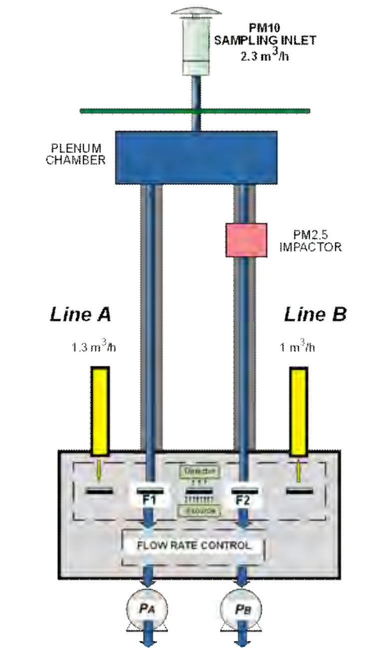
</table>



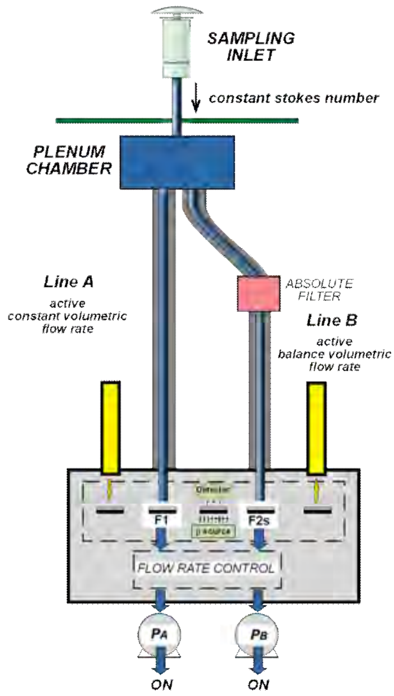
EXAMPLE CONFIGURATION 3

Simultaneous PM_{10} and $PM_{2.5}$ sampling using a single sampling inlet

Example:

- *use of a PM10 EU Low Volume 2.3m³/h sampling inlet*
- *use of an EPA WINS PM2.5 impactor on line B*
- *Flow rate Line B = 1 m^3/h*
- *Flow rate Line A = 1.3 m^3/h*

$$Q_A + Q_B = Q_{inlet} = 2.3\ m^3/h$$



EXAMPLE CONFIGURATION 4

Reference configuration at constant Stokes number

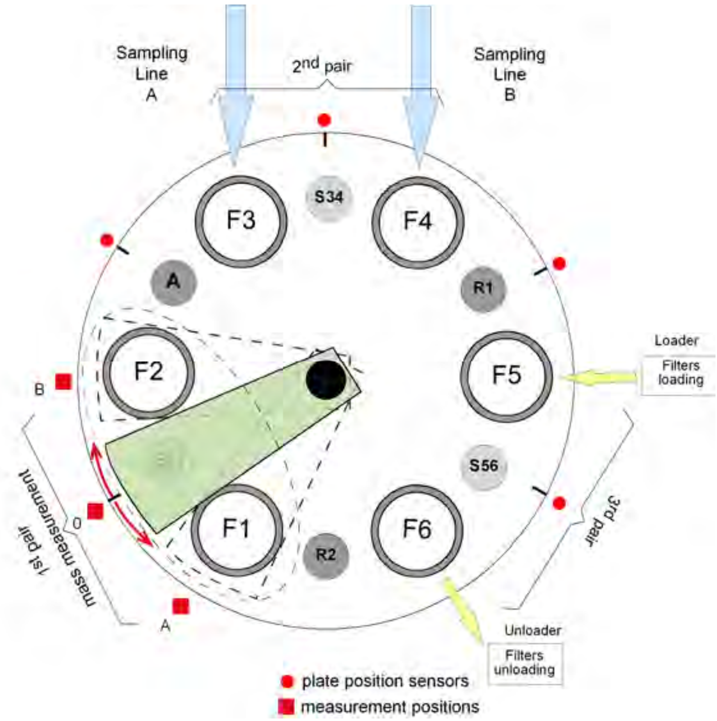
possibility of operating at an inlet flow rate at the sampling inlet level such as the Stokes number associated with the impactor is constant

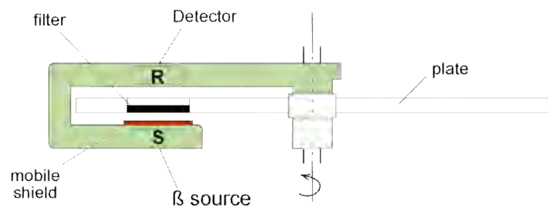
- Line A constant volumetric flow rate
- Line B balance flow rate
- Q_{inlet}/η= constant

$$Q_A + Q_B = Q_{inlet}$$

APPENDIX 11: Mass measurement

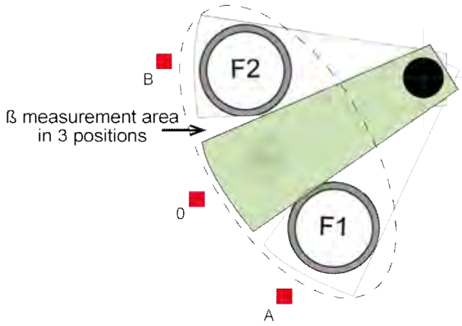
The mass measurement module is made up of an arm keeping Source and Detector mechanically bound. The arm rotates on the plate axis, placing Source and Detector in three different positions in order to perform the expected measurements. On the arm a mobile shield is placed that, when required by the measurement sequence, interposes between Source and Detector.





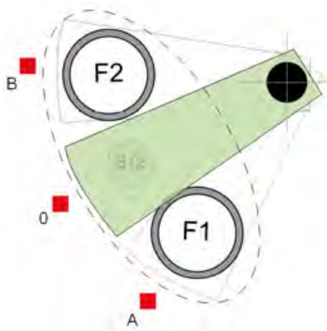
BLANK MEASUREMENT PROCESS IN DETAIL

1. The instrument verifies that the Geiger is in “0” position and that the shield is closed. Then it goes on with the *Dark* flux measurement

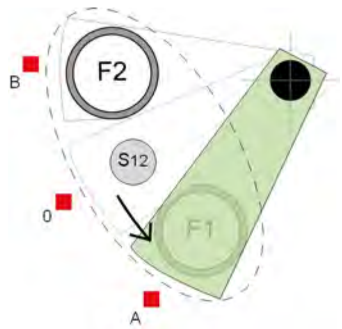


2. Opening of the mobile shield and measurement of the flux on filter S12 (measurement length: 5’)

3. Arm moving to A position and measurement of the flux on filter F1 (measurement length: 10')

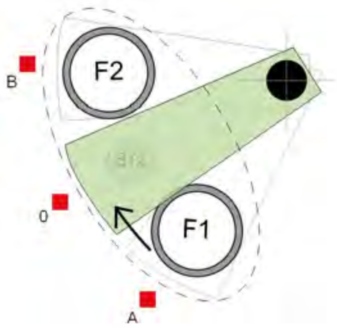


$$M^b = \begin{bmatrix} S_{12}^{11} & F_1^{b1} & S_{12}^{12} & F_2^{b1} & S_{12}^{13} \\ S_{12}^{21} & F_1^{b2} & S_{12}^{22} & F_2^{b2} & S_{12}^{23} \\ S_{12}^{31} & F_1^{b3} & S_{12}^{32} & F_2^{b3} & S_{12}^{33} \\ S_{12}^{41} & F_1^{b4} & S_{12}^{42} & F_2^{b4} & S_{12}^{43} \end{bmatrix}$$



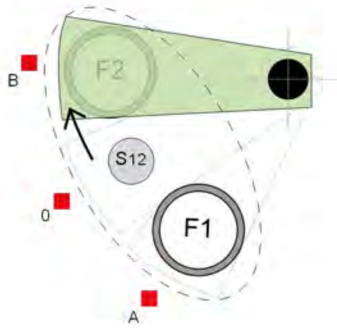
$$M^b = \begin{bmatrix} S_{12}^{11} & F_1^{b1} & S_{12}^{12} & F_2^{b1} & S_{12}^{13} \\ S_{12}^{21} & F_1^{b2} & S_{12}^{22} & F_2^{b2} & S_{12}^{23} \\ S_{12}^{31} & F_1^{b3} & S_{12}^{32} & F_2^{b3} & S_{12}^{33} \\ S_{12}^{41} & F_1^{b4} & S_{12}^{42} & F_2^{b4} & S_{12}^{43} \end{bmatrix}$$

4. arm moving to 0 position and measurement of the flux on filter S12 (measurement length: 5’)



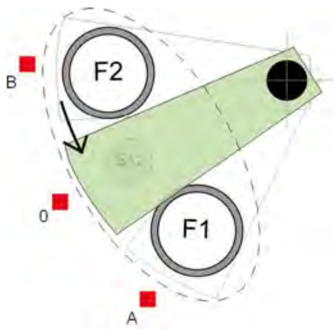
$$M^b = \begin{bmatrix} S_{12}^{11} & F_1^{bl} & S_{12}^{12} \end{bmatrix}$$

5. arm moving to B position and measurement of the flux on filter F2 (measurement length: 10')



$$M^b = \begin{bmatrix} S_{12}^{11} & F_1^{bl} & S_{12}^{12} & F_2^{bl} \end{bmatrix}$$

6. arm moving to 0 position and measurement of the flux on the filter S12 (measurement length: 2' 30")



$$M^b = \begin{bmatrix} S_{12}^{11} & F_1^{bl} & S_{12}^{12} & F_2^{bl} & S_{12}^{13} \end{bmatrix}$$

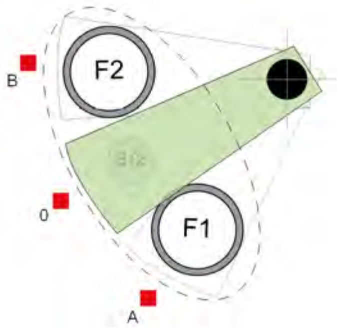
7. the phases from 1 to 6 repeat themselves *n* times in order to complete the matrix of the Blank measurements Mb

with:
n=4 for ≤ 8 hours long sampling cycles
n=6 for ≥ 12 hours long sampling cycles

Here below an example of a matrix of measurements with n = 4

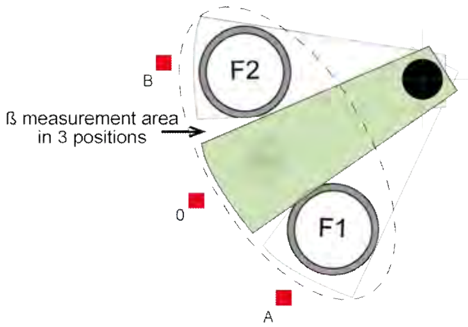
$$M^b = \begin{bmatrix} S_{12}^{11} & F_1^{b1} & S_{12}^{12} & F_2^{b1} & S_{12}^{13} \\ S_{12}^{21} & F_1^{b2} & S_{12}^{22} & F_2^{b2} & S_{12}^{23} \\ S_{12}^{31} & F_1^{b3} & S_{12}^{32} & F_2^{b3} & S_{12}^{33} \\ S_{12}^{41} & F_1^{b4} & S_{12}^{42} & F_2^{b4} & S_{12}^{43} \end{bmatrix}$$

8. The shield closes and the instrument repeats the Dark flux measurement in 0 position

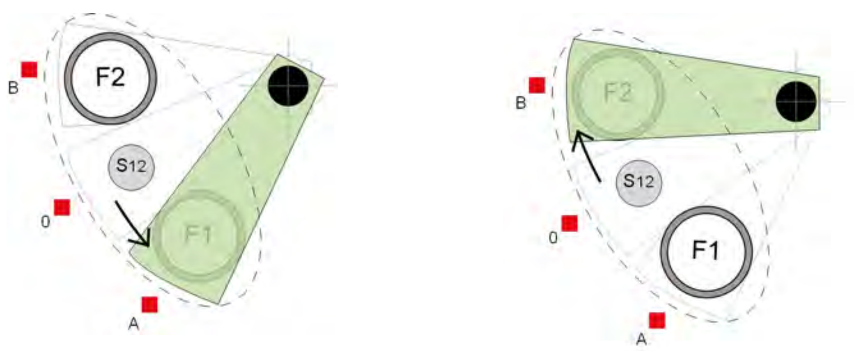


COLLECT MEASUREMENT PROCESS IN DETAIL

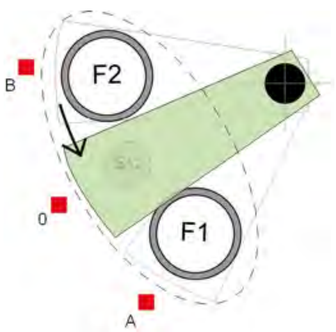
1. The instrument verify that the Geiger is in "0" position and that the shield is closed. Then it goes on with the *Dark* flux measurement



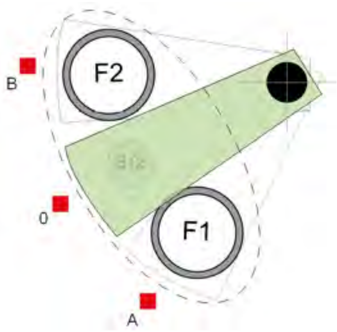
2. Measurement of the *Natural* fluxes on the 1st filter pair. Arm moving to A position (Natural flux measurement F1), arm moving to B position (Natural flux measurement F2)



3. Arm moving to 0 position and shield opening

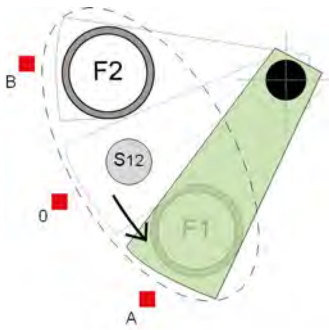


4. flux measurement on filter S12 (measurement length: 5’)



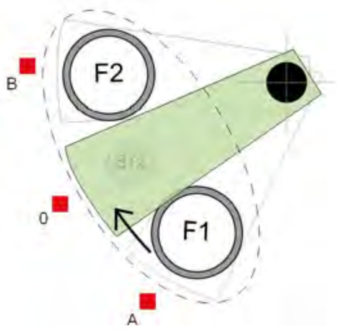
$$M^c = \begin{bmatrix} S_{12}^{11} & F_1^{c1} & S_{12}^{12} & F_2^{c1} & S_{12}^{13} \\ S_{12}^{21} & F_1^{c2} & S_{12}^{22} & F_2^{c2} & S_{12}^{23} \\ S_{12}^{31} & F_1^{c3} & S_{12}^{32} & F_2^{c3} & S_{12}^{33} \\ S_{12}^{41} & F_1^{c4} & S_{12}^{42} & F_2^{c4} & S_{12}^{43} \end{bmatrix}$$

5. Arm moving to A position and measurement of the flux on filter F1 (measurement length: 10')



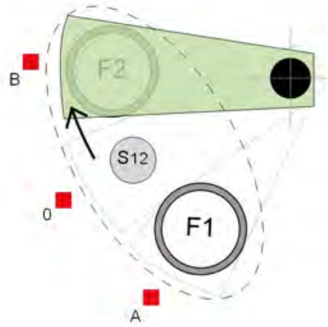
$$M^c = \begin{bmatrix} S_{12}^{11} & F_1^{c1} & S_{12}^{12} & F_2^{c1} & S_{12}^{13} \\ S_{12}^{21} & F_1^{c2} & S_{12}^{22} & F_2^{c2} & S_{12}^{23} \\ S_{12}^{31} & F_1^{c3} & S_{12}^{32} & F_2^{c3} & S_{12}^{33} \\ S_{12}^{41} & F_1^{c4} & S_{12}^{42} & F_2^{c4} & S_{12}^{43} \end{bmatrix}$$

6. Arm moving to 0 position and flux measurement on S12 (length: 5’)



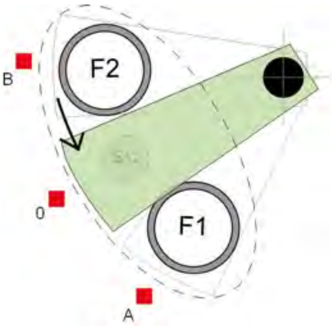
$$M^c = \begin{bmatrix} S_{12}^{11} & F_1^{c1} & S_{12}^{12} & F_2^{c1} & S_{12}^{13} \\ S_{12}^{21} & F_1^{c2} & S_{12}^{22} & F_2^{c2} & S_{12}^{23} \\ S_{12}^{31} & F_1^{c3} & S_{12}^{32} & F_2^{c3} & S_{12}^{33} \\ S_{12}^{41} & F_1^{c4} & S_{12}^{42} & F_2^{c4} & S_{12}^{43} \end{bmatrix}$$

7. Arm moving to B position and flux measurement on filter F2 (measurement length: 10')



$$M^c = \begin{bmatrix} S_{12}^{11} & F_1^{c1} & S_{12}^{12} & F_2^{c1} & S_{12}^{13} \\ S_{12}^{21} & F_1^{c2} & S_{12}^{22} & F_2^{c2} & S_{12}^{23} \\ S_{12}^{31} & F_1^{c3} & S_{12}^{32} & F_2^{c3} & S_{12}^{33} \\ S_{12}^{41} & F_1^{c4} & S_{12}^{42} & F_2^{c4} & S_{12}^{43} \end{bmatrix}$$

8. Arm moving to 0 position and flux measurement on S12 (length: 5')



$$M^c = \begin{bmatrix} S_{12}^{11} & F_1^{c1} & S_{12}^{12} & F_2^{c1} & S_{12}^{13} \\ S_{12}^{21} & F_1^{c2} & S_{12}^{22} & F_2^{c2} & S_{12}^{23} \\ S_{12}^{31} & F_1^{c3} & S_{12}^{32} & F_2^{c3} & S_{12}^{33} \\ S_{12}^{41} & F_1^{c4} & S_{12}^{42} & F_2^{c4} & S_{12}^{43} \end{bmatrix}$$

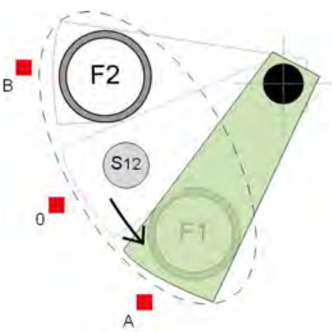
9. the phases from 4 to 8 repeat themselves *n* times in order to complete the matrix of the Collect measurements M^c

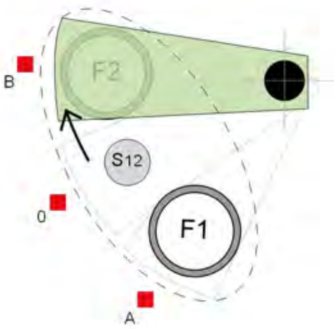
with:
n=4 for ≤ 8 hours long sampling cycles
n=6 for ≥ 12 hours long sampling cycles

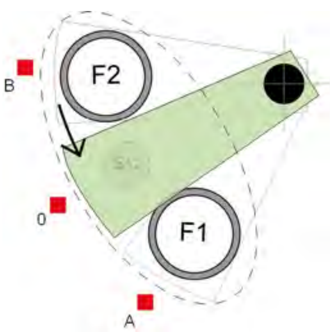
Here below an example of a matrix of measurements with n = 4

$$M^c = \begin{bmatrix} S_{12}^{11} & F_1^{c1} & S_{12}^{12} & F_2^{c1} & S_{12}^{13} \\ S_{12}^{21} & F_1^{c2} & S_{12}^{22} & F_2^{c2} & S_{12}^{23} \\ S_{12}^{31} & F_1^{c3} & S_{12}^{32} & F_2^{c3} & S_{12}^{33} \\ S_{12}^{41} & F_1^{c4} & S_{12}^{42} & F_2^{c4} & S_{12}^{43} \end{bmatrix}$$

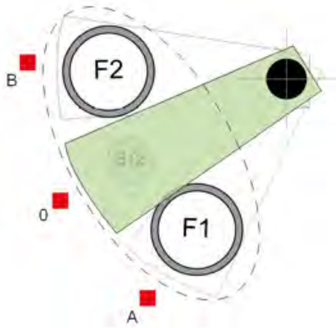
10. At the end of the *n* measurement sequences, shield closing and repetition of the two Natural flux measurements on the filters F1 and F2







11. Arm moving to 0 position and *Dark* flux measurement

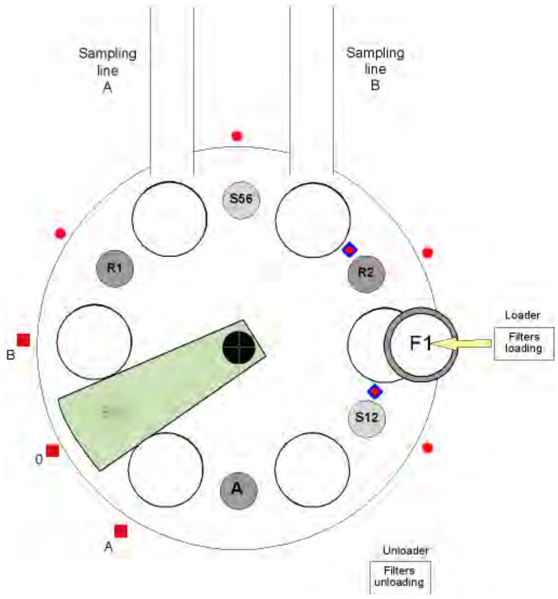


APPENDIX 12: Sequentialization operative steps

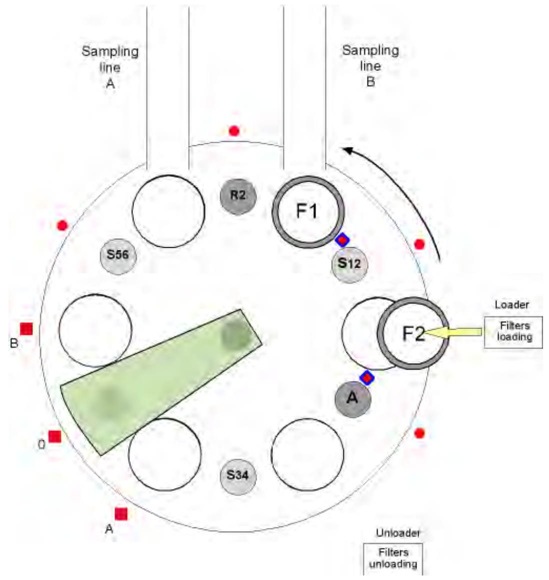
Filters management in Monitor Mode A&B

The figures here below show the sequentialization of the virgin filters loading at instrument start in Monitor Mode A&B.

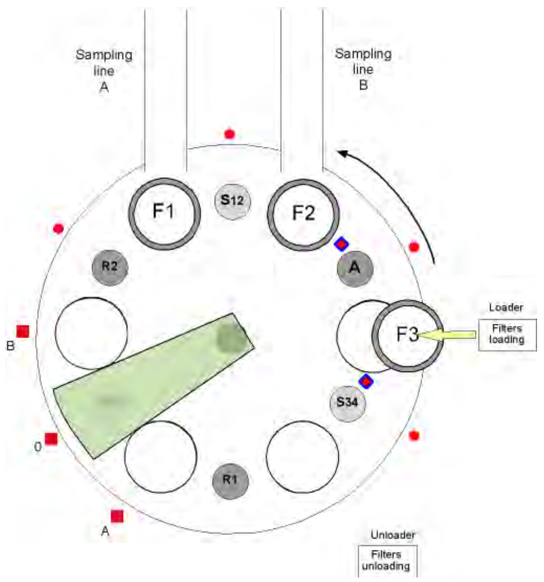
1) Loading of filter 1



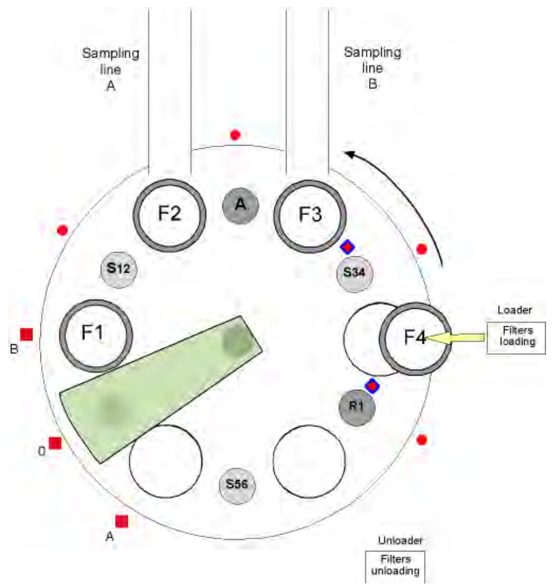
2) Loading of filter 2



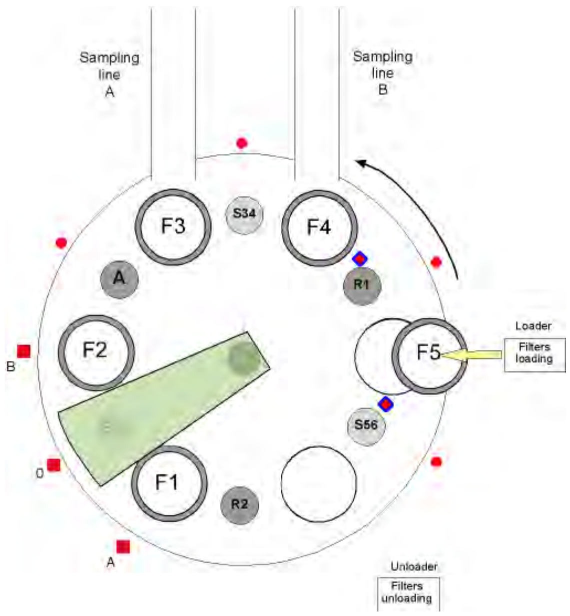
3) Loading of filter 3



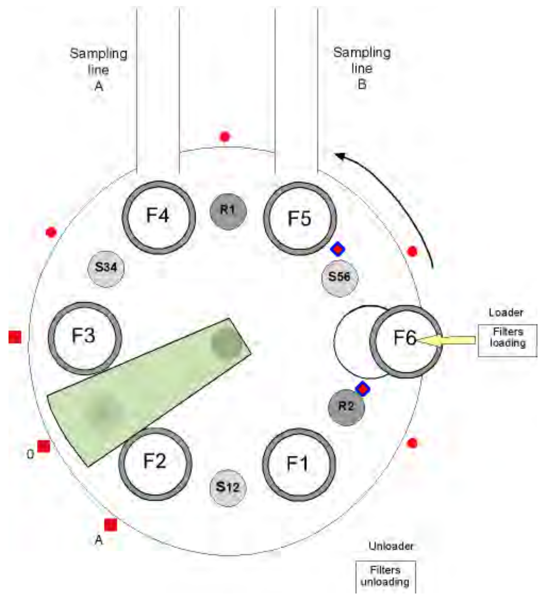
4) Loading of filter 4



5) Loading of filter 5

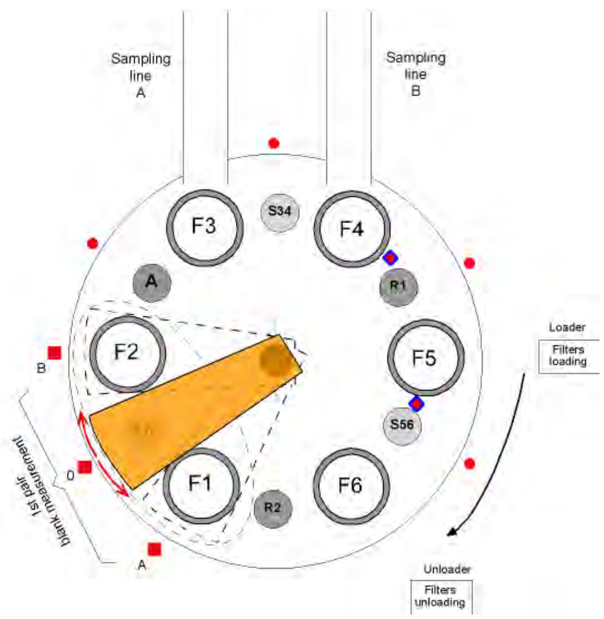


6) Loading of filter 6

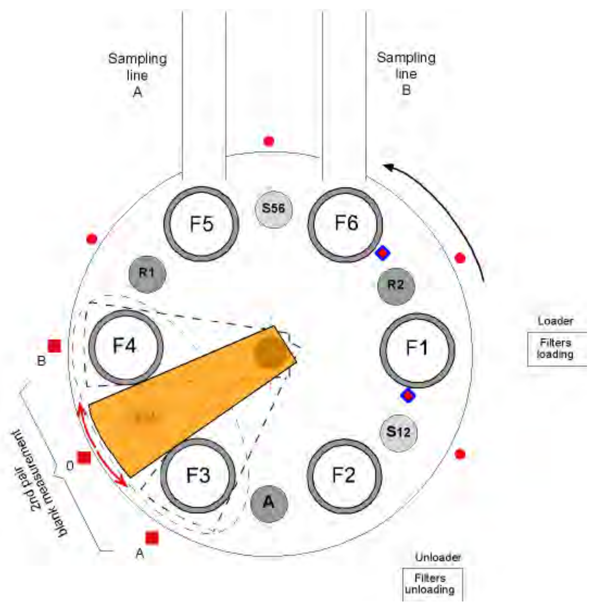


The figures below show the sequence of the operative filters loading, sampling, mass measurement (Blank and Collect), unloading steps, after the start of the instrument in Monitor Mode A&B

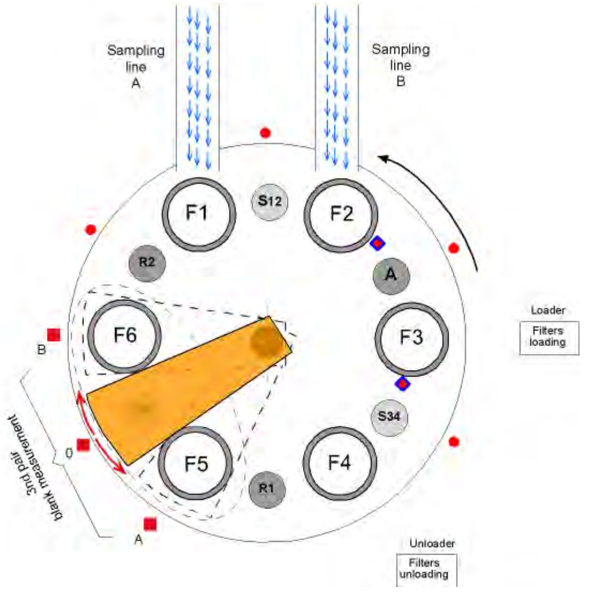
7) In Status Delay the instrument performs the Blank measurements on filters F1 and F2



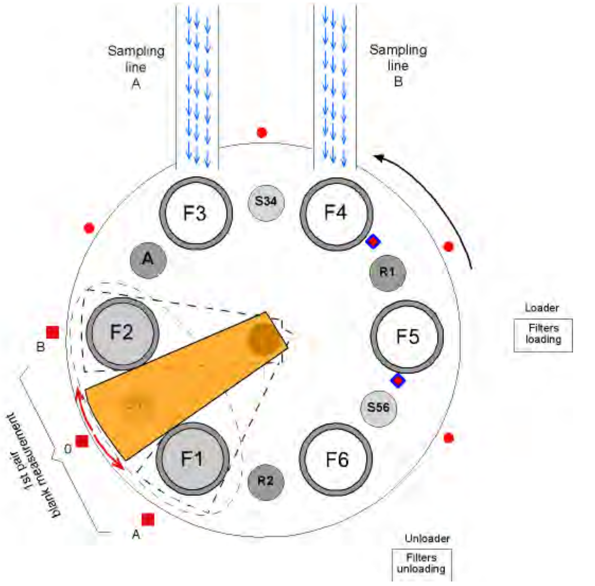
8) In Status Delay the instrument performs the Blank measurements on filters F3 and F4



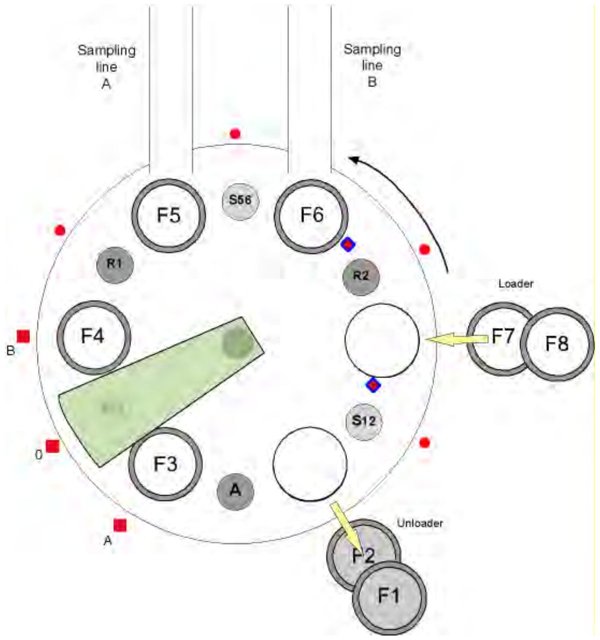
9) At the programmed date and time the instrument starts sampling filters F1 and F2. During the sampling process the Blank measurement is performed on filters F5 and F6



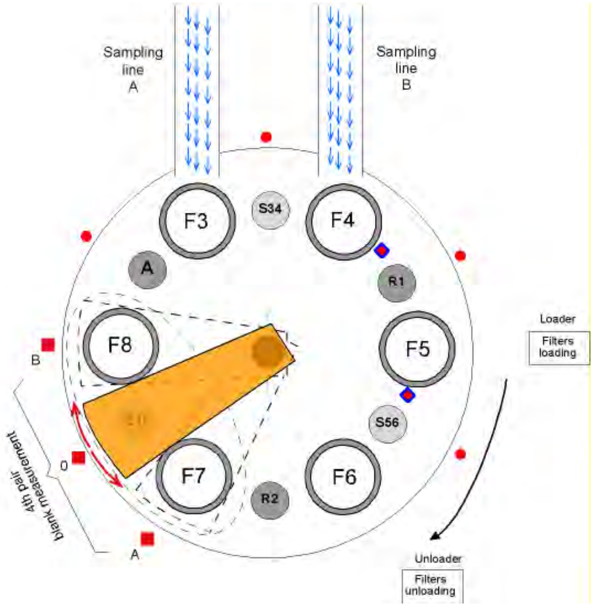
10) At the end of the sampling on filters F1 and F2, the Collect measurement starts and simultaneously the instrument starts sampling filters F3 and F4



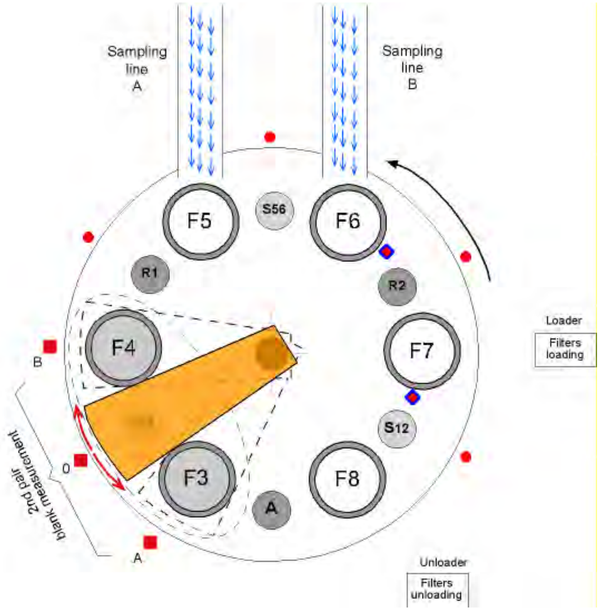
11) At the end of the Collect measurement, the filters F1 and F2 are stored in the Unloader and filters F7 and F8 are loaded on the plate (in order to perform this operation the pumps stop for about 30 s).



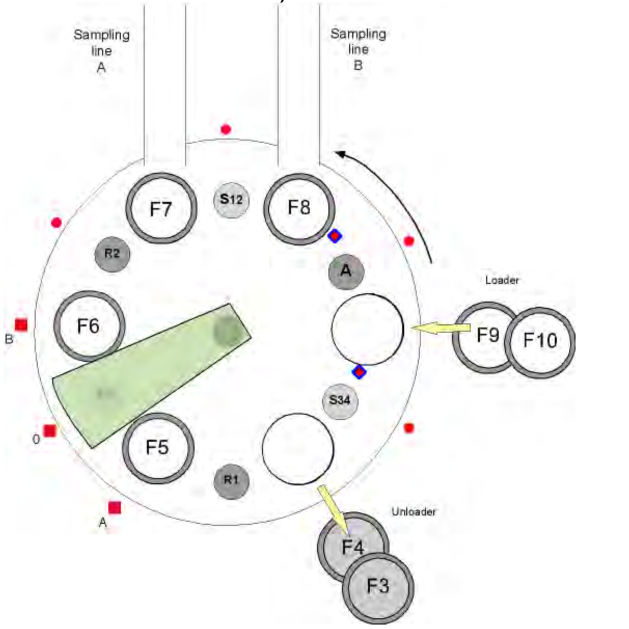
12) The F3 and F4 filters are placed again in the sampling area to complete the sampling process. Simultaneously the Blank measurement is performed on filters F7 and F8.



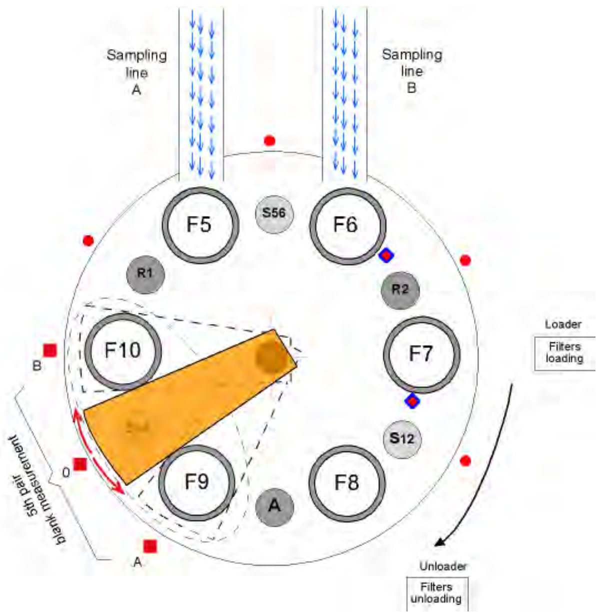
13) At the of the sampling process on filters F3 and F4, the Collect measurement is performed and simultaneously the sampling process on filters F5 and F6 starts.



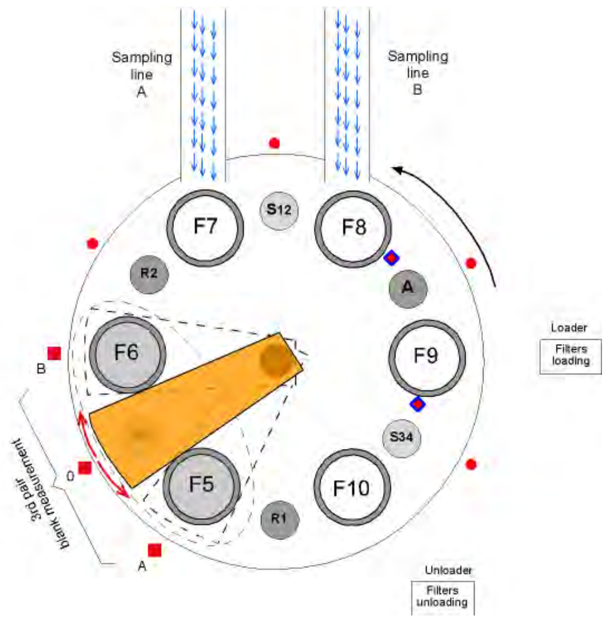
14) At the end of the Collect measurement, the filters F3 and F4 are stored in the Unloader and the filters F7 and F8 are loaded on the plate (in order to perform this operation the pumps stop for about 30 seconds).



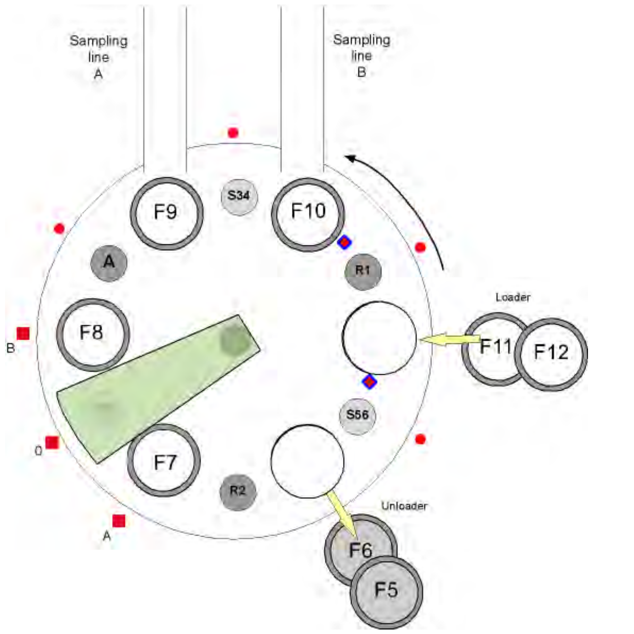
15) The filters F5 and F6 are placed again in the sampling area to complete the sampling process. Simultaneously the Blank measurement is performed on filters F9 and F10.



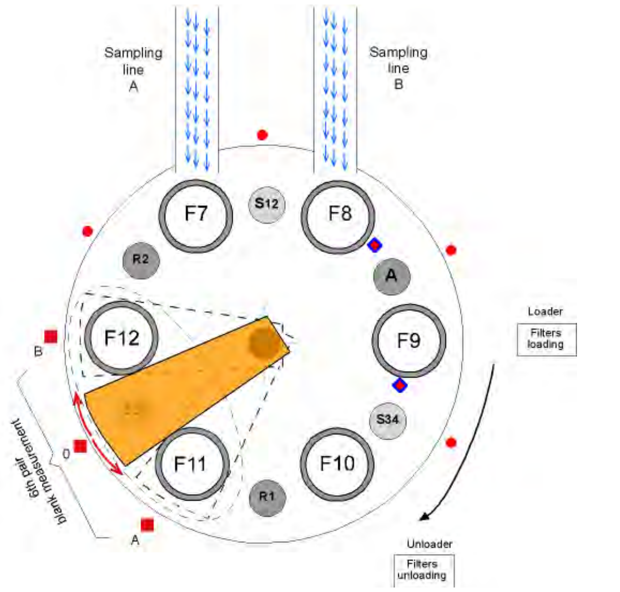
16) At the of the sampling process on filters F5 and F6, the Collect measurement is performed and simultaneously the sampling process on filters F7 and F8 starts.



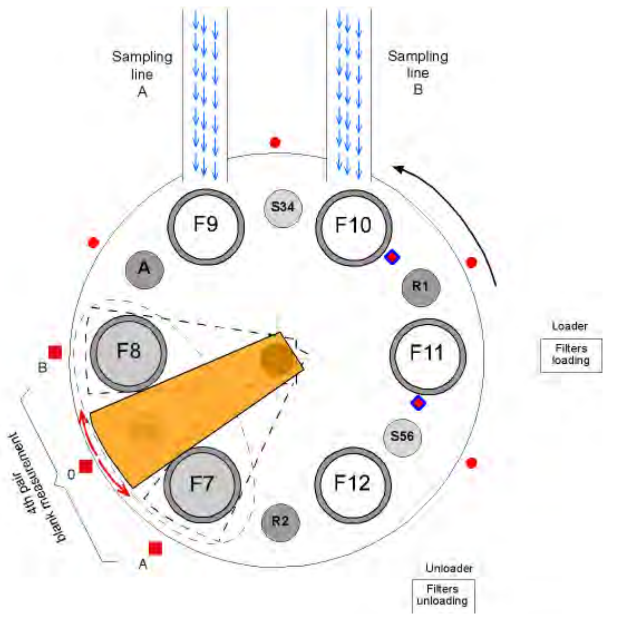
17) At the end of the Collect measurement, the filters F5 and F6 are stored in the Unloader and the filters F11 and F12 are loaded on the plate (in order to perform this operation the pumps stop for about 30 seconds).



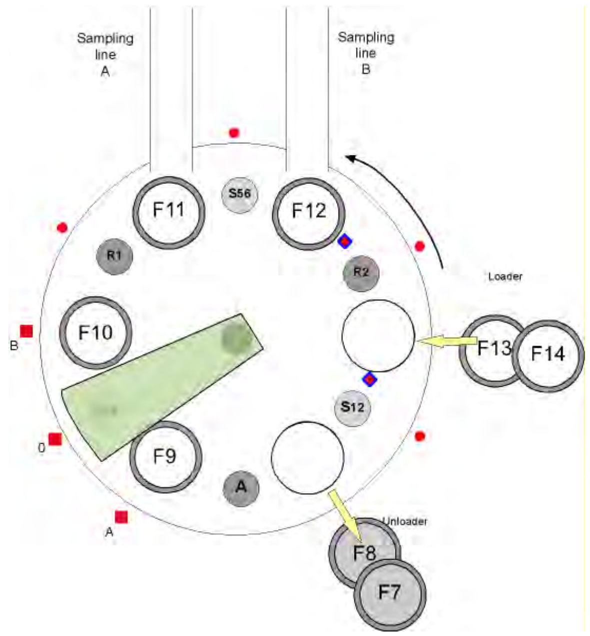
18) The filters F7 and F8 are placed again in the sampling area to complete the sampling process. Simultaneously the Blank measurement is performed on filters F11 and F12.



19) At the of the sampling process on filters F7 and F8, the Collect measurement is performed and simultaneously the sampling process on filters F9 and F10 starts.



20) At the end of the Collect measurement, the filters F7 and F8 are stored in the Unloader and the filters F13 and F14 are loaded on the plate (in order to perform this operation the pumps stop for about 30 seconds).

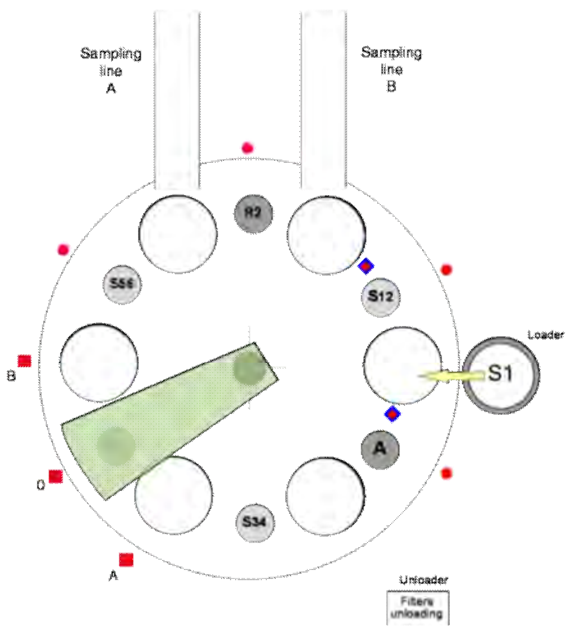


The filters loading, sampling, mass measurement (Blank and Collect) and unloading sequence goes on till the sampling and measurement cycles stop or till a virgin filters depletion.

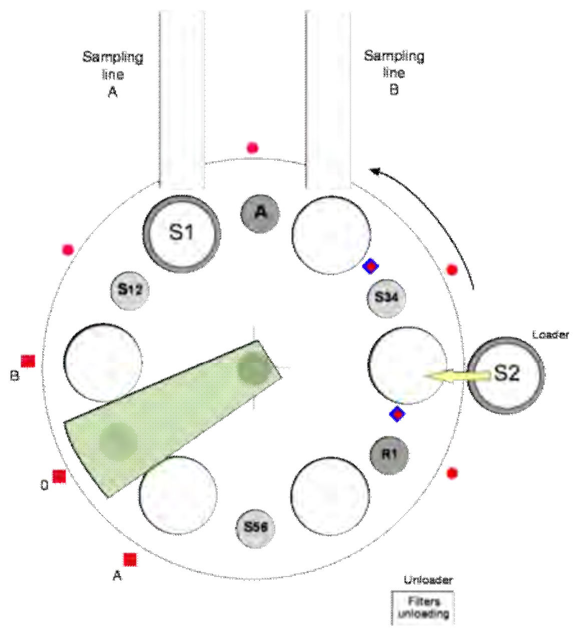
Filters management in Monitor Mode A

The figures here below show the sequentialization of the virgin filters loading at instrument start in Monitor Mode A.

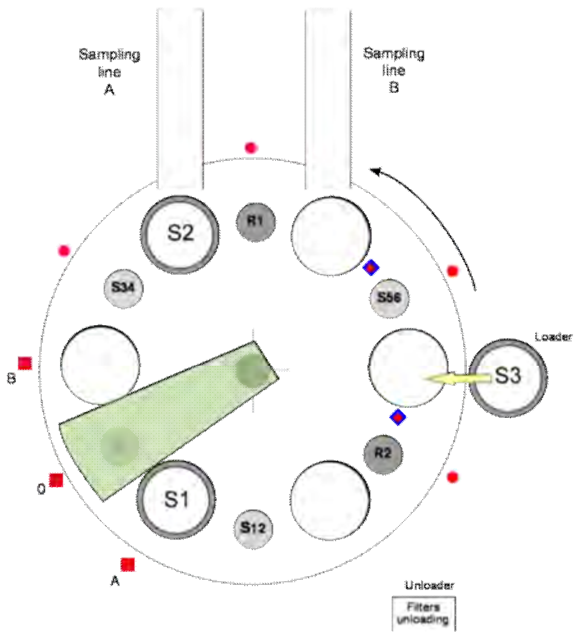
1) Loading of the additional spy filter S1



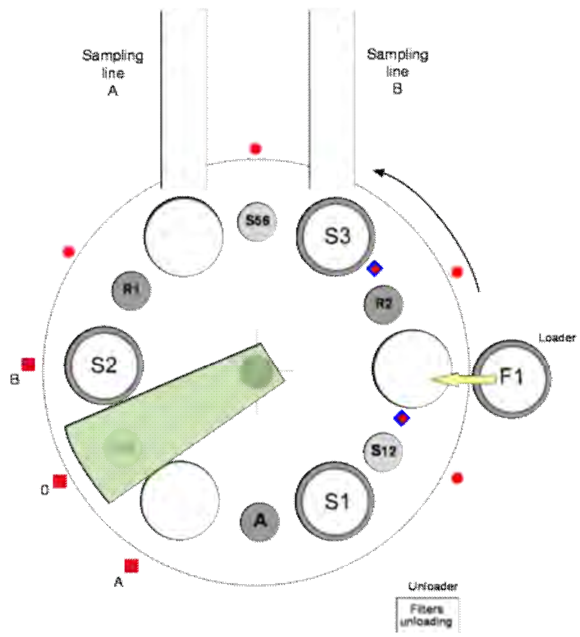
2) Loading of the additional spy filter S2



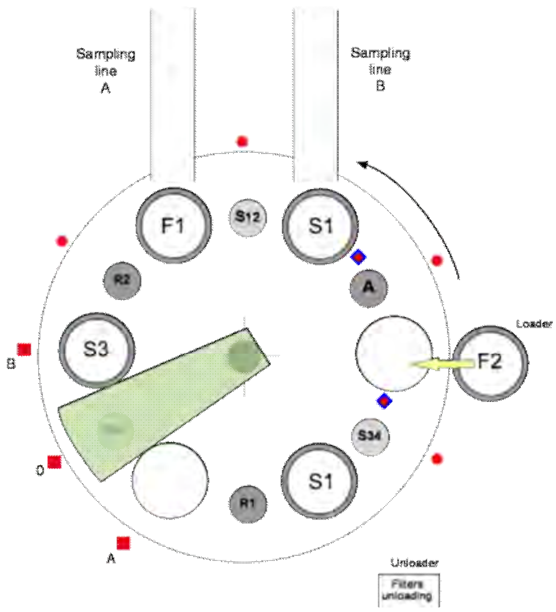
3) Loading of the additional spy filter S3



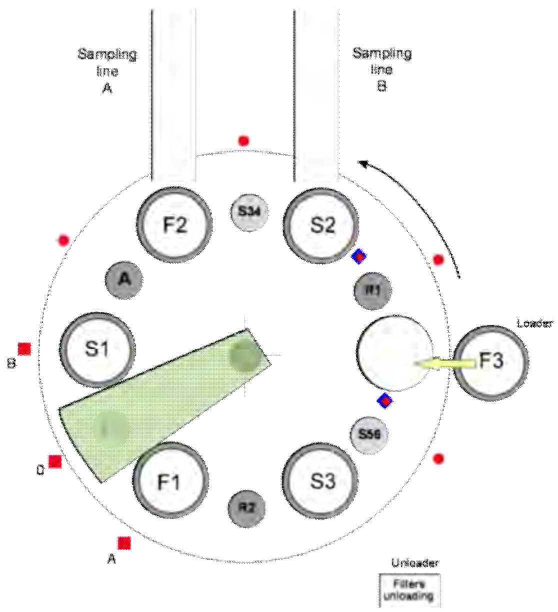
4) Loading of filter 1



5) Loading of filter 2

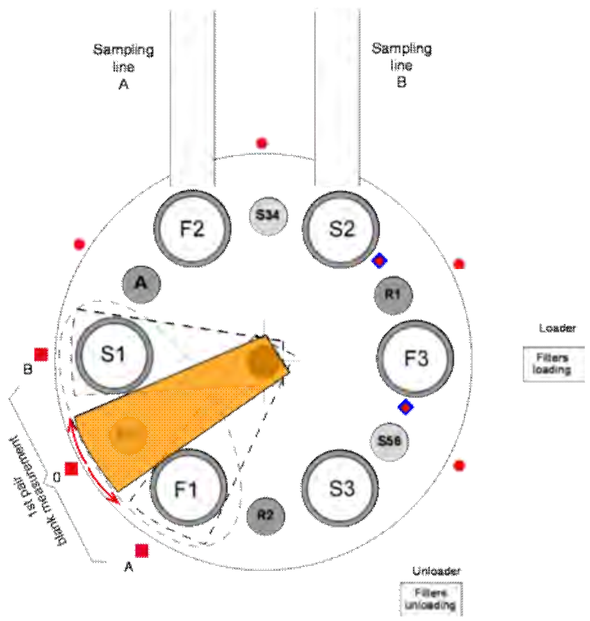


6) Loading of filter 3

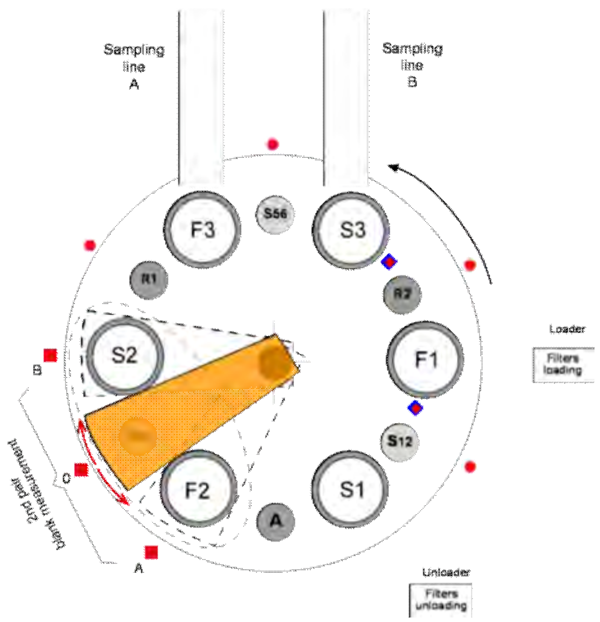


The figures below show the sequence of the filters loading, sampling, mass measurement (Blank and Collect) and unloading operative steps, after the instrument start in Monitor Mode A

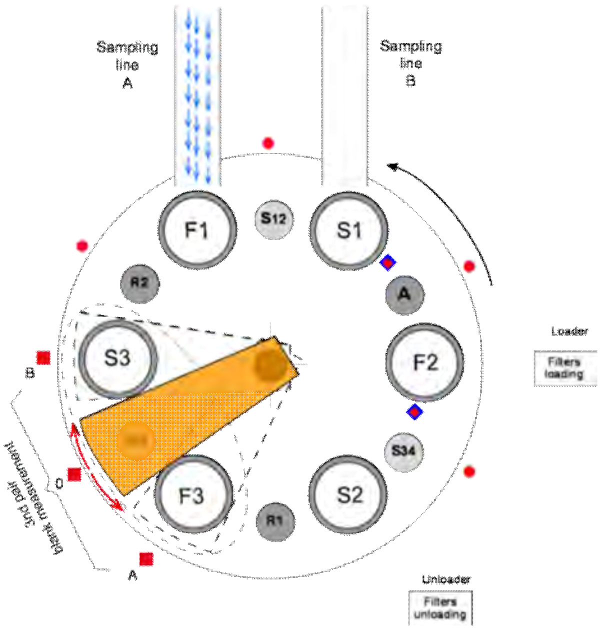
7) In Delay Status the Blank measurements on filters F1 and S1 are performed



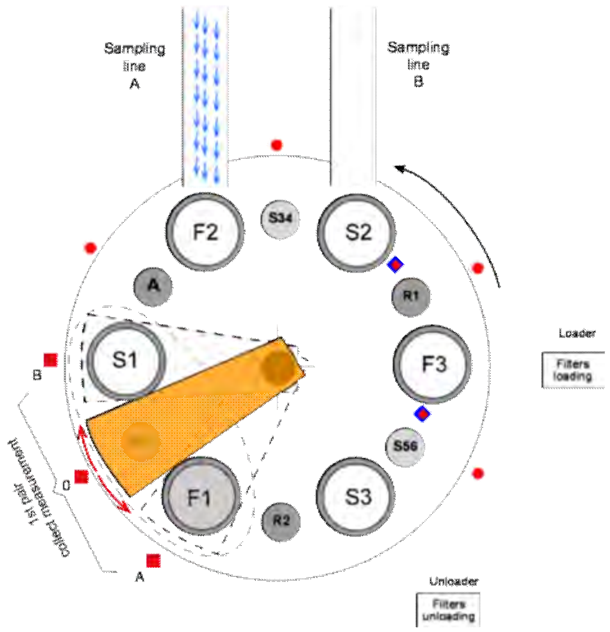
8) In Delay Status the Blank measurements on filters F2 and S2 are performed



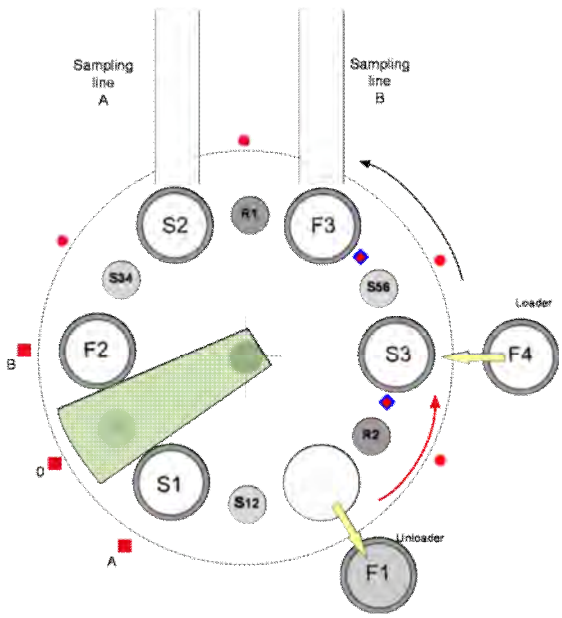
9) At programmed date and time the instrument starts sampling filters F1. During the sampling process the Blank measurement is performed on filters F3 and S3



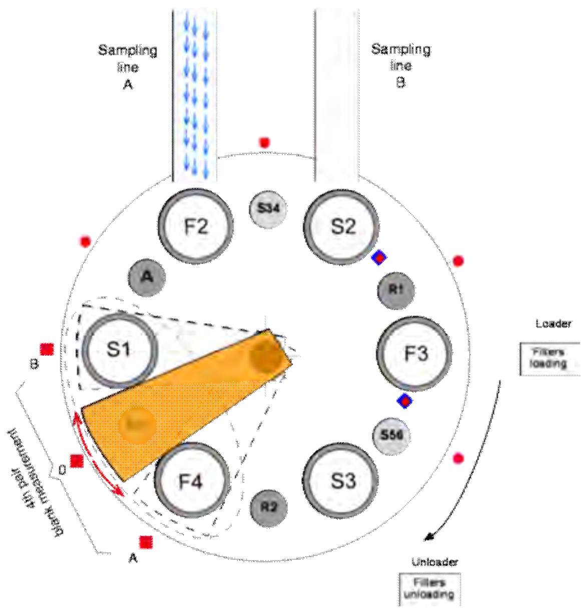
10) At the end of the sampling on filters F1 and S1, the Collect measurement starts and simultaneously the instrument starts sampling filter F2



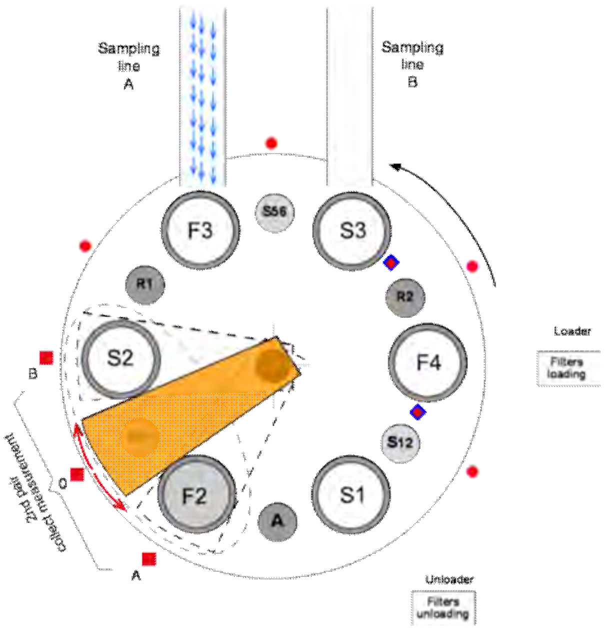
11) At the end of the Collect measurement, the filter F1 is stored in the Unloader and filter F4 is loaded on the plate (in order to perform this operation the pump stops for about 30 sec).



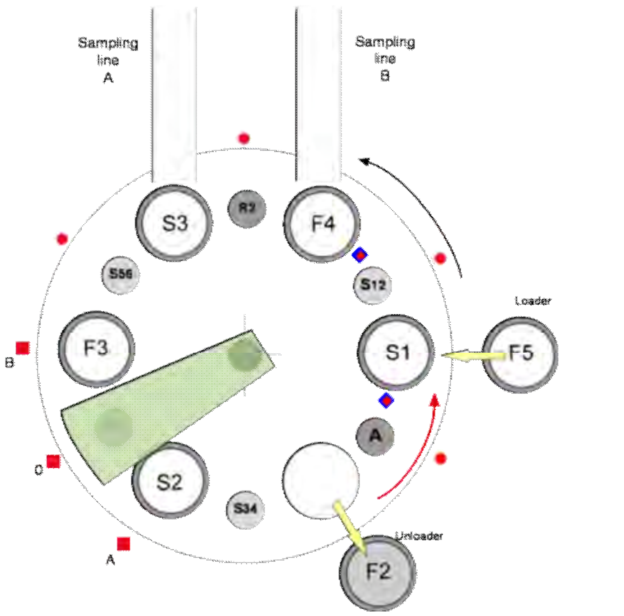
12) The F2 filter is placed again in the sampling area to complete the sampling process. Simultaneously the Blank measurement is performed on filters F4 and S1.



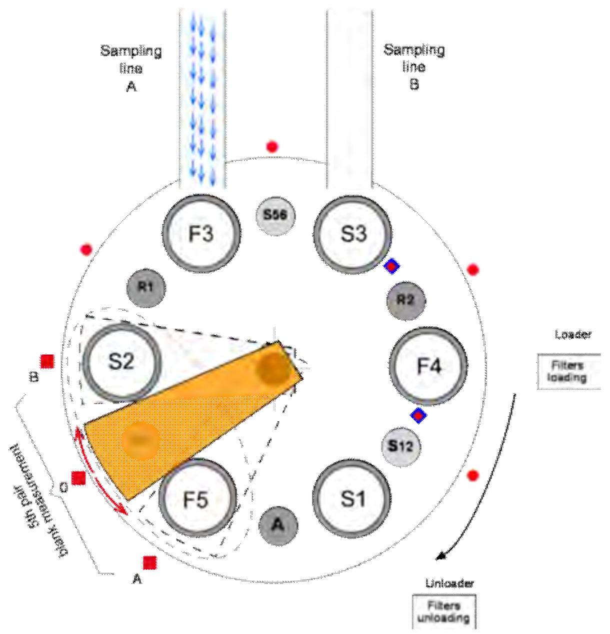
13) At the end of the sampling on filters F2 and S2, the Collect measurement starts and simultaneously the instrument starts sampling filter F3



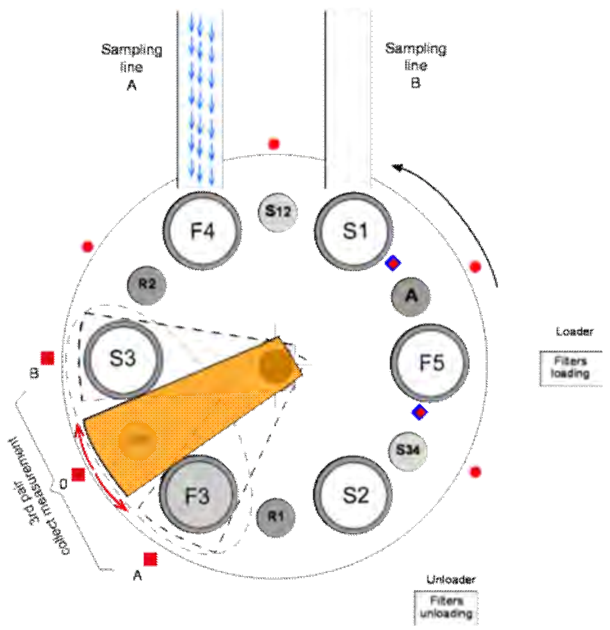
14) At the end of the Collect measurement, the filter F2 is stored in the Unloader and filter F5 is loaded on the plate (in order to perform this operation the pump stops for about 30 sec).



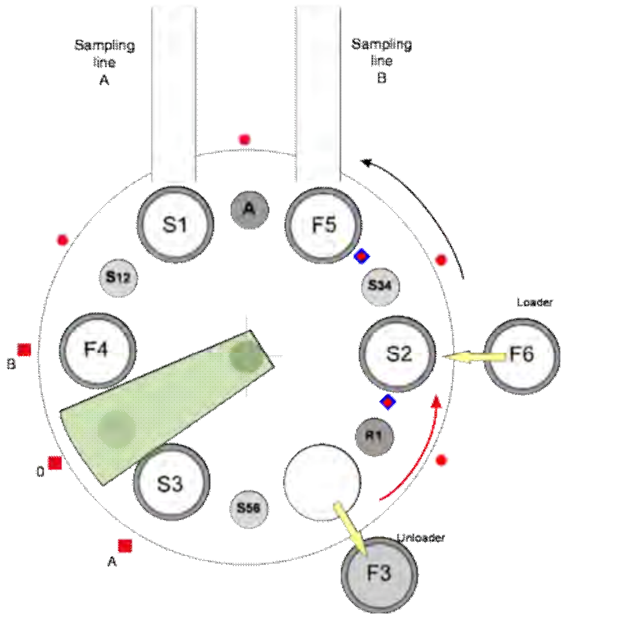
15) The F3 filter is placed again in the sampling area to complete the sampling process. Simultaneously the Blank measurement is performed on filters F5 and S2.



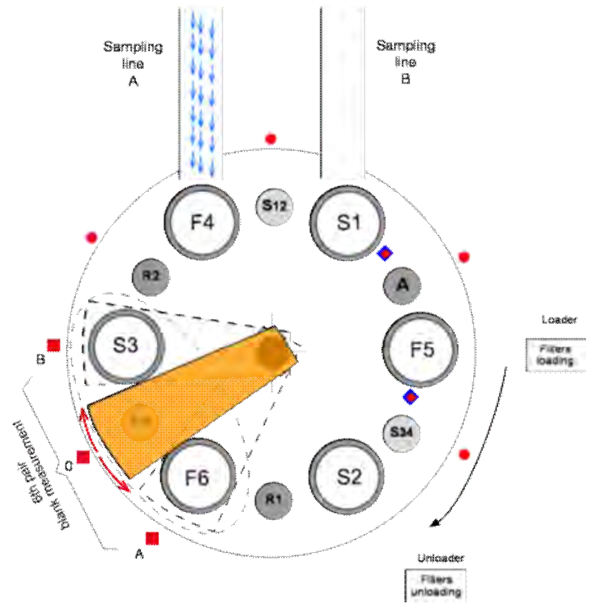
16) At the end of the sampling on filters F3 and S3, the Collect measurement starts and simultaneously the instrument starts sampling filter F4



17) At the end of the Collect measurement, the filter F3 is stored in the Unloader and filter F6 is loaded on the plate (in order to perform this operation the pump stops for about 30 sec).



18) The F4 filter is placed again in the sampling area to complete the sampling process. Simultaneously the Blank measurement is performed on filters F6 and S3.

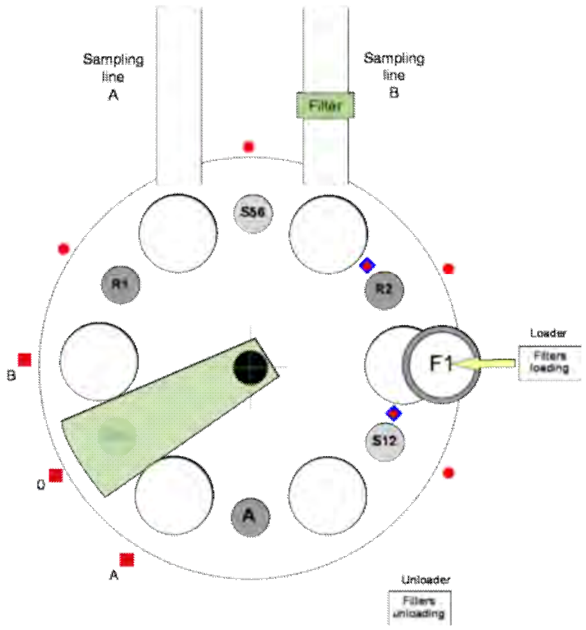


The filters loading, sampling, mass measurement (Blank and Collect) and unloading sequence goes on till the sampling and measurement cycles stop or till a virgin filters depletion.

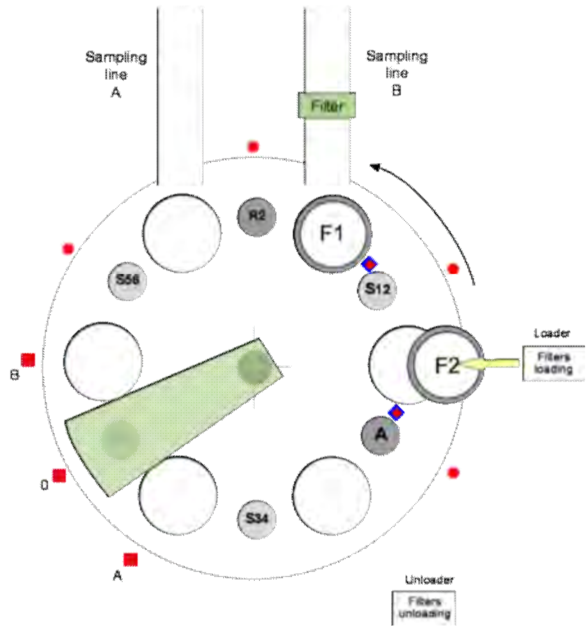
Filters management in Reference Mode

The figures here below show the sequentialization of the virgin filters loading at instrument start in reference Mode.

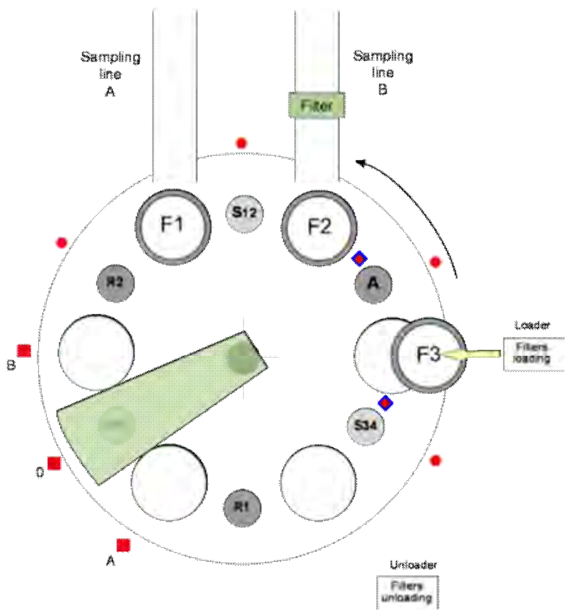
1) Loading of filter 1



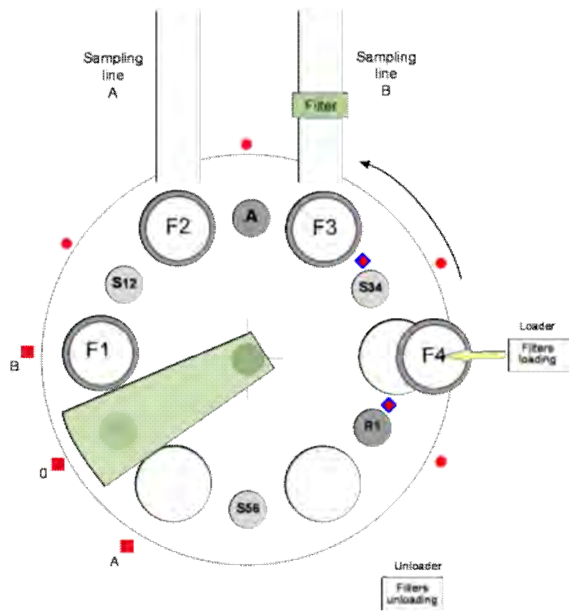
2) Loading of filter 2



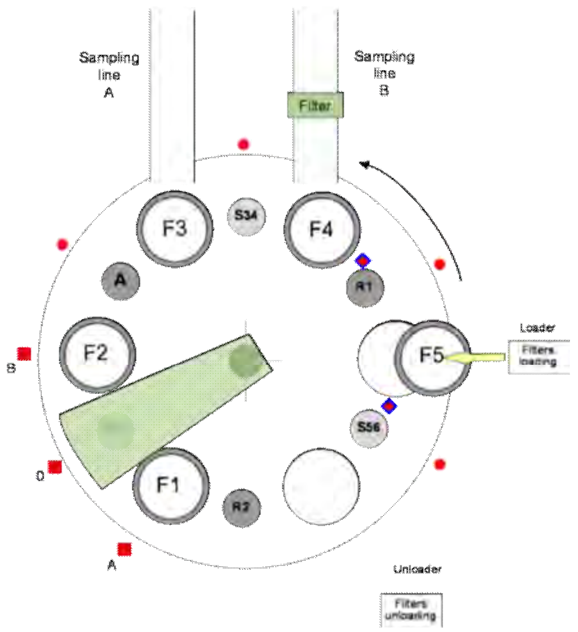
3) Loading of filter 3



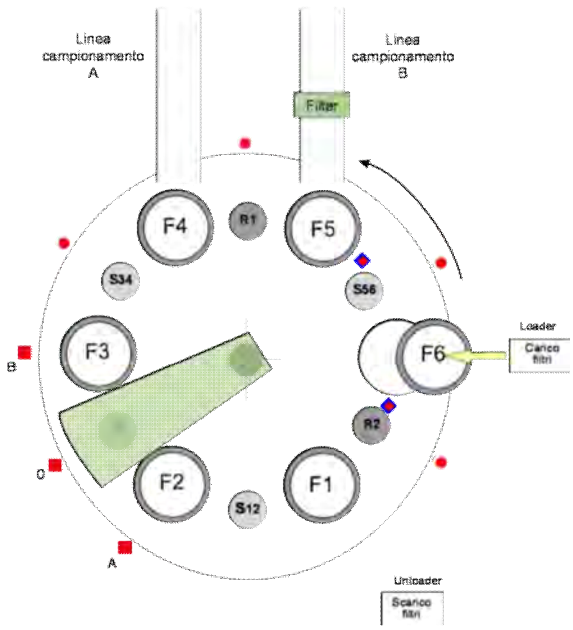
4) Loading of filter 4



5) Loading of filter 5

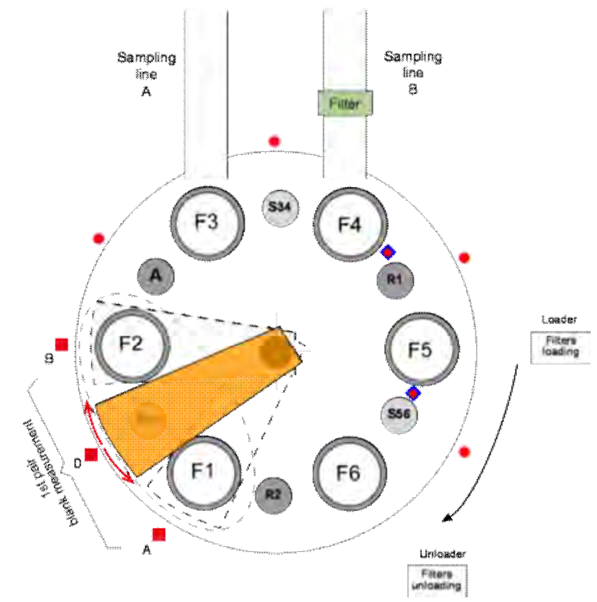


6) Loading of filter 6

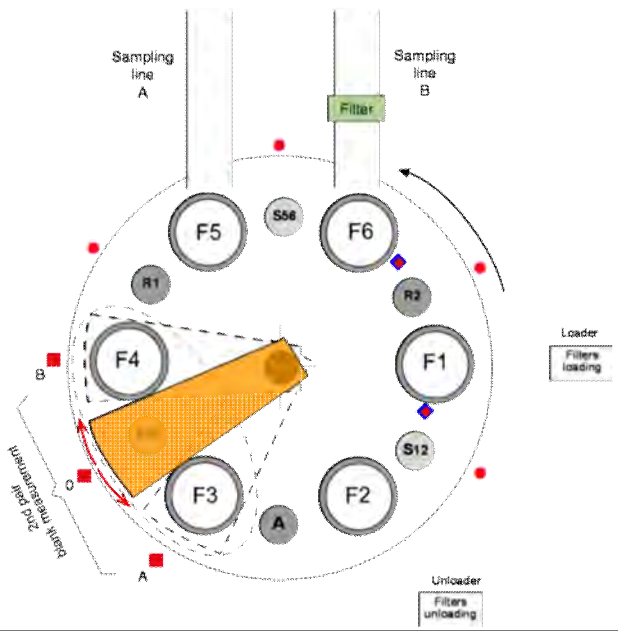


The figures below show the sequence of the filters loading, sampling, mass measurement (Blank and Collect) and unloading operative steps, after the instrument start in Reference Mode.

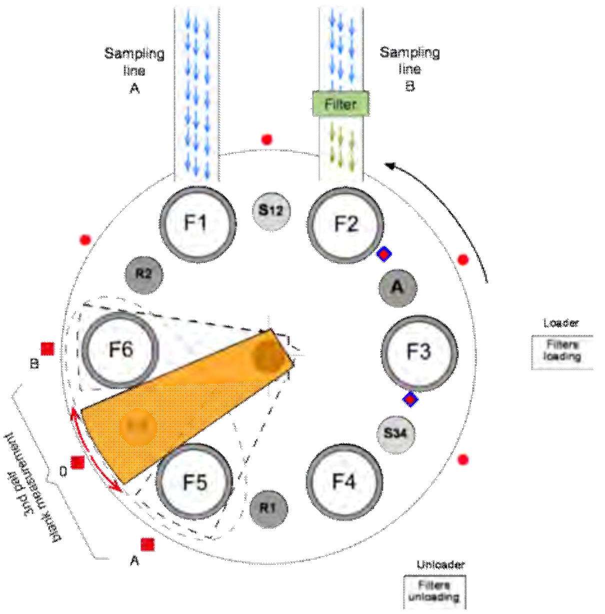
7) In Delay Status the Blank measurements on filters F1 and F2 are performed



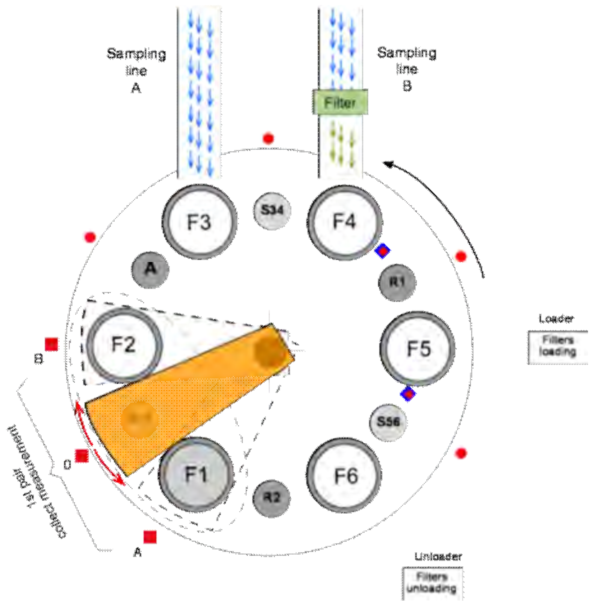
8) In Delay Status the Blank measurements on filters F3 and F4 are performed



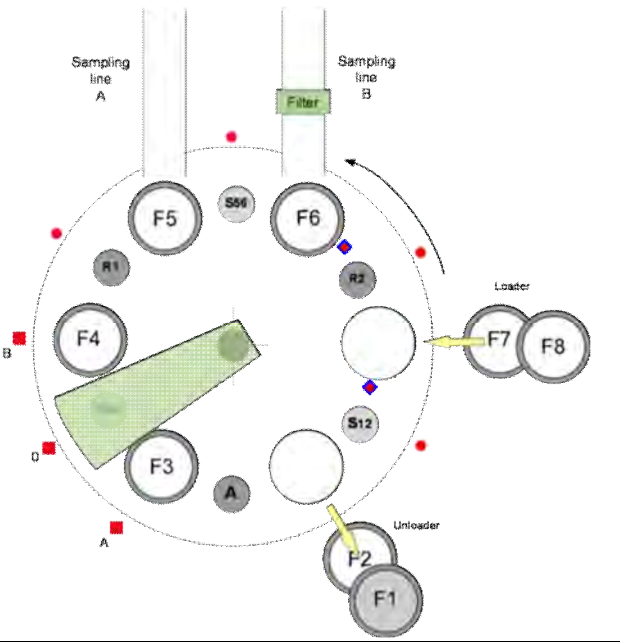
9) At programmed date and time the instrument starts sampling filters F1 and F2 (field blank). During the sampling process the Blank measurement is performed on filters F5 and F6



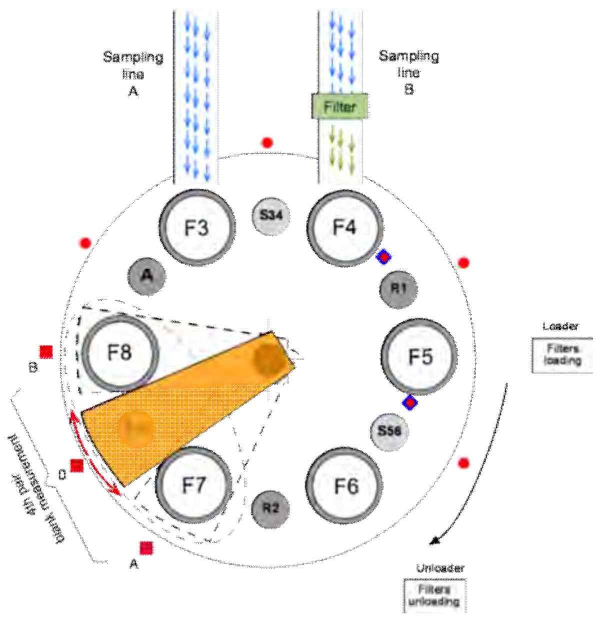
10) At the end of the sampling on filters F1 and F2, the Collect measurement starts and simultaneously the instrument starts sampling filters F3 and F4 (field blank)



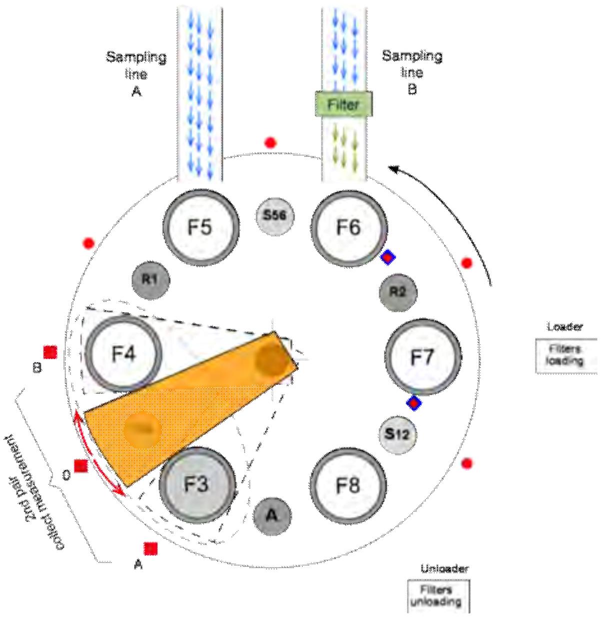
11) At the end of the Collect measurement, the filters F1 and F2 are stored in the Unloader and filters F7 and F8 are loaded on the plate (in order to perform this operation the pumps stop for about 30 sec).



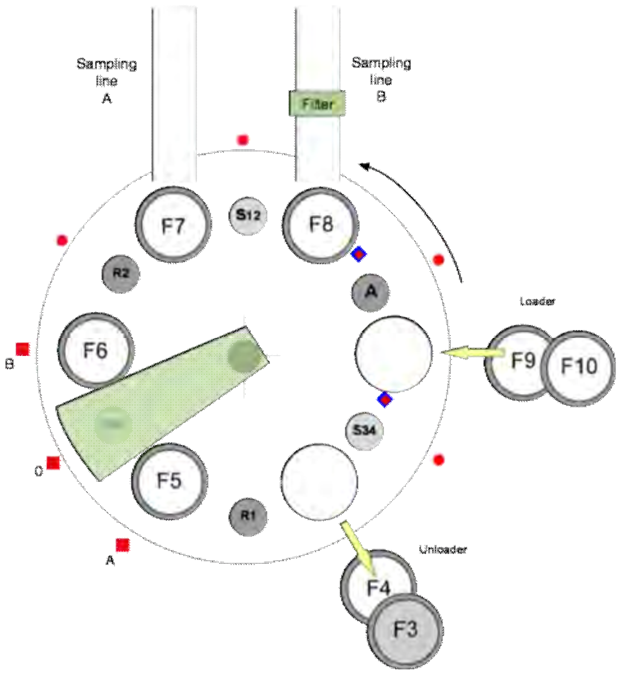
12) The F3 and F4 filters are placed again in the sampling area to complete the sampling process. Simultaneously the Blank measurement is performed on filters F7 and F8.



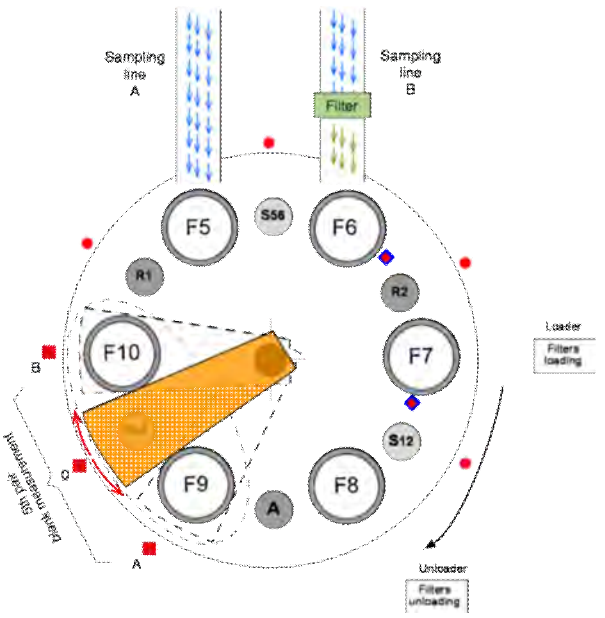
13) At the end of the sampling on filters F3 and F4, the Collect measurement starts and simultaneously the instrument starts sampling filters F5 and F6 (field blank).



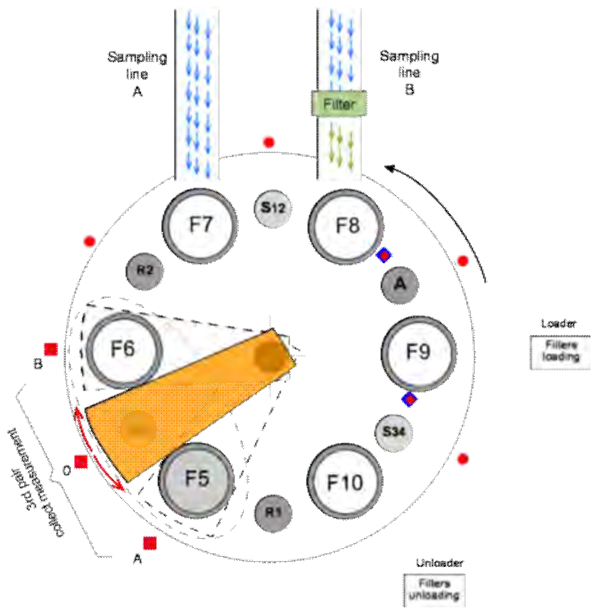
14) At the end of the Collect measurement, the filters F3 and F4 are stored in the Unloader and filters F7 and F8 are loaded on the plate (in order to perform this operation the pump stops for about 30 sec).



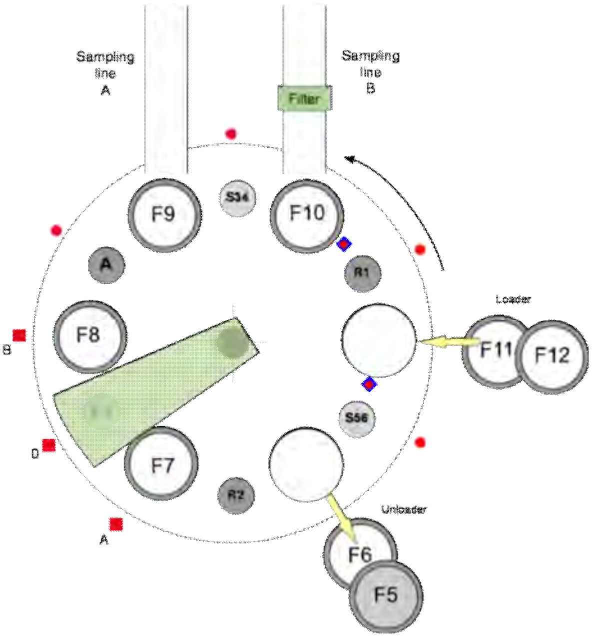
15) The filters F5 and F6 are placed again in the sampling area to complete the sampling process. Simultaneously the Blank measurement is performed on filters F9 and F10.



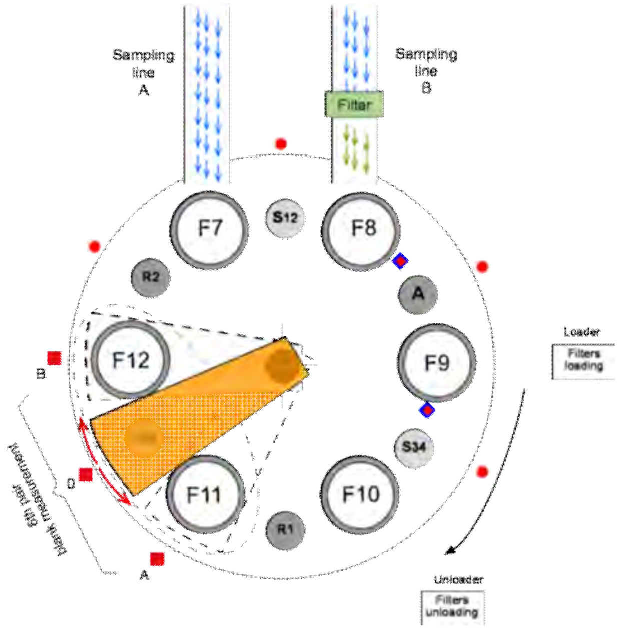
16) At the end of the sampling on filters F5 and F6, the Collect measurement starts and simultaneously the instrument starts sampling filters F7 and F8 (field blank).



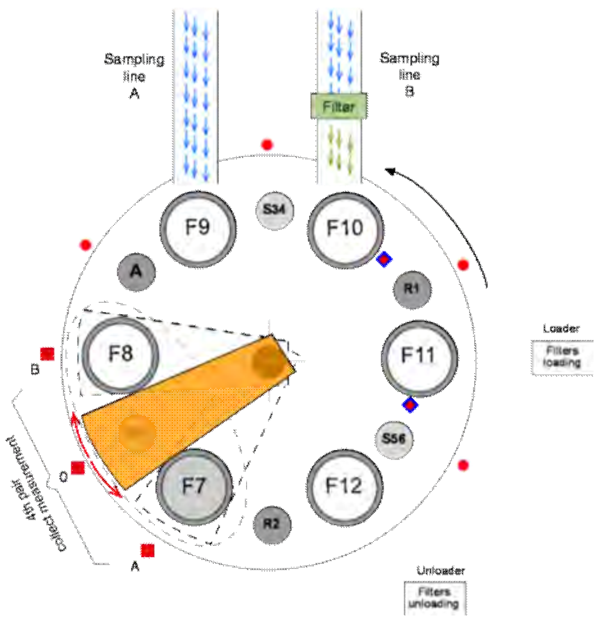
17) At the end of the Collect measurement, the filters F5 and F6 are stored in the Unloader and the filters F11 and F12 are loaded on the plate (in order to perform this operation the pumps stop for about 30 seconds).



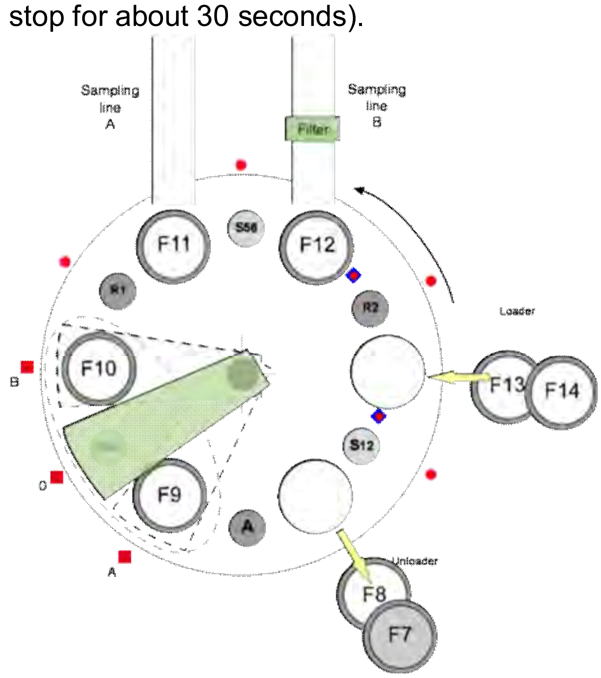
18) The filters F7 and F8 are placed again in the sampling area to complete the sampling process. Simultaneously the Blank measurement is performed on filters F11 and F12.



19) At the of the sampling process on filters F7 and F8, the Collect measurement is performed and simultaneously the sampling process on filters F9 and F10 starts (field blank).

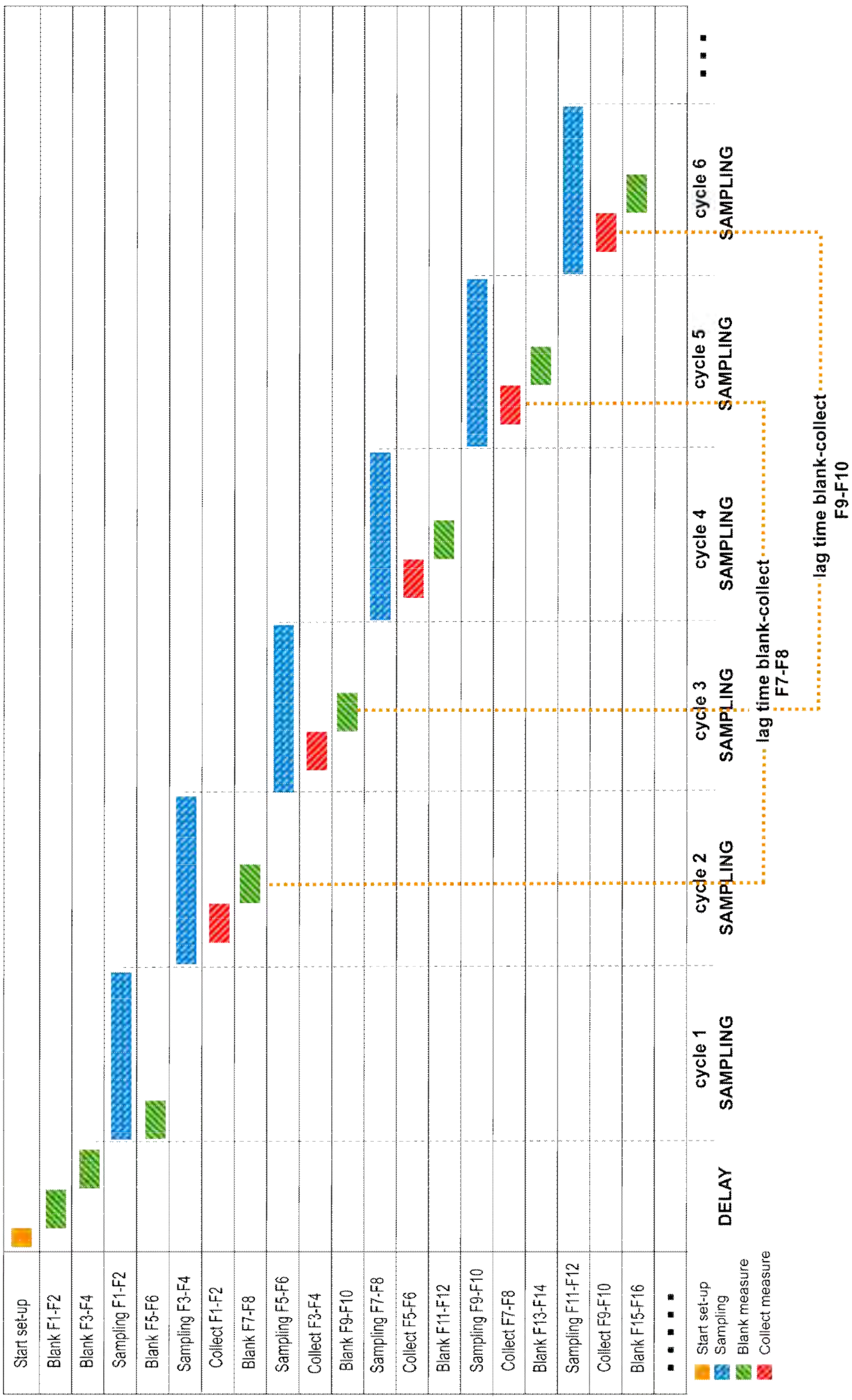


20) At the end of the Collect measurement, the filters F7 and F8 are stored in the Unloader and the filters F13 and F14 are loaded on the plate (in order to perform this operation the pumps stop for about 30 seconds).



The filters loading, sampling, mass measurement (Blank and Collect) and unloading sequence goes on till the sampling and measurement cycles stop or till a virgin filters depletion.

The figure here below shows an example of the time sequence of the operations performed by the instruments (in Monitor Mode A&B) during the filter membranes loading, sampling, mass measurement (Blank And Collect) and unloading steps.



TÜV RHEINLAND ENERGY GMBH

ADDENDUM

Addendum to TÜV test report no. 936/21207522/A dated 23 March 2009 on performance testing of the SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for suspended particulate matter $PM_{2.5}$ and PM_{10} manufactured by FAI Instruments s.r.l

TÜV report: 936/21239762/B
Cologne, 07 September 2018

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TÜV Rheinland Energy GmbH and its Ambient Air Quality department in particular
is accredited for the following activities:

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

according to EN ISO/IEC 17025.

The accreditation will expire on 22-01-2018. DAkkS registration number: D-PL-11120-02-00.

TÜV Rheinland Energy GmbH
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1. Summary Overview

FAI Instruments s.r.l commissioned TÜV Rheinland Energy GmbH to carry out performance testing on the SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for suspended particulate matter $PM_{2.5}$ and PM_{10} according to the following Standards.

- VDI Guideline 4202, Part 1 – "Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants," dated June 2002.
- VDI Guideline 4203, part 3 – "Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", dated August 2004
- EN 12341 "Air Quality - Determination of the PM_{10} fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods", German version EN 12341 1998
- European standard EN 14907, "Ambient air quality – Standard gravimetric measurement method for the determination of $PM_{2.5}$ mass fraction of suspended particulate matter", German version EN 14907: 2005
- Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods", English version dated November 2005

Based on the requirements for testing stated above, the SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for suspended particulate matter PM_{10} and $PM_{2.5}$ have already been performance tested and publically announced as such as follows:

- SWAM 5a Dual Channel Monitor for PM_{10} and $PM_{2.5}$, UBA announcement dated 03 August 2009 (BAnz. 25 August 2009, no. 125, page 2929, chapter II no. 2.1) – initial publication

- SWAM 5a Dual Channel Monitor for PM_{10} and $PM_{2.5}$, UBA announcement dated 15 July 2011 (BAnz. 29 July 2011, no. 113, page 2725, chapter III 7th notification) – notification as required by EN 15267 regarding the manufacturing process and its quality management system
- SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for PM_{10} and $PM_{2.5}$, UBA announcement dated 23 February 2012 (BAnz. 2 March 2012, no. 36, page 920, chapter V, 2nd notification) – notification regarding the approval of instrument version SWAM 5a Dual Channel Hourly Mode Monitor with 1h-measurement mode and its OEM version Model 602 BetaPlus offered by Teledyne Advanced Pollution Instrumentation.
- SWAM 5a Dual Channel Monitor for PM_{10} and $PM_{2.5}$ and SWAM 5a Monitor for PM_{10} or $PM_{2.5}$, UBA announcement dated 23 February 2012 (BAnz. 2 March 2012, no. 36, page 920, chapter V, 3rd notification) – notification regarding the approval of instrument version SWAM 5a Monitor (single channel design)
- SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for PM_{10} and $PM_{2.5}$ and SWAM 5a Monitor for PM_{10} or $PM_{2.5}$, UBA announcement dated 12 February 2013 (BAnz AT 05.03.2013 B10, chapter V 12th notification) – notification on the new software version for the instrument version SWAM 5a Dual Channel Monitor
- SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for PM_{10} and $PM_{2.5}$ and SWAM 5a Monitor for PM_{10} or $PM_{2.5}$, UBA announcement dated 25 February 2015 (BAnz AT 02.04.2015 B5, chapter IV 8th notification) – notification regarding the new software version for instrument version SWAM 5a Dual Channel Monitor, SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor, optional Ethernet board for the SWAM 5a Dual Channel Hourly Mode Monitor.

- SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for PM_{10} and $PM_{2.5}$ and SWAM 5a Monitor for PM_{10} or $PM_{2.5}$, UBA announcement dated 22 July 2015 (BAnz AT 26.08.2015 B4, chapter V 44th notification) – notification regarding the availability of standard sample inlets in accordance with annex A of standard EN 12341 (August 2014)

Standard EN 16450 "Ambient air — Automated measuring systems for the measurement of the concentration of particulate matter (PM_{10}; $PM_{2,5}$) has been available since July 2017. This standard, for the first time, harmonises requirements for the performance testing of automated measuring systems for the determination of dust concentrations (PM_{10} and $PM_{2.5}$) on an European level and will form the basis for the approval of such AMS in the future.

The present addendum assesses the SWAM 5a measuring system (instrument versions SWAM 5a Dual Channel Monitor, SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor) in terms of compliance with the requirements of standard EN 16450 (July 2017).

As most of the performance characteristic and performance criteria defined in chapter 7 of standard EN 16450 (July 2017) have been tested and assessed already in the context of the original performance test, the majority of test results can be taken from and/or re-assessed on the basis of the original test report or tests performed in the context of obtaining approval for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor as documented in the corresponding notifications. Entirely new tests were performed only for test items 7.4.4 "7.4.4 Flow rate accuracy", 7.4.8 "7.4.8 Dependence of span on supply voltage" and 7.4.9 "7.4.9 Dependence of reading on water vapour concentration" in Summer 2017.

All tests were performed with instrument version SWAM 5a Dual Channel Monitor. For the purpose of obtaining approval for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor, additional equivalence tests were performed on the basis of test plans approved by the relevant body on 20 March 2010 (SWAM 5a Dual Channel Hourly Mode Monitor) and on 18 June 2011 (SWAM 5a Monitor). These tests of equivalence are also presented in this addendum.

All test results obtained as well as the conclusions drawn and statements made fully apply to all three instrument versions.

On its publication, this addendum becomes an integral part of TÜV Rheinland test report no. 936/21207522/A dated 23 March 2009 and will be available at www.qal1.de.

The SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor are automated and sequential measuring systems for the determination of particles on filter membranes. The systems are operated either with two completely independent sampling lines (SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor) or with a single sampling line (SWAM 5a Monitor). As part of the tests reported on in the present addendum, for the dual channel versions, one sampling line was equipped with a PM_{10} sampling head while the other was equipped with a $PM_{2.5}$ sampling head – other configurations are possible. The dual channel versions use pumps to suck in ambient air via the PM_{10} sampling head or via the $PM_{2.5}$ sampling head. Dust-loaded sample air is then precipitated on a filter (1 x PM_{10}, 1 x $PM_{2,5}$). For the single channel version, sampling is performed accordingly for a single PM fraction.

The determination of the mass concentration precipitated on a filer is then performed relying on the principle of beta absorption. The temporal resolution (cycle time) of the measurement was 24h during testing (SWAM 5a Dual Channel Monitor and SWAM 5a Monitor) and 1h (SWAM 5a Dual Channel Hourly Mode Monitor).

There is an option to weigh filters gravimetrically. Moreover, filters are available for further analytical methods (e.g. heavy metal analysis).

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

The field table over a period of several months was performed at the locations specified in Table 1 to Table 3.

Table 1: Description of the measurement sites (SWAM 5a Dual Channel Monitor), see [11]

	Cologne Parking lot	Bonn, Belderberg	Teddington, UK	Brühl
Period	10/2007–02/2008	02/2008–04/2008	07/2008–11/2008	09/2008–12/2008
Number of measurement pairs: Test specimens	100	64	83	55
Description	Urban background	Traffic	Urban background	Gravel plant
Classification of ambient air pollution	average to high	average to high	low to average	average

Table 2: Description of the measurement sites (SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor), see [12]

	Cologne Parking lot
Period	02/2011–05/2011
Number of Measurement pairs SWAM 5a DC:	67 ($PM_{2.5}$) 80 (PM_{10})
Number of Measurement pairs SWAM 5a DC HM:	77
Description	Urban background
Classification of ambient air pollution	average to high

Table 3: Description of the measurement sites (SWAM 5a Dual Channel Monitor and SWAM 5a Monitor, see [13]

	Bornheim
Period	08/2011–10/2011
Number of Measurement pairs SWAM 5a DC:	73
Number of Measurement pairs SWAM 5a $PM_{2,5}$:	47
Number of Measurement pairs SWAM 5a PM_{10}:	71
Description	Rural area + motorway
Classification of ambient air pollution	low

The data from Table 1 to Table 3 for the instrument version SWAM 5a Dual Channel Monitor was consolidated and re-assessed in order to have as comprehensive and robust a data set as possible for the equivalence assessment.

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

Table 4: Results of the equivalence tests (raw data)

Number	Instrument version	PM_x	Slope	Ordinate intercept	All Data sets W_{CM}<25 % Raw data	Calibration yes/no	All Data sets W_{CM}<25% cal. Data
1	SWAM 5a DC	PM_{10}	1.051	-0.271	yes	yes *	yes
2	SWAM 5a DC	$PM_{2,5}$	0.973	0.355	yes	yes *	yes
3	SWAM 5a DC HM**	PM_{10}	0.972	-0.305	yes	no	-
4	SWAM 5a DC HM**	$PM_{2,5}$	0.998	0.685	yes	no	-
5	SWAM 5a**	PM_{10}	1.007	-0.900	yes	no	-
6	SWAM 5a**	$PM_{2,5}$	0.971	0.235	yes	no	-

* Given the significance of the slope or the ordinate intercept, a calibration became necessary.
** The evaluation takes into account a single comparison campaign.

1.1 Summary report on test results

Summary of test results in accordance with standard EN 16450 (July 2017)

Performance criterion	Requirement	Test result	satis-fied	Page
1 Measuring ranges	0 µg/m³ to 1000 µg/m³ as a 24-hour average value 0 µg/m³ to 10,000 µg/m³ as a 1-hour average value, if applicable	Instrument versions SWAM 5a Dual Channel Monitor and SWAM 5a Monitor facilitate monitoring of measuring ranges of more than 2,000 µg/m³ in the 24-h cycle. Instrument version SWAM 5a Dual Channel Hourly Mode Monitor facilitates monitoring of a measuring range of up to 10,000 µg/m³ in the 1-h cycle.	yes	74
2 Negative signals	Shall not be suppressed	Negative signals are directly displayed and correctly output by the measuring system.	yes	75
3 Zero level and detection limit	Zero level: ≤ 2.0 µg/m³ Detection limit: ≤ 2.0 µg/m³	On the basis of testing both instruments, the zero level was determined at a maximum of 0.39 µg/m³ and the detection limit at a maximum of 0.71 µg/m³.	yes	76
4 Flow rate accuracy (7.4.4)	≤ 2.0%	The relative difference determined for the mean of the measuring results at +5°C and at +40°C did not exceed 1.17%.	yes	78
5 Constancy of sample flow rate (7.4.5)	≤ 2.0% sampling flow (averaged flow) ≤ 5% rated flow (instantaneous flow)	The 24h-averages deviate from their rated values by less then ± 2.0%, all instantaneous values deviate by less than ± 5%.	yes	80
6 Leak tightness of the sampling system (7.4.6)	≤ 2.0% of sample flow rate	For instrument 1 (SN127), leakage did not exceed 0.24%. For instrument 2 (SN 131), leakage did not exceed 0.30% each at a residual pressure in the system p0. At an air pressure of 102.8kPa, the leakage of instrument 1 (SN 127) did not exceed 0.08%, for instrument 2 (SN 131), it did not exceed 0.06%.	yes	84

Performance criterion	Requirement	Test result	satis-fied	Page
7 Dependence of measured value on surrounding temperature (7.4.7)	≤ 2.0 µg/m³	The tested temperature range at the site of installation was +5 °C to +40 °C. Taking into account at the values displayed by the instrument, we determined a maximum dependence of the zero point on the on surrounding temperature of 0.64 µg/m³.	yes	86
8 Dependence of measured value (span) on surrounding temperature (7.4.7)	≤ 5% from the value at the nominal test temperature	The tested temperature range at the site of installation was +5 °C to +40 °C. At span point, the deviations determined did not exceed 0.1%.	yes	89
9 Dependence of span on supply voltage (7.4.8)	≤ 5% from the value at the nominal test voltage	Voltage variations did not result in deviations > -0.4% compared to the initial value of 230 V.	yes	92
10 Effect of failure of mains voltage	Instrument parameters shall be secured against loss. On return of main voltage the instrument shall automatically resume functioning.	Buffering protects all instrument parameters against loss. On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring.	yes	94

Performance criterion	Requirement	Test result	satis-fied	Page
11 Dependence of reading on water vapour concentration (7.4.9)	≤ 2.0 µg/m³ in zero air	The maximum difference between measured values determined at 40% and at 90% humidity did not exceed 1.9 µg/m³.	yes	95
12 Zero checks (7.5.3)	Absolute value ≤ 3.0 µg/m³	The maximum measured value determined at zero point was 2.4 µg/m³.	yes	98
13 Recording of operational parameters (7.5.4)	Measuring systems shall be able to provide data of operational states for telemetric transmission of – at minimum – the following parameters: Flow rate pressure drop over sample filter (if relevant) Sampling time Sampling volume (if relevant); Mass concentration of relevant PM fraction(s) Ambient temperature Ambient 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	105
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	107
15 Availability (7.5.6)	At least 90%.	The availability for instrument 1 (SN 127) was 99.1%, for instrument 2 (SN 131) it was 97.8%, for SN 145 it was 96.7% and for SN 149, it was 100%.	yes	108

Performance criterion	Requirement	Test result	satis-fied	Page
16 Between-AMS uncertainty ubs,AMS (7.5.8.4)	≤ 2.5 µg/m³	At no more than 0.79 µg/m³ for $PM_{2.5}$ and no more than 1.19 µg/m³ for PM_{10}, the uncertainty between the candidate systems u_{bs} for the SWAM 5a Dual Channel Monitor remains well below the permissible maximum of 2.5 µg/m³. At no more than 0.74 µg/m³ for $PM_{2.5}$ and no more than 0.73 µg/m³ for PM_{10}, the uncertainty between the candidate systems u_{bs} for the SWAM 5a Dual Channel Hourly Mode Monitor remains well below the permissible maximum of 2.5 µg/m³. Finally, at no more than 0.56 µg/m³ for $PM_{2.5}$ and no more than 0.63 µg/m³ for PM_{10}, the uncertainty between the candidate systems u_{bs} for the SWAM 5a Monitor also remains below the permissible maximum of 2.5 µg/m³.	yes	112
17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8)	≤ 25 % at the level of the relevant limit value related to 24-hour average results (if required, after calibration)	Without the need for any correction factors, the expanded uncertainties WAMS for instrument version SWAM 5a Dual Channel Monitor were below the expanded, relative uncertainty Wdqo defined for fine dust at 25% for PM2.5 and PM10 for all data sets observed. This also applies to the uncertainties WAMS determined for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor.	yes	128
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	Even without the need for any correction factors, the expanded uncertainties W_{AMS} were below the expanded, relative uncertainty W_{dqo} defined for fine dust at 25% for $PM_{2.5}$ and PM_{10} for all data sets observed. After applying correction factors for instrument version SWAM 5a Dual Channel Monitor, the candidate systems continue to meet the requirements for data quality for ambient air monitoring for all data sets. A minor deterioration of the expanded uncertainty for the $PM_{2.5}$ data set was observed. However, a considerable improvement of the expanded uncertainty for the PM_{10} data set was observed at the same time.	yes	161

Performance criterion	Requirement	Test result	satis-fied	Page
18 Maintenance interval (7.5.7)	At least 14 d	The maintenance interval is determined by the necessary maintenance tasks (filter replacement/cleaning the sampling head if necessary). It is 15 days for PM2.5 and 30 days for PM10.	yes	169
19 Automatic diagnostic check (7.5.4)	Shall be possible for the AMS	The instrument saves the results of internal tests for the purpose of quality assurance/functional tests e.g. leak tightness of the system, flow calibration and radiometric determination of mass concentrations.	yes	170
20 Checks of temperature sensors, pressure and/or humidity sensors	Shall be checked for the AMS to be within the following criteria ± 2 °C ± 1 kPa ± 5 % RH	It is easy to check and adjust the relevant external sensors for determining ambient temperature and ambient pressure on-site. It is also possible to check the internal sensors (e.g. in the filter area during sampling or with regard to flow measurement). However, this requires disassembly of the installation and should therefore ideally be performed in a laboratory as part of the annual checks according to standard EN 16450, Table 4,	yes	171

2. Task Definition

2.1 Nature of the test

FAI Instruments s.r.l commissioned TÜV Rheinland Energy GmbH to carry out performance testing on the SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor.

The SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor for suspended particulate matter PM_{10} and $PM_{2.5}$ have already been performance tested and publically announced in the Federal Gazette.

The present addendum assesses the SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor in terms of compliance with the requirements for automated measuring systems for the determination of dust concentrations as defined by the new standard EN 16450 (July 2017).

2.2 Objectives

The measuring systems are designed to determine the PM_{10} and $PM_{2.5}$ fractions of dust concentrations in the range between 0 and 200 µg/m3 in ambient air.

The existing performance test had been performed in respect of the requirements applicable at the time of testing while at the same time taking into account the latest developments.

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

- VDI Guideline 4202, Part 1 – "Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants," dated June 2002 [1]
- VDI Guideline 4203, part 3 – "Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", dated August 2004 [2]
- European standard EN 12341 "Air Quality - Determination of the PM_{10} fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods", German version EN 12341: 1998, [3]
- European standard EN 14907, "Ambient air quality – Standard gravimetric measurement method for the determination of $PM_{2.5}$ mass fraction of suspended particulate matter", German version EN 14907: 2005 [4]
- Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods", English version dated November 2005 [5]

Standard

- EN 16450 "Ambient air — Automated measuring systems for the measurement of the concentration of particulate matter (PM_{10}; $PM_{2,5}$), German version EN 16450:2017 [9]

has been available since July 2017.

This standard, for the first time, harmonises requirements for the performance testing of automated measuring systems for the determination of dust concentrations (PM_{10} and $PM_{2.5}$) on a European level and will form the basis for the approval of such AMS in the future.

The present addendum assesses the SWAM 5a measuring system (instrument versions SWAM 5a Dual Channel Monitor, SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor) in terms of compliance with the requirements of standard EN 16450 (July 2017).

As most of the performance characteristic and performance criteria defined in chapter 7 of standard EN 16450 (July 2017) have been tested and assessed already in the context of the original performance test, the majority of test results can be taken from and/or re-assessed on the basis of the original test report or tests performed in the context of obtaining approval for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor as documented in the corresponding notifications. Completely new tests were performed in Summer 2017 only for test items 6.1 4 Flow rate accuracy (7.4.4), 6.1 9 Dependence of span on supply voltage (7.4.8) and 6.1 11 Dependence of reading on water vapour concentration (7.4.9).

All tests were performed with instrument version SWAM 5a Dual Channel Monitor. For the purpose of obtaining approval for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor, additional equivalence tests were performed on the basis of test plans approved by the relevant body on 20 March 2010 (SWAM 5a Dual Channel Hourly Mode Monitor) and on 18 June 2011 (SWAM 5a Monitor). These tests of equivalence are also presented in this addendum.

All test results obtained as well as the conclusions drawn and statements made fully apply to all three instrument versions.

On its publication, this addendum becomes an integral part of TÜV Rheinland test report no. 936/21207522/A dated 23 March 2009 and will be available at www.qal1.de.

3. Description of the AMS tested

3.1 Measuring principle

For mass measurement of separated particles, the SWAM 5a Dual Channel Monitor, SWAM 5a Monitor and SWAM 5a Dual Channel Hourly Mode Monitor measuring systems rely on the principle of beta attenuation observed on passing through a thin film of material.

The relation between a beta flux attenuated after passing through a thin film of material and the mass density of that material can be described in a relationship.

Mass measurement x_p of particles collected on the filter relies on exact quantification of the relative variation sustained by a flux of β electrons achieving an opposite detector, this film being present or absent.

Overly simplified, the following association generally applies: $m_p=S*x_p$ where

$$x_p = k(z) \cdot \ln \frac{Flux_{blank}}{Flux_{collect}}$$

Where	m_p	is the mass of dust particles
	S	is the deposited surface
	x_p	is the mass density of dust particles
	k(z)	is the mass absorption coefficient function
	$Flux_{blank}$	is the beta flux before sampling
	$Flux_{collect}$	is the beta flux after sampling

Beta fluxes measured may contain systematic fluctuations not attributable to the presence of particulate matter mass accumulated on the filter. These contributions primarily result from:

- the variation of the filtering medium mass thickness (e.g. humidity effects)
- air density fluctuations
- detector response efficiency fluctuations

The SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor instrument versions provide a feature called spy filter to quantify these influences and take them into account for calculations. The spy filters consist of the same filter material as the filters used for measurement and are permanently implemented in the instrument. During measurements, measurement and spy filters are alternated and measured. The beta influence determined with the help of the spy filter potential biases caused by the influences listed above can be taken into account.

The following relationship applies:

$$m_P = S \cdot x_p = S \cdot \bar{k}(z) \cdot Z_{r1}^{*} \cong S \cdot k_{sh} \cdot \left[\bar{k}(z) \cdot \ln\left(\frac{\bar{\Phi}^i(x_{Fr})}{\bar{\Phi}^j(x_{Fr} + x_p)} \frac{\bar{\Phi}^j(x_{Fs})}{\bar{\Phi}^i(x_{Fs})} \right) + offset \right]$$

where k_{sh} is 1 by definition.

p = particle, F_r = measurement filter, F_s = spy filter and

x_{Fr} = blank and x_{Fr}+X_p = collect

The manufacturer determines the function k(z) with the help of 6 reference aluminium foils and implements it in the measuring system.

This calibration can be verified on every restart of the instrument (or manually at the start of the next measurement cycle) with the help of two reference aluminium foils with known mass density. The values thus obtained are compared to pre-defined values and potential deviations indicated as a percentage. The result of the previous “beta span test” can be recalled at any time.

Note concerning SWAM 5a Monitor:

The SWAM 5a Monitor instrument version does not use spy filters for an additional correction of the radiometric mass measurement. In practice, however, the Geiger counter and its voltage supply prove very stable to drift. Moreover, for the SWAM 5a Monitor, too, performance of the Geiger counter and its voltage supply is constantly monitored as part of internal quality assurance procedures. In the event of deviations from tolerances, the instrument issues warnings and alarms.
The instrument is operated in a temperature-controlled environment (air-conditioned measurement rack or container) in order to avoid temperature fluctuations inside the instrument. Consequently, when properly operating the SWAM 5a Monitor, fluctuations of radiometric measurements caused by influence listed above are highly unlikely, and—should they occur—they will be detected in time given appropriate warnings/alarms. Potential negative effects on mass measurement can be traced at any time.

3.2 Functioning of the measuring system

The SWAM 5a Dual Channel Monitor measuring system is an automated and sequential measuring systems for the determination of particles on filter membranes. The system is operated with two completely independent sampling lines. As part of the tests reported on in the present addendum, one sampling line was equipped with a PM_{10} sampling head while the other was equipped with a $PM_{2.5}$ sampling head – other configurations are possible. Pumps are used to suck in ambient air via the PM_{10} sampling head or via the $PM_{2.5}$ sampling head. Dust-loaded sample air is then precipitated on a filter (1 x PM_{10}, 1 x $PM_{2,5}$). The determination of the mass concentration precipitated on a filer is then performed relying on the principle of beta absorption. A single radiometric mass mass measurement module is used to determine the dust mass deposited on the filters for both sampling lines.

The SWAM 5a Dual Channel Hourly Mode Monitor differs from the SWAM 5a Dual Channel Monitor measuring system in the following way.

1. The collection surface of the filter (filter spot area) is 2.27 cm² and thus is smaller than that of the SWAM 5a Dual Channel Monitor version (5.20 cm² during testing, alternatively: 2.54 cm², 7.07 cm² and 11.95 cm²).
2. During radiometric measurement, the beta source is closer to the filter.
3. In total, 3 filters are inserted 8 times a day per line (time resolution 1h instead of 24h).

The SWAM 5a Monitor differs from the SWAM 5a Dual Channel Monitor measuring system in the following way.

1. Instead of two sampling lines operated in parallel as is the case for the SWAM 5a Dual Channel Monitor, the SWAM 5a Monitor operates a single sampling line.

2. The SWAM 5a does not use spy filters for an additional correction of the radiometric mass measurement.

If not specified otherwise, the following remarks apply to the functioning of all three instrument versions. Additional details are available in the corresponding operation manual.

a) AMS operating modes

The two-channel versions of the measuring system can be operated in one of two modes: Monitor Mode and Reference Mode.

Monitor mode

The Monitor Mode allows the particulate matter sampling and mass measurement on two independent lines (SWAM 5a DC and SWAM 5a DC HM) or on a single line (SWAM 5a). For the dual-channel versions, this mode allows to simultaneously determine two PM fractions (e.g. PM_{10} and $PM_{2.5}$). Moreover, configurations for metrological evaluations such as the following are possible:

- the evaluation of the volatile material losses thanks to the possibility of heating (cooling) one line and cooling (heating) the other;
- the evaluation of the performances/comparability of two different sampling inlets.

In the context of this test, the instruments were exclusively operated in the Monitor Mode, two channel versions were configured to determine PM_{10} on one line and $PM_{2.5}$ on the other.

Reference mode (SWAM 5a DC HM and SWAM 5a DC only)

In Reference Mode the instrument is used as improved, high-quality standard reference single-channel monitor. In this mode one sampling line is used for PM sampling as usual, while the other line is equipped with a zero filter that will serve as “field blank”. This configuration provides a field blank for every measured value.

b) Mass measurement

SWAM 5a Dual Channel Hourly Mode Monitor / SWAM 5a Dual Channel Monitor

The module for radiometric mass measurement is mounted to a mechanic swivel arm. The source and the detector are connected to one another and can be moved to the desired position together (see Figure 1).

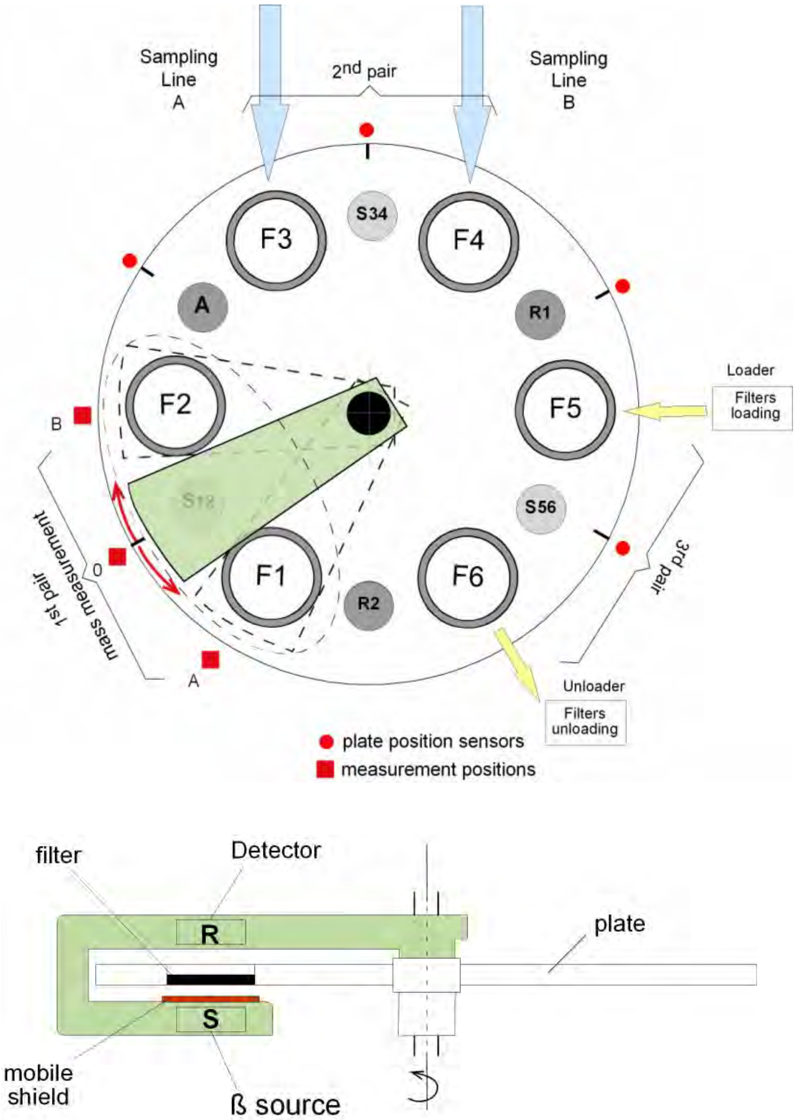


Figure 1: Mass measurement with the SWAM 5a Dual Channel Monitor

SWAM 5a Monitor

There is no need for the radiometric measurement unit to move which is why it is fixed (see Figure 2).

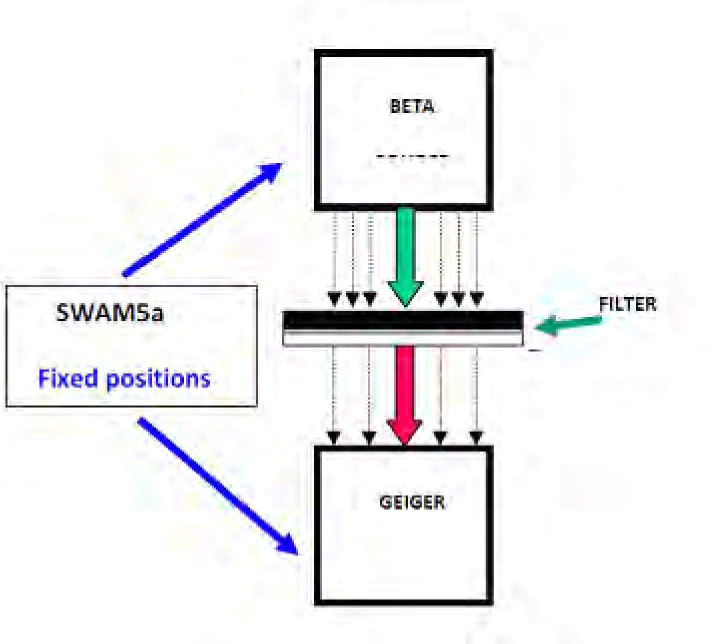


Figure 2: Mass measurement SWAM 5a Monitor

Using the example of the SWAM 5a Dual Channel Monitor, the measurement cycle can be described as follows.

Every measurement session, whether blank or collect measurement, consists of a sequence of beta flux measurement cycles. Every cycle is alternately performed on the operative filtering mediums F_{r1} and F_{r2} and on the spy filter F_s. The matrix describing the sequence of the measurements contained in the n measurement cycles is:

$$\begin{bmatrix} F_s^{11} & F_{r1}^{1} & F_s^{12} & F_{r2}^{1} & F_s^{13} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ F_s^{n1} & F_{r1}^{n} & F_s^{n2} & F_{r2}^{n} & F_s^{n3} \end{bmatrix} \quad \text{with } 4 \le n \le 6$$

Radiometric measurement times Tm relative to the single phases are:

- 10 min for measurement filter F_r
- 5 min for the spy filters

The number of measurement cycles depends on the sampling cycle.

n=4 for 8 h sampling cycles

n = 6 for 12 h or longer sampling cycles

A normal cycle time of 24 h (n=6) results in every measurement filter being measured 6 times per measurement and every spy filter being measured 18 times.

Moreover, for the purpose of quality assurance, every measurement cycle includes a measurement of background noise of the beta measurement (= dark) – with the radiation source shielded – and a measurement of the beta ray influence without the use of filters between the beta source and the detector (= beta flux in the air). The former allows to determine the background noise, while the latter facilitates the stability assessment of the Geiger-Müller detector.

c) Pneumatic system

Two vacuum pumps are used to adjust the flow rate in the range between 0.5–2.5 m³/h (a single vacuum pump for the SWAM 5a Monitor). A regulation valve moved by a step motor serves to control the flow rate.

Two solenoid valves, one placed in each sampling line, allow to switch the pneumatic circuit from the sampling configuration to the span test configuration (automatic check of the flow rate measurement system calibration) and to the leak test configuration (automatic check of the pneumatic circuit seal).

The three possible pneumatic configurations are as follows (see Figure 3):

- Sampling: EV1 open, EV2 closed
- Leakage test: EV1 closed, EV2 closed
- Span test: EV1 closed, EV2 open

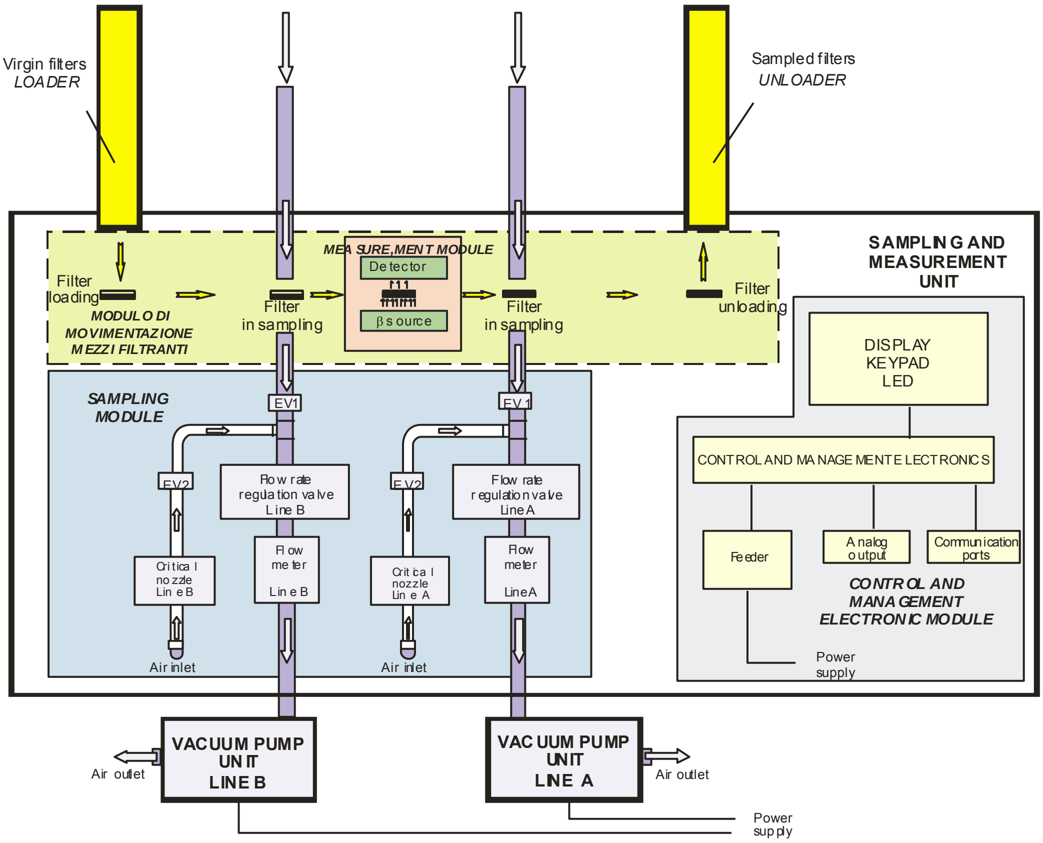


Figure 3: Schematic layout of the sampling unit, dual channel version

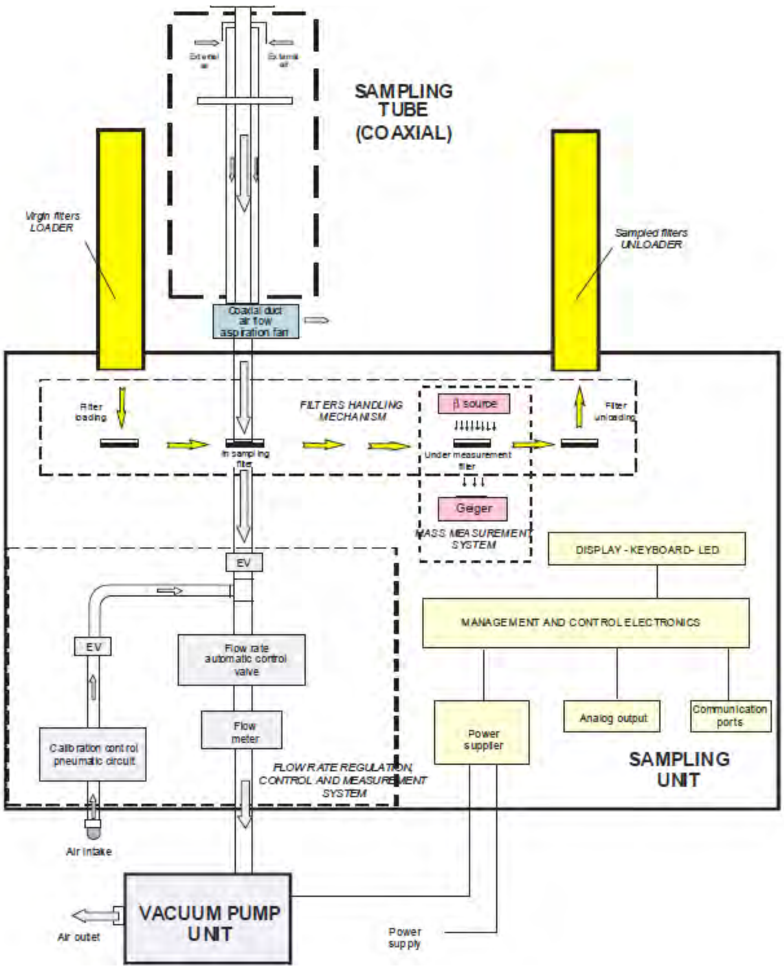


Figure 4: Schematic layout of the sampling unit, single channel version

The sampling flow rate measurement is based on the physical laws controlling the air mass transfer through a nozzle that in the AMS is placed downstream the regulation valve.

By measuring the pressure value P_p, downstream of the nozzle, the nozzle pressure drop ΔP and the air temperature value T_m in the measurement area, it is possible to calculate the standard flow rate value Q_s using the following relation:

Qs = f(z) where $z = \sqrt{\frac{\Delta p \cdot (2P_p - \Delta p)}{T_m}}$

The AMS approximates the form of the function f(z) to a second-order polynomial in z whose coefficients are determined using a multipoint calibration procedure.

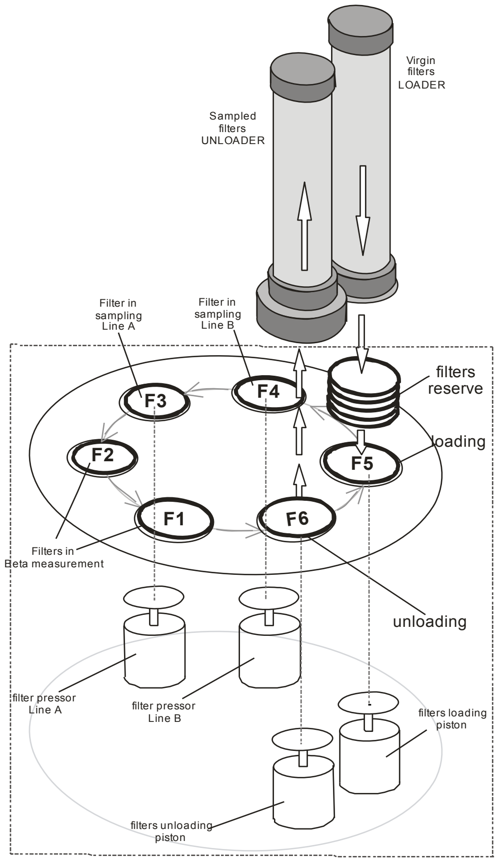
d) Filter membrane management

The AMS can handle a maximum of 72 filters. At the end of every sampling and measurement cycle the sampled filters can be removed from the unloader.

The filter membranes management module comprises the following main components:

- Rotating plate for measurement filters F, spy filters S (not for SWAM 5a Monitor) and reference foils R; it has a hole A the measurement of the air beta flux.
- Virgin filter loader
- Virgin filter reserve (inside the instrument)
- Sampled filter unloader
- Electro-pneumatic pistons for filter loading and unloading
- Electro-pneumatic filter-presser pistons for the operative positioning of the filters

Figure 5 provides a design overview of the filter membrane management module using the example of the SWAM 5a Dual Channel Monitor.



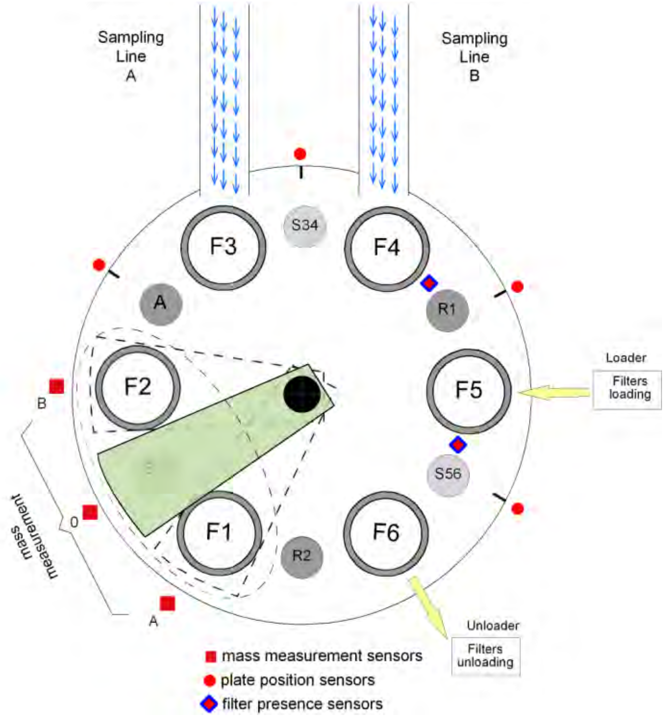


figure 4.1

Figure 5: Filter membrane management system

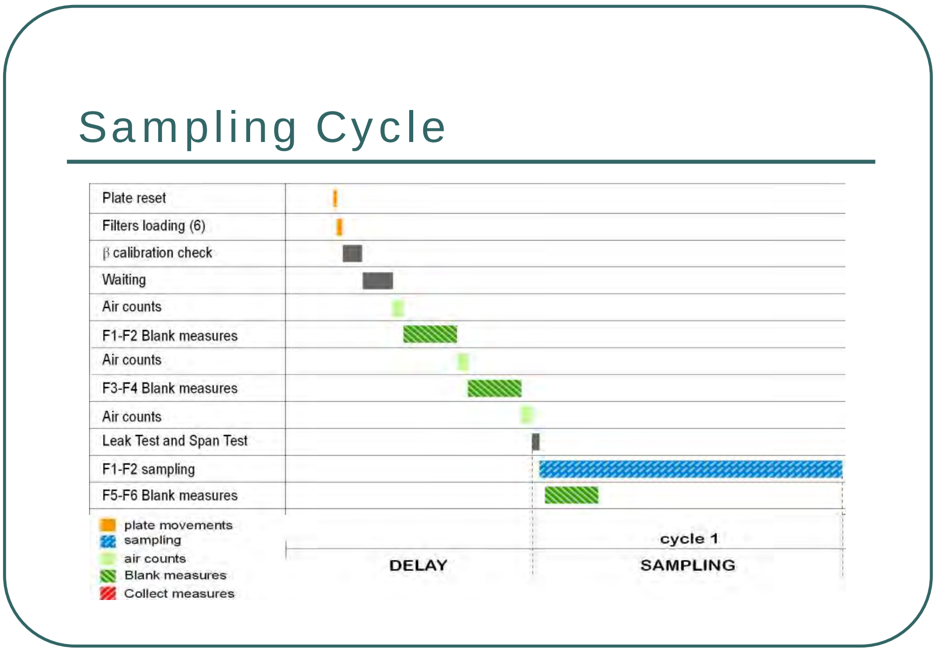
Measurement filters (∅ 47 mm) are inserted into specific filter cartridges. Depending on the dust load to be expected, filter cartridges may contain filters with smaller or larger spot areas (starting from 2.54 cm² for low dust concentrations up to 11.95 cm² for higher concentrations in the SWAM 5a Dual Channel Monitor/SWAM 5a Monitor and 2.25 cm² for the SWAM 5a Dual Channel Hourly Mode Monitor). The size of the spot area needs to be taken into account for parameterisation.

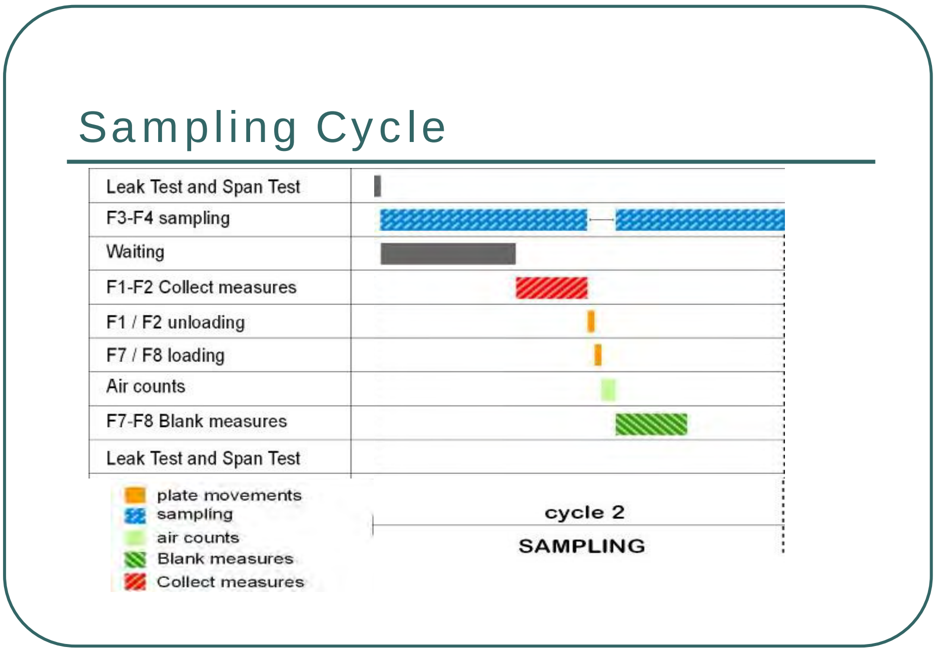
During the performance test of the SWAM 5a Dual Channel Monitor and SWAM 5a Monitor, filter cartridges with a 5.20 cm² spot area were used; for the SWAM 5a Dual Channel Hourly Mode Monitor 2.27 cm² spot areas were used.

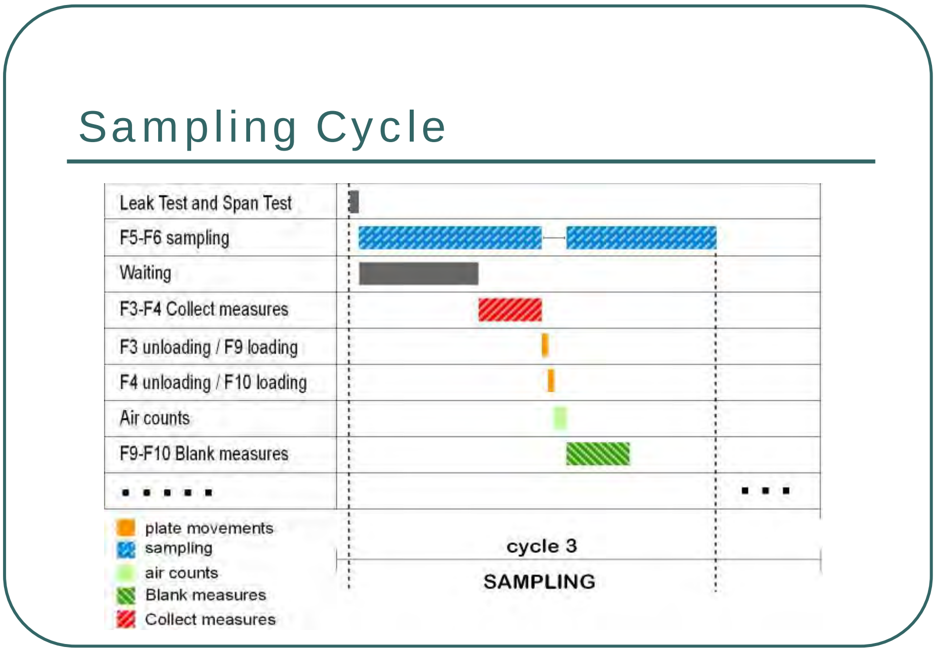
Filter cartridges with virgin filters are inserted into the loader. As part of performance testing, 36-filter cartridges were inserted into the filter loader. When operating two lines in parallel and at a cycle time of 24 h, the measuring system can then be operated for 18 days without the need to stock up filters. Stocking up filters can take place at any time without having to interrupt AMS operation.

e) Overview of the sequence of steps followed for three consecutive sampling cycles

The following figure illustrates the sequence of steps followed during three consecutive sampling cycles and, in doing so, the functioning of the measuring system as well as the filter positions inside the instrument.






Sampling Cycle
Leak Test and Span Test
F5-F6 sampling
Waiting
F3-F4 Collect measures
F3 unloading / F9 loading
F4 unloading / F10 loading
Air counts
F9-F10 Blank measures
plate movements
sampling
air counts
Blank measures
Collect measures
cycle 3
SAMPLING

f) Quality assurance

The measuring system provides for a number of internal tests for quality checks in order to verify and ensure correct operation.

The results of these quality checks can be reviewed in the data stored for each measurement. For some of the parameters monitored, warnings or alarms are issued when certain, specified limits are exceeded.

The annexes to the relevant operation manuals provide an overview of warnings and alarms issued.

Among others, the following parameters are being monitored:

- Leak tightness of the pneumatic system (before every measurement cycle)
- Test of the flow rate calibration (before every measurement cycle)
- Flow rate stability (continually during every measurement cycle)
- Pressure drop at the measurement filter (continually during every measurement cycle)
- Monitoring of pressure and temperature sensors (continually during every measurement cycle)
- Background noise of the beta flux (before every measurement cycle)
- Stability test of the Geiger counter (continually during every measurement cycle)
- Test of the mass calibration (before every restart or manually initiated at the beginning of the upcoming measurement cycle)
- Use of sensors to establish proper mechanical functioning

3.3 AMS scope and set-up

SWAM 5a Dual Channel Hourly Mode Monitor / SWAM 5a Dual Channel Monitor:

The measuring system consists of two sampling heads (PM_{10} and $PM_{2.5}$), two sampling lines, two vacuum pumps, the instrument, the compressor for generating compressed air and the two filter cartridges for virgin and sampled filters.

SWAM 5a Monitor

The measuring system consists of one sampling head (PM_{10} or $PM_{2.5}$), one sampling line, one vacuum pump, the instrument, the compressor for generating compressed air and the two filter cartridges for virgin and sampled filters.

The individual components are described below:

Measuring system/sampling unit

The sampling unit contains all the servo mechanics, the pneumatic and beta measurement component as well as all electronic parts and microprocessors for operation, control and monitoring of the measuring system. The control panel with display is located at the front of the system; pneumatic and electronic connections as well as communication interfaces are located at the back of the system. Filter loader/unloader housings and sampling lines are located on the upper instrument surface.

Figure 6: SWAM 5a Dual Channel Monitor measuring system

Figure 7: SWAM 5a Monitor measuring system

Vacuum Pump

Ambient air is taken in through the sampling inlets, the two sampling lines and the two filters with the help of the vacuum pump (1 pump and 1 filter for the SWAM 5a Monitor). They consist of a piston pump with with an upstream silencer filter to balance out pressure fluctuations. Automatic flow rate control takes place for each sampling line independently.

In principle, it is possible to use a different pump type (e.g. graphite rotary vane pump) as long as the required pump performance is ensured at any given time.

Figure 8: Vacuum pump

Service air compressor unit

The instrument is equipped with a service air compressor able to supply compressed air (200–300 kPa) used for the servomechanisms movements (e.g. for loading/unloading filters into the relevant housing). A compressor generates the necessary compressed air.

Figure 9: Compressor for generating compressed air

Sampling inlets

The measuring system is equipped with two sampling inlets for PM_{10} and $PM_{2.5}$. The sampling inlets are manufactured by the instrument manufacturer and are available for various flow rates (2.3 m³/h or 1 m³/h).

During performance testing, sampling inlets with a throughput of 2.3 m³/h were used which, in terms of design, comply with the reference standards applicable at the time of testing, namely EN 12341:1998 (PM_{10}) and EN 14907:2005 ($PM_{2.5}$).

Standards EN 12341: 1998 and EN 14907:2005 have been revised in the meantime and consolidated in the new standard EN 12341 (August 2014) version. Annex A to the new standard provides normative requirements for instrument design of standard sampling inlets for PM_{10} and $PM_{2.5}$ for a flow rate of 2.3 m³/h. For PM_{10} in particular, requirements for standard sampling inlets in the new standard have been revised and slightly modified. This is why, FAI Instruments s.r.l have included sampling inlets in compliance with the new standard EN 12341 (August 2014 version) in their range of products, which may be used alternatively with the measuring system.

The new sampling inlets are clearly labelled as PM_{10}-EN12341-2014 and $PM_{2.5}$-EN12341-2014 respectively and are manufactured in compliance with Annex A to standard EN 12341 (August 2014 version).

Figure 10: Sampling inlets FAI

Sampling line

Ambient air containing particles is taken in through the sampling inlet, it passes through the sampling line and finally reaches the filter.

In situations with high amounts of volatile dust components it is possible to have the sampling line purged co-axially with ambient air (it may alternatively heated or cooled).

As part of the test at hand, neither purging with ambient air, nor active heating or cooling took place. Inside the measuring rack, the sampling line was isolated by wrapping foamed material around it.

For the field test, the measuring systems were installed in an outdoor rack specifically designed and distributed by the manufacturer. The measuring rack consists of a minimum of three modules:

Module 1 for housing the measuring system

Module 2 for housing the rack's temperature control

Module 3 for housing pumps and the compressor

Of course, the measuring system can be installed in any conventional measuring rack. In that case it should be noted that the SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Monitor require two roof ducts for the two sampling lines.

Figure 11: Outdoor measurement racks at the field test site in Bonn, Belderberg

Figure 12: SWAM 5a Dual Channel Monitor inside the outdoor measurement rack

The measuring system is operated via a membrane keypad combined with a display at the front of the instrument. This is where all necessary parameters can be adjusted (e.g. sampling time). Moreover, information regarding the current instrument status (on-going sampling), data saved on completed measurements and numerous parameters for quality assurance can be accessed here.

In addition to direct communication via the control panel/display, the system can be fully operated, controlled and parameterised via the RS-232 serial interfaces and a standard terminal programme (e.g. Hyperterminal) or the software component Dr. FAI Manager (version 0.6.6.0 used during performance testing), either directly or indirectly via a GSM modem. This provides a convenient possibility to read stored data as a text file and use them for further processing. Figure 13 to Figure 19 provide an overview of information provided and available monitoring and control features offered by the Dr. FAI Manager.

An analogue output provides measured values and status signals if this is desired.

Moreover, the measuring system provides a feature which informs its user about the instrument status and the latest measured values via SMS.

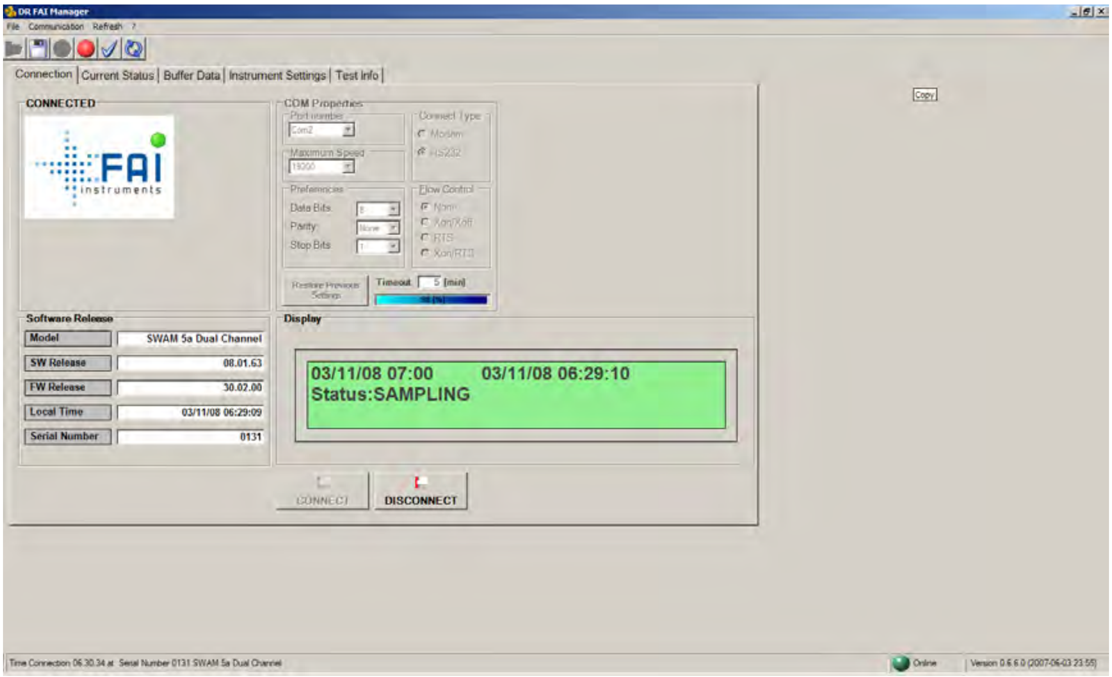


Figure 13: Dr. FAI Manager operating software

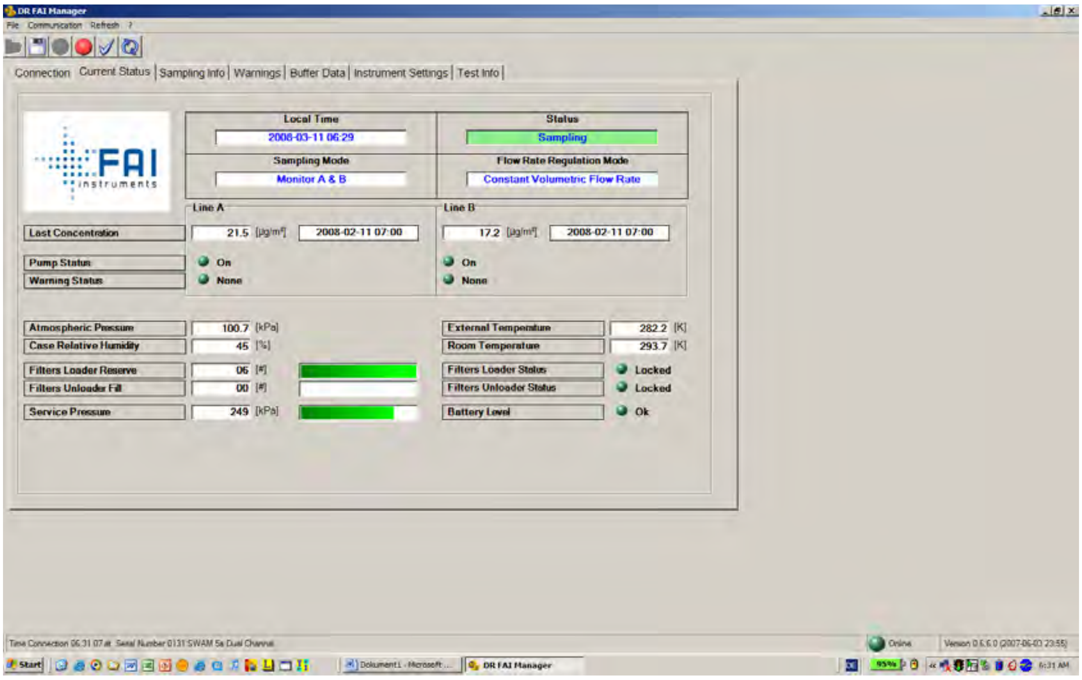


Figure 14: Dr. FAI Manager operating software (sampling information)

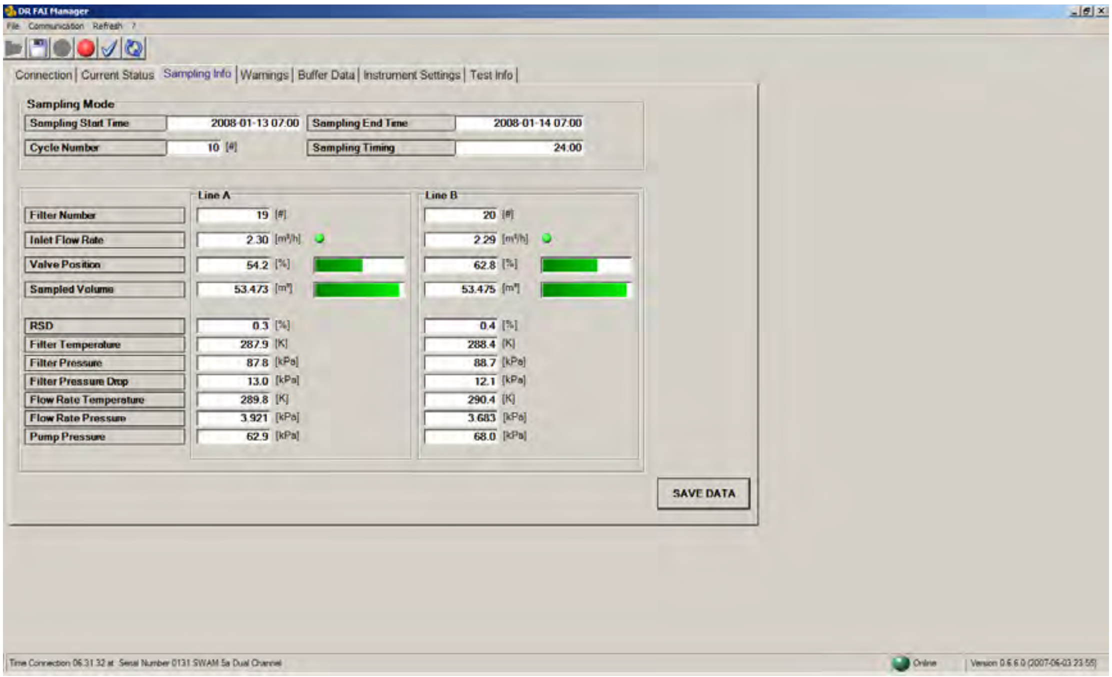


Figure 15: Dr. FAI Manager operating software

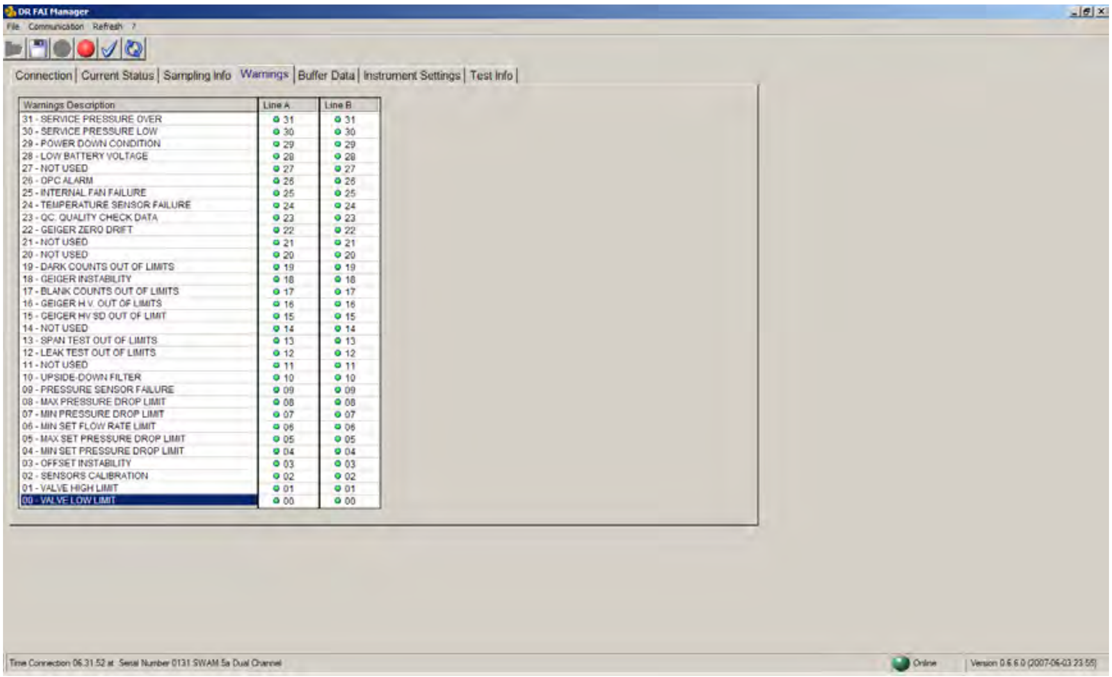


Figure 16: Dr. FAI Manager operating software (warnings)

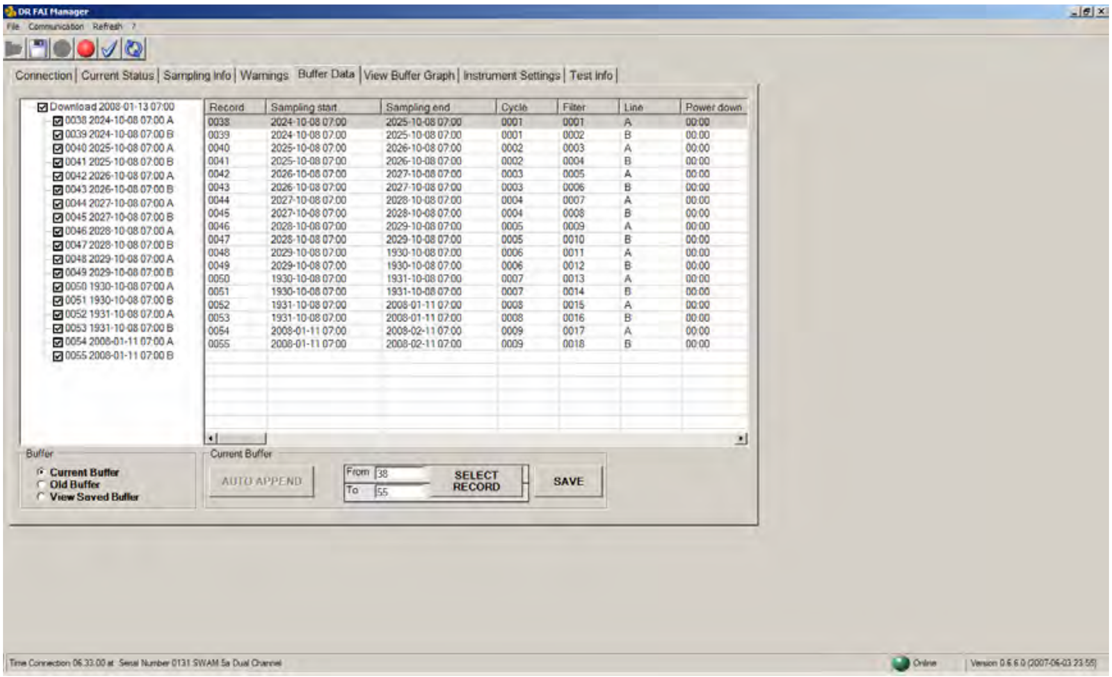


Figure 17: Dr. FAI Manager operating software (saving data)

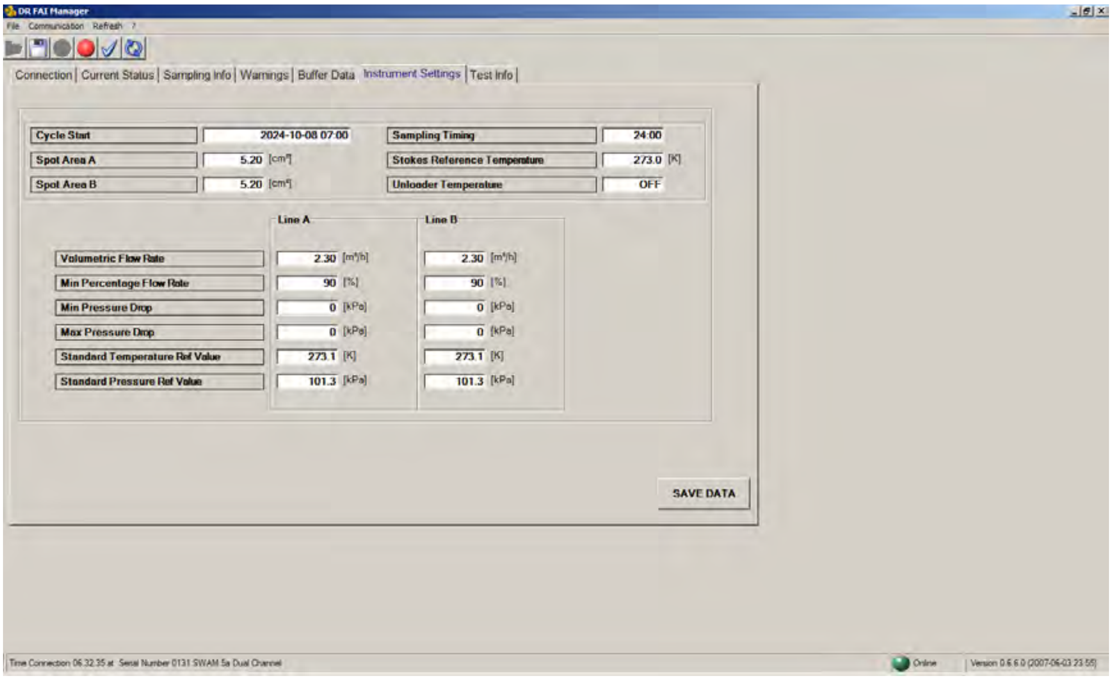


Figure 18: Dr. FAI Manager operating software (system parameterisation)

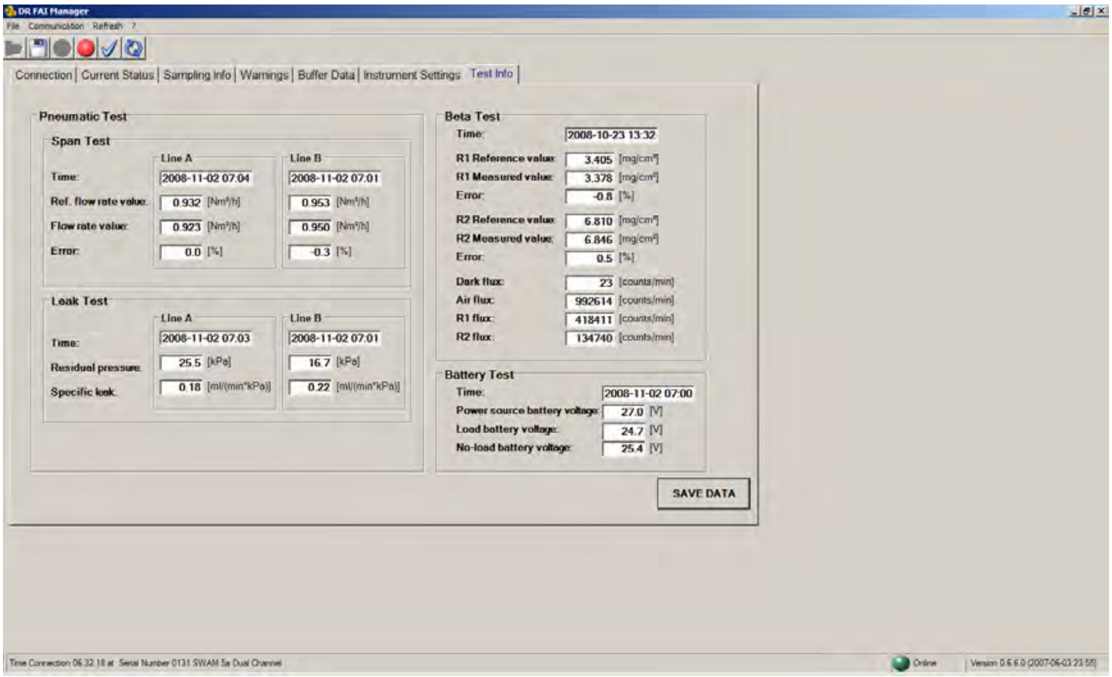


Figure 19: Dr. FAI Manager operating software (results of internal tests)

Instead of a sampling inlet, a zero filter placed at the instrument inlet is used for the purpose of zero checks and the determination of the offset. The use of this filter allows the provision of PM-free air.

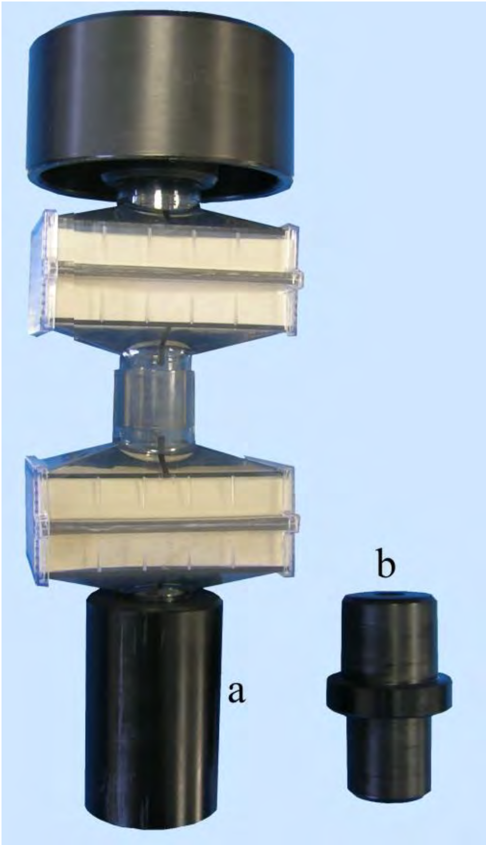


Figure 20: Zero filter (a = zero filter, b = adapter connecting to the sampling line)

The radiometric calibration can be verified on every restart of the instrument (or manually at the start of the next measurement cycle) with the help of two reference aluminium foils with a known mass density. The values thus obtained are compared to pre-defined values and potential deviations indicated as a percentage. The result of the previous "beta span test" can be recalled at any time.

In addition, the manufacturer provides a set of reference aluminium foils for checking and, if necessary, recalibrating the radiometric measurement. There are 6 foils in this set. The necessary procedure is described in detail in the operation manual.

Table 5 lists the most important instrument characteristics of the SWAM 5a measuring system.

Table 5: SWAM 5a instrument characteristics (manufacturer specifications)

Dimensions / weight	**SWAM 5a**
Measuring device	430 x 540 x 370 mm / 36 kg (SWAM 5a DC/DC HM) 430 x 540 x 240 mm / 33 kg (SWAM 5a)
Vacuum pump	200 x 320 x 200 mm / 10 kg
Compressor	180 x 320 x 200 mm / 18 kg
Sampling tube	1.5 m
Sampling inlet	FAI, 2.3 m³/h, PM_{10} & $PM_{2.5}$
Outdoor measuring cabinet	700 x 700 x 1950 mm / 95 kg
Power supply	230 V±10 %, 50 Hz
Power requirement	max. 1.200 W / 1000 W (SWAM 5a)
Ambient conditions	
Temperature	+5 - +40 °C during performance testing
Moisture	not condensing (<85%)
Sample flow rate	0.8–2.5 m³/h, adjustable 2.3 m³/h = 38.33 l/min during performance testing
Radiometric source	^{14}C, 3.7 MBq (100 µCi)
Detector	Geiger-Müller
Mass measurement	
Measuring range mass density	10 mg/cm²
Reproducibility of the mass density determination	±2 µg/cm²

Spot area (β equivalent spot area) in cm², depends on the filter material, flow rate and concentration level	2.54 / 5.20 / 7.07 / 11.95 (SWAM 5a DC / SWAM 5a) 2.27 (SWAM 5a DC HM)
Reproducibility of the mass measurement	±10 µg at a spot area of 5.2 cm²
Sampling	
Filter replacement interval (cycle time)	adjustable, 8–12–24–48–72–96–120–144–168 h 1h for SWAM 5a DC HM
Maximum permissible flow rate at filter	40 kPa at 2.3 m³/h
Data storage capacity (internal)	1 500 data sets
Data saved for each measurement	see operation manual
Analogue output	0–5 V – parameterisable, 200 µg/m³ by default, others selectable
Digital output	2 x RS 232 (for PC and for Modem) – interface for (remote) data transmission
Status signals/error messages	available, consult operation manual for overview

4. Test programme

4.1. General

The original performance test [11] was carried out with two identical instruments, type SWAM 5a Dual Channel Monitor, serial numbers 127 and 131.SWAM 5aSWAM 5a Tests in the context of the scheduled test programme "Combined MCERTS and TÜV PM Equivalence Testing Programme" were performed simultaneously at the sites in Teddington and in German and with two identical instruments, serial numbers 145 and 149.

At the beginning of the performance test, the candidate systems operated software version Rel 04-08.01.63-30.02.00. In the course of testing, software versions were continually updated to reach version no. Rel 04-08.01.65-30.02.00 in the end.

Changes having led to software version Rel 04-08.01.65-30.02.00 are unlikely to impact instrument performance.

The original test comprised a laboratory test to determine the performance characteristics as well as several field tests over a period of several months at various sites.

Additional tests performed for the purpose of approving instrument version SWAM 5a Dual Channel Hourly Monitor were performed with two identical instruments of that type, serial numbers 111 and 112 as well as with two identical instruments, type SWAM 5a Dual Channel Monitor, serial numbers 127 and 131.

Additional tests performed for the purpose of approving instrument version SWAM 5a Monitor were performed with a total of four instruments identical in design except for the sampling inlets, serial numbers 329 and 330 (PM_{10}) as well as 331 and 333 ($PM_{2.5}$) and with two identical instruments of the approved SWAM 5a Dual Channel Monitor version, serial numbers 248 and 249 [13].

The additional tests for test items 6.1 4 Flow rate accuracy (7.4.4), 6.1 9 Dependence of span on supply voltage (7.4.8) and 6.1 11 Dependence of reading on water vapour concentration (7.4.9) were performed with two identical systems instrument type SWAM 5a Dual Channel Monitor, serial numbers 111 and 395.

During performance testing, each instrument ran the up-to-date, most recently announced software version.

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

The present addendum assesses the SWAM 5a measuring system (instrument versions SWAM 5a Dual Channel Monitor, SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor) in terms of compliance with the requirements of standard EN 16450 [9].

In this report, the heading for each performance criterion cites the requirements according to the relevant standard [9] including its chapter number and wording.

4.2 Laboratory test

The laboratory test was performed in the context of the existing performance test [1]. For the present report, test results were either taken from the previous report or re-assessed.

For the following test items, additional tests had to be performed in 2017.

- Flow rate accuracy
- Influence of mains voltage on measured signal
- Effect of humidity on measured value

The following devices were used to determined the performance characteristics during the laboratory tests.

- Climatic chamber (temperature range –20°C to +50°C, accuracy better than 1°C).
- Isolating transformer,
- 1 reference flow meter, type BIOS Met Lab 500 (manufacturer: Mesa Lab)
- Zero filter (absolute filter) for producing PM-free air
- Reference foils R1&R2 (implemented in the instrument)

Measured values were read with the help of the DR FAI Manager software installed on a notebook.

Chapter 6 summarizes the results of the laboratory tests.

4.3 Field test

The field test for instrument version SWAM 5a Dual Channel Monitor [11] was performed at the field test sites in Cologne (parking lot 2007), Bonn (Belderberg) and Brühl using two identical instruments with the following serial numbers:

AMS 1: No. SN 127 (SWAM 5a Dual Channel Monitor)
AMS 2: No. SN 131 (SWAM 5a Dual Channel Monitor)

Tests in Teddington (UK) were performed as part of the "Combined MCERTS and TUV PM Equivalence Testing" programme" using a second set of instruments identical in design with the following serial numbers:

AMS 1: No. SN 145 (SWAM 5a Dual Channel Monitor)
AMS 2: No. SN 149 (SWAM 5a Dual Channel Monitor)

As part of the supplementary test for the purpose of approving instrument version SWAM 5a Dual Channel Hourly Monitor, a comparison campaign was performed in Cologne (parking lot, 2011) with the following instruments [12]:

AMS 1: No. SN 111 (SWAM 5a Dual Channel Hourly Mode Monitor)
AMS 2: No. SN 112 (SWAM 5a Dual Channel Hourly Mode Monitor)
AMS 3: No. SN 127 (SWAM 5a Dual Channel Monitor)
AMS 4: No. SN 131 (SWAM 5a Dual Channel Monitor)

As part of the supplementary test for the purpose of approving instrument version SWAM 5a Monitor, a comparison campaign was performed in Bornheim with the following instruments [13]:

AMS 1: No. SN 329 (SWAM 5a PM_{10})
AMS 2: No. SN 330 (SWAM 5a PM_{10})
AMS 3: No. SN 331 (SWAM 5a $PM_{2.5}$)
AMS 4: No. SN 333 (SWAM 5a $PM_{2.5}$)
AMS 5: No. SN 248 (SWAM 5a Dual Channel Monitor)
AMS 6: No. SN 249 (SWAM 5a Dual Channel Monitor)

In order to take into consideration the overall dataset for the purpose of equivalence testing of the SWAM 5a Dual Channel Monitor instrument version, the data sets of all six comparison campaigns were combined to provide as comprehensive a data pool as possible.

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

The following instruments were used during the field test.

- Outdoor measurement racks for the candidate systems manufactured by FAI Instruments s.r.l
- Measurement container provided by TÜV Rheinland, air-conditioned to about 20 °C and DEFRA measurement station in Teddington
- Weather station (WS 777 manufactured by Conrad Elektronik AG / WS 500 manufactured by ELV Elektronik AG or MK III Series manufactured by Rainwise (US) in UK) for collecting meteorological data such as temperature, air pressure, humidity, wind speed, wind direction and precipitation.
- 2 reference measuring systems, SEQ47/50 or LVS3 for PM_{10} in accordance with item 5 (Germany) and LVS3 (UK)
- 2 reference measuring systems LVS3 for $PM_{2.5}$ in accordance with item 5 (Germany and UK)
- 1 gas meter, dry version
- 1 mass flow meter Model 4043 (manufacturer: TSI)
- Measuring system for power consumption; Metratester 5 (manufacturer: Gossen Metrawatt)
- Zero filter for generating dust-free air
- Reference foils R1&R2 (implemented in the instrument)

During the field test, the candidate systems manufactured by FAI Instruments s.r.l. were operated in parallel with two reference instruments each for PM_{10} and $PM_{2.5}$ and a classification instrument over a period of 24h (Cologne only, parking lot 2007, Bonn, Brühl). The classification instrument and the reference system for $PM_{2.5}$ (all sites) and PM_{10} (Teddington (UK), Cologne, parking lot 2011, Bornheim) operate discontinually, i.e. filters have to be replaced manually after sampling.

Impaction plates of the PM_{10} and $PM_{2.5}$ sampling inlets were cleaned approximately every two weeks and greased with silicone grease in order to ensure reliable separation of particles.

The flow rates of the tested and the reference instruments were checked before and after the field test as well as before and after each change of 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

During the field test, the measuring systems were installed in outdoor measurement cabinets. When installing the instruments, care was taken to place the cabinets with candidate system in proximity with the reference measuring systems.

The field test was performed at the following measurement sites:

Table 6: Field test sites

No.	Version	Measurement site	Period	Description
1	SWAM 5a DC	Cologne Parking lot, 2007	10/2007 –02/2008	Urban background
2	SWAM 5a DC	Bonn, Belderberg	02/2008–04/2008	Traffic
3	SWAM 5a DC	Teddington (UK)	07/2008–10/2008	Urban background
4	SWAM 5a DC	Brühl	09/2008–11/2008	Gravel plant
5	SWAM 5a DC SWAM 5a DC HM	Cologne Parking lot, 2011	02/2011 –05/2011	Urban background
6	SWAM 5a DC SWAM 5a	Bornheim	08/2011–10/2011	Rural area + motorway

Figure 21 to Figure 32 show the levels of PM concentrations at the field test sites as determined by the reference measuring systems .

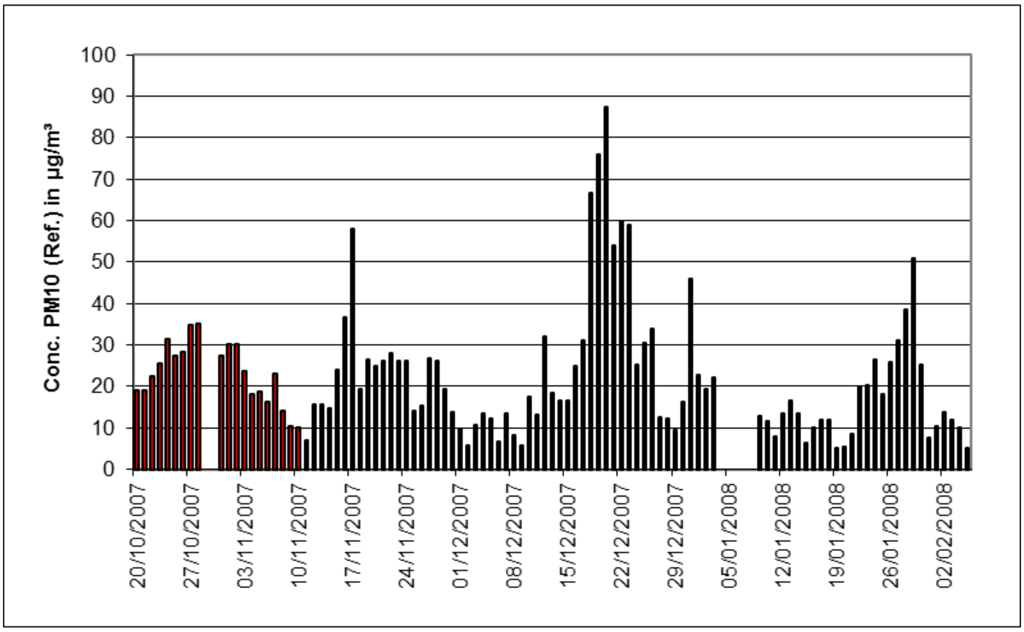


Figure 21: PM$_{10}$ (reference) levels at the site “Cologne, parking lot, 2007”

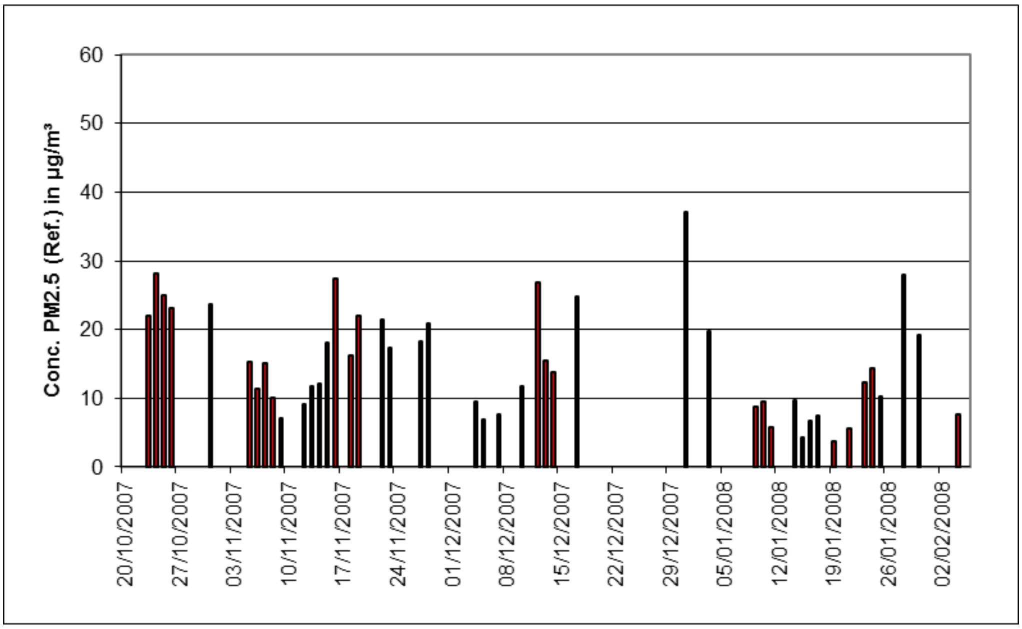


Figure 22: PM$_{2.5}$ (reference) levels at the site “Cologne, parking lot, 2007”

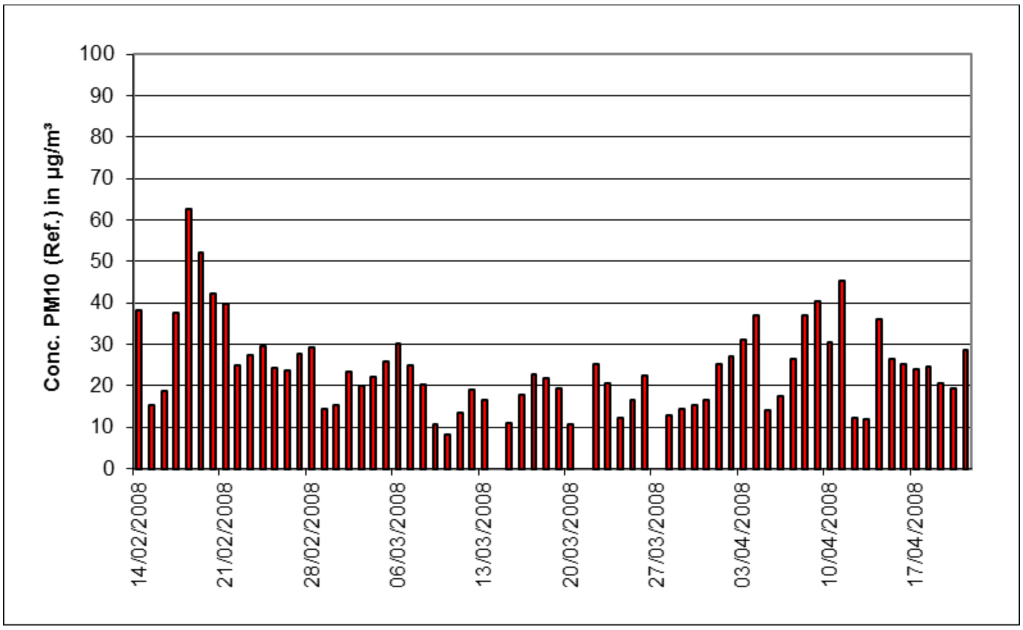


Figure 23: PM$_{10}$ (reference) levels at the site "Bonn, Belderberg"

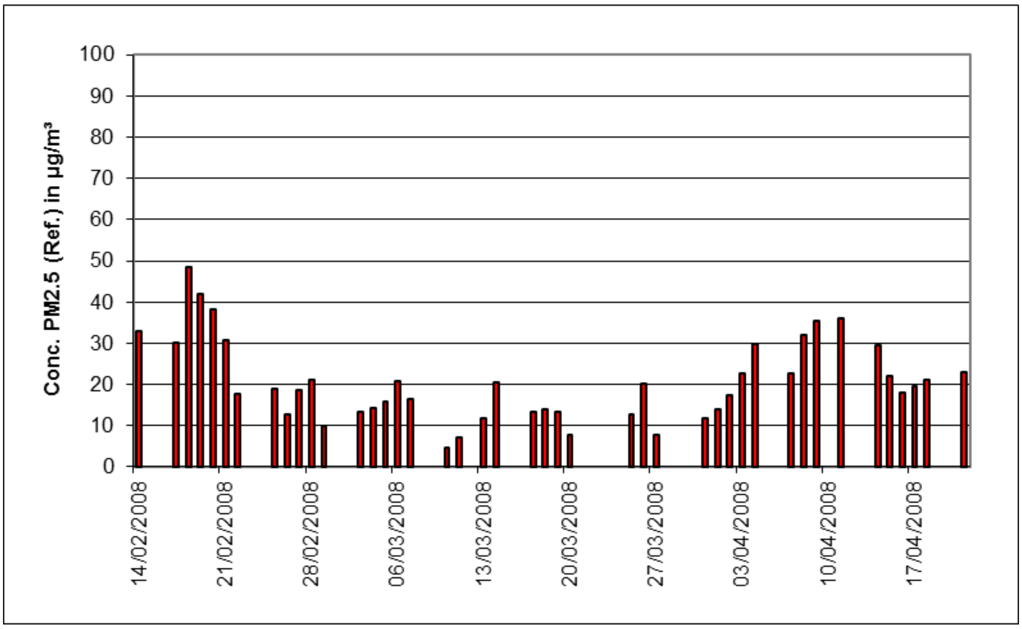


Figure 24: PM$_{2.5}$ (reference) levels at the site "Bonn, Belderberg"

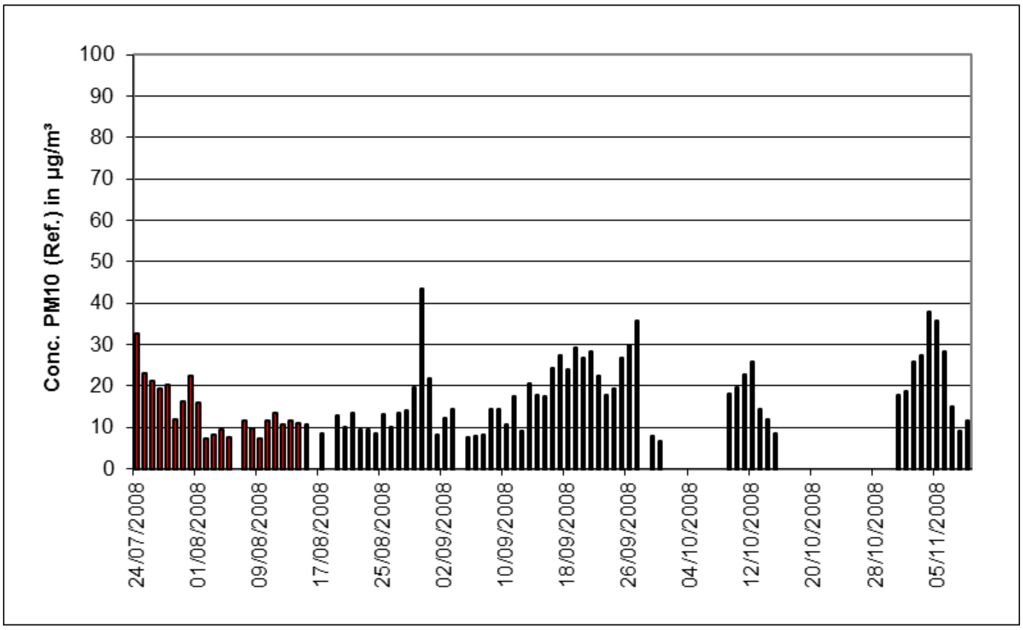


Figure 25: PM_{10} (reference) levels at the site “Teddington (UK)”

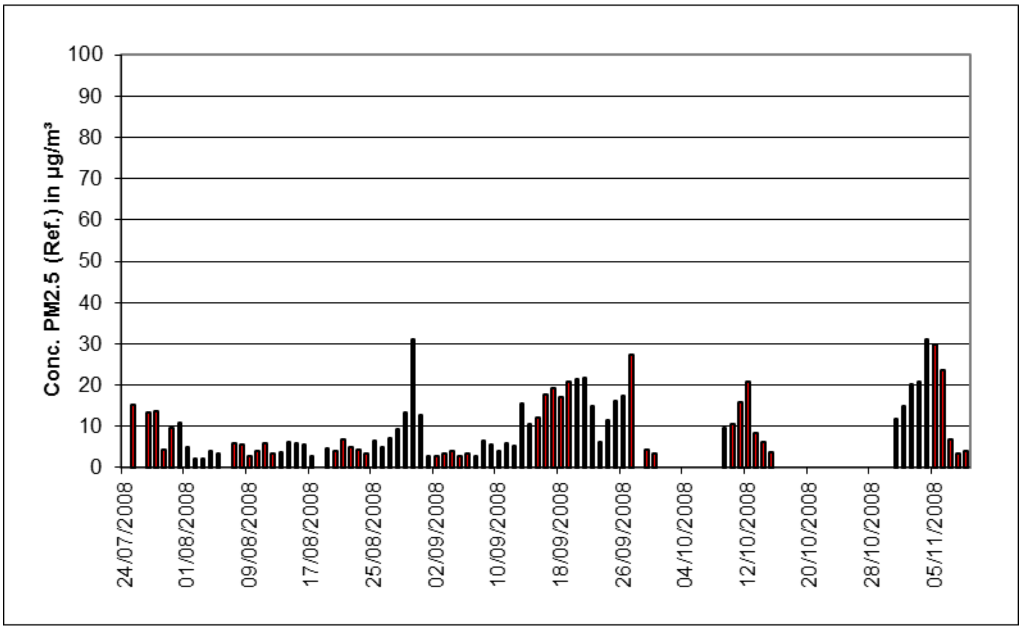


Figure 26: $PM_{2.5}$ (reference) levels at the site “Teddington (UK)”

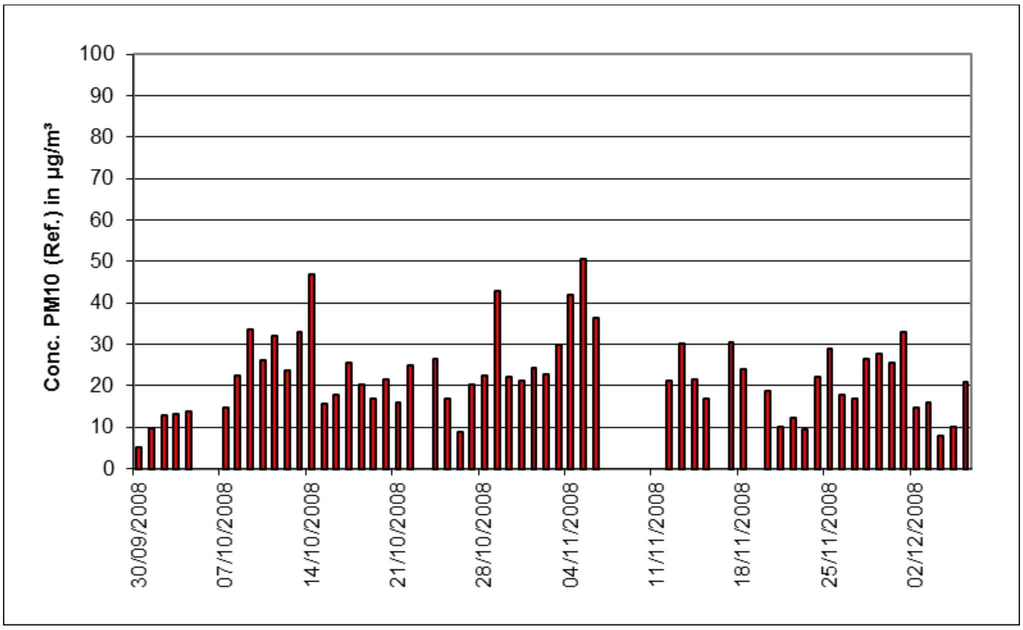


Figure 27: PM_{10} (reference) levels at the site “Brühl”

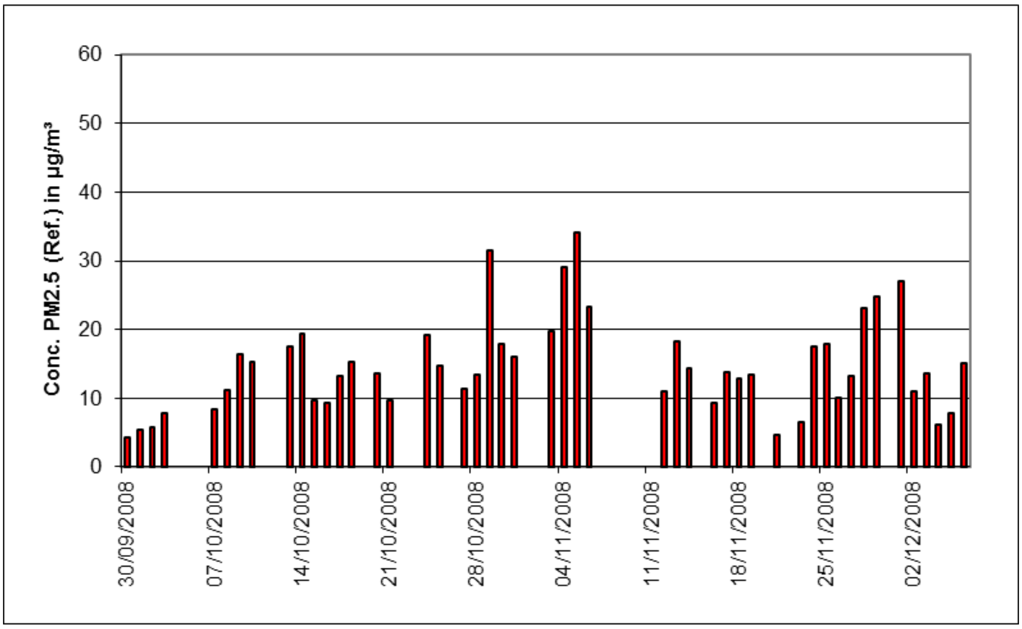


Figure 28: $PM_{2.5}$ (reference) levels at the site “Brühl”

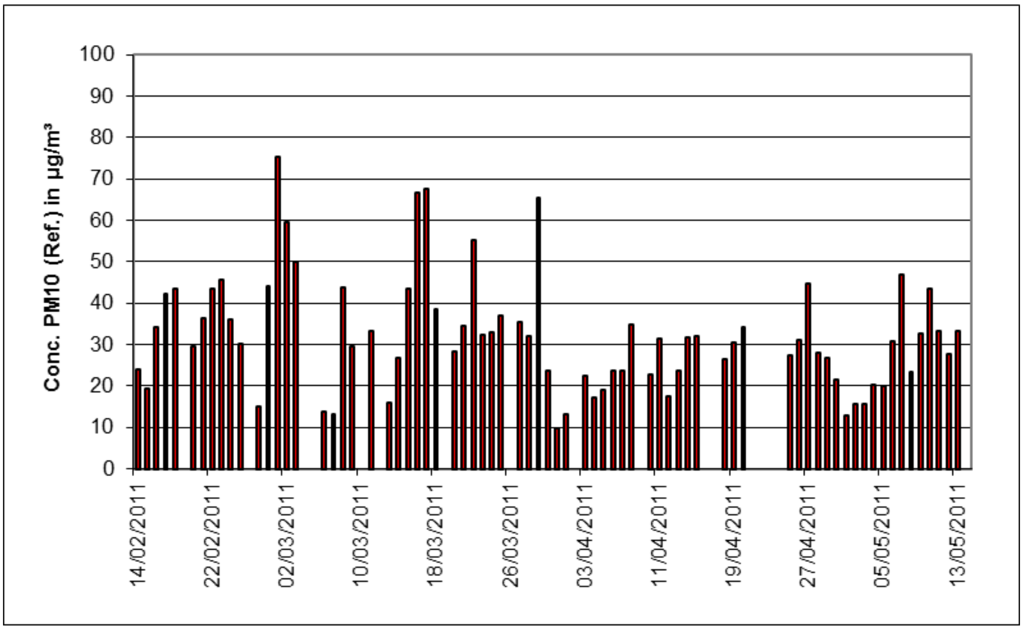


Figure 29: PM_{10} (reference) levels at the site "Cologne, parking lot, 2011"

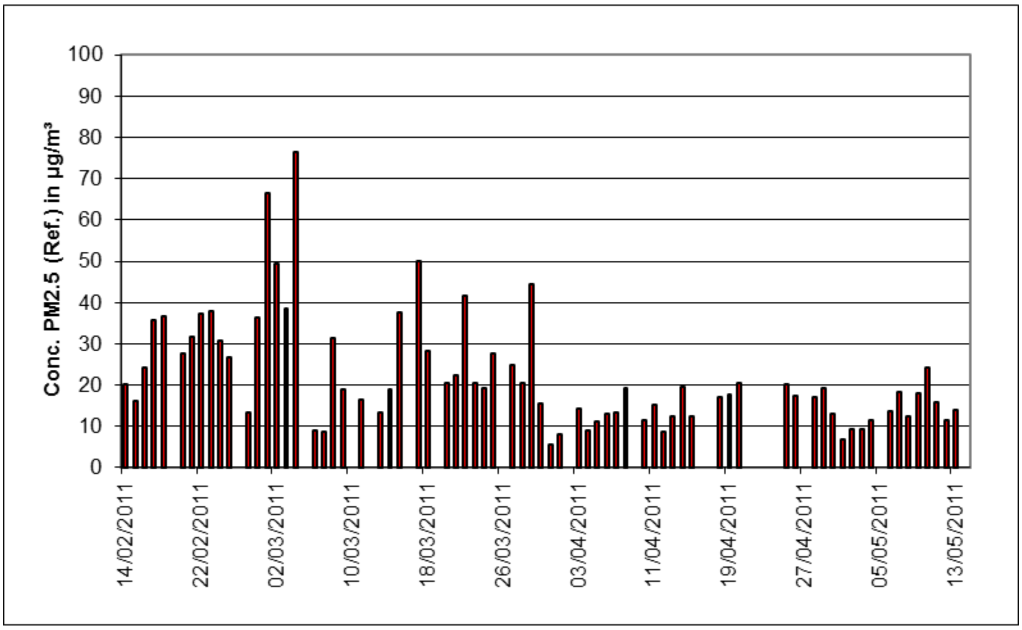


Figure 30: $PM_{2.5}$ (reference) levels at the site "Cologne, parking lot, 2011"

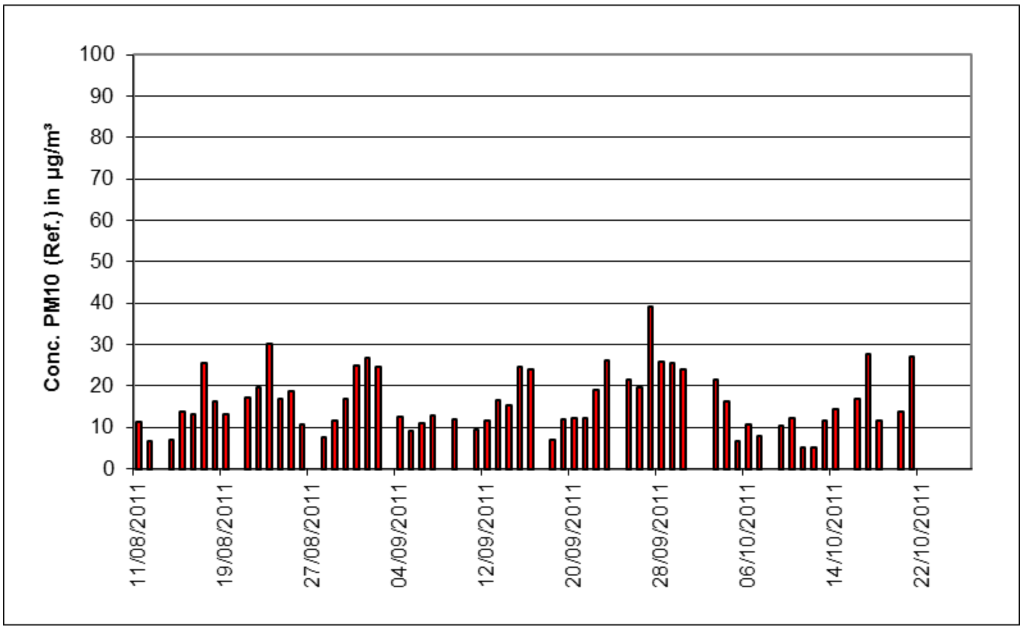


Figure 31: PM_{10} (reference) levels at the site "Bornheim"

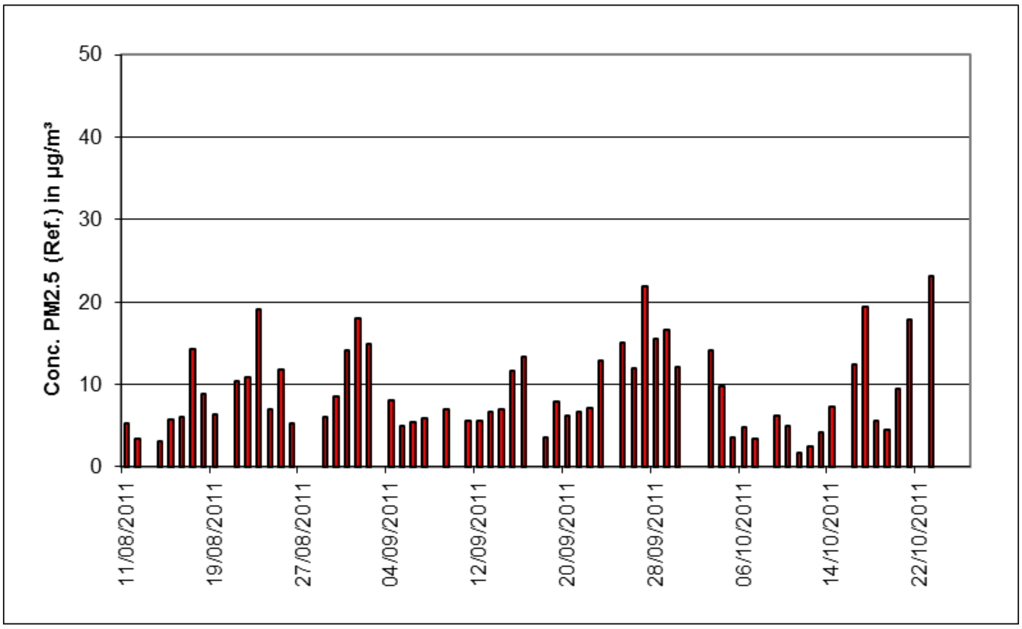


Figure 32: $PM_{2.5}$ (reference) levels at the site "Bornheim"

The following pictures show the measurement cabinet at the field test sites in cologne (parking lot) 2007 & 2011, Bonn (Belderberg), Teddington (UK), Brühl and Bornheim.

Figure 33: Field test site Cologne, parking lot, 2007

Figure 34: Field test site Bonn-Belderberg

Figure 35: Field test site Teddington

Figure 36: Field test site Brühl

Figure 37: Field test site Cologne, parking lot, 2011, reference measuring systems (LVS 3) installed in the middle trailer

Figure 38: Field test site in Bornheim, reference measuring system (LVS 3) installed in the middle trailer

In addition tothe air quality measuring systems for monitoring suspended particulate matter, a data logger for meteorological data was installed in the container. Data on air temperature, pressure, humidity, wind speed, wind direction and precipitation were continually measured. 30-minute mean values were recorded.

The following dimensions describe the design of the measurement rack and container as well as the position of the sampling probes.

- Height outdoor measurement rack: ~2.0 m above ground level
- Height sampling probe SWAM 5a DC, Line A, PM_{10}: ~3.2 m above ground level
- Height sampling probe SWAM 5a DC, Line B, $PM_{2.5}$: ~2.9 m above ground level
- Height sampling probe SWAM 5a, PM_{10} or $PM_{2.5}$: ~2.9 above ground level
- Height container roof: ~2.7 m
- Height of the sampling probe for ref: PM_{10}/ Ref. PM2,5/ TSP: ~ 1.2 / 1.2 / 1.0m above container roof i.e. ~ 3.9 / 3.9 / 3.7 m above ground level
- Height of the wind vane: ~4.5 m above ground level

In addition to an overview of the meteorological conditions determined during measurements at the 6 field test sites, the following Table 7 also provides information on the concentrations of suspended particulate matter. Given that the TÜV measurement station had to be replaced at the site in Brühl, no further meteorological data was collected after 3 November 2008. Meteorological data for the site in Teddington was only available after 17 September 2008. All individual values are presented in annexes 5 to 8.

Table 7: Ambient conditions at the field test sites indicated as daily averages

	Cologne, Parking lot, 2007	**Bonn, Belderberg**	**Teddington (UK)***	**Brühl****
Number of value pairs provided by reference PM_{10} (total)	102	65	80	51
Number of value pairs provided by reference $PM_{2.5}$ (total)	46	43	81	41
Ratio of $PM_{2.5}$ to PM_{10} [%]				
Range	54.6–91.0	53.1–90.8	22.3–83.2	41.4–90.2
Average	73.8	73.5	53.6	65.4
Air temperature [°C]				
Range	-3.4–12.4	0.6–13.6	4.2–15.4	4.4–16.2
Average	5.3	7.0	11.2	10.3
Air pressure [hPa]				
Range	982–1033	975–1034	984–1016	992–1024
Average	1012	1003	1000	1008
Rel. Humidity [%]				
Range	55.2–86.9	45.3–81.0	64–95	61.6–82
Average	72.5	64.8	81.4	74.5
Wind speed [m/s]				
Range	0.0–6.8	0.0–4.8	0.0–1.8	0–8.3
Average	2.1	1.3	0.5	2.2
Precipitation rate [mm]				
Range	0.0–31.0	0.0–20.4	Not available	0.0–16.5
Average	2.7	2.6		2.2

* Weather data only available after 17/09/2008
** Weather data not available after 03/11/2008

	Cologne, Parking lot, 2011	**Bornheim**
Number of value pairs provided by reference PM_{10} (total)	73	59
Number of value pairs provided by reference $PM_{2.5}$ (total)	71	60
Ratio of $PM_{2.5}$ to PM_{10} [%]		
Range	38.8–93.5	31.2–73.7
Average	65.7	53.7
Air temperature [°C]		
Range	-2.7–22.1	5.2–24.5
Average	10.3	15.6
Air pressure [hPa]		
Range	992–1031	997–1024
Average	1013	1008
Rel. Humidity [%]		
Range	34.2–94.2	53.8–91.1
Average	63.9	74.4
Wind speed [m/s]		
Range	0.3–5.3	0.3–3.9
Average	2.2	1.4
Precipitation rate [mm]		
Range	0.0–11.1	0.0–29.1
Average	1.0	2.3

Sampling duration

Standard EN 12341 fixes the sampling time at 24h. However, longer sampling times are permissible for low concentrations as are shorter times for higher concentrations.

Standard EN 14907 fixes the sampling time at 24h + 1h.

While the sampling time was always set to 24h in the field test, shorter times were set during some laboratory tests in order to collect a higher number of measured values.

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 the critical value. The January 2010 version of the guideline [5] requires that no more than 2.5% of the data pairs be detected and removed as outliers.

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

Table 8 and Table 9 present an overview of the measured value pairs which have been detected and expunged as significant outliers (reference).

Table 8: Results of the Grubb's test for outliers – reference PM_{10}

Site	Sampler	Number of data-pairs	Maximum Number that can be deleted	Number Identified	Number Deleted	Number of data-pairs remaining
Cologne 2007	PM_{10} Reference	102	3	0	0	102
Bonn	PM_{10} Reference	65	2	0	0	65
Teddington	PM_{10} Reference	83	2	3	2	81
Bruehl	PM_{10} Reference	60	2	2	2	58
Cologne 2011	PM_{10} Reference	74	2	1	1	73
Bornheim	PM_{10} Reference	61	2	5	2	59

Table 9: Results of the Grubb's test for outliers – reference $PM_{2.5}$

Site	Sampler	Number of data-pairs	Maximum Number that can be deleted	Number Identified	Number Deleted	Number of data-pairs remaining
Cologne 2007	$PM_{2.5}$ Reference	47	1	1	1	46
Bonn	$PM_{2.5}$ Reference	43	1	0	0	43
Teddington	$PM_{2.5}$ Reference	83	2	2	2	81
Bruehl	$PM_{2.5}$ Reference	49	1	3	1	48
Cologne 2011	$PM_{2.5}$ Reference	73	2	2	2	71
Bornheim	$PM_{2.5}$ Reference	60	2	0	0	60

The following value pairs have been discarded:

Table 10: Value pairs (reference PM_{10}) discarded from the data set following Grubb's test

Location	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]
Teddington	16.08.2008	13.9	21.0
Teddington	04.09.2008	10.4	5.3
Brühl	16.11.2008	19.7	16.3
Brühl	19.11.2008	32.1	27.3
Cologne, parking lot 2011	04.03.2011	83.3	87.6
Bornheim	19.10.2011	19.8	9.1
Bornheim	23.10.2011	32.6	27.6

Table 11: Value pairs (reference $PM_{2.5}$) discarded from the data set following Grubb's test

Location	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]
Cologne, parking lot 2007	20.10.2007	16.1	23.0
Teddington	24.07.2008	32.5	27.8
Teddington	26.07.2008	16.1	13.8
Brühl	11.10.2008	28.5	24.5
Cologne, parking lot 2011	16.03.2011	55	57.8
Cologne, parking lot 2011	05.05.2011	11.2	14.8

Moreover, the following reference measurement values were not taken into consideration, because in each case only one measured value was available (no paired measurement).

Table 12: Measured values not taken into consideration (no paired measurement)

Fraction	Location	Date	Reference 1 [µg/m³]	Reference 2 [µg/m³]
PM_{10}	Bonn	14.03.2008	14.3	-
PM_{10}	Bonn	21.03.2008	21.3	-
$PM_{2,5}$	Brühl	20.11.2008	11.3	-

Filter handling – Mass measurement

The following filters were used during performance testing:

Table 13: Filter material used

Measuring device	Filter material, type	Manufacturer
Reference devices Cologne 2007, Bonn, Brühl	Quartz fibre, ∅ 50 mm	Whatman
Reference devices Teddington, Cologne 2011, Bornheim	Emfab™, ∅ 47 mm	Pall

In the context of the “Combined MCERTS and TUV PM Equivalence Testing Programme” and at the request of the British project partners Emfab™ (teflon-coated glass fibre filter) was used as a filter material for the first time, since the British project partner considered this material the best suited for the measurement task at hand [10]. This filter material was also used during the measurement campaigns in 2011.

Filter handling was performed in compliance with EN 14907.

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

5. Reference Measurement Method

The following instruments were used in compliance with EN 12341 and EN 14907 in the context of the field test.

1. as PM_{10} reference system:

Sequential sampler SEQ47/50, Indoor version, (sites in Cologne 2007, Bonn, Brühl))
Manufacturer: Ingenieurbüro Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2005
PM_{10} sampling head

and

Low Volume Sampler LVS3 (sites Teddington (UK), Cologne 2011 and Bornheim)
Manufacturer: Ingenieurbüro Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2007
PM_{10} sampling head

2. as $PM_{2.5}$ reference system:

Low Volume Sampler LVS3
Manufacturer: Ingenieurbüro Sven Leckel, Leberstraße 63, Berlin, Germany
Date of manufacture: 2007
$PM_{2.5}$ sampling head

During the tests, two reference systems 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.

At the sites in Cologne, parking lot 2007, Bonn and Brühl, two reference systems, SEQ47/50 filter changer, were used for the measured component PM_{10}. It was installed as an indoor version, i.e. the sequential sampler itself was installed inside the measurement cabinet, an sampling line ensured the connection with the sample inlet. The entire sampling system is cooled by an air jacket – this is why the actual sampling line is installed in an aluminium cladding tube.

Technically speaking, the sequential sampler is based on the low volume sampler LVS3 and, given its design, essentially complies with the requirements for reference samplers as specified in EN 12341. The filter replacement mechanism combined with the filter cartridge and unloader system facilitates continuous 24-hour sampling for a period of up to 14 days (+ field blank).

For the LVS3 and the SEQ47/50, the rotary vane vacuum pump takes in sample air via the sampling inlet. The volumetric flow is measured between the filter and the vacuum pump with the help of a measuring orifice. The air taken in flows from the pump via a separator for the abrasion of the rotary vane to the air outlet.

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

The PM_{10} and $PM_{2.5}$ concentrations were determined by dividing the quantity of suspended particulate matter on each filter determined in the laboratory with a gravimetric method by the corresponding throughput of sample air flow as operating m³.

6. Test results

6.1 1 Measuring ranges

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

6.2 Equipment

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

6.3 Testing

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

6.4 Evaluation

In theory, the upper limit of measurement for mass measurement using beta ray absorption is 10 mg/cm² (calibration of beta measurement using reference foils up to 9.773 mg/cm² (foil F16)).

Depending on the filter material used and the expected dust concentrations, the measuring system allows the use of filter cartridges with filter spot areas of varying sizes (2.54 m², 5.20 m², 7.07 m² and 11.95 m² for SWAM 5a Dual Channel Monitor and SWAM 5a Monitor, 2.27 m² for SWAM 5a Dual Channel Hourly Mode Monitor.

For instrument versions SWAM 5a Dual Channel Monitor and SWAM 5a Monitor this would correspond to theoretical masses of 25.4 mg to 119.5 mg. For 24h-sampling, this would in turn correspond to dust concentrations of 460 µg/m³ to > 2000 µg/m³.

A filter spot area of 5.20 cm² was used during performance testing.

For instrument version SWAM 5a Dual Channel Hourly Mode Monitor, a theoretical mass of 22.7 mg can be determined at a filter spot area of 2.27 cm². For 1h-sampling (at a throughput flow of ~2.25 m³ per 1-hour cycle), this would in turn correspond to dust concentrations of 10,100 µg/m³.

6.5 Assessment

Instrument versions SWAM 5a Dual Channel Monitor and SWAM 5a Monitor facilitate monitoring of measuring ranges of more than 2,000 µg/m³ in the 24-h cycle. Instrument version SWAM 5a Dual Channel Hourly Mode Monitor facilitates monitoring of a measuring range of up to 10,000 µg/m³ in the 1-h cycle.

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 displays negative values for mass and concentration via its display as well as via analogue and digital outputs.

6.5 Assessment

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion.

6.1 3 Zero level and detection limit

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

6.2 Equipment

Zero filter for zero checks.

6.3 Testing

The zero level and detection limit of the AMS shall be determined by measurement of 15 24-hour average readings obtained by sampling from zero air (no rolling or overlapped averages are permitted). The mean of these 15 24-h averages is used as the zero level. The detection limit is calculated as 3,3 times the standard deviation of the 15 24h-averages.

The zero level and the detection limit were determined with zero filters installed at the AMS inlets of instruments with SN 127 and SN 131 during normal operation. Air free of suspended particulate matter was applied over a period of 18 days for a duration of 24h each.

6.4 Evaluation

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

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

6.5 Assessment

On the basis of testing both instruments, the zero level was determined at a maximum of 0.39 µg/m³ and the detection limit at a maximum of 0.71 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 14: Zero level and detection limit SN 127, lines A and B

		Device SN 127, Line A	Device SN 127, Line B
Number of values n		18	18
Average of the zero values (Zero level) $\overline{x}_0$	µg/m³	0.28	0.39
Standard deviation of the values s_{x0}	µg/m³	0.20	0.18
Detection limit x	µg/m³	**0.65**	**0.60**

Table 15: Zero level and detection limit SN 131, lines A and B

		Device SN 131, Line A	Device SN 131, Line B
Number of values n		18	18
Average of the zero values (Zero level) $\overline{x}_0$	µg/m³	0.22	0.24
Standard deviation of the values s_{x0}	µg/m³	0.20	0.21
Detection limit x	µg/m³	**0.65**	**0.71**

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

6.1 4 Flow rate accuracy (7.4.4)

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

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

6.2 Equipment

Climatic chamber for the temperature range of +5°C to +40°C; a reference flow meter in accordance with item 4 was provided.

6.3 Testing

The SWAM 5a measuring systems operate at a flow rate of 38.33 l/min under ambient conditions.

Using a reference flow meter, the flow rate was determined at +5°C and +40°C for both measuring systems, instrument versions SWAM 5a Dual Channel Monitor, was determined at both sampling lines by way of 10 measurements over a period of about 2 hours using the operational flow rate defined 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 +5°C and at +40°C did not exceed 1.17%.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 16 and Table 17 summarise the results of the flow rate measurements.

Table 16: Flow rate accuracy at +5°C and +40°C (SN 111)

		Device SN 111, Line A	Device SN 111, Line B
Nominal value flow rate	l/min	38.33	38.33
Mean value at 5°C	l/min	38.10	38.13
Dev. from nominal value	%	-0.60	-0.52
Mean value at 40°C	l/min	38.25	38.04
Dev. from nominal value	%	-0.22	-0.75

Table 17: Flow rate accuracy at +5°C and +40°C (SN 395)

		Device SN 395, Line A	Device SN 395, Line B
Nominal value flow rate	l/min	38.33	38.33
Mean value at 5°C	l/min	38.38	38.30
Dev. from nominal value	%	0.14	-0.09
Mean value at 40°C	l/min	38.60	38.78
Dev. from nominal value	%	0.69	1.17

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

6.1 5 Constancy of sample flow rate (7.4.5)

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

6.2 Equipment

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

6.3 Testing

The SWAM 5a measuring systems operate at a flow rate of 38.33 l/min under ambient conditions.

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

6.4 Evaluation

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

6.5 Assessment

The charts illustrating the constancy of the sample flow rate demonstrate that all measured values determined during sampling deviate from their respective rated values by less than ±5%. At 38.33 l/min, the deviation of the 24h-mean for the overall flow rate also remains well below the required maximum of ±2.0% from the rated value.

The 24h-averages deviate from their rated values by less then ± 2.0%, all instantaneous values deviate by less than ± 5%.

Criterion satisfied? yes

6.6 Detailed presentation of test results for the rated flow

Table 18 and Table 19 present the characteristics determined for the flow rate. Figure 39 to Figure 42 provide a chart of the flow rate measurement for both instruments - SN 127 and SN 131.

Table 18: Characteristics of the total flow rate measurement (24h-mean), SN 217

		Device SN 127, Line A	Device SN 127, Line B
Mean value	l/min	38.05	37.83
Dev. from nominal value	%	-0.75	-1.31
Standard deviation	l/min	0.17	0.15
Minimum value	l/min	36.46	37.00
Maximum value	l/min	38.24	38.30

Table 19: Characteristics of the total flow rate measurement (24h-mean), SN 217131

		Device SN 131, Line A	Device SN 131, Line B
Mean value	l/min	38.13	38.97
Dev. from nominal value	%	-0.54	1.65
Standard deviation	l/min	0.10	0.14
Minimum value	l/min	37.33	37.37
Maximum value	l/min	38.24	39.15

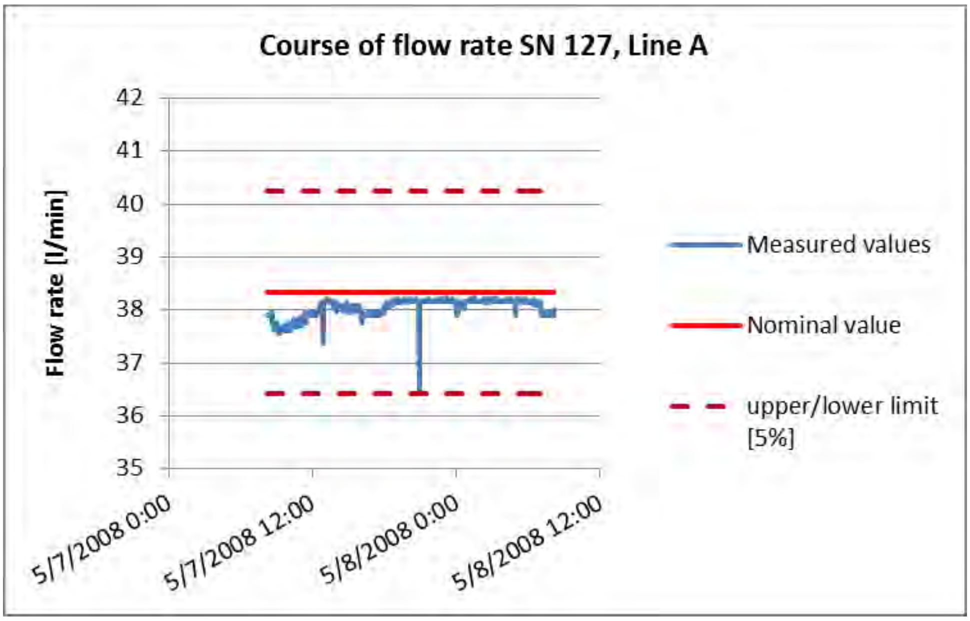


Figure 39: Flow rate for candidate system SN 127, line A

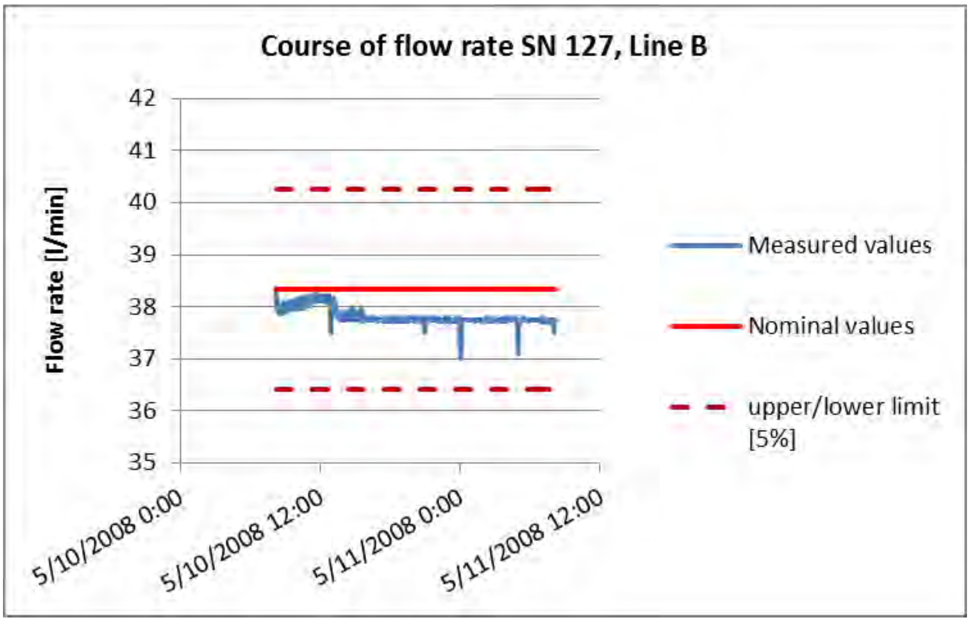


Figure 40: Flow rate for candidate system SN 127, line B

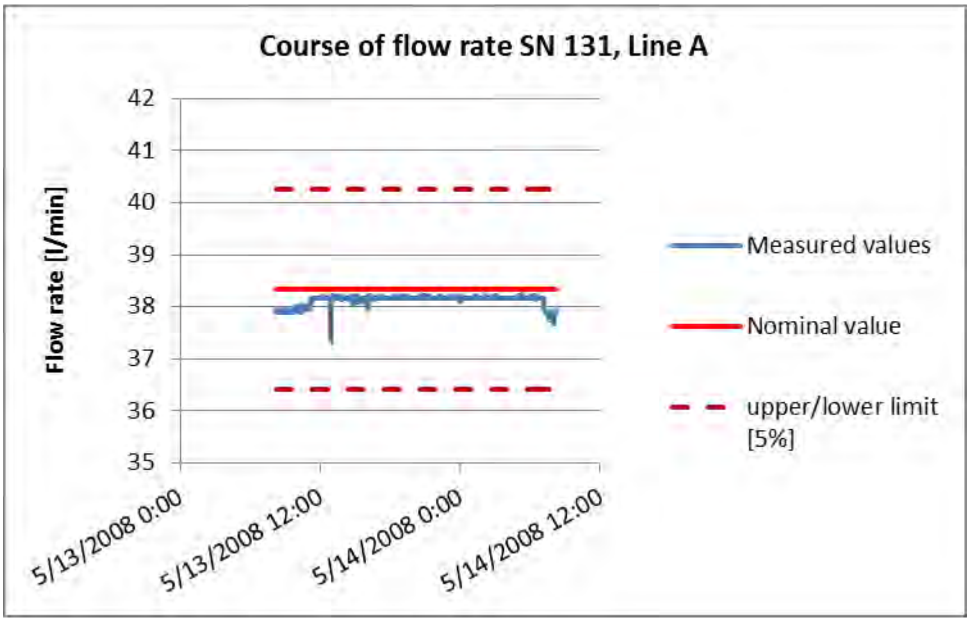


Figure 41: Flow rate for candidate system SN 131, line A

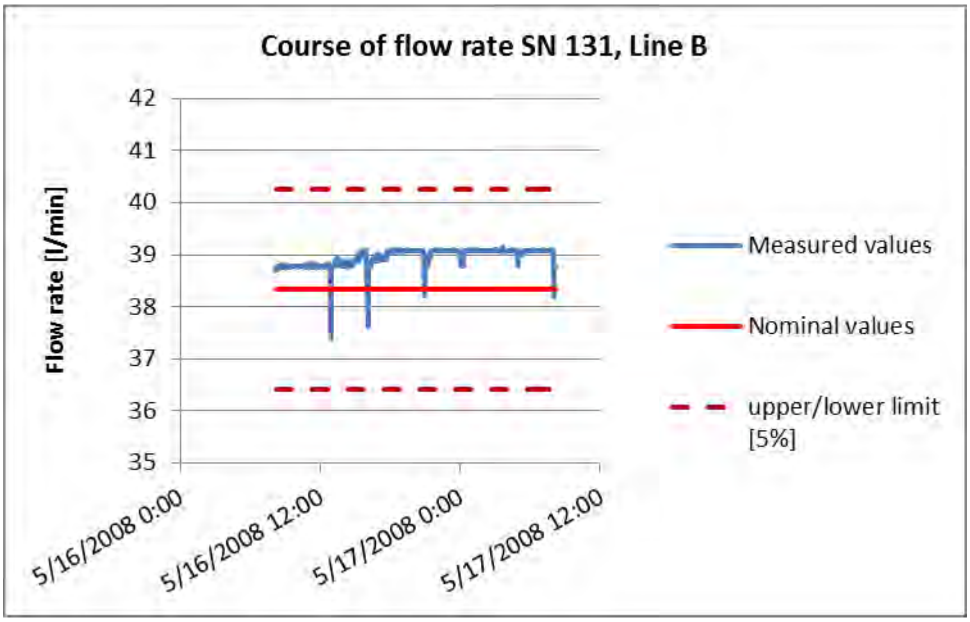


Figure 42: Flow rate for candidate system SN 131, line B

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

Cover flap, clock

6.3 Testing

The test of leak tightness was performed following the instructions of the AMS manual (manual leak tightness test, case 3). During the test, a cover flap served to block the instrument inlet of the sampling line to be tested; a filter was then inserted in the sampling position. Subsequently the air was evacuated from the instrument using the pneumatic system until the minimum residual pressure was reached. After having switched of the pump, changes in the internal pressure in the system were observed. Pressure slowly increases. The speed of this increase depends on potential leaks. Taking into account the overall volume of the instrument, this procedure served to determine the leak rate.

The estimated total volume of the instrument is 1.85 l for line A and 1.75 l for line B.

6.4 Evaluation

The leak rate is $\dot{V}_L$ calculated according to the following equation:

$$\dot{V}_L = \frac{\Delta p}{p_0} \frac{V_{ges}}{\Delta t}$$

Where:

Δp is the pressure difference determined for the time interval Δt

p_0 is the pressure at t_0

V_{ges} is the estimated total volume of the system (lag volume);

Δt time interval needed for the pressure decrease by Δp

The maximum of five observed leak rates was determined.

6.5 Assessment

For instrument 1 (SN127), leakage did not exceed 0.24%. For instrument 2 (SN 131), leakage did not exceed 0.30% each at a residual pressure in the system p_0. At an air pressure of 102.8kPa, the leakage of instrument 1 (SN 127) did not exceed 0.08%, for instrument 2 (SN 131), it did not exceed 0.06%.

Thus, the values are clearly below the minimum requirement at 1%.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 20 and Table 21 present the values determined for the leak tightness test.

Table 20: Determination of the leak rate, SN 127

SN 127, Line A									
No.	Date	p_0 [kPa]	p_t [kPa]	Δp [kPa]	Δt [min]	V_{ges} [m³]	Leak rate [l/min]	% of nominal, at p0	% of nominal, at pa = 102,8 kPa
1	12/8/2008	26.6	27.8	1.2	1	0.00185	0.083	0.218	0.056
2	12/8/2008	27.8	28.9	1.1	1	0.00185	0.073	0.191	0.052
3	12/8/2008	28.9	30	1.1	1	0.00185	0.070	0.184	0.052
4	12/8/2008	30	31	1	1	0.00185	0.062	0.161	0.047
5	12/8/2008	31	32.1	1.1	1	0.00185	0.066	0.171	0.052
1-5	12/8/2008	26.6	32.1	5.5	5	0.00185	0.077	0.200	0.052
SN 127, Line B									
No.	Date	p_0 [kPa]	p_t [kPa]	Δp [kPa]	Δt [min]	V_{ges} [m³]	Leak rate [l/min]	% of nominal, at p0	% of nominal, at pa = 102,8 kPa
1	12/8/2008	32.9	34.6	1.7	1	0.00175	0.090	0.236	0.076
2	12/8/2008	34.6	36.4	1.8	1	0.00175	0.091	0.238	0.080
3	12/8/2008	36.4	37.9	1.5	1	0.00175	0.072	0.188	0.067
4	12/8/2008	37.9	39.4	1.5	1	0.00175	0.069	0.181	0.067
5	12/8/2008	39.4	41	1.6	1	0.00175	0.071	0.185	0.071
1-5	12/8/2008	32.9	41	8.1	5	0.00175	0.086	0.225	0.072

Table 21: Determination of the leak rate, SN 131

SN 131, Line A									
No.	Date	p_0 [kPa]	p_t [kPa]	Δp [kPa]	Δt [min]	V_{ges} [m³]	Leak rate [l/min]	% of nominal, at p0	% of nominal, at pa = 102,8 kPa
1	12/8/2008	36.7	37.6	0.9	1	0.00185	0.045	0.118	0.042
2	12/8/2008	37.6	38.4	0.8	1	0.00185	0.039	0.103	0.038
3	12/8/2008	38.4	39.2	0.8	1	0.00185	0.039	0.101	0.038
4	12/8/2008	39.2	40.1	0.9	1	0.00185	0.042	0.111	0.042
5	12/8/2008	40.1	40.8	0.7	1	0.00185	0.032	0.084	0.033
1-5	12/8/2008	36.7	40.8	4.1	5	0.00185	0.041	0.108	0.039
SN 131, Line B									
No.	Date	p_0 [kPa]	p_t [kPa]	Δp [kPa]	Δt [min]	V_{ges} [m³]	Leak rate [l/min]	% of nominal, at p0	% of nominal, at pa = 102,8 kPa
1	12/8/2008	19.9	21.2	1.3	1	0.00175	0.114	0.298	0.058
2	12/8/2008	21.2	22.4	1.2	1	0.00175	0.099	0.258	0.053
3	12/8/2008	22.4	23.7	1.3	1	0.00175	0.102	0.265	0.058
4	12/8/2008	23.7	25	1.3	1	0.00175	0.096	0.250	0.058
5	12/8/2008	25	26.3	1.3	1	0.00175	0.091	0.237	0.058
1-5	12/8/2008	19.9	26.3	6.4	5	0.00175	0.113	0.294	0.057

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

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

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

6.2 Equipment

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

6.3 Testing

The dependence of the zero reading on the surrounding temperature was determined at the following temperatures (within the specifications of the manufacturer):

a) at a nominal temperature $T_{S,n}$ = +20 °C;

b) at a minimum temperature $T_{S,1}$ = +5 °C;

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

For the purpose of determining the dependence of the zero reading on the surrounding temperature, the measuring systems were operated in the climatic chamber without the outdoor measurement rack.

Sample air, free of suspended particles, was supplied to the two candidate systems after fitting two zero filters at the AMS inlet in order to perform zero point checks.

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

Readings were recorded at zero point after an equilibration period of 24h for every temperature step (3 readings each).

6.4 Evaluation

Readings for mass values were obtained from 8-hour individual measurements and the related to the rated flow for 24h sampling for the purpose of conversion.

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

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

6.5 Assessment

The tested temperature range at the site of installation was +5 °C to +40 °C. Taking into account at the values displayed by the instrument, we determined a maximum dependence of the zero point on the on surrounding temperature of 0.64 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 22: Dependence of measured value on surrounding temperature, deviations in µg/m³, average from three readings, SN 127, lines A&B

Temperature	SN 127, Line A		SN 127, Line B	
	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	0.03	-0.12	0.23	-0.02
5	0.47	0.31	0.27	0.01
20	0.13	-0.02	0.27	0.01
40	0.60	0.44	0.63	0.38
20	0.30	0.14	0.27	0.01
Mean value at 20°C	0.16	-	0.26	-

Table 23: Dependence of measured value on surrounding temperature, deviations in µg/m³, average from three readings, SN 131, lines A&B

Temperature	SN 131, Line A		SN 131, Line B	
	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	0.17	-0.06	0.17	-0.02
5	0.23	0.01	0.13	-0.06
20	0.10	-0.12	0.13	-0.06
40	0.70	0.48	0.83	0.64
20	0.40	0.18	0.27	0.08
Mean value at 20°C	0.22	-	0.19	-

Annex 3 in the appendix contains the individual measuring results.

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

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

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

6.2 Equipment

Climatic chamber for the temperature range between +5 and +40 °C; reference foils R1 & R2 for span checks

6.3 Testing

The dependence of AMS sensitivity (span) on the surrounding temperature was determined at the following temperatures (within the specifications of the manufacturer):

a) at a nominal temperature $T_{S,n}$ = +20 °C;

b) at a minimum temperature $T_{S,1}$ = +5 °C;

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

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

In order to allow for testing this sensitivity, the internal procedure for stability testing provided by the radiometric measuring system by means of the two reference aluminium foils implemented in the system with a known mass density was used (BETA SPAN TEST).

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

Readings were recorded at zero point after an equilibration period of 24h for every temperature step (3 readings each).

6.4 Evaluation

Values for the mass density were determined from individual readings with reference aluminium foils and then evaluated.

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

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

6.5 Assessment

The tested temperature range at the site of installation was +5 °C to +40 °C. At span point, the deviations determined did not exceed 0.1%.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 24: Dependence of the sensitivity (reference foil) on the surrounding temperature; deviation in %, average from three measurements, SN 127

Temperature	SN 127 R1		SN 127 R2	
	Measured value	Deviation to mean value at 20°C	Measured value	Deviation to mean value at 20°C
°C	[mg/cm²]	%	[mg/cm²]	%
20	3.454	0.1	6.833	0.1
5	3.451	0.0	6.831	0.0
20	3.452	0.0	6.830	0.0
40	3.448	-0.1	6.826	0.0
20	3.448	-0.1	6.825	-0.1
Mean value at 20°C	3.451	-	6.829	-

Table 25: Dependence of the sensitivity (reference foil) on the surrounding temperature; deviation in %, average from three measurements, SN 131

Temperature	SN 131 R1		SN 131 R2	
	Measured value	Deviation to mean value at 20°C	Measured value	Deviation to mean value at 20°C
°C	[mg/cm²]	%	[mg/cm²]	%
20	3.399	-0.1	6.869	0.0
5	3.402	0.0	6.873	0.0
20	3.402	0.0	6.874	0.0
40	3.403	0.1	6.874	0.0
20	3.402	0.0	6.869	0.0
Mean value at 20°C	3.401	-	6.871	-

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

6.1 9 Dependence of span on supply voltage (7.4.8)

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

6.2 Equipment

Isolating transformer, reference foils R1 & R2 for span point checks

6.3 Testing

In order to test the dependence of span on supply voltage, supply voltage was reduced to 195 V starting from 230 V, it was then increased to 253 V via an intermediary step of 230 V.

In order to allow for testing this sensitivity, the internal procedure for stability testing provided by the radiometric measuring system by means of the two reference aluminium foils implemented in the system with a known mass density was used (BETA SPAN TEST).

6.4 Evaluation

At span point, the percentage change of the measured value determined for every step related to the starting point at 230 V was considered.

6.5 Assessment

Voltage variations did not result in deviations > -0.4% compared to the initial value of 230 V.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 27 and Table 26 summarise the test results.

Table 26: Dependence of the measured value on supply voltage, deviation in %, SN 111

Supply voltage	SN 111, R1		SN 111, R2	
	Measured value	Deviation to start value at 230 V	Measured value	Deviation to start value at 230 V
V	[mg/cm²]	%	[mg/cm²]	%
230	3.456	-	6.801	-
195	3.444	-0.4	6.789	-0.2
230	3.442	-0.4	6.786	-0.2
253	3.445	-0.3	6.788	-0.2
230	3.445	-0.3	6.787	-0.2

Table 27: Dependence of the measured value on supply voltage, deviation in %, SN 395

Supply voltage	SN 395, R1		SN 395, R2	
	Measured value	Deviation to start value at 230 V	Measured value	Deviation to start value at 230 V
V	[mg/cm²]	%	[mg/cm²]	%
230	3.294	-	6.606	-
195	3.304	0.3	6.602	-0.1
230	3.293	0.0	6.601	-0.1
253	3.294	0.0	6.601	-0.1
230	3.292	-0.1	6.601	-0.1

Annex 4 in the appendix contains the individual results.

6.1 10 Effect of failure of mains voltage

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

6.2 Equipment

Not required for this performance criterion

6.3 Testing

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

6.4 Evaluation

Buffering protects all instrument parameters against loss.

In the event of a failure in mains voltage, the measuring system is equipped with two rechargeable backup batteries. This enables the measuring system to continue any ongoing beta measurements and consequently allows seamless resuming of measurement operation under the previously programmed cycle conditions on return of the mains voltage.

In the event of a failure in mains voltage:

- ongoing sampling will stop (pump switches off),
- the battery status is checked (charge status, remaining operation time),
- the instrument will end any on-going beta measurements (battery capacity permitting),
- the ideal mechanical configuration of the AMS will be set in order to correctly return to the next sampling cycle on return of the mains voltage,
- the instrument will perform an automatic switch-off procedure after having set the ideal mechanical configuration until the return of the mains voltage.

Outage times due to failure in mains voltage are documented for the measurements in question.

6.5 Assessment

Buffering protects all instrument parameters against loss.
On return of mains voltage, the instrument returns to normal operating mode and automatically resumes measuring.

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, instrument version SWAM 5a Dual Channel Monitor, c/w measurement rack was operated in the climatic chamber and the relative humidity of the entire surrounding atmosphere was controlled. Sample air, free of suspended particles was supplied to the instruments SN 111 and SN 395 after fitting two zero filters at either AMS inlet in order to perform zero point checks.

The measuring systems were operated with a cycle time of 8 hours and readings for mass values were obtained from 8-hour individual measurements and the related to the rated flow for 24h sampling for the purpose of conversion. Once the humidity level had stabilised, the concentration mass values of the AMS averaged over 24h were determined at 40% relative humidity and recorded accordingly. In order to correctly synchronise the cycle time of the measuring system with the adjustment of the relative humidity, the latter was increased to 90% over a period of 24h. The time needed until an equilibrium was reached (ramp) and the measured value over an averaging time of 24h at 90% relative humidity was recorded. Subsequently, relative humidity was decreased to 40% over another 24h period. Again, the time needed until an equilibrium was reached (ramp) and the measured value over an averaging time of 24h at 40% relative humidity was recorded.

6.4 Evaluation

The measured value for the zero zero level of 8-hour individual measurements at stable humidity levels were obtained, averaged over 24 hours and then 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

The maximum difference between measured values determined at 40% and at 90% humidity did not exceed 1.9 µg/m³.

Criterion satisfied? yes

Table 28: Dependence of reading on water vapour concentration, difference in µg/m³, SN 111

rel. Humidity	SN 111, Line A		SN 111, Line B	
	Measured value	Deviation to previous value	Measured value	Deviation to previous value
%	µg/m³	µg/m³	µg/m³	µg/m³
40	0.0	-	0.1	-
90	1.9	1.9	1.7	1.6
40	0.7	-1.2	0.6	-1.1
Maximum deviation	1.9		1.6	

Table 29: Dependence of reading on water vapour concentration, difference in µg/m³, SN 395

rel. Humidity	SN 395, Line A		SN 395, Line B	
	Measured value	Deviation to previous value	Measured value	Deviation to previous value
%	µg/m³	µg/m³	µg/m³	µg/m³
40	0.4	-	0.5	-
90	2.0	1.5	1.7	1.2
40	1.3	-0.6	1.1	-0.6
Maximum deviation	1.5		1.2	

6.6 Detailed presentation of test results

Table 30: Dependence of reading on water vapour concentration, difference in µg/m³, SN 111, individual readings

rel. Luftfeuchte	SN 395, Line A				SN 395, Line B			
	Messwert 1	Messwert 2	Messwert 3	Mittelwert	Messwert 1	Messwert 2	Messwert 3	Mittelwert
%	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
40	1.3	0.3	-0.4	0.4	1.3	0.1	0.0	0.5
40 → 90*	0.8	1.1	2.4	1.4	0.5	0.7	1.2	0.8
90	2.4	1.9	1.6	2.0	1.9	1.8	1.5	1.7
90 → 40*	2.3	1.8	0.7	1.6	1.4	1.2	0.6	1.1
40	0.5	1.3	2.2	1.3	0.4	1.2	1.7	1.1

* nur informativ

Table 31: Dependence of reading on water vapour concentration, difference in µg/m³, SN 395, individual readings

rel. Humidity	SN 395, Line A				SN 395, Line B			
	Measured value 1	Measured value 2	Measured value 3	Mean value	Measured value 1	Measured value 2	Measured value 3	Mean value
%	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
40	1.3	0.3	-0.4	0.4	1.3	0.1	0.0	0.5
40 → 90*	0.8	1.1	2.4	1.4	0.5	0.7	1.2	0.8
90	2.4	1.9	1.6	2.0	1.9	1.8	1.5	1.7
90 → 40*	2.3	1.8	0.7	1.6	1.4	1.2	0.6	1.1
40	0.5	1.3	2.2	1.3	0.4	1.2	1.7	1.1

* only informative

6.1 12 Zero checks (7.5.3)

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

6.2 Equipment

Zero filter for zero checks.

6.3 Testing

This test was performed as part of the field test in the context of initial testing over a total period of about a year at the German sites.

As part of regular checks, the measuring systems were operated with zero filters fitted to the AMS inlets over a period of at least 24h about once a month (Cologne and Bonn) as well as twice near the end of the field test (Brühl) and zero readings were evaluated. The same test were performed at the site in Teddington (UK) using instruments SN 145 and SN 149.

6.4 Evaluation

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

6.5 Assessment

The maximum measured value determined at zero point was 2.4 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 32 to Table 35 list the measured value obtained for the zero point in µg/m³.

Figure 43 to Figure 50 illustrate the zero drift observed during the test period.

Table 32: Zero checks using zero filters for SN 127, Cologne 2007, Bonn and Brühl

Date	SN 127, Line A		Date	SN 127, Line B	
	Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³		Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³
10/30/2007	0.1	ok	10/30/2007	0.3	ok
12/6/2007	0.7	ok	12/6/2007	0.6	ok
1/8/2008	1.1	ok	1/8/2008	0.0	ok
2/13/2008	0.4	ok	2/13/2008	0.6	ok
3/12/2008	0.3	ok	3/12/2008	0.5	ok
4/10/2008	1.2	ok	4/10/2008	0.7	ok
11/11/2008	1.2	ok	11/11/2008	1.2	ok
12/9/2008	1.1	ok	12/9/2008	0.8	ok

Table 33: Zero checks using zero filters for SN 131, Cologne 2007, Bonn and Brühl

Date	SN 131, Line A		Date	SN 131, Line B	
	Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³		Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³
10/30/2007	0.5	ok	10/30/2007	0.6	ok
12/6/2007	0.4	ok	12/6/2007	0.7	ok
1/8/2008	0.0	ok	1/8/2008	0.4	ok
2/13/2008	0.0	ok	2/13/2008	0.4	ok
3/12/2008	0.0	ok	3/12/2008	0.0	ok
4/10/2008	0.7	ok	4/10/2008	0.5	ok
11/11/2008	1.3	ok	11/11/2008	2.4	ok
12/9/2008	0.3	ok	12/9/2008	0.4	ok

Table 34: Zero checks using zero filters for SN 145, Teddington

Date	SN 145, Line A		Date	SN 145, Line B	
	Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³		Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³
7/24/2008	0.5	ok	7/24/2008	0.7	ok
8/18/2008	0.4	ok	8/18/2008	0.3	ok
9/23/2008	0.0	ok	9/23/2008	0.1	ok

Table 35: Zero checks using zero filters for SN 149, Teddington

Date	SN 149, Line A		Date	SN 149, Line B	
	Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³		Measured Value µg/m³	Measured value (absolute) ≤ 3.0 µg/m³
7/24/2008	0.8	ok	7/24/2008	0.6	ok
8/18/2008	0.7	ok	8/18/2008	0.5	ok
9/23/2008	0.5	ok	9/23/2008	0.1	ok

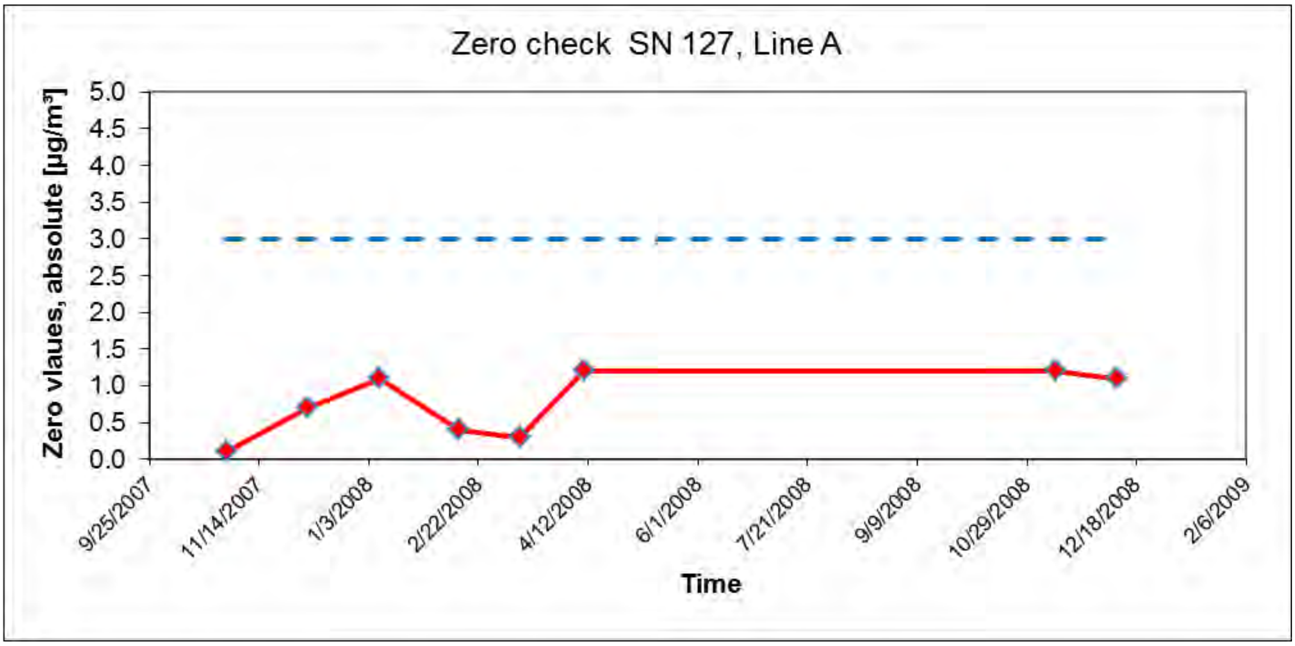


Figure 43: Zero drift SN 127, line A

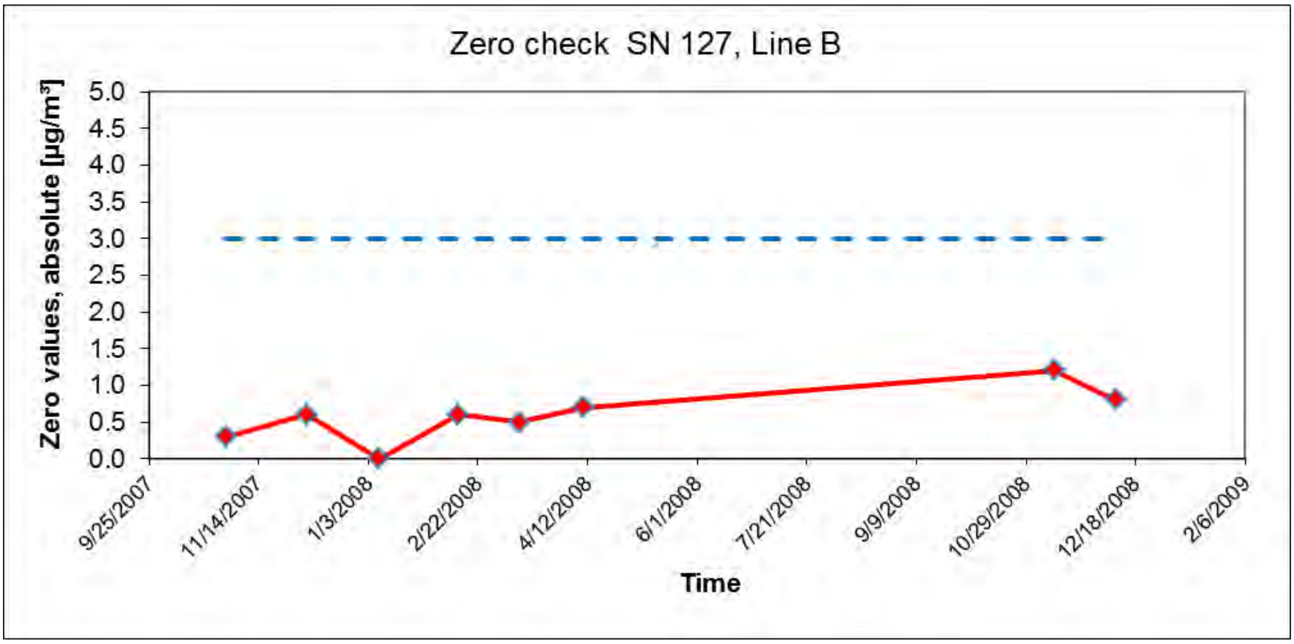


Figure 44: Zero drift SN 127, line B

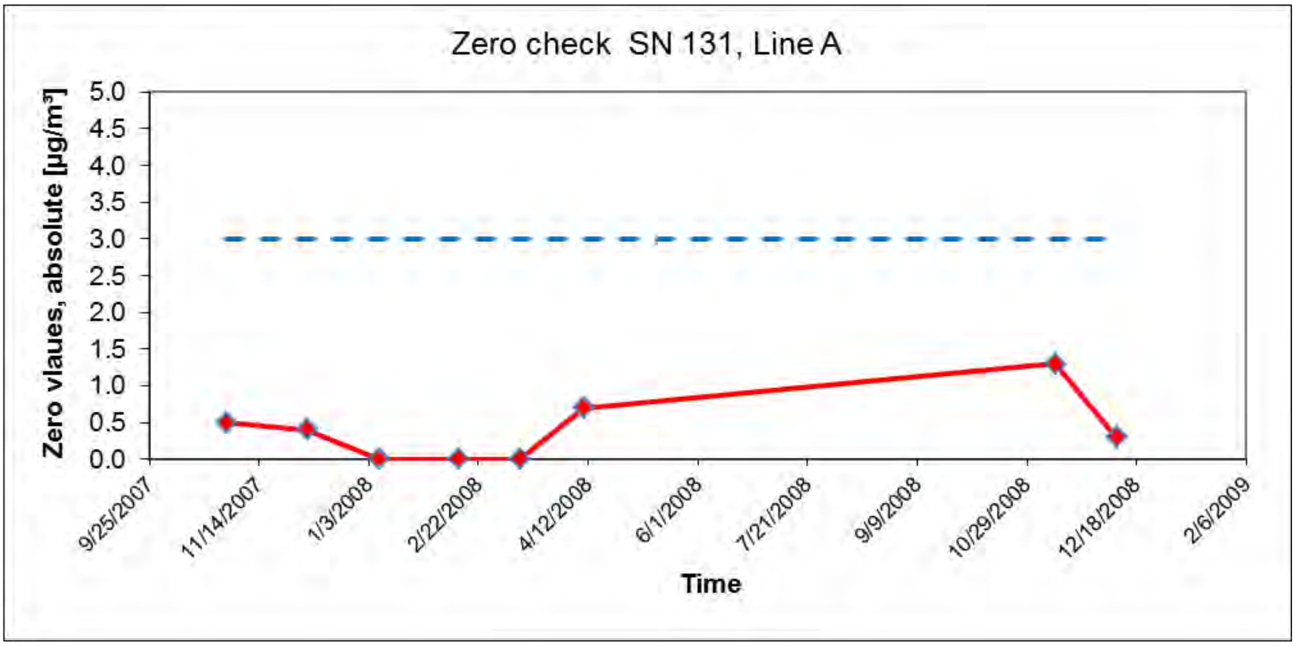


Figure 45: Zero drift SN 131, line A

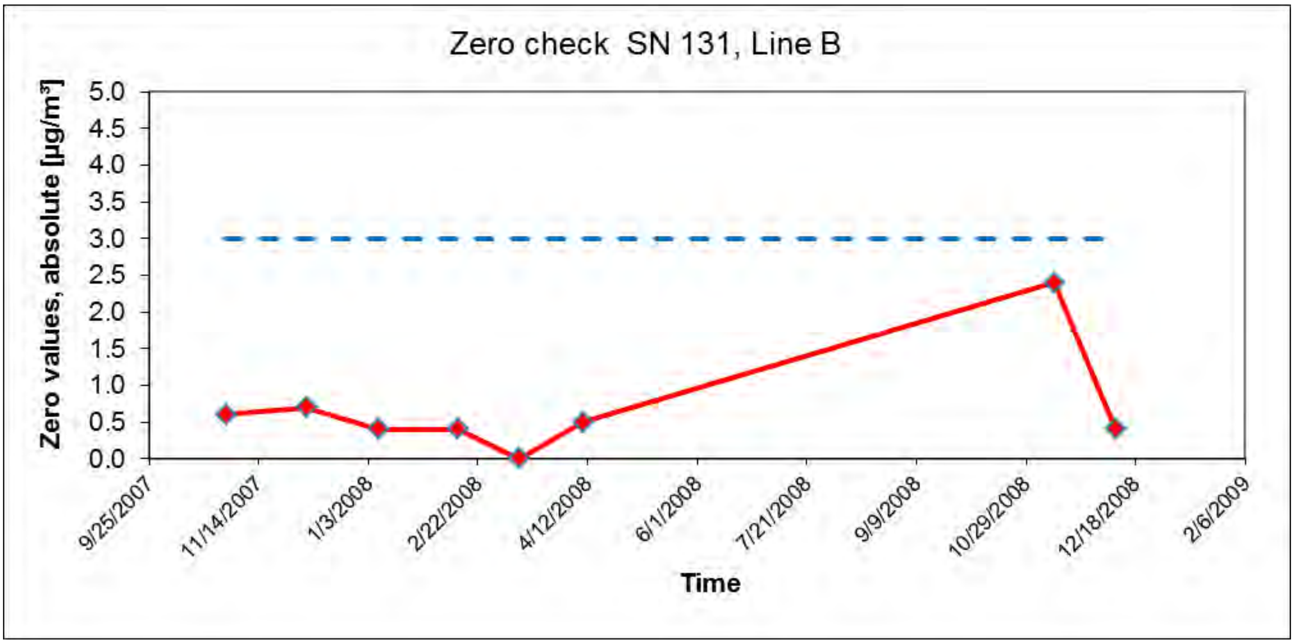


Figure 46: Zero drift SN 131, line B

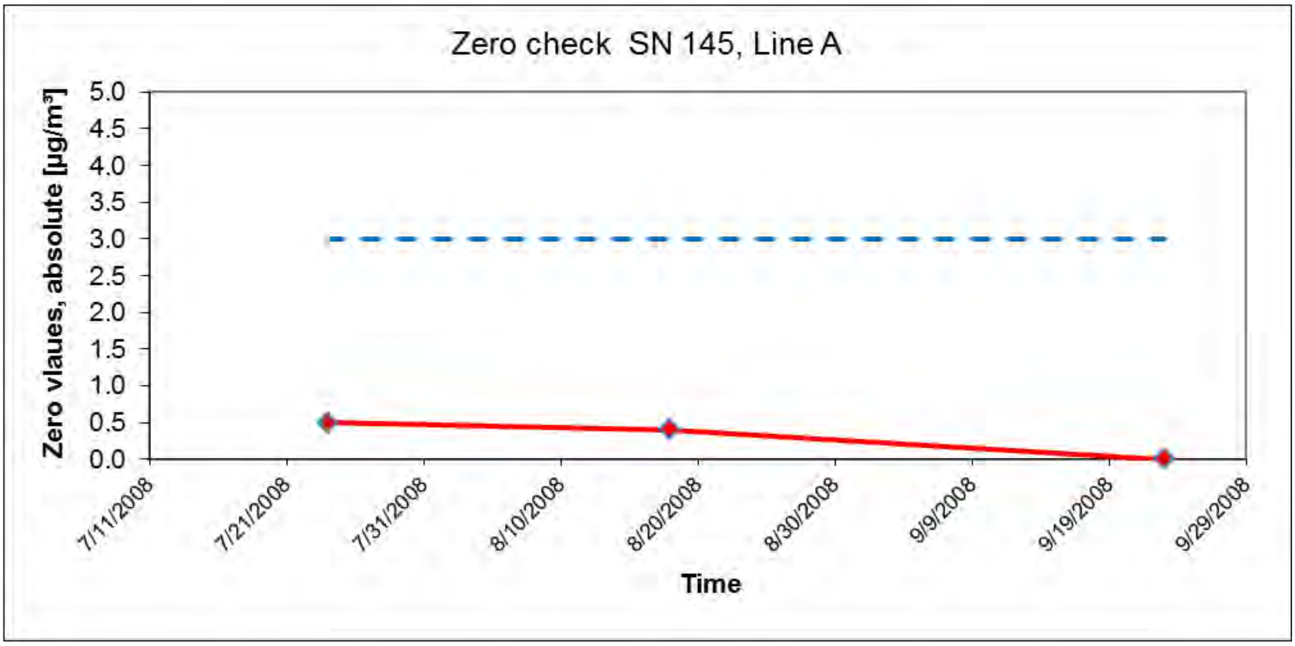


Figure 47: Zero drift SN 145, line A

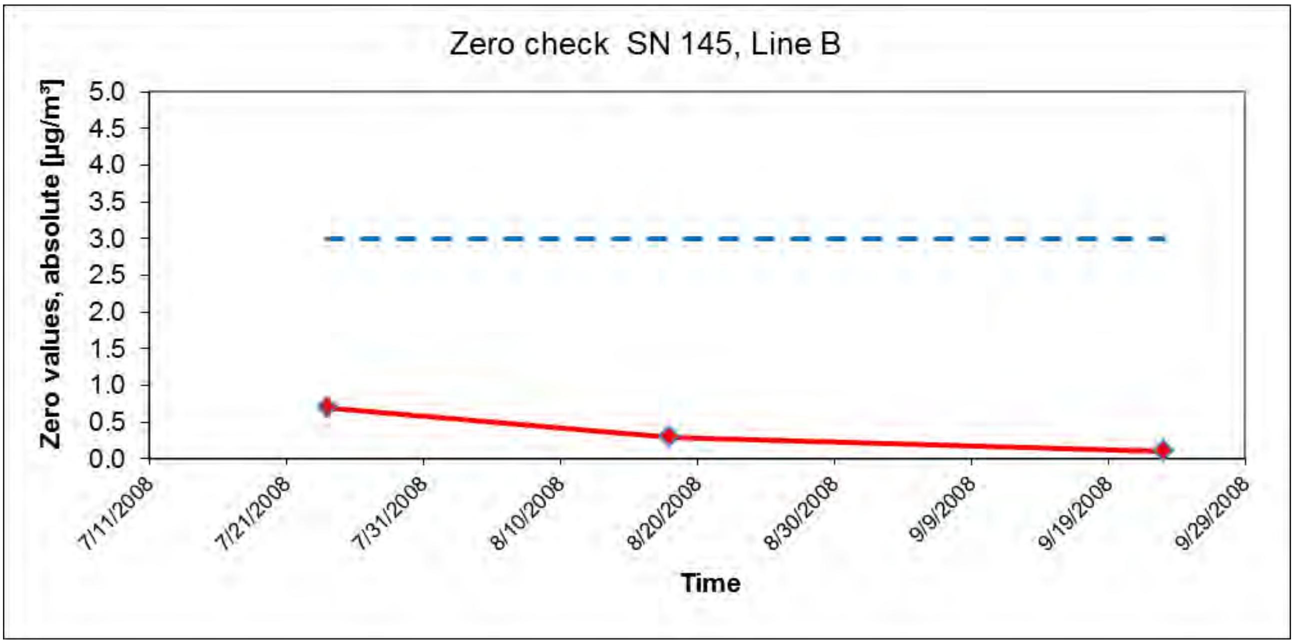


Figure 48: Zero drift SN 145, line B

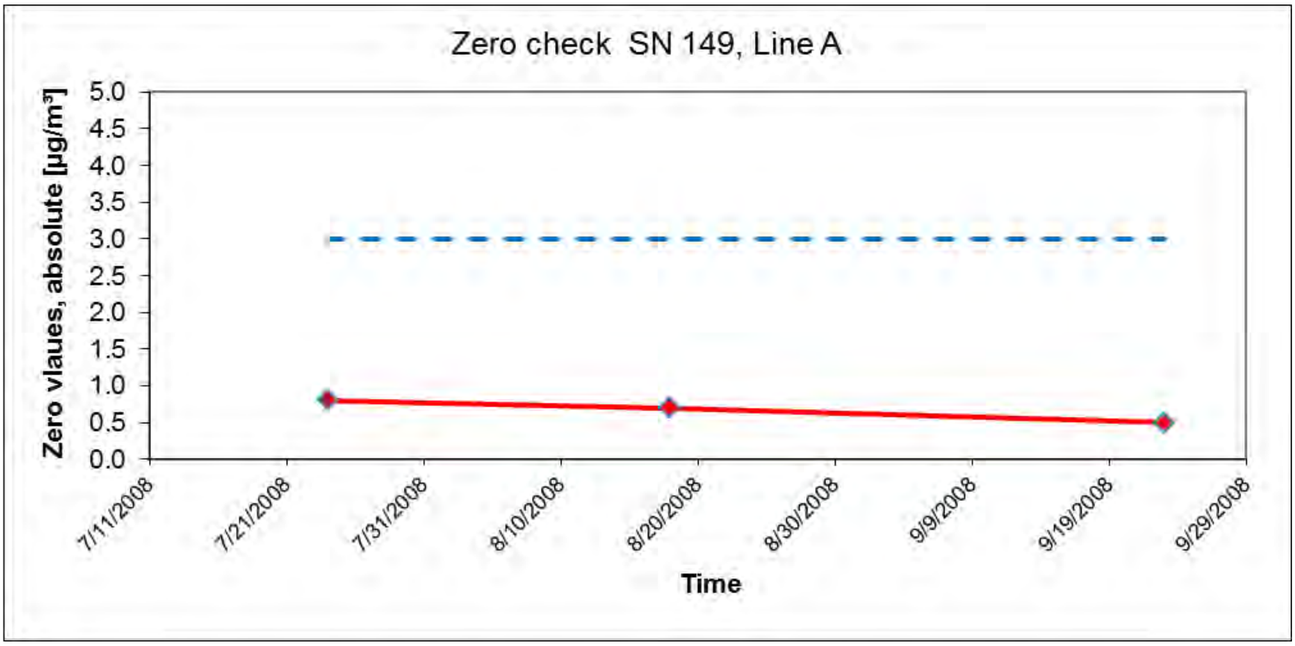


Figure 49: Zero drift SN 149, line A

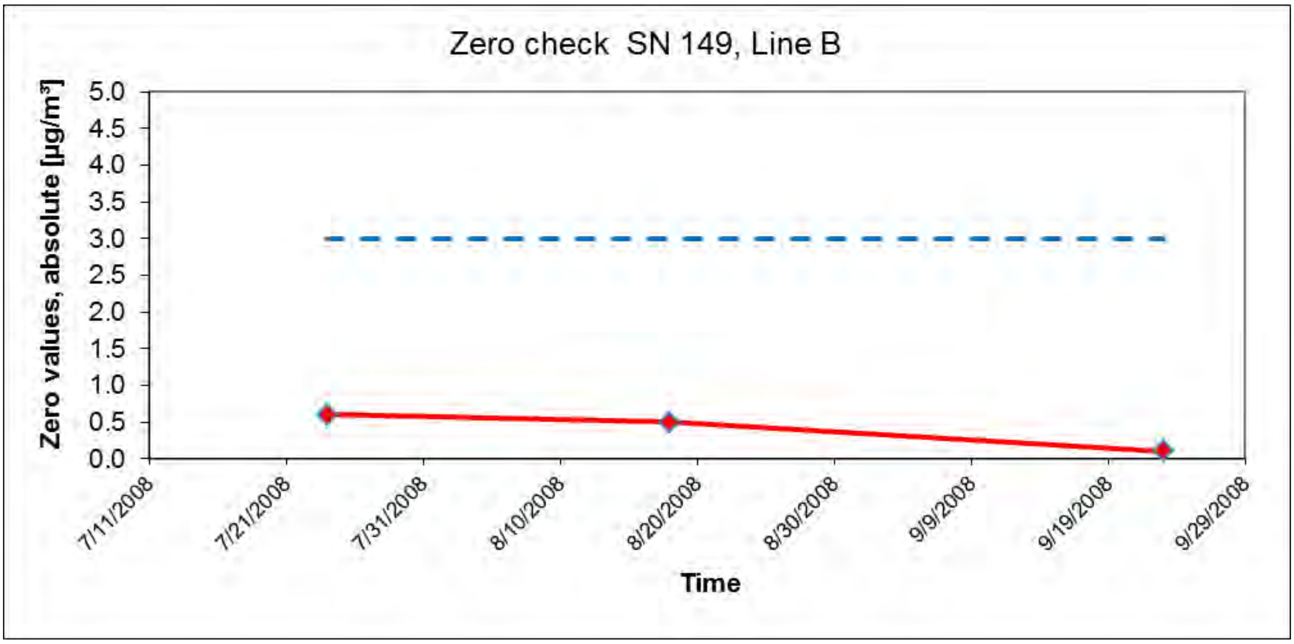


Figure 50: Zero drift SN 149, line B

6.1 13 Recording of operational parameters (7.5.4)

Measuring systems shall be able to provide data of operational states for telemetric transmission of – at minimum – the following parameters:

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

Results of automated/functional checks, where available, shall be recorded.

6.2 Equipment

Modem, PC c/w software “DR FAI Manager” or Hyperterminal

6.3 Testing

A modem was connected to the measuring system. Among other, status signals provided by the AMS were recorded relying on remote data transmission.

Access options provided by the DR FAI Manager operating system and the Hyperterminal were checked.

The measuring system allows for comprehensive monitoring and control functions. A number of reading, writing and control commands are available; a complete overview of which is provided in the AMS operating manual.

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

- Flow rate
- Pressure drop via the sampling filter
- Sampling time
- Sample flow
- Mass concentrations of the relevant PM fraction
- Ambient temperature, pressure, humidity
- Temperature at the point of sampling (filter)...

Furthermore, the system saves the results of internal checks for the purpose of quality assurance / functional checks.

The DR FAI Manager operating software conveniently provides options to monitor the operating status and provides data saved as text files (also see Figure 13 to Figure 19 in section 3.3 AMS scope and set-up).

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

As part of the performance test, a PC was connected directly connected to the AMS via RS232 to test the transfer of data and the instrument status.

6.4 Evaluation

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

6.5 Assessment

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

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 14 Daily averages (7.5.5)

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

6.2 Equipment

For this test, a clock was additionally provided.

6.3 Testing

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

6.4 Evaluation

For SWAM 5a Dual Channel Monitor / SWAM 5a Monitor

The measuring system allows for the formation of averages for sampling periods between 8h and 168h. A total of 11–12 min are required for tasks such as filter replacement/filter movements in the instrument and QA measures performed for every cycle (internal leak tests, and internal flow rate checks. This corresponds to about 0.8% of the averaging time (24h).

For SWAM 5a Dual Channel Hourly Monitor

This measuring system operates at a cycle time of 1h. About 1–2 min are required for filter replacement/filter movements in the instrument (for every cycle). Moreover, two of the 24 daily cycles include further QA measures (sensor tests) – this requires apx. 3 min per cycle; this corresponds to about 5% of the averaging time. For this instrument version, the internal leak test and the internal flow rate check are performed at each programme start and can be initiated by sending a command to this effect e.g. via RS232. The time needed for such measures amounts to about 10 minutes. Thus, in this case the real sampling time in a given cycle also adds up to more than 75% of the cycle time.

Thus, the formation of daily averages is ensured.

For every measurement, the measuring system saves the ratio of actual sampling time and cycle time as a percentage.

6.5 Assessment

It is possible to form valid daily averages.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not applicable.

6.1 15 Availability (7.5.6)

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

6.2 Equipment

Not required for this performance criterion

6.3 Testing

The start and end times at each of the four field test sites from the initial test [11] 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) shall 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;

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

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

As part of the initial test, a total of two identical systems were operated as follows:

- SN 127 & SN 131 at the field test sits in Cologne, Bonn and Brühl
- SN 145 & SN 145 at the field test site in Teddington

The overall availability was determined separately for the various sets of tested instruments.

6.4 Evaluation

a) SN 127 & SN 131 at the field test sits in Cologne, Bonn and Brühl

Table 36 lists all operating, maintenance and down times at the field test sites in Cologne (2007), Bonn and Brühl. During the field test, the measuring systems were operated for a total of 245 measuring days. Outages caused by external events not attributable to the measuring system were recorded on 28/10/2007 and 29/10/2007 (changing from daylight saving to regular time), on 06/01/2008 and 07/01/2008 (filter stocks exhausted), on 26/03/2008 and 27/03/2008 (change to daylight saving time), on 03/11/2008 and 04/11/2008 (filter stocks exhausted) and from 06/11/2008 to 10/11/2008 (5d for replacing the TÜV measurement station). This reduces the total time of operation to 232 measuring days.

Regular checks of the zero point as part of the drift test resulted in a total of 7 days of down time.

Maintenance tasks during the tests were primarily caused by cleaning the sampling heads (13 times) and checking flow rates as well as leak tightness (16 times during testing). Daily averages did not have to be discarded as a result of such maintenance. These tasks cause down times of less than 1h per check (16 times during testing) and did not require daily averages to be discarded.

As a result of water ingress, measured values obtained by instrument SN 127 had to be discarded on 22/10/2007 and 23/10/2007.

A cable break of the swivel arm for beta measurements resulted in down times of instrument SN 131 from 19/10/2008 to 23/10/2008. In order to prevent such down times, the cable in question will be replaced by a more stable version which will be positioned and fastened at a more suitable location inside the instrument.

No further errors in functioning were observed:

b) SN 145 & SN 149 at the field test site in Teddington

Table 37 lists the operating, maintenance and down times recorded at the field test sites in Teddington. During the field test, the measuring systems were operated for a total of 91 measuring days. Outages caused by external events not attributable to the measuring system were recorded on August 6, 2008 (power failure). This reduces the total time of operation to 90 measuring days.

Regular checks of the zero point as part of the drift test resulted in a total of 3 days of down time.

Maintenance tasks during the tests were primarily caused by cleaning the sampling heads (7 times) and checking flow rates as well as leak tightness (once). These tasks cause down times of less than 1h per check (8 times during testing) and did not require daily averages to be discarded.

A defective sensor for determining the position of the beta source's cover resulted in down times of instrument SN 145 from 27/08/2008 to 29/08/2008. FAI Instruments s.r.l replaced the defective sensor.

No further errors in functioning were observed:

6.5 Assessment

The availability for instrument 1 (SN 127) was 99.1%, for instrument 2 (SN 131) it was 97.8%, for SN 145 it was 96.7% and for SN 149, it was 100%.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Table 36: Determination of the availability (Cologne 2007, Bonn, Brühl)

		System 1 (SN 127)	System 2 (SN 131)
Operation time (t_{field})	h	5568	5568
Outage time	h	48	120
Maintenance time incl. zero filter ($t_{cal,maint}$)	h	184	184
Actual operating time (t_{valid})	h	5336	5264
Availability	%	99.1	97.8

Table 37: Determination of the availability (Teddington)

		System 1 (SN 145)	System 2 (SN 149)
Operation time (t_{field})	h	2160	2160
Outage time	h	72	-
Maintenance time incl. zero filter ($t_{cal,maint}$)	h	80	80
Actual operating time (t_{valid})	h	2008	2080
Availability	%	96.7	100

6.1 Method used for equivalence testing (7.5.8.4 & 7.5.8.8)

The 2010 Guide [5] requires compliance with the following five criteria in order to recognise equivalence:

1. Of the full data set, at least 20% of the concentration values (determined with the reference method)shall be greater than the upper assessment threshold specified in 2008/50/EC [8], i.e. 28 µg/m³ for PM_{10} and 17 µg/m³ for $PM_{2.5}$. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.
2. Between-AMS uncertainty shall remain below 2.5 µg/m³ for the overall data and for data sets with data larger than/equal to 30 µg/m³ PM_{10} and 18 µg/m³ $PM_{2.5}$.
3. The uncertainty between reference systems shall not exceed 2.0 µg/m³.
4. The expanded uncertainty (W_{CM}) is calculated at 50 µg/m³ for PM_{10} and at 30 µg/m³ for $PM_{2.5}$ for every individual candidate system and checked against the average of the reference method. For each of the following cases, the expanded uncertainty shall not exceed 25%:
   - Full data set:
   - datasets representing PM concentrations greater than/equal to 30 µg/m³ for PM_{10}, or concentrations greater than/equal to 18 µg/m³ for $PM_{2.5}$, provided that the set contains 40 or more valid data pairs
   - Datasets for each individual site
5. Preconditions for acceptance of the full dataset are that the slope b is insignificantly different from $|b-1| \leq 2 \cdot u(b)$ and the intercept a is insignificantly different from 0: $|a| \leq 2 \cdot u(a)$. If these preconditions are not met, the candidate method may be calibrated using the values obtained for slope and/or intercept.

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

Chapter 6.1 16 Between-AMS uncertainty $u_{bs,AMS}$ (7.5.8.4) addresses verification of criteria 1 and 2.

Verification of criteria 3, 4 and 5 is reported on in chapter 6.1 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8)

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

6.1 16 Between-AMS uncertainty $u_{bs,AMS}$ (7.5.8.4)

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

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

For instrument version SWAM 5a Dual Channel Monitor, this test was part of the original field test as well as of the campaigns for qualifying instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor; a total of 6 comparison campaigns have been performed. Different seasons as well as different concentrations of $PM_{2.5}$ and PM_{10} were taken into consideration.

In the full dataset, at least 20% of the results obtained using the reference method should be greater than the upper assessment threshold of the annual limit value specified in 2008/50/EC [8]. The assessment threshold for $PM_{2.5}$ is 17 µg/m³, for PM_{10} it is 28 µg/m³. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.

For each comparison campaign, at least 40 valid value pairs were determined. Of the full data set (6 comparisons, for PM_{10}: 409 valid pairs of measured values for SN 127 / SN 145 and SN 248, 419 valid pairs of measured values for SN 131, SN 149 and SN 249; for $PM_{2.5}$: 327 valid pairs of measured values for SN 127 / SN 145 and SN 248, 325 valid pairs of measured values for SN 131, SN 149 and SN 249) 35% of the measured values are above the upper assessment threshold of 17 µg/m³ for $PM_{2.5}$ and 25.8% of the measured values are above the upper assessment threshold of 28 µg/m³ for PM_{10}. The concentrations measured were related to the ambient conditions.

One exemplary measurement campaign each served to demonstrate equivalence of the reference method for the SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor instrument versions.

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 shall not be stated.

Uncertainty is determined for:

- All locations or comparisons together (full data set)
- 1 data set with measured values ≥ 18 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)
- 1 data set with measured values ≥ 30 µg/m³ for PM_{10} (basis: averages reference measurement)

Furthermore, this report also covers an informative evaluation of the following data sets:

- Every location or comparison separately
- 1 data set with measured values < 18 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)
- 1 data set with measured values < 30 µg/m³ for $PM_{2.5}$ (basis: averages reference measurement)

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

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

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

6.5 Assessment

At no more than 0.79 µg/m³ for $PM_{2.5}$ and no more than 1.19 µg/m³ for PM_{10}, the uncertainty between the candidate systems u_{bs} for the SWAM 5a Dual Channel Monitor remains well below the permissible maximum of 2.5 µg/m³. At no more than 0.74 µg/m³ for $PM_{2.5}$ and no more than 0.73 µg/m³ for PM_{10}, the uncertainty between the candidate systems u_{bs} for the SWAM 5a Dual Channel Hourly Mode Monitor remains well below the permissible maximum of 2.5 µg/m³. Finally, at no more than 0.56 µg/m³ for $PM_{2.5}$ and no more than 0.63 µg/m³ for PM_{10}, the uncertainty between the candidate systems u_{bs} for the SWAM 5a Monitor also remains below the permissible maximum of 2.5 µg/m³.

Criterion satisfied? yes

6.6 Detailed presentation of test results

For SWAM 5a Dual Channel Monitor:

Table 38 and Table 39 list the calculated values for the between-AMS uncertainties u_{bs}. A corresponding chart is provided in Figure 51 to Figure 68.

For SWAM 5a Dual Channel Hourly Mode Monitor:

Table 40 and Table 41 list the calculated values for the between-AMS uncertainties u_{bs}. A corresponding chart is provided in Figure 69 to Figure 70.

For SWAM 5a Monitor:

Table 42 and Table 43 list the calculated values for the between-AMS uncertainties u_{bs}. A corresponding chart is provided in Figure 71 to Figure 72.

Table 38: Between-AMS uncertainty $u_{bs,AMS}$ for instruments SN 127 / 145 / 248 and SN 131 / 149 / 249, version SWAM 5a Dual Channel Monitor, component $PM_{2.5}$

Tested instruments	**Test site**	**Number of measurements**	**Uncertainty $u_{bs,AMS}$**
SN			µg/m³
All	**All test sites**	**442**	**0.71**
Individual test sites			
127 / 131	Cologne, parking lot, 2007	100	0.69
127 / 131	Bonn, Belderberg	64	0.42
127 / 131	Brühl	55	0.63
145 / 149	Teddington	83	0.44
127 / 131	Cologne, parking lot, 2011	67	1.33
248 / 249	Bornheim	73	0.32
Classing over reference values			
All	**Values ≥ 18 µg/m³**	**91**	**0.79**
All	Values < 18 µg/m³	221	0.45

Table 39: Between-AMS uncertainty $u_{bs,AMS}$ for instruments SN 127 / 145 / 248 and SN 131 / 149 / 249, version SWAM 5a Dual Channel Monitor, component PM_{10}

Tested instruments	**Test site**	**Number of measurements**	**Uncertainty $u_{bs,AMS}$**
SN			µg/m³
All	**All test sites**	**455**	**0.66**
Individual test sites			
127 / 131	Cologne, parking lot, 2007	100	0.87
127 / 131	Bonn, Belderberg	64	0.45
127 / 131	Brühl	55	0.56
145 / 149	Teddington	83	0.53
127 / 131	Cologne, parking lot, 2011	80	0.88
248 / 249	Bornheim	73	0.35
Classing over reference values			
All	**Values ≥ 30 µg/m³**	**91**	**1.19**
All	Values < 30 µg/m³	221	0.46

Table 40: Between-AMS uncertainty $u_{bs,AMS}$ for instruments SN 111 and SN 112, version SWAM 5a Dual Channel Hourly Mode Monitor, component $PM_{2.5}$

Tested instruments	**Test site**	**Number of measurements**	**Uncertainty $u_{bs,AMS}$**
111 / 112	Cologne, parking lot, 2011	77	0.74

Table 41: Between-AMS uncertainty $u_{bs,AMS}$ for instruments SN 111 and SN 112, version SWAM 5a Dual Channel Hourly Mode Monitor, component PM_{10}

Tested instruments	**Test site**	**Number of measurements**	**Uncertainty $u_{bs,AMS}$**
111 / 112	Cologne, parking lot, 2011	77	0.73

Table 42: Between-AMS uncertainty $u_{bs,AMS}$ for instruments SN 331 and SN 333, version SWAM 5a Monitor, component $PM_{2.5}$

Tested instruments	**Test site**	**Number of measurements**	**Uncertainty $u_{bs,AMS}$**
331 / 333	Bornheim	53	0.56

Table 43: Between-AMS uncertainty $u_{bs,AMS}$ for instruments SN 329 and SN 330, version SWAM 5a Monitor, component PM_{10}

Tested instruments	**Test site**	**Number of measurements**	**Uncertainty $u_{bs,AMS}$**
329 / 330	Bornheim	77	0.63

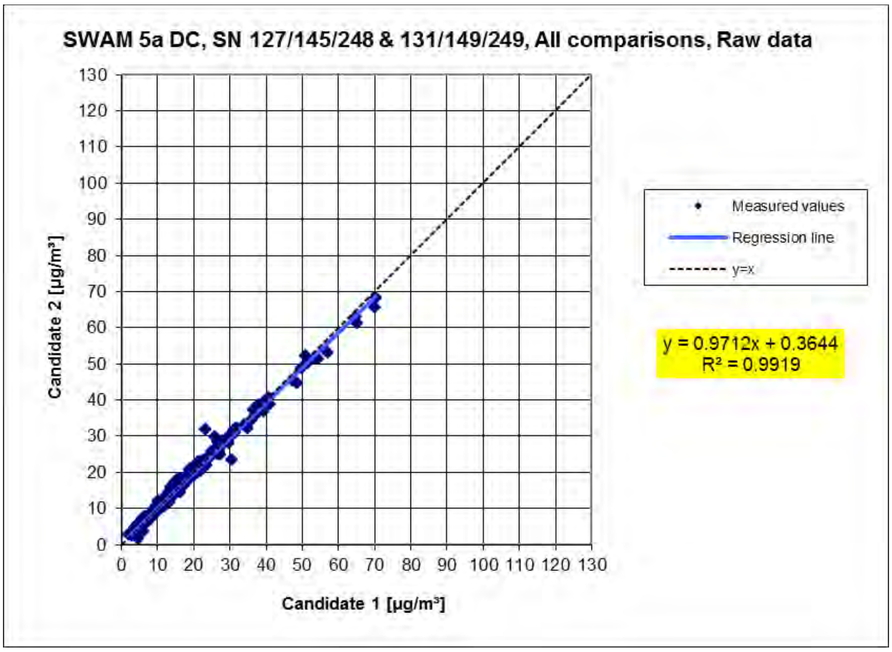


Figure 51: Result of the parallel measurement with instruments SN 127/145/248 and SN 131/149/249, SWAM 5a DC, component $PM_{2.5}$, all sites

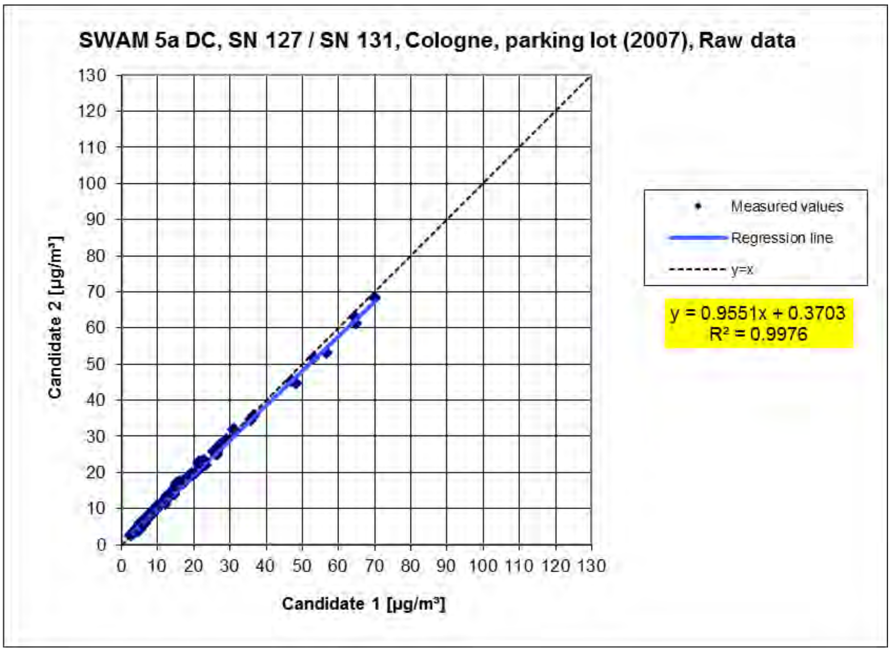


Figure 52: Results of the parallel measurement with instruments SN 127 / SN 131, component $PM_{2,5}$, SWAM 5a DC, Cologne, parking lot (2007)

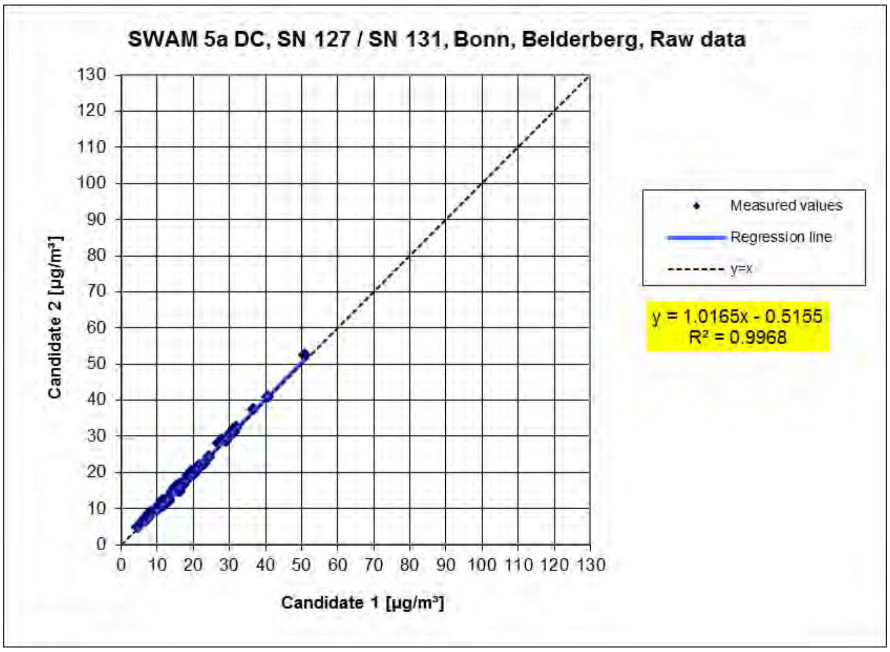


Figure 53: Results of the parallel measurement with instruments SN 127 / SN 131, Component $PM_{2,5}$, SWAM 5a DC, Bonn, Belderberg

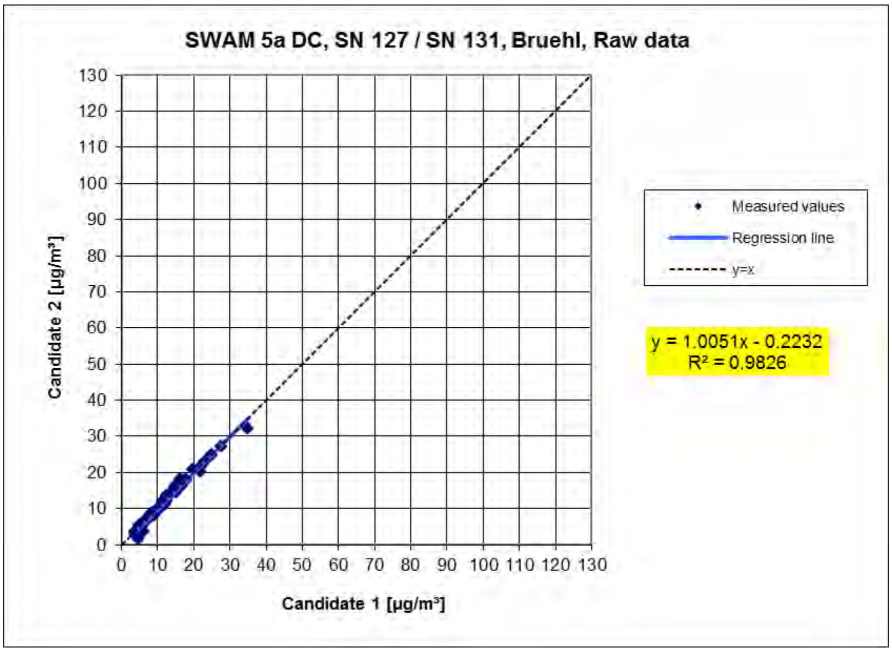


Figure 54: Results of the parallel measurement with instruments SN 127 / SN 131, component $PM_{2,5}$, SWAM 5a DC, Brühl

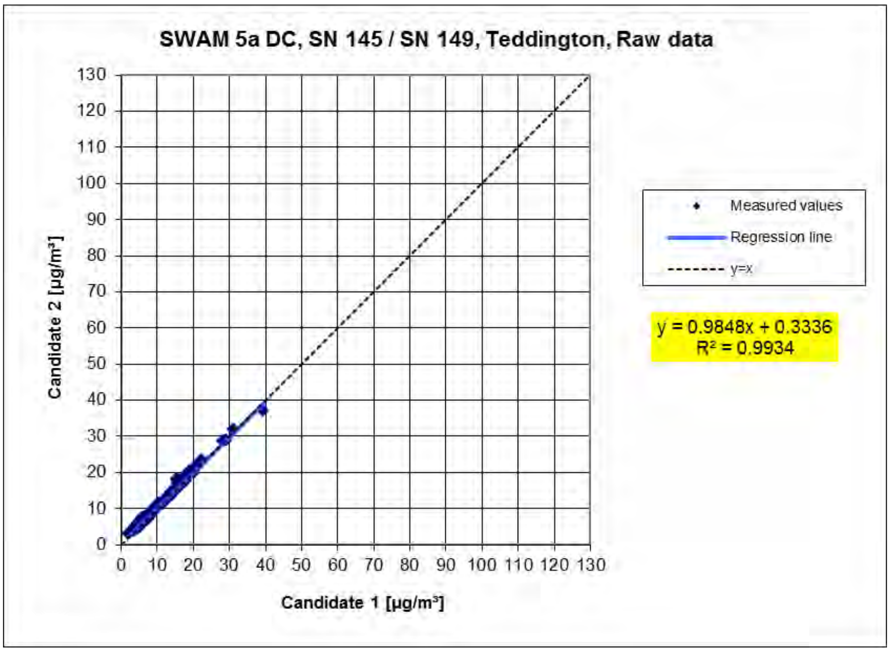


Figure 55: Results of the parallel measurement with instruments SN 145 / SN 149, component $PM_{2,5}$, SWAM 5a DC, Teddington

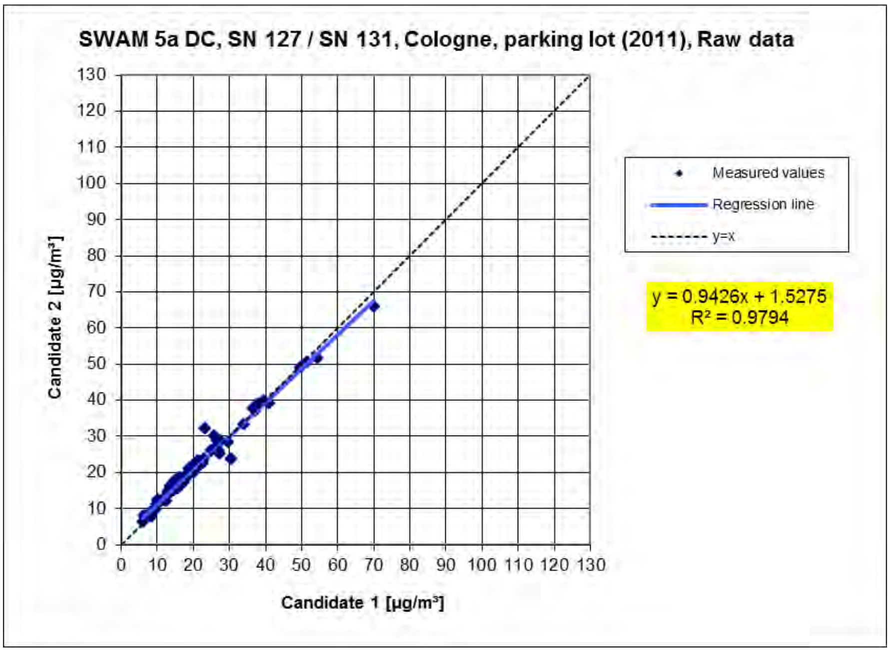


Figure 56: Results of the parallel measurement with instruments SN 127 / SN 131, component $PM_{2,5}$, SWAM 5a DC, Cologne, parking lot (2011)

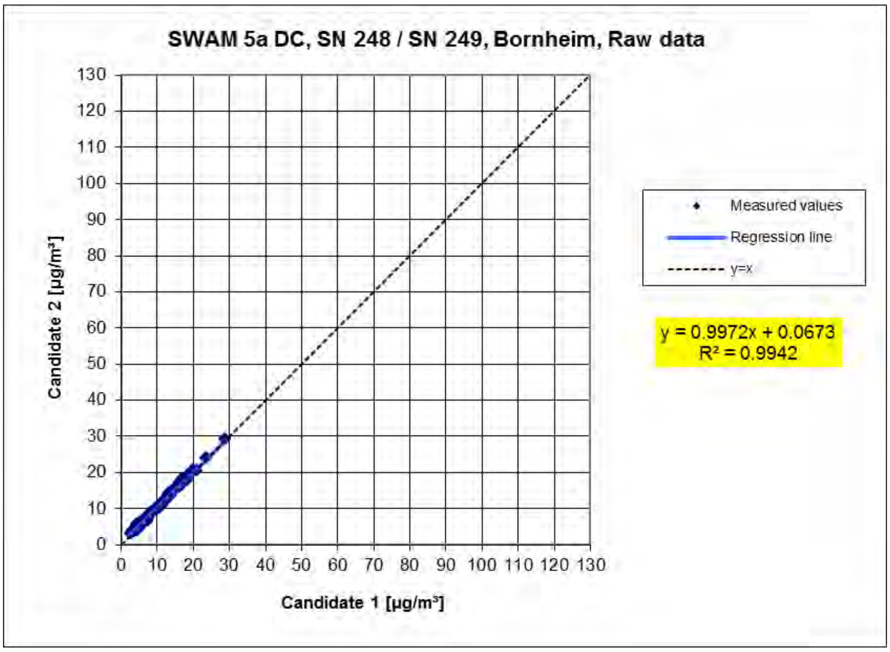


Figure 57: Results of the parallel measurement with instruments SN 248 / SN 249, component $PM_{2,5}$, SWAM 5a DC, Bornheim

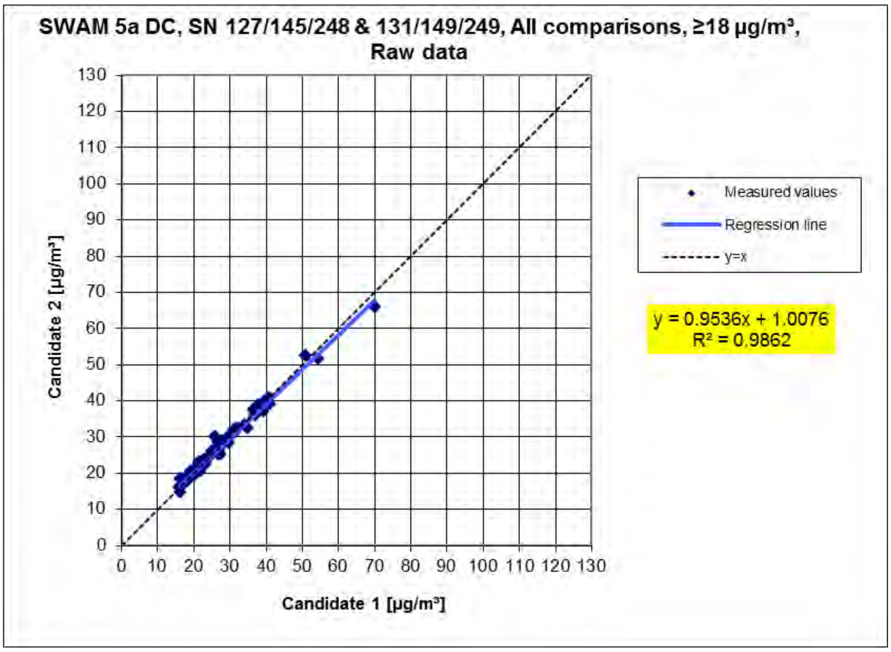


Figure 58: Result of the parallel measurement with instruments SN 127/145/248 and SN 131/149/249, SWAM 5a DC, component $PM_{2.5}$, all sites, values ≥ 18

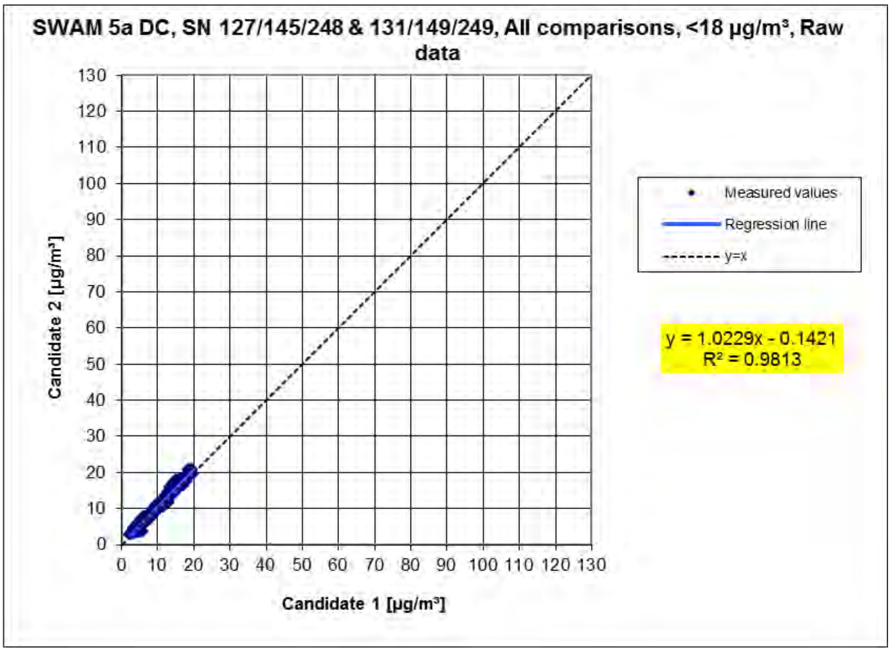


Figure 59: Result of the parallel measurement with instruments SN 127/145/248 and SN 131/149/249, SWAM 5a DC, component $PM_{2.5}$, all sites, values < 18

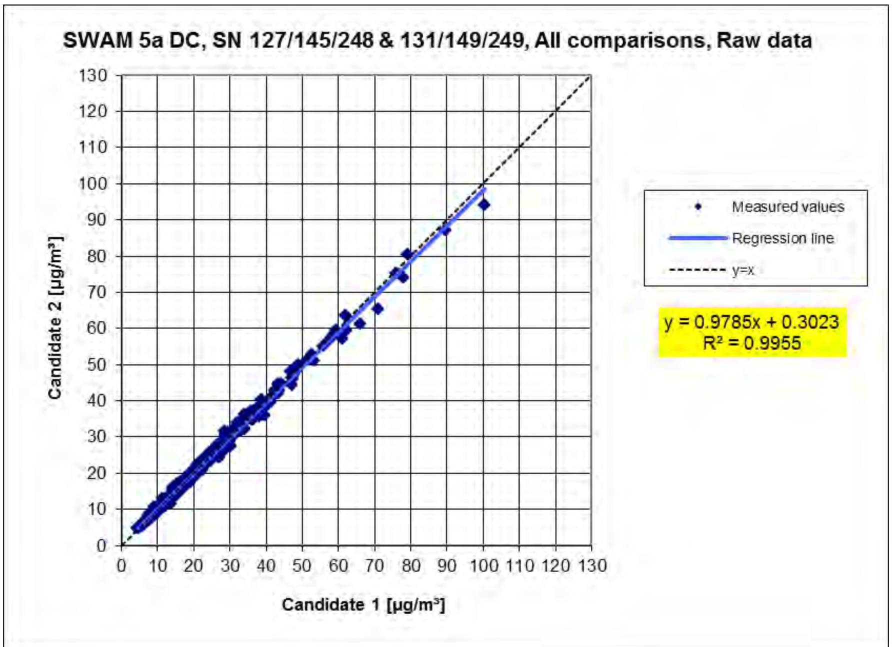


Figure 60: Result of the parallel measurement with instruments SN 127/145/248 and SN 131/149/249, SWAM 5a DC, component PM_{10}, all sites

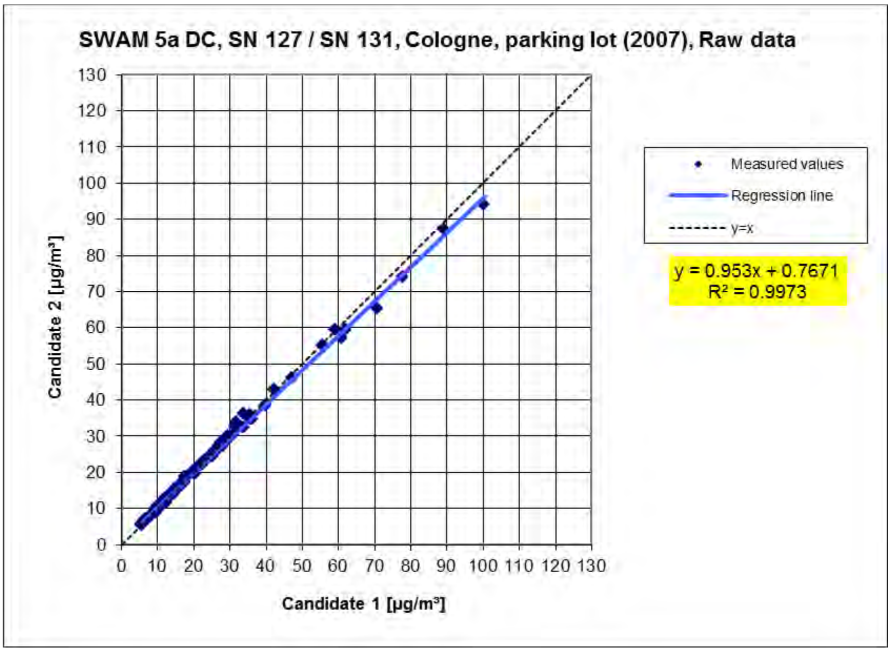


Figure 61: Results of the parallel measurement with instruments SN 127 / SN 131, Component PM_{10}, SWAM 5a DC, Cologne, parking lot (2007)

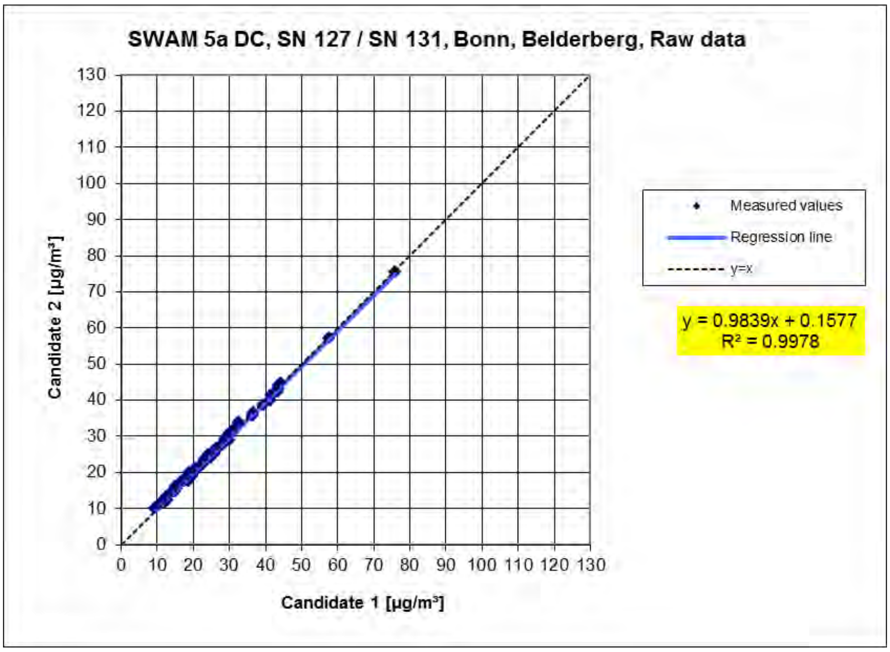


Figure 62: Results of the parallel measurement with instruments SN 127 / SN 131, component PM_{10}, SWAM 5a DC, Bonn, Belderberg

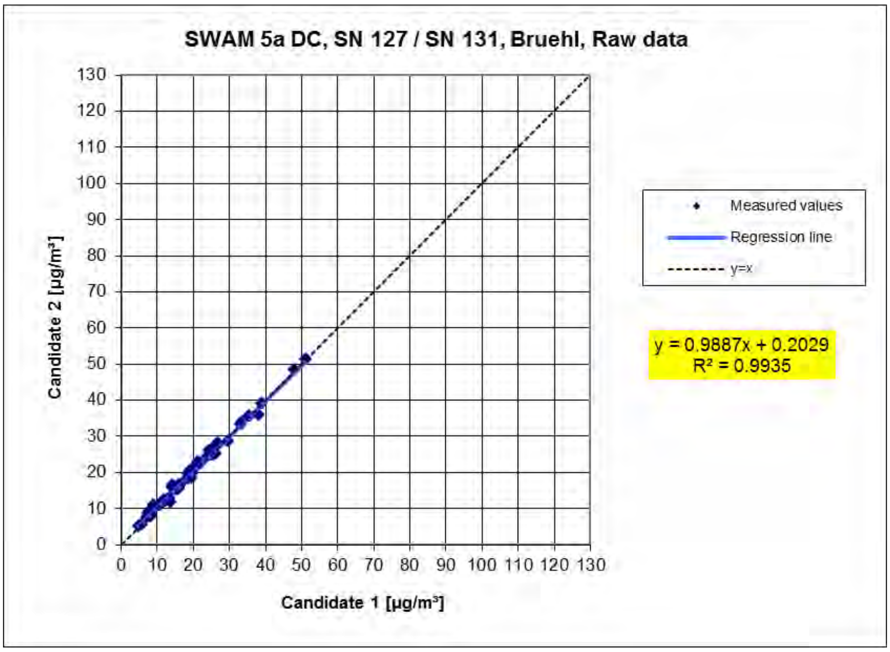


Figure 63: Results of the parallel measurement with instruments SN 127 / SN 131, component PM_{10}, SWAM 5a DC, Brühl

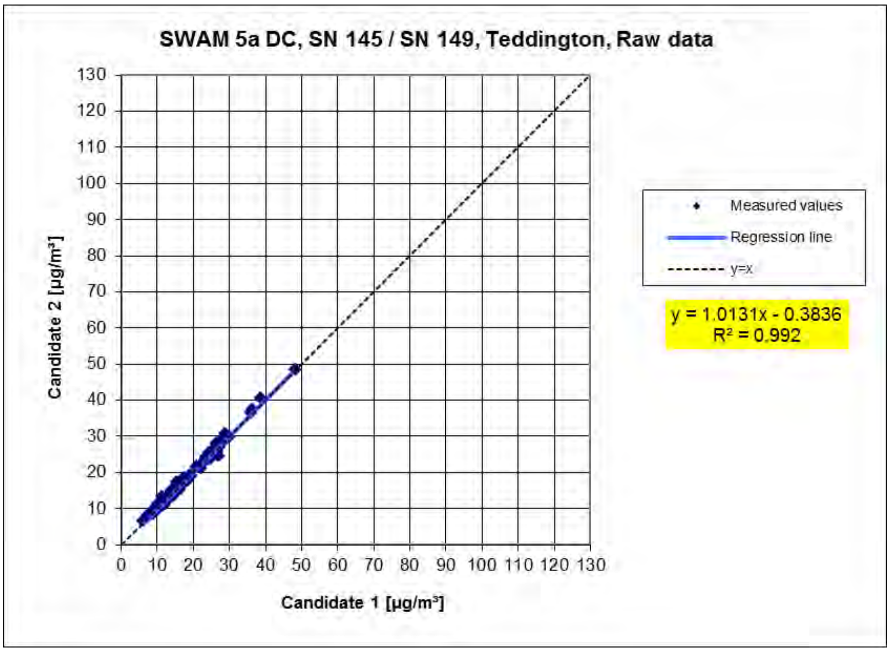


Figure 64: Results of the parallel measurement with instruments SN 145 / SN 149, Component PM_{10}, SWAM 5a DC, Teddington

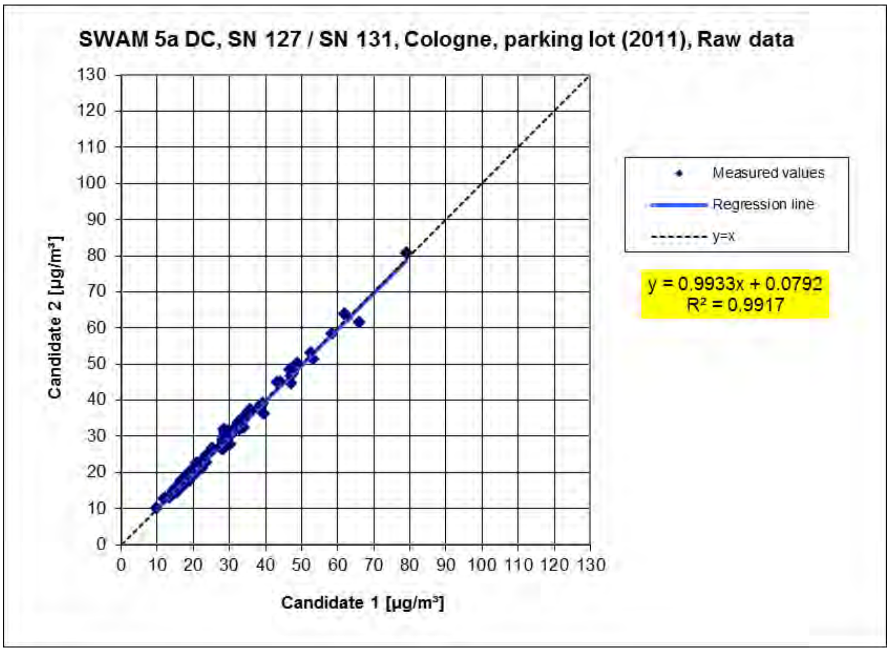


Figure 65: Results of the parallel measurement with instruments SN 127 / SN 131, component PM_{10}, SWAM 5a DC, Cologne, parking lot (2011)

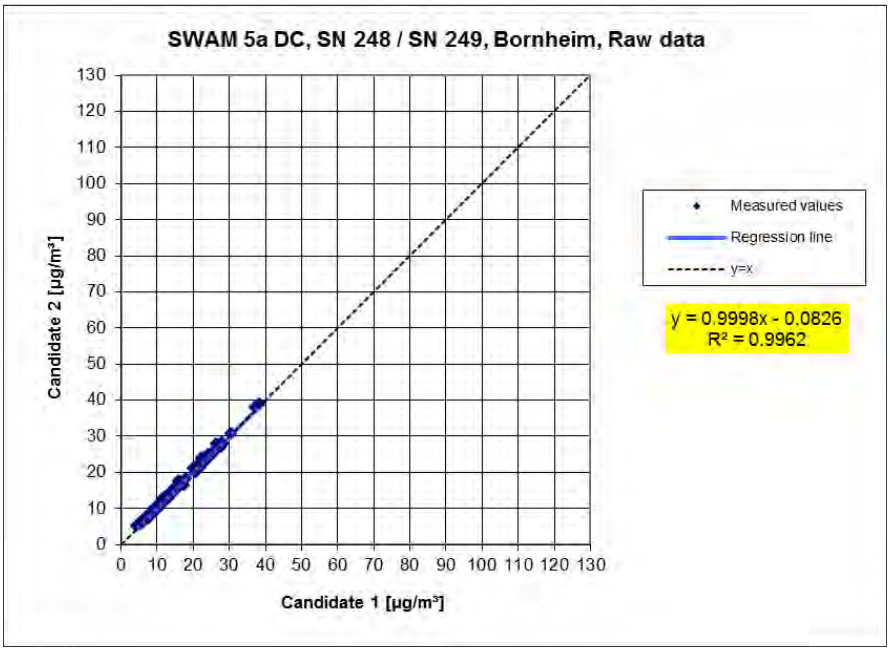


Figure 66: Results of the parallel measurement with instruments SN 248 / SN 249, Component PM_{10}, SWAM 5a DC, Bornheim

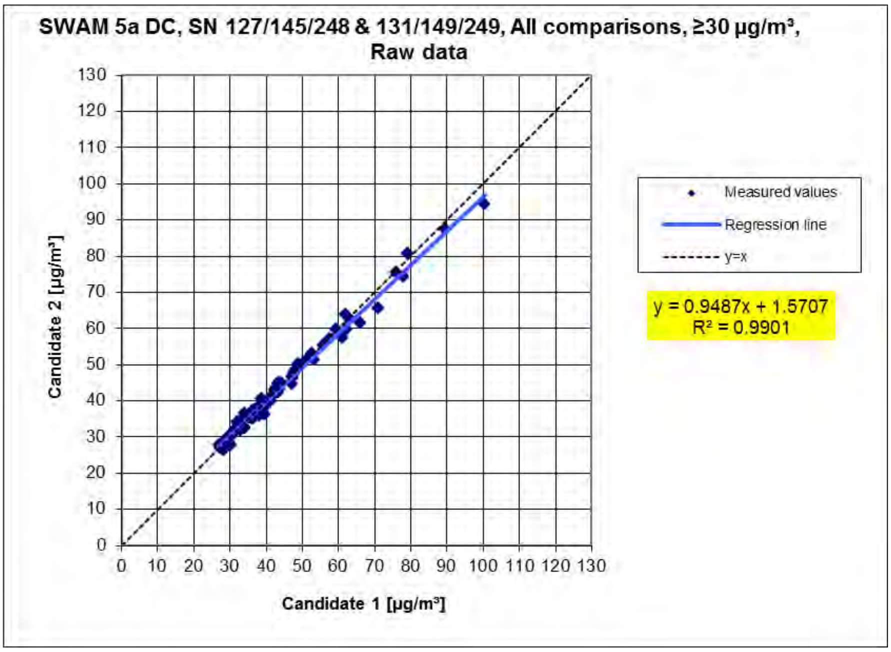


Figure 67: Result of the parallel measurement with instruments SN 127/145/248 and SN 131/149/249, SWAM 5a DC, component PM_{10}, all sites, values ≥ 30 µg/m³

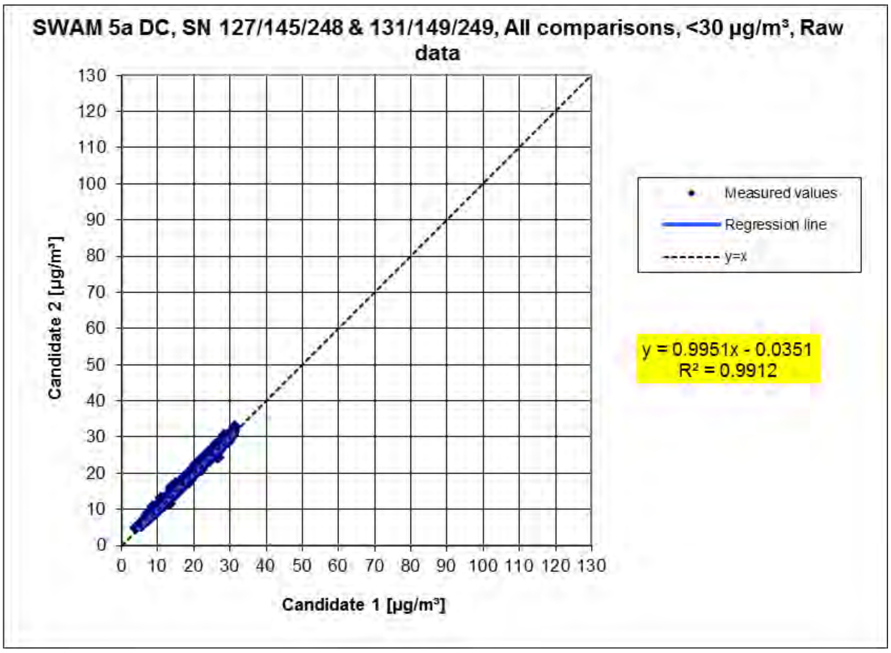


Figure 68: Result of the parallel measurement with instruments SN 127/145/248 and SN 131/149/249, SWAM 5a DC, component PM_{10}, all sites, values < 30 µg/m³

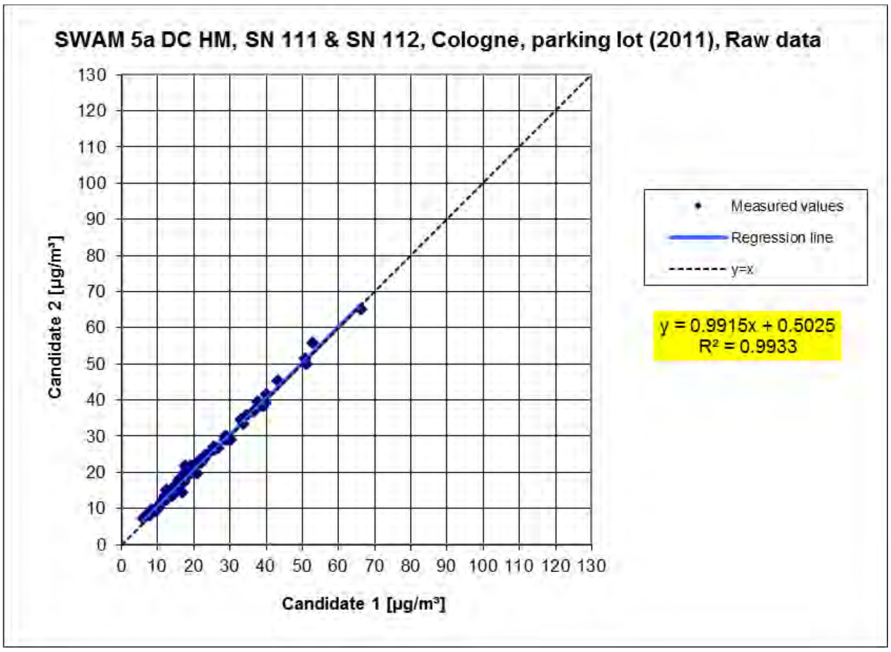


Figure 69: Results of the parallel measurement with instruments SN 111 / SN 112, component $PM_{2.5}$, SWAM 5a DC HM, Cologne, parking lot (2011)

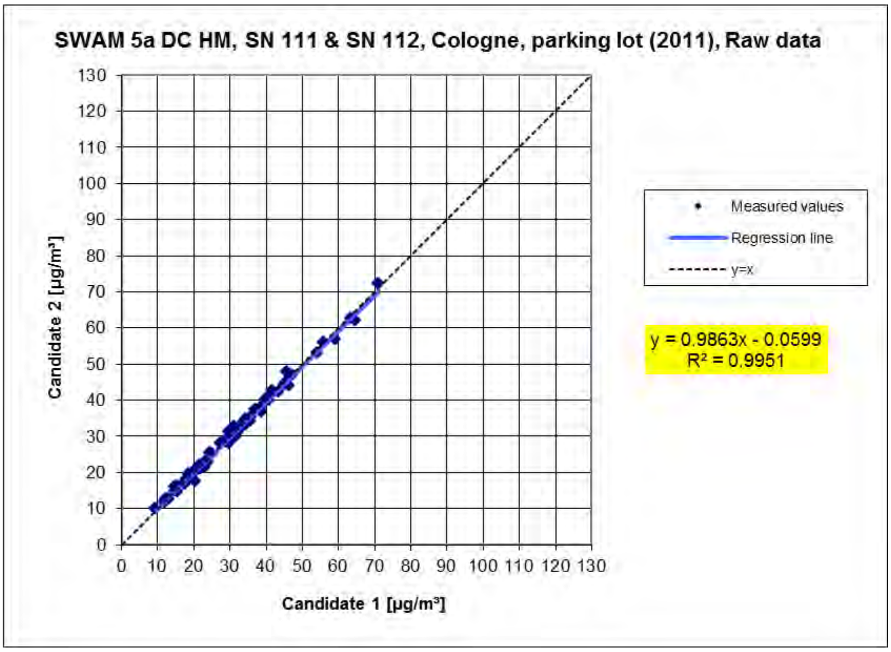


Figure 70: Results of the parallel measurement with instruments SN 111 / SN 112, Component PM_{10}, SWAM 5a DC HM, Cologne, parking lot (2011)

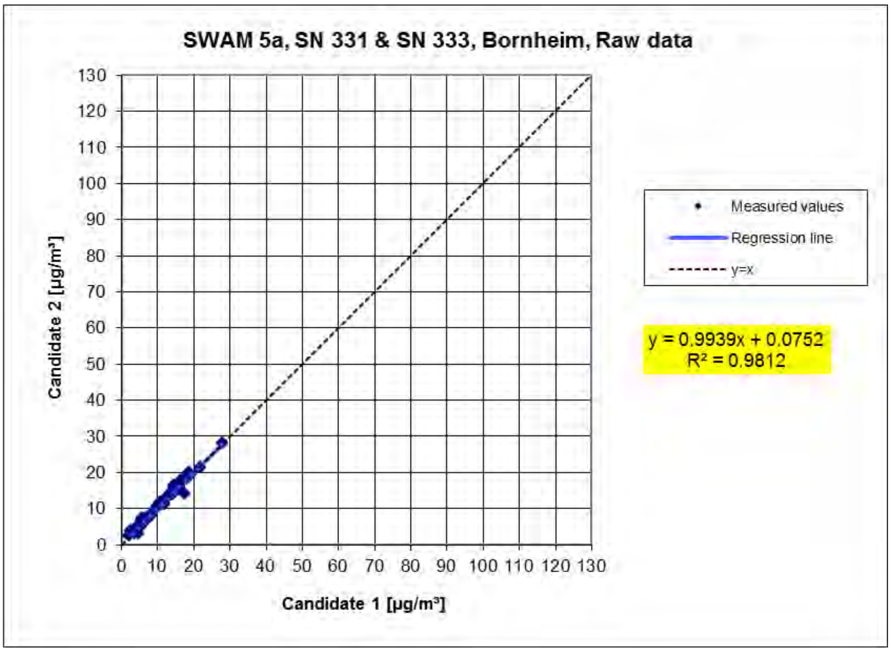


Figure 71: Results of the parallel measurement with instruments SN 331 / SN 333, component $PM_{2.5}$, SWAM 5a, Bornheim

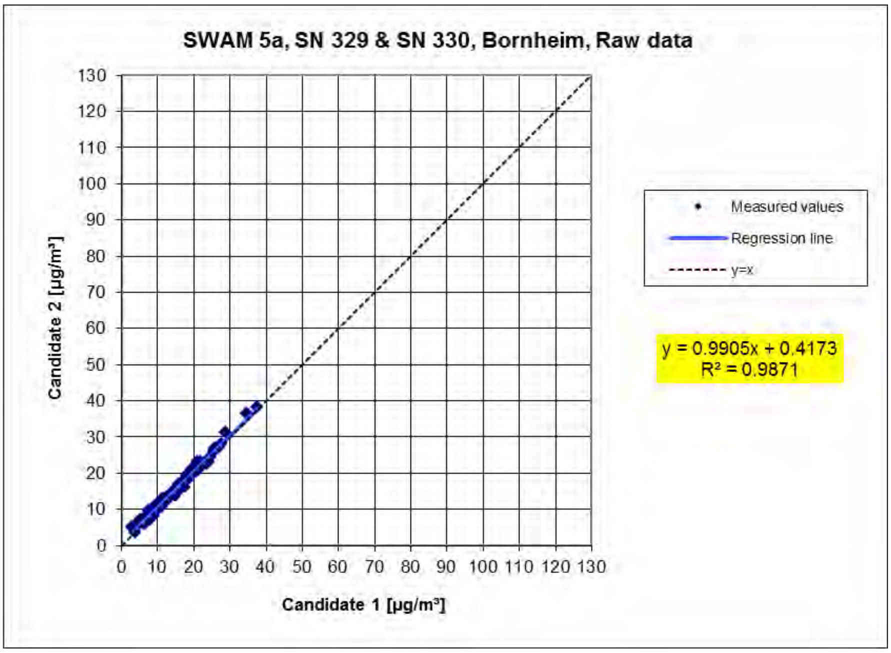


Figure 72: Results of the parallel measurement with instruments SN 329 / SN 330, Component PM_{10}, SWAM 5a DC, Bornheim

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

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

6.2 Equipment

Additional equipment as described in chapter 5 of this report was used for this test.

6.3 Testing

For instrument version SWAM 5a Dual Channel Monitor, this test was part of the original field test as well as of the campaigns for qualifying instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor; a total of 6 comparison campaigns have been performed. 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 shall be greater than the upper assessment threshold of the annual limit value specified in 2008/50/EC [8]. The assessment threshold for $PM_{2.5}$ is 17 µg/m³, for PM_{10} it is 28 µg/m³. Should this not be assured because of low concentration levels, a minimum of 32 value pairs is considered sufficient.

For each comparison campaign, at least 40 valid value pairs were determined. Of the full data set (6 comparisons, for PM_{10}: 409 valid pairs of measured values for SN 127 / SN 145 and SN 248, 419 valid pairs of measured values for SN 131, SN 149 and SN 249; for $PM_{2.5}$: 327 valid pairs of measured values for SN 127 / SN 145 and SN 248, 325 valid pairs of measured values for SN 131, SN 149 and SN 249) 35% of the measured values are above the upper assessment threshold of 17 µg/m³ for $PM_{2.5}$ and 25.8% of the measured values are above the upper assessment threshold of 28 µg/m³ for PM_{10}. The concentrations measured were related to the ambient conditions.

One exemplary measurement campaign each served to demonstrate equivalence of the reference method for the SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor instrument versions.

6.4 Evaluation

[EN 16450, 7.5.8.3]

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

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

Results of the evaluation are summarised in section 6.6.

[EN 16450, 7.5.8.5 & 7.5.8.6]

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

The regression is calculated for:

- all sites or comparisons respectively together
- Every location or comparison separately

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

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

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

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

u_{RM} = is the random uncertainty of the reference method; u_{RM} is calculated as $u_{bs,RM}/\sqrt{2}$, while $u_{bs,RM}$ is the uncertainty between the reference measurement

The algorithms for calculating ordinate intercept a and slope b as well as their variance by means of orthogonal regression are described in detail in the annex to [9].

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

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

Uncertainty u_{CR} is calculated for:

- all sites or comparisons respectively together
- Every location or comparison separately
- 1 data set with measured values $PM_{2.5}$ ≥ 18 µg/m³ (basis: averages of reference measurement)
- 1 data set with measured values PM_{10} ≥ 30 µg/m³ (basis: averages of reference measurement)

The Guide 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 ordinate 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 ordinate intercept calculated as the square root of the variance. If the prerequisites are not met, it is possible to calibrate the measuring systems in accordance with section 9.7 of the Guideline (also see 6.1 17 Use of correction factors/terms). The calibration may only be performed for the full data set.

[EN 16450, 7.5.8.7] For all datasets the combined relative uncertainty of the AMS $w_{c,CM}$ is calculated from a combination of contributions from 9.5.3.1 and 9.5.3.2 in accordance with the following equation:

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

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

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

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

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

[Item 9.6]

The largest resulting uncertainty W_{AMS} is compared and assessed against the criteria for data quality of air quality measurements in accordance with EU Directive [8]. Two situations are conceivable:

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

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

6.5 Assessment

Without the need for any correction factors, the expanded uncertainties WAMS for instrument version SWAM 5a Dual Channel Monitor were below the expanded, relative uncertainty Wdqo defined for fine dust at 25% for $PM_{2.5}$ and PM_{10} for all data sets observed. This also applies to the uncertainties W_{AMS} determined for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a Monitor.

Criterion satisfied? yes

Given the significance of the slope and the intercept for the full data set for $PM_{2.5}$ and the significance of the slope of the full data set for PM_{10} for instrument version SWAM 5a Dual Channel Monitor, correction factors were used in accordance with chapter 6.1 17 Use of correction factors/terms .

During the comparison campaign, no significance of the slope and intercepts were determined for instrument versions SWAM 5a Dual Channel Hourly Mode Monitor and SWAM 5a. In this instance, no correction factors were used.

For SWAM 5a Dual Channel Monitor:

Table 44 and Table 45 below provide an overview of the results of all equivalence tests performed for SWAM 5a Dual Channel Monitor for $PM_{2.5}$ and PM_{10}. Where a criterion was not satisfied, the corresponding line is marked in red.

Table 44: Overview of equivalence testing performed for SWAM 5a Dual Channel Monitor for $PM_{2.5}$

Comparison candidate with reference according to Standard EN 16450: 2017					
Candidate	SWAM 5a DC		SN	N 127/145/248 & SN 131/149/249	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.51**	**µg/m³**			
Uncertainty between Candidates	**0.71**	**µg/m³**			
SN 127/145/248 & SN 131/149/249					
Number of data pairs	**312**				
Slope b	**0.973**	**significant**			
Uncertainty of b	**0.010**				
Ordinate intercept a	**0.355**	**not significant**			
Uncertainty of a	**0.184**				
Expanded meas. uncertainty W_{CM}	**12.22**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.64**	**µg/m³**			
Uncertainty between Candidates	**0.79**	**µg/m³**			
SN 127/145/248 & SN 131/149/249					
Number of data pairs	**91**				
Slope b	**1.051**				
Uncertainty of b	**0.029**				
Ordinate intercept a	**-2.028**				
Uncertainty of a	**0.804**				
Expanded meas. uncertainty W_{CM}	**15.55**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.50**	**µg/m³**			
Uncertainty between Candidates	**0.45**	**µg/m³**			
SN 127/145/248 & SN 131/149/249					
Number of data pairs	**221**				
Slope b	**0.959**				
Uncertainty of b	**0.022**				
Ordinate intercept a	**0.606**				
Uncertainty of a	**0.237**				
Expanded meas. uncertainty W_{CM}	**10.77**	**%**			

Comparison candidate with reference according to Standard EN 16450: 2017				
Candidate	SWAM 5a DC	SN	N 127/145/248 & SN 131/149/249	
		Limit value	30	µg/m³
Status of measured values	Raw data	Allowed uncertainty	25	%
Cologne, parking lot (2007)				
Uncertainty between Reference	0.67	µg/m³		
Uncertainty between Candidates	0.69	µg/m³		
	SN 127		SN 131	
Number of data pairs	45		46	
Slope b	1.000		0.967	
Uncertainty of b	0.023		0.022	
Ordinate intercept a	-0.275		-0.002	
Uncertainty of a	0.382		0.380	
Expanded meas. uncertainty W_{CM}	7.35	%	9.71	%
Bonn, Belderberg				
Uncertainty between Reference	0.46	µg/m³		
Uncertainty between Candidates	0.42	µg/m³		
	SN 127		SN 131	
Number of data pairs	41		41	
Slope b	0.996		1.023	
Uncertainty of b	0.019		0.021	
Ordinate intercept a	-1.208		-2.010	
Uncertainty of a	0.443		0.490	
Expanded meas. uncertainty W_{CM}	11.72	%	12.31	%
Bruehl				
Uncertainty between Reference	0.65	µg/m³		
Uncertainty between Candidates	0.63	µg/m³		
	SN 127		SN 131	
Number of data pairs	43		45	
Slope b	0.985		1.003	
Uncertainty of b	0.032		0.032	
Ordinate intercept a	-0.956		-1.187	
Uncertainty of a	0.495		0.519	
Expanded meas. uncertainty W_{CM}	12.78	%	12.01	%
Teddington				
Uncertainty between Reference	0.33	µg/m³		
Uncertainty between Candidates	0.44	µg/m³		
	SN 145		SN 149	
Number of data pairs	74		80	
Slope b	0.977		0.974	
Uncertainty of b	0.022		0.020	
Ordinate intercept a	1.139		1.352	
Uncertainty of a	0.282		0.245	
Expanded meas. uncertainty W_{CM}	10.12	%	9.48	%
Cologne, parking lot (2011)				
Uncertainty between Reference	0.52	µg/m³		
Uncertainty between Candidates	1.33	µg/m³		
	SN 127		SN 131	
Number of data pairs	67		53	
Slope b	1.024		0.972	
Uncertainty of b	0.026		0.031	
Ordinate intercept a	-0.511		0.642	
Uncertainty of a	0.617		0.802	
Expanded meas. uncertainty W_{CM}	16.12	%	18.59	%
Bornheim				
Uncertainty between Reference	0.65	µg/m³		
Uncertainty between Candidates	0.32	µg/m³		
	SN 248		SN 249	
Number of data pairs	57		60	
Slope b	1.053		1.062	
Uncertainty of b	0.040		0.042	
Ordinate intercept a	0.159		0.040	
Uncertainty of a	0.429		0.443	
Expanded meas. uncertainty W_{CM}	15.50	%	16.72	%
All comparisons, ≥18 µg/m³				
Uncertainty between Reference	0.64	µg/m³		
Uncertainty between Candidates	0.79	µg/m³		
	SN 127 / SN 145 / SN 248		SN 131 / SN 149 / SN 249	
Number of data pairs	95		95	
Slope b	1.067		1.023	
Uncertainty of b	0.029		0.029	
Ordinate intercept a	-2.358		-1.408	
Uncertainty of a	0.810		0.81	
Expanded meas. uncertainty W_{CM}	15.83	%	16.22	%
All comparisons, <18 µg/m³				
Uncertainty between Reference	0.50	µg/m³		
Uncertainty between Candidates	0.45	µg/m³		
	SN 127 / SN 145 / SN 248		SN 131 / SN 149 / SN 249	
Number of data pairs	232		230	
Slope b	0.958		0.985	
Uncertainty of b	0.021		0.024	
Ordinate intercept a	0.593		0.413	
Uncertainty of a	0.226		0.252	
Expanded meas. uncertainty W_{CM}	10.47	%	10.92	%
All comparisons				
Uncertainty between Reference	0.51	µg/m³		
Uncertainty between Candidates	0.71	µg/m³		
	SN 127 / SN 145 / SN 248		SN 131 / SN 149 / SN 249	
Number of data pairs	327		325	
Slope b	0.981	not significant	0.963	significant
Uncertainty of b	0.010		0.011	
Ordinate intercept a	0.247	not significant	0.496	significant
Uncertainty of a	0.182		0.188	
Expanded meas. uncertainty W_{CM}	12.00	%	13.01	%

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: For candidate systems SN 131/149/249, the slope and the intercept for the evaluation of the full data set significantly exceeds the permissible value.

Additional: The slope determined for the full data set regarding both candidate systems combined was at 0.973, the ordinate intercept was at 0.355 at a total ex panded uncertainty of 12.22%.

Table 45: Overview of equivalence testing performed for SWAM 5a Dual Channel Monitor for PM_{10}

Comparison candidate with reference according to Standard EN 16450: 2017					
Candidate	SWAM 5a DC		SN	N 127/145/248 & SN 131/149/249	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.75**	**µg/m³**			
Uncertainty between Candidates	**0.66**	**µg/m³**			
	SN 127/145/248 & SN 131/149/249				
Number of data pairs	**404**				
Slope b	**1.051**	**significant**			
Uncertainty of b	**0.009**				
Ordinate intercept a	**-0.271**	**not significant**			
Uncertainty of a	**0.240**				
Expanded measured uncertainty WCM	**13.08**	**%**			
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	**0.78**	**µg/m³**			
Uncertainty between Candidates	**1.19**	**µg/m³**			
	SN 127/145/248 & SN 131/149/249				
Number of data pairs	**83**				
Slope b	**1.169**				
Uncertainty of b	**0.032**				
Ordinate intercept a	**-5.643**				
Uncertainty of a	**1.374**				
Expanded measured uncertainty WCM	**18.07**	**%**			
All comparisons, <30 µg/m³					
Uncertainty between Reference	**0.74**	**µg/m³**			
Uncertainty between Candidates	**0.46**	**µg/m³**			
	SN 127/145/248 & SN 131/149/249				
Number of data pairs	**321**				
Slope b	**1.013**				
Uncertainty of b	**0.016**				
Ordinate intercept a	**0.519**				
Uncertainty of a	**0.290**				
Expanded measured uncertainty WCM	**8.59**	**%**			

Comparison candidate with reference according to Standard EN 16450: 2017				
Candidate	SWAM 5a DC	SN	N 127/145/248 & SN 131/149/249	
		Limit value	50	µg/m³
Status of measured values	Raw data	Allowed uncertainty	25	%
Cologne, parking lot (2007)				
Uncertainty between Reference	1.12	µg/m³		
Uncertainty between Candidates	0.87	µg/m³		
	SN 127		**SN 131**	
Number of data pairs	98		100	
Slope b	1.126		1.074	
Uncertainty of b	0.012		0.011	
Ordinate intercept a	-0.329		0.408	
Uncertainty of a	0.338		0.310	
Expanded measured uncertainty W_{CM}	24.78	%	17.49	%
Bonn, Belderberg				
Uncertainty between Reference	0.53	µg/m³		
Uncertainty between Candidates	0.45	µg/m³		
	SN 127		**SN 131**	
Number of data pairs	62		62	
Slope b	1.131		1.115	
Uncertainty of b	0.022		0.020	
Ordinate intercept a	-1.185		-1.051	
Uncertainty of a	0.570		0.540	
Expanded measured uncertainty W_{CM}	22.66	%	19.87	%
Bruehl				
Uncertainty between Reference	0.77	µg/m³		
Uncertainty between Candidates	0.56	µg/m³		
	SN 127		**SN 131**	
Number of data pairs	51		53	
Slope b	1.048		1.037	
Uncertainty of b	0.027		0.025	
Ordinate intercept a	-1.928		-1.693	
Uncertainty of a	0.646		0.600	
Expanded measured uncertainty W_{CM}	7.31	%	6.70	%
Teddington				
Uncertainty between Reference	0.45	µg/m³		
Uncertainty between Candidates	0.53	µg/m³		
	SN 145		**SN 149**	
Number of data pairs	73		79	
Slope b	0.949		0.970	
Uncertainty of b	0.021		0.021	
Ordinate intercept a	2.478		2.010	
Uncertainty of a	0.398		0.390	
Expanded measured uncertainty W_{CM}	5.93	%	6.30	%
Cologne, parking lot (2011)				
Uncertainty between Reference	0.59	µg/m³		
Uncertainty between Candidates	0.88	µg/m³		
	SN 127		**SN 131**	
Number of data pairs	69		66	
Slope b	1.034		1.034	
Uncertainty of b	0.022		0.025	
Ordinate intercept a	-1.681		-2.100	
Uncertainty of a	0.765		0.879	
Expanded measured uncertainty W_{CM}	9.75	%	11.11	%
Bornheim				
Uncertainty between Reference	0.63	µg/m³		
Uncertainty between Candidates	0.35	µg/m³		
	SN 248		**SN 249**	
Number of data pairs	56		59	
Slope b	1.043		1.042	
Uncertainty of b	0.033		0.034	
Ordinate intercept a	-0.628		-0.786	
Uncertainty of a	0.582		0.598	
Expanded measured uncertainty W_{CM}	9.28	%	9.03	%
All comparisons, ≥30 µg/m³				
Uncertainty between Reference	0.78	µg/m³		
Uncertainty between Candidates	1.19	µg/m³		
	SN 127 / SN 145 / SN 248		**SN 131 / SN 149 / SN 249**	
Number of data pairs	86		85	
Slope b	1.197		1.143	
Uncertainty of b	0.033		0.032	
Ordinate intercept a	-6.504		-4.923	
Uncertainty of a	1.399		1.39	
Expanded measured uncertainty W_{CM}	19.79	%	16.77	%
All comparisons, <30 µg/m³				
Uncertainty between Reference	0.74	µg/m³		
Uncertainty between Candidates	0.46	µg/m³		
	SN 127 / SN 145 / SN 248		**SN 131 / SN 149 / SN 249**	
Number of data pairs	323		334	
Slope b	1.016		1.016	
Uncertainty of b	0.016		0.015	
Ordinate intercept a	0.538		0.414	
Uncertainty of a	0.296		0.286	
Expanded measured uncertainty W_{CM}	9.10	%	8.71	%
All comparisons				
Uncertainty between Reference	0.75	µg/m³		
Uncertainty between Candidates	0.66	µg/m³		
	SN 127 / SN 145 / SN 248		**SN 131 / SN 149 / SN 249**	
Number of data pairs	409		419	
Slope b	1.062	significant	1.038	significant
Uncertainty of b	0.010		0.009	
Ordinate intercept a	-0.416	not significant	-0.091	not significant
Uncertainty of a	0.249		0.235	
Expanded measured uncertainty W_{CM}	14.54	%	11.70	%

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

Criterion 1: More than 38 valid value pairs exceed 28 µg/m³.

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

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

Criterion 4: All expanded uncertainties remained below 25%.

Criterion 5: For both sets of candidate systems the slope determined when assessing the full data set exceeded permissible limits.

Additional: The slope determined for the full data set regarding both candidate systems combined was at 1.051, the ordinate intercept was at -0.271 at a total expand ed uncertainty of 13.08%.

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

Consequently and according to Table 44, the slope and intercept of SN 131/149/249 for $PM_{2.5}$ need to be corrected. Given the significance determined for PM_{10} for both sets of candidate systems as illustrated in Table 45, the slope had to be corrected.

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

For $PM_{2.5}$:

The slope for the entire data set is 0.973.

The intercept for the full data set is 0.355.

This is why chapter 6.1 17 Use of correction factors/terms contains an additional assessment for which the corresponding calibration factors were applied to the data sets.

For PM_{10}:

The slope for the entire data set is 1.051.

This is why chapter 6.1 17 Use of correction factors/terms contains an additional assessment for which the corresponding calibration factor was applied to the data sets.

For compliant monitoring, the revised version of the January 2010 Guide and standard EN 16450 require continuous random checks of a certain number of instruments in a measurement grid and specify the number of measurement sites to be checked as a function of the expanded uncertainty of a measuring system. The operator of the measurement grid or the competent authority of a member state is responsible for compliant implementation. However, TÜV Rheinland recommend that the expanded uncertainty of the entire data set (in the present case, the uncorrected raw data) be used for this purpose: 12.22% for $PM_{2.5}$, implying annual checks at three measurement locations and 13.08% for PM_{10} also implying checks a year at three measurement locations (Guide [5], Chapter 9.9.2, Table 6 or EN 16450 [9], Chapter 8.6.2, Table 5).

As a result of the necessary use of calibration factors, this assessment shall be based on on the evaluation of the corrected data sets (see chapter 6.1 17 Use of correction factors/terms).

For SWAM 5a Dual Channel Hourly Mode Monitor:

Table 46 and Table 47 below provide and overview of the results for equivalence testing obtained for instrument version SWAM 5a Dual Channel Hourly Mode Monitor for $PM_{2.5}$ and PM_{10}. Where a criterion was not satisfied, the corresponding line is marked in red.

Table 46: Overview of equivalence testing performed for SWAM 5a Dual Channel Hourly Mode Monitor for $PM_{2.5}$

Comparison candidate with reference according to Standard EN 16450: 2017					
Candidate	SWAM 5a DC HM		SN	SN 111 & SN 112	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.52**	**µg/m³**			
Uncertainty between Candidates	**0.74**	**µg/m³**			
	SN 111 & SN 112				
Number of data pairs	**61**				
Slope b	**0.998**	**not significant**			
Uncertainty of b	**0.016**				
Ordinate intercept a	**0.685**	**not significant**			
Uncertainty of a	**0.393**				
Expanded meas. uncertainty W_{CM}	**10.68**	**%**			
Cologne, parking lot (2011)					
Uncertainty between Reference	**0.52**	**µg/m³**			
Uncertainty between Candidates	**0.74**	**µg/m³**			
	SN 111			**SN 112**	
Number of data pairs	**68**			**61**	
Slope b	**1.005**			**0.992**	
Uncertainty of b	**0.018**			**0.018**	
Ordinate intercept a	**0.657**			**0.901**	
Uncertainty of a	**0.429**			**0.428**	
Expanded meas. uncertainty W_{CM}	**12.28**	**%**		**11.58**	**%**

Table 47: Overview of equivalence testing performed for SWAM 5a Dual Channel Hourly Mode Monitor for PM_{10}

Comparison candidate with reference according to Standard EN 16450: 2017					
Candidate	SWAM 5a DC HM		SN	SN 111 & SN 112	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.59**	**µg/m³**			
Uncertainty between Candidates	**0.73**	**µg/m³**			
	SN 111 & SN 112				
Number of data pairs	**63**				
Slope b	**0.972**	**not significant**			
Uncertainty of b	**0.016**				
Ordinate intercept a	**-0.305**	**not significant**			
Uncertainty of a	**0.548**				
Expanded measured uncertainty WCM	**9.47**	**%**			
Cologne, parking lot (2011)					
Uncertainty between Reference	**0.59**	**µg/m³**			
Uncertainty between Candidates	**0.73**	**µg/m³**			
	SN 111			**SN 112**	
Number of data pairs	**71**			**63**	
Slope b	**0.982**			**0.965**	
Uncertainty of b	**0.018**			**0.015**	
Ordinate intercept a	**-0.079**			**-0.314**	
Uncertainty of a	**0.634**			**0.535**	
Expanded measured uncertainty W_{CM}	**8.92**	**%**		**10.50**	**%**

For SWAM 5a Monitor:

Table 48 and Table 49 below provide an overview of the results of all equivalence tests performed for swam 5a Monitor for $PM_{2.5}$ and PM_{10}. Where a criterion was not satisfied, the corresponding line is marked in red.

Table 48: Overview of equivalence testing performed for SWAM 5a Monitor for $PM_{2.5}$

Comparison candidate with reference according to Standard EN 16450: 2017					
Candidate	SWAM 5a		SN	SN 331 & SN 333	
			Limit value	30	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.65**	**µg/m³**			
Uncertainty between Candidates	**0.56**	**µg/m³**			
	SN 331 & SN 333				
Number of data pairs	**40**				
Slope b	**0.971**	**not significant**			
Uncertainty of b	**0.041**				
Ordinate intercept a	**0.235**	**not significant**			
Uncertainty of a	**0.455**				
Expanded meas. uncertainty W_{CM}	**10.01**	**%**			
Bornheim					
Uncertainty between Reference	**0.65**	**µg/m³**			
Uncertainty between Candidates	**0.56**	**µg/m³**			
	SN 331			**SN 333**	
Number of data pairs	**40**			**60**	
Slope b	**0.976**			**1.031**	
Uncertainty of b	**0.038**			**0.047**	
Ordinate intercept a	**0.157**			**-0.022**	
Uncertainty of a	**0.419**			**0.491**	
Expanded meas. uncertainty W_{CM}	**9.03**	**%**		**13.60**	**%**

Table 49: Overview of equivalence testing performed for SWAM 5a Monitor for PM_{10}

Comparison candidate with reference according to Standard EN 16450: 2017					
Candidate	SWAM 5a		SN	SN 329 & SN 330	
			Limit value	50	µg/m³
Status of measured values	Raw data		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.63**	**µg/m³**			
Uncertainty between Candidates	**0.63**	**µg/m³**			
	SN 329 & SN 330				
Number of data pairs	**59**				
Slope b	**1.007**	**not significant**			
Uncertainty of b	**0.035**				
Ordinate intercept a	**-0.900**	**not significant**			
Uncertainty of a	**0.627**				
Expanded measured uncertainty WCM	**8.04**	**%**			
Bornheim					
Uncertainty between Reference	**0.63**	**µg/m³**			
Uncertainty between Candidates	**0.63**	**µg/m³**			
	SN 329			**SN 330**	
Number of data pairs	**59**			**59**	
Slope b	**1.012**			**1.006**	
Uncertainty of b	**0.037**			**0.036**	
Ordinate intercept a	**-1.111**			**-0.746**	
Uncertainty of a	**0.648**			**0.636**	
Expanded measured uncertainty W_{CM}	**8.29**	**%**		**8.06**	**%**

6.6 Detailed presentation of test results

Table 50 and Table 51 provide an overview of the between-RM uncertainties $u_{bs,RM}$ determined during the field tests.

Table 50: Between-RM uncertainty $u_{bs,RM}$ for $PM_{2.5}$

Reference instruments	Test site	Number of measurements	Uncertainty $u_{bs,RM}$
No.			µg/m³
1 / 2	Cologne, parking lot, 2007	46	0.67
1 / 2	Bonn, Belderberg	43	0.46
1 / 2	Brühl	48	0.65
1 / 2	Teddington	81	0.33
1 / 2	Cologne, parking lot, 2011	71	0.52
1 / 2	Bornheim	60	0.65
1 / 2	All test sites	332	0.71

Table 51: Between-RM uncertainty $u_{bs,RM}$ for PM_{10}

Reference instruments	Test site	Number of measurements	Uncertainty $u_{bs,RM}$
No.			µg/m³
1 / 2	Cologne, parking lot, 2007	102	1.12
1 / 2	Bonn, Belderberg	65	0.53
1 / 2	Brühl	58	0.77
1 / 2	Teddington	81	0.45
1 / 2	Cologne, parking lot, 2011	73	0.59
1 / 2	Bornheim	59	0.63
1 / 2	All test sites	423	0.75

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

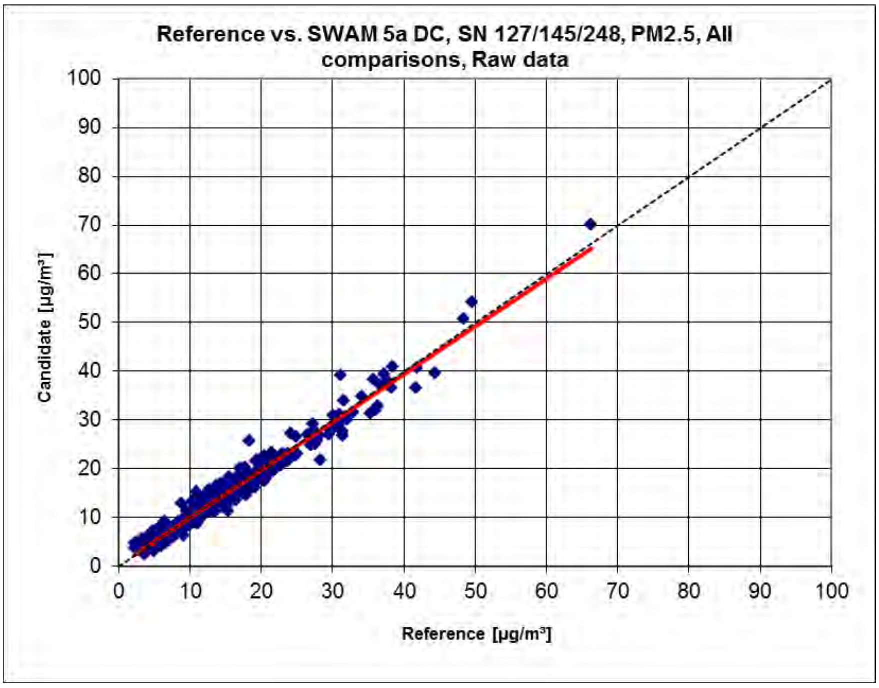


Figure 73: Reference vs. candidate system, SWAM 5a DC, SN 127/145/248, component $PM_{2.5}$, all sites

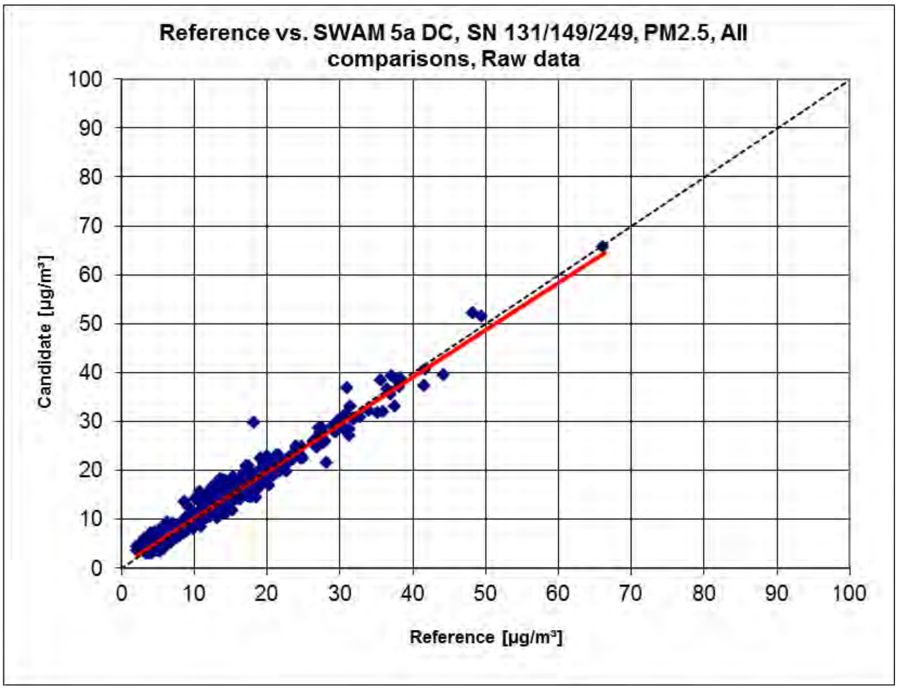


Figure 74: Reference vs. candidate system, SWAM 5a DC, SN 131/149/249, component $PM_{2.5}$, all sites

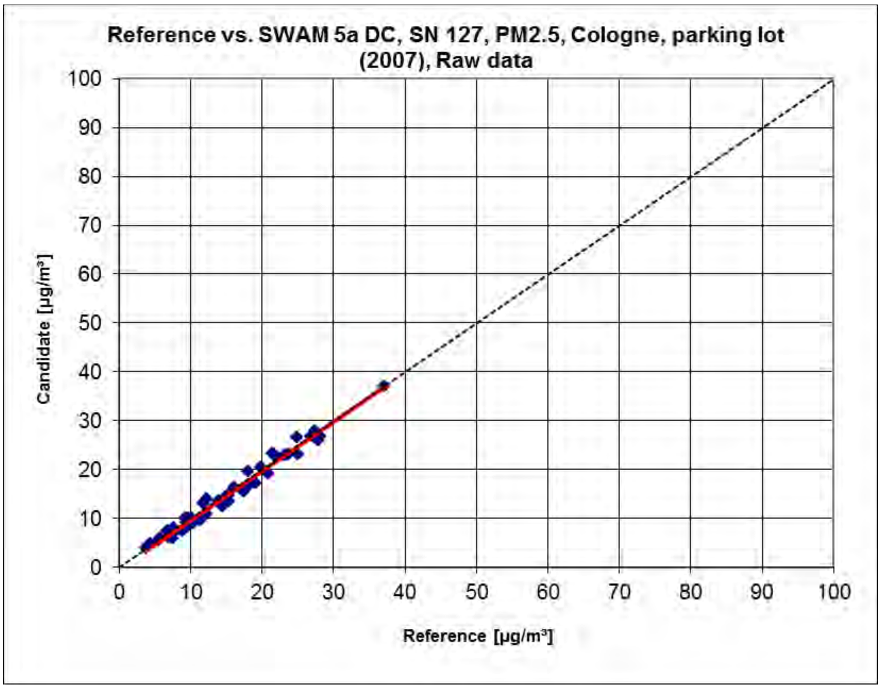


Figure 75: Reference vs. candidate system, SWAM 5a DC, SN 127, component $PM_{2.5}$, Cologne, parking lot (2007)

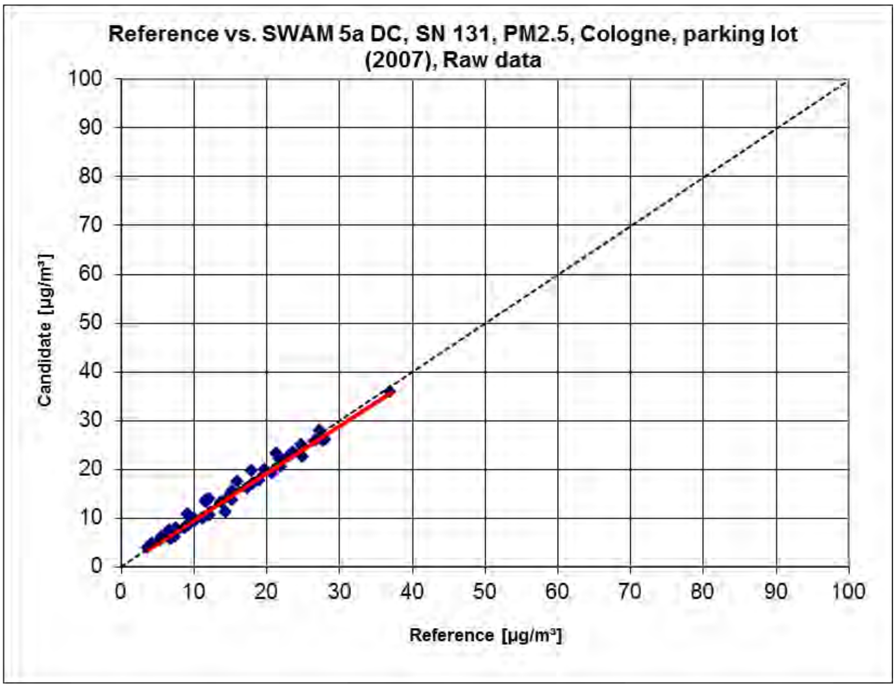


Figure 76: Reference Vs. candidate system, SWAM 5a DC, SN 131, component $PM_{2.5}$, Cologne, parking lot (2007)

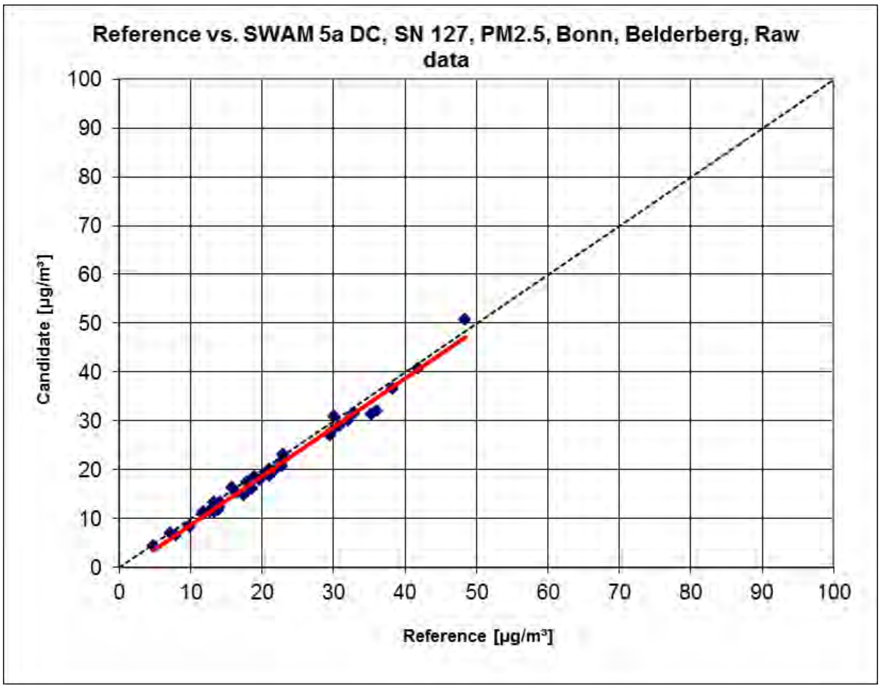


Figure 77: Reference Vs. candidate system, SWAM 5a DC, SN 127, component $PM_{2.5}$, Bonn, Belderberg

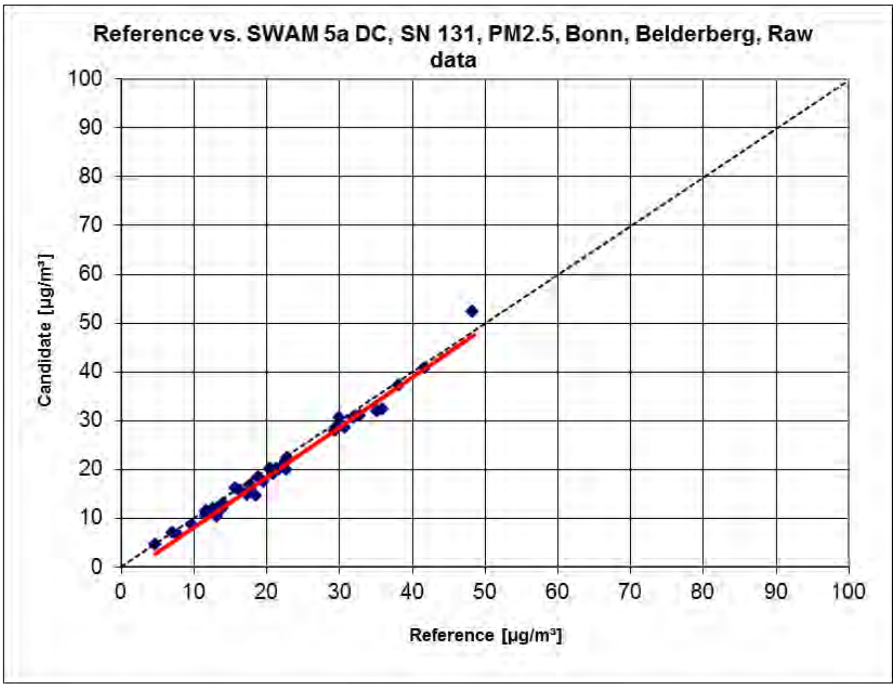


Figure 78: Reference vs. candidate system, SWAM 5a DC, SN 131, component $PM_{2.5}$, Bonn, Belderberg

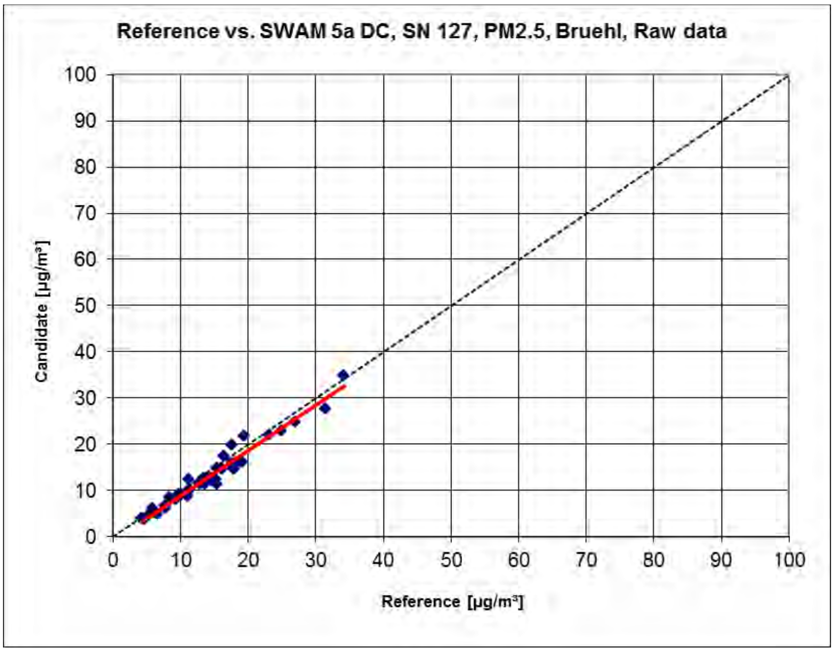


Figure 79: Reference vs. candidate system, SWAM 5a DC, SN 127, component $PM_{2.5}$, Brühl

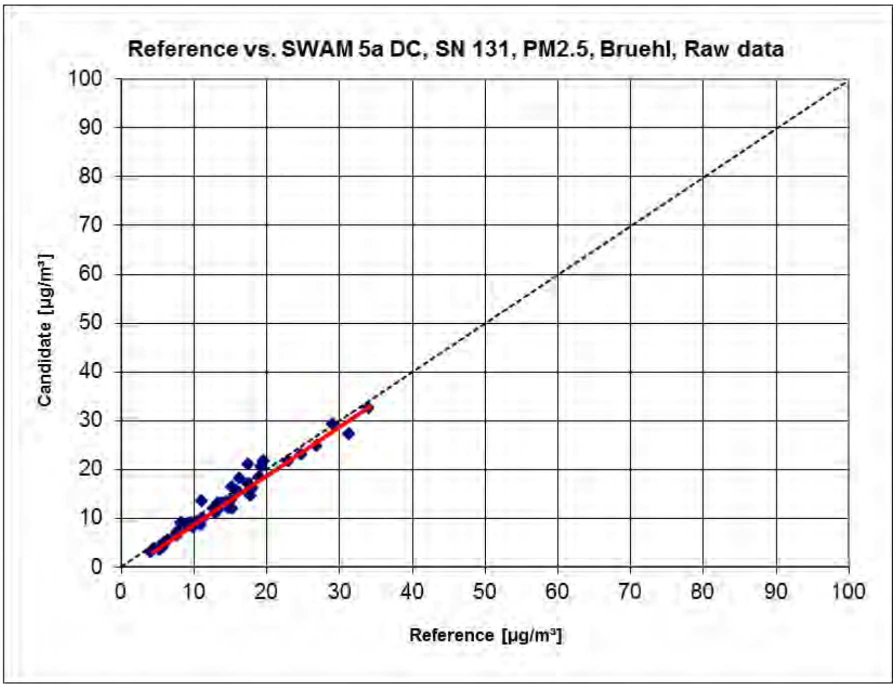


Figure 80: Reference vs. candidate system, SWAM 5a DC, SN 131, component $PM_{2.5}$, Brühl

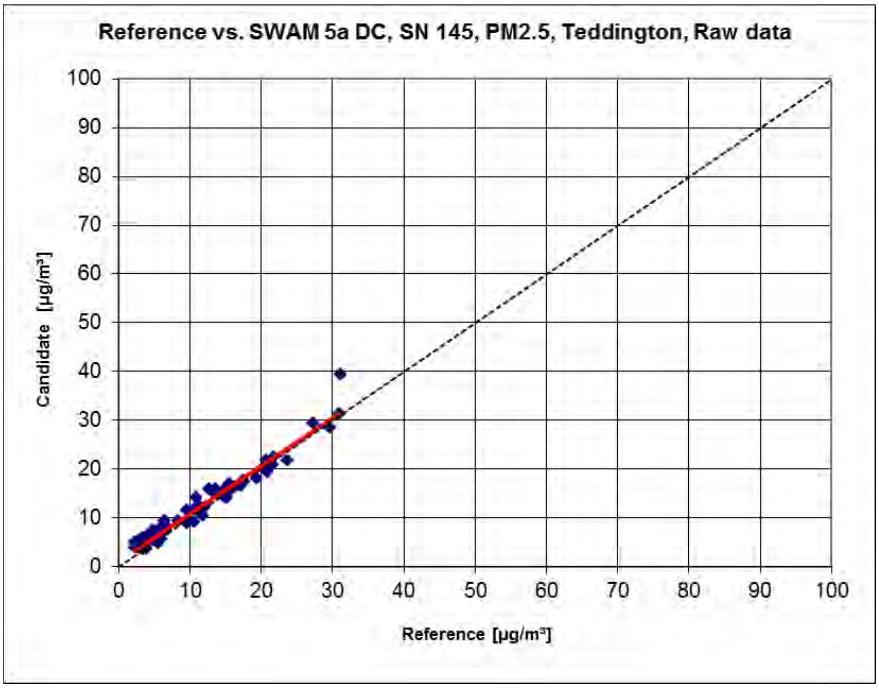


Figure 81: Reference vs. candidate system, SWAM 5a DC, SN 145, component $PM_{2.5}$, Teddington

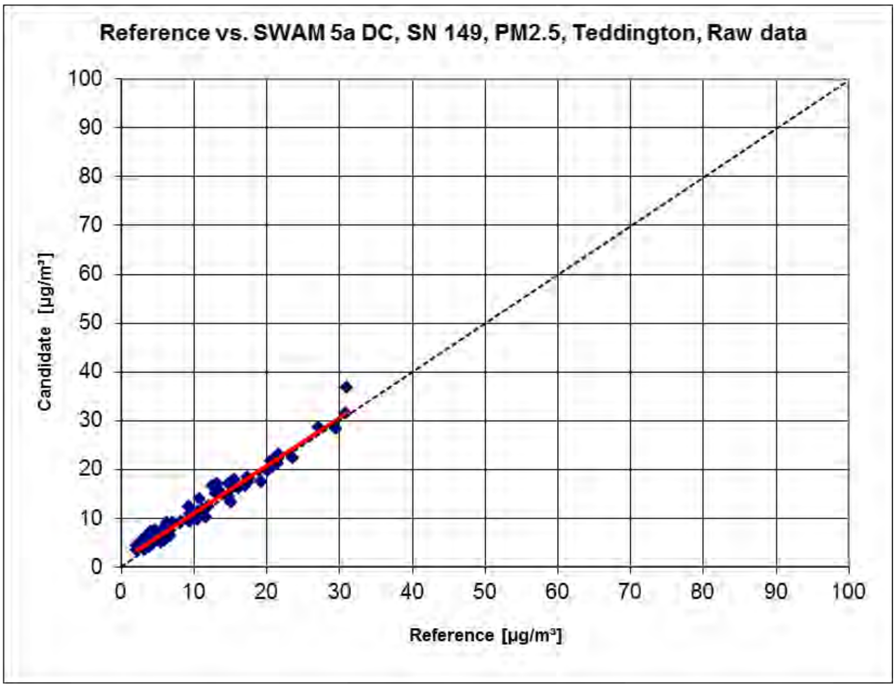


Figure 82: Reference vs. candidate system, SWAM 5a DC, SN 149, component $PM_{2.5}$, Teddington

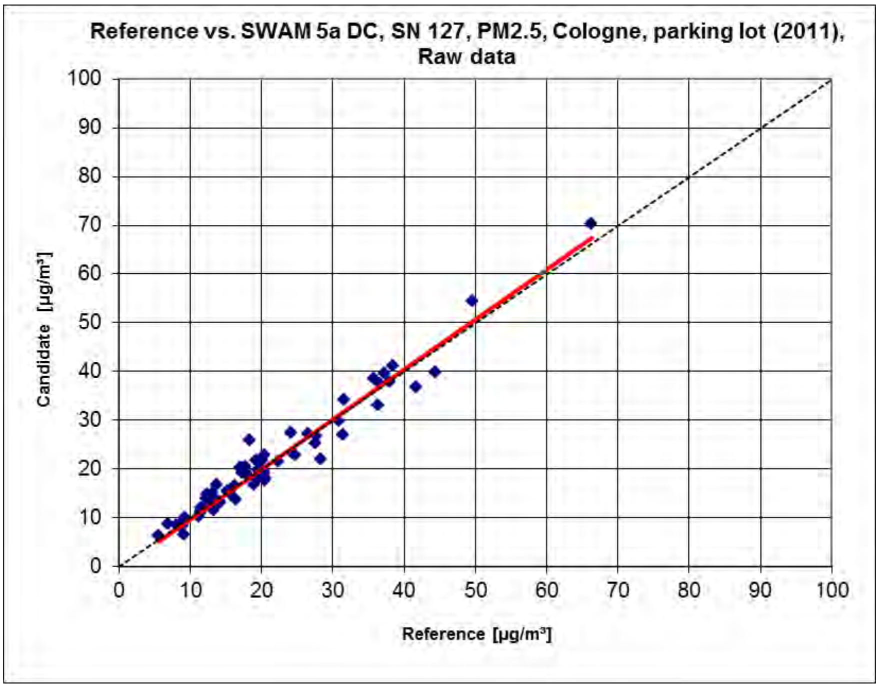


Figure 83: Reference vs. candidate system, SWAM 5a DC, SN 127, component $PM_{2.5}$, Cologne, parking lot (2011)

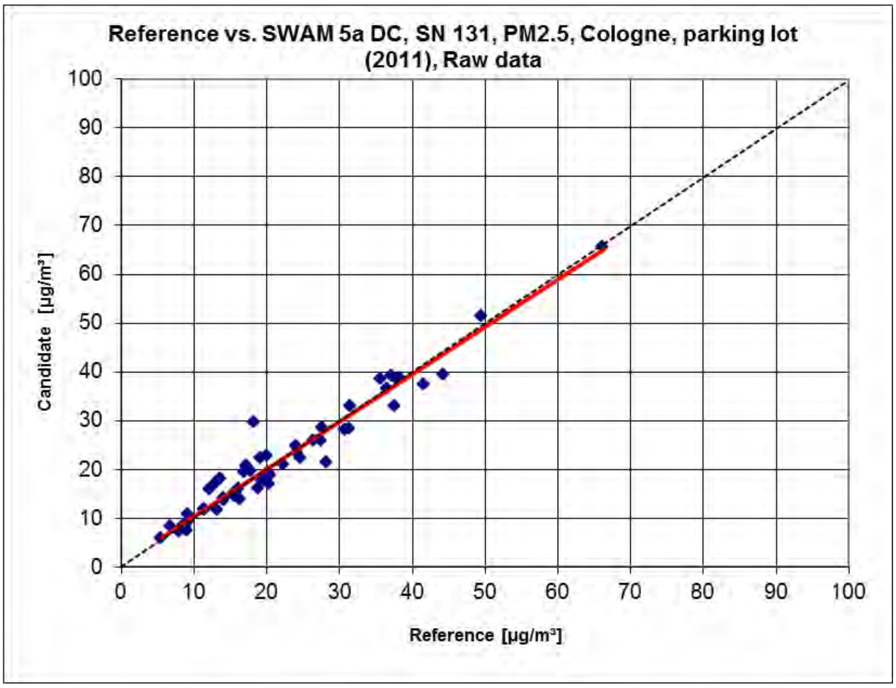


Figure 84: Reference vs. candidate system, SWAM 5a DC, SN 131, component $PM_{2.5}$, Cologne, parking lot (2011)

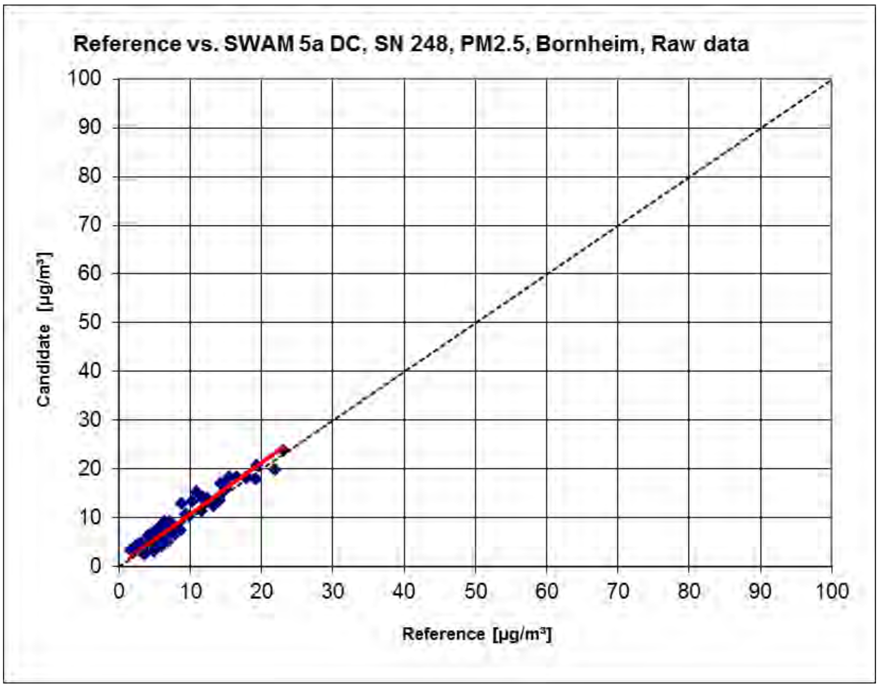


Figure 85: Reference vs. candidate system, SWAM 5a DC, SN 248, component $PM_{2.5}$, Bornheim

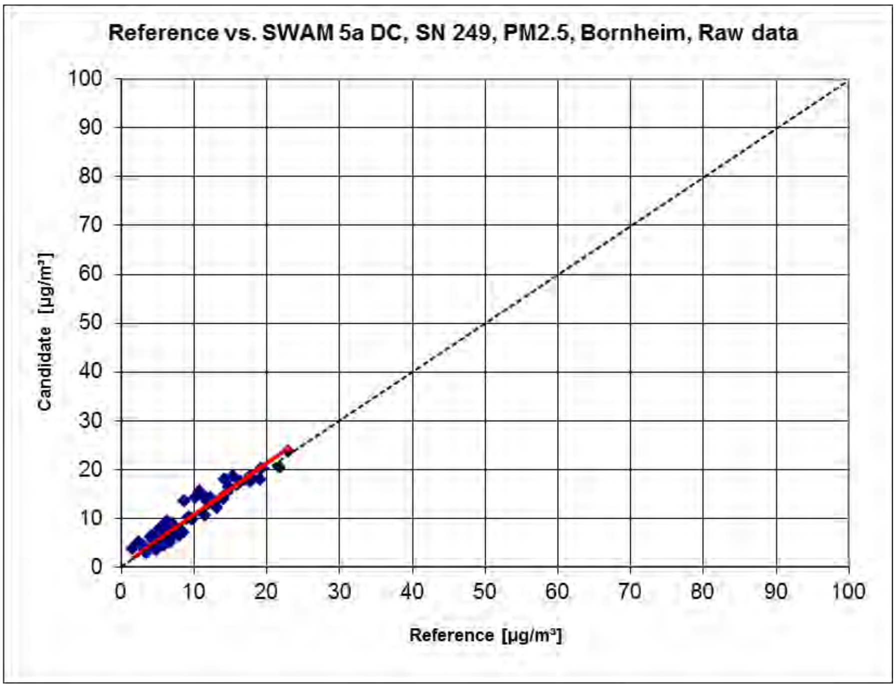


Figure 86: Reference vs. candidate system, SWAM 5a DC, SN 249, component $PM_{2.5}$, Bornheim

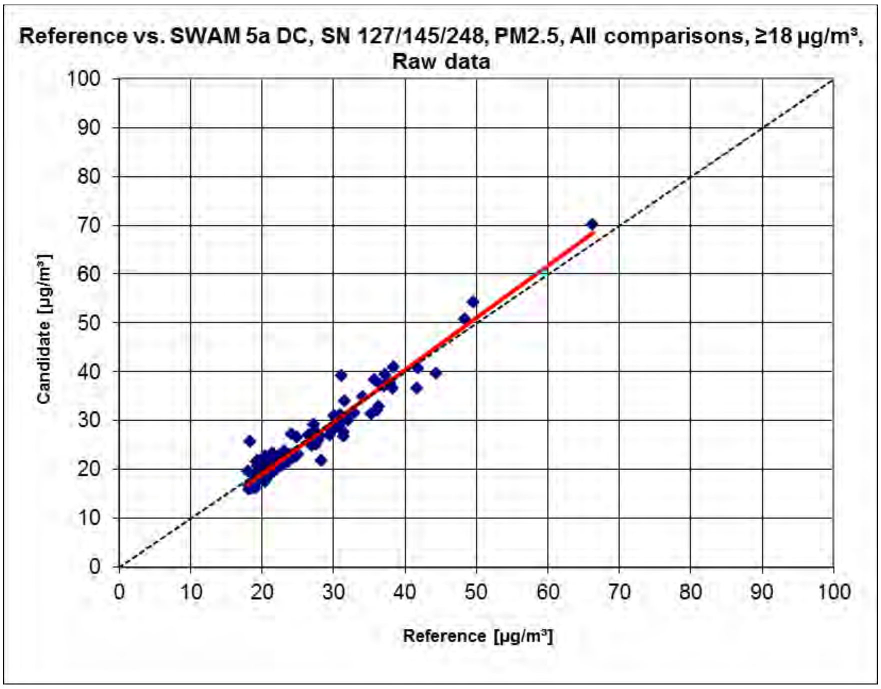


Figure 87: Reference vs. candidate system, SWAM 5a DC, SN 127/145/248, component $PM_{2.5}$, values ≥ 18 µg/m³

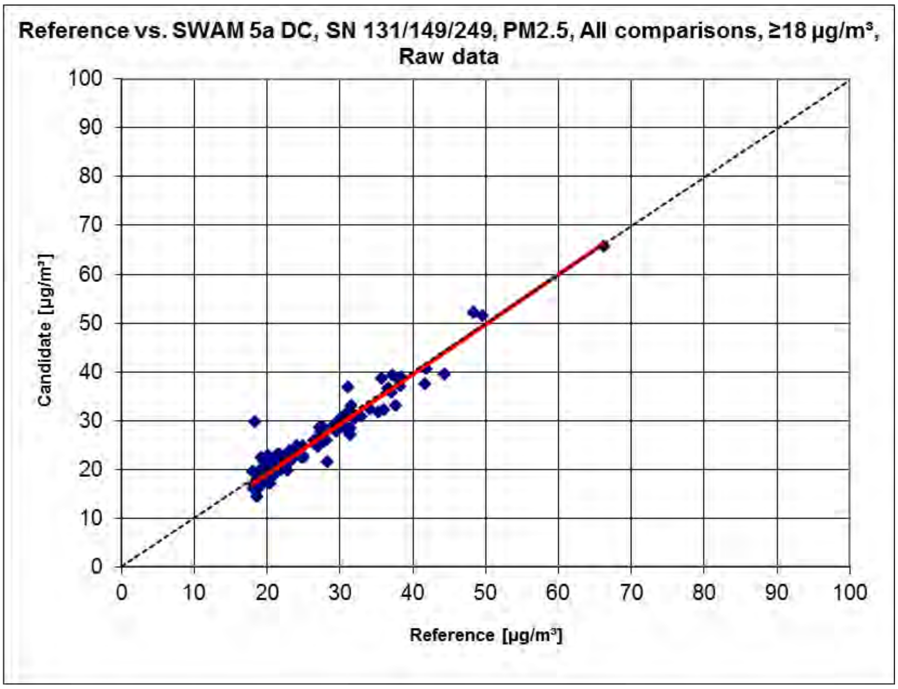


Figure 88: Reference vs. candidate system, SWAM 5a DC, SN 131/149/249, component $PM_{2.5}$, values ≥ 18 µg/m³

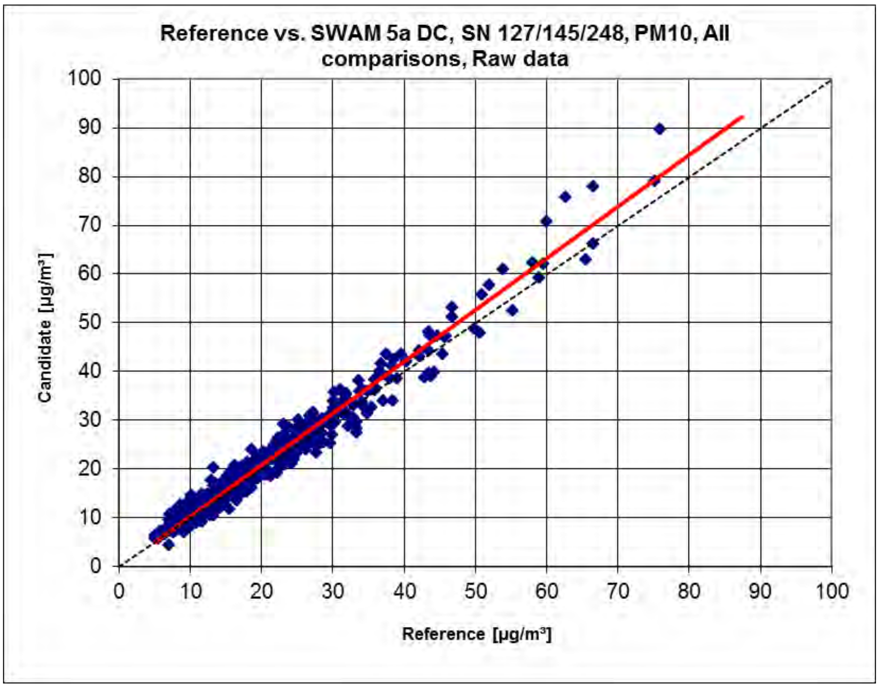


Figure 89: Reference vs. candidate system, SWAM 5a DC, SN 127/145/248, component PM_{10}, all sites

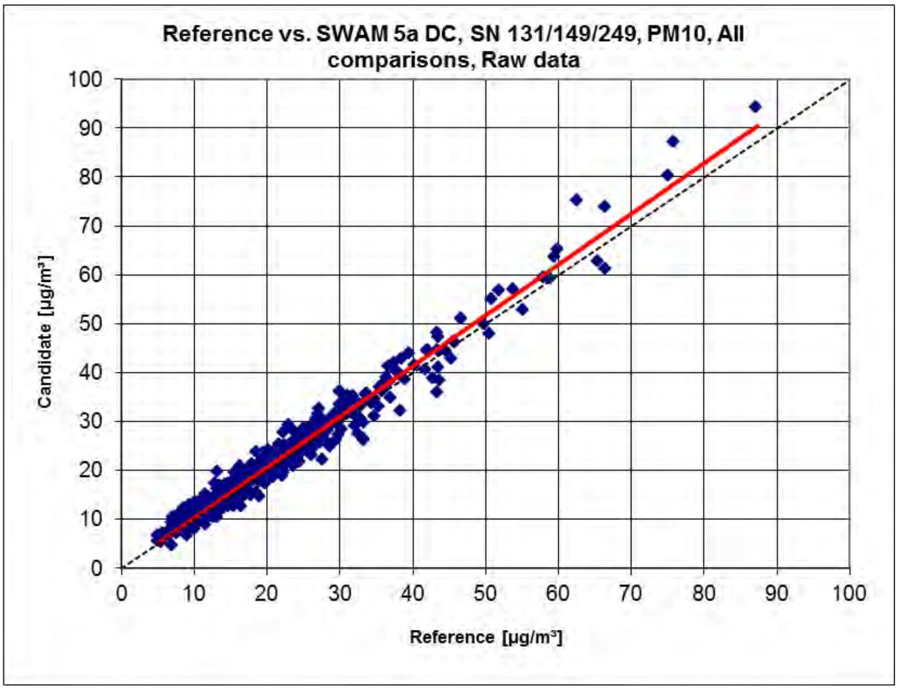


Figure 90: Reference vs. candidate system, SWAM 5a DC, SN 131/149/249, component PM_{10}, all sites

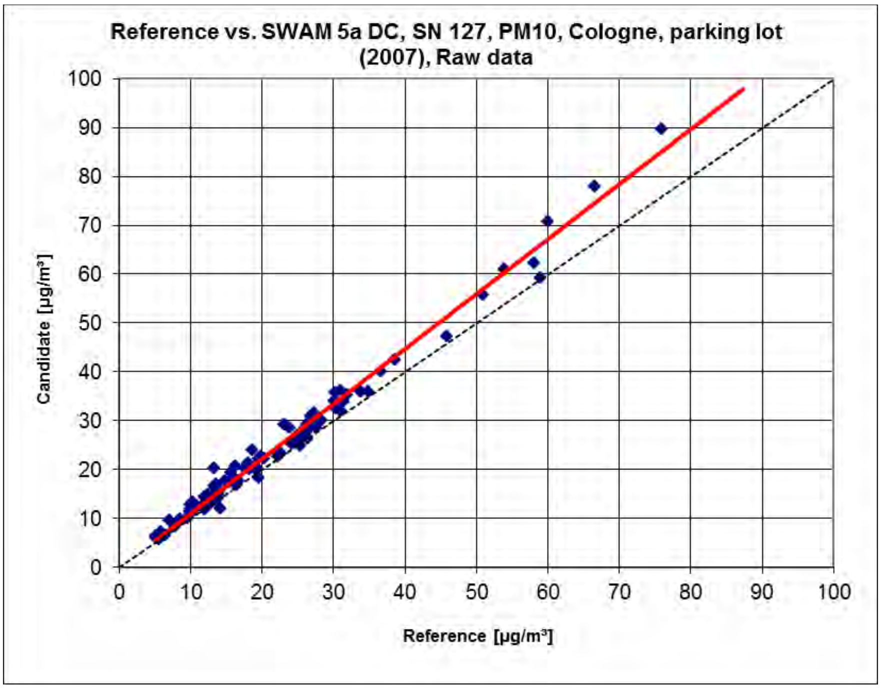


Figure 91: Reference vs. candidate system, SWAM 5a DC, SN 127, component PM_{10}, Cologne, parking lot (2007)

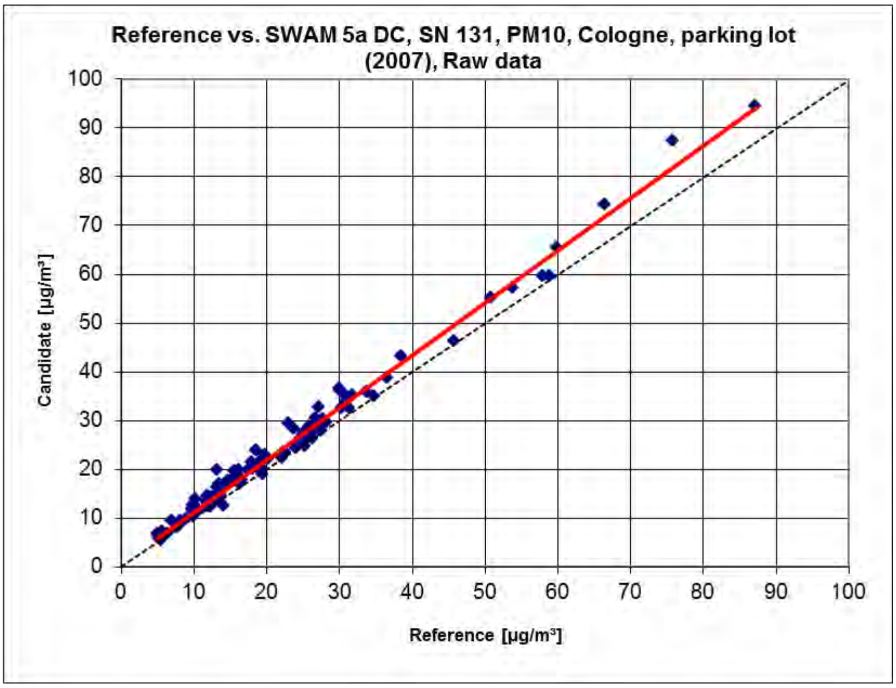


Figure 92: Reference vs. candidate system, SWAM 5a DC, SN 131, component PM_{10}, Cologne, parking lot (2007)

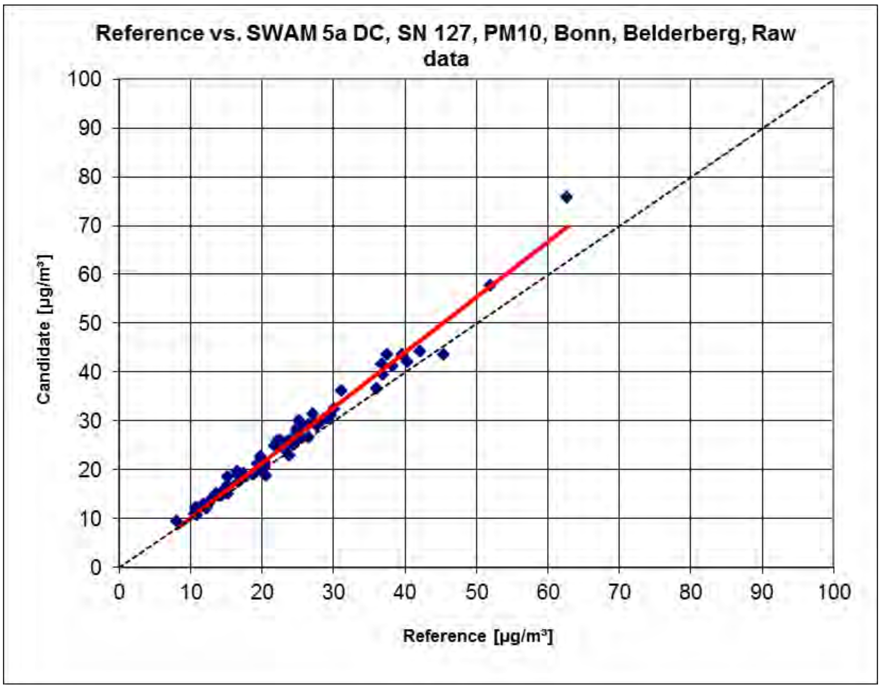


Figure 93: Reference vs. candidate system, SWAM 5a DC, SN 127, component PM_{10}, Bonn, Belderberg

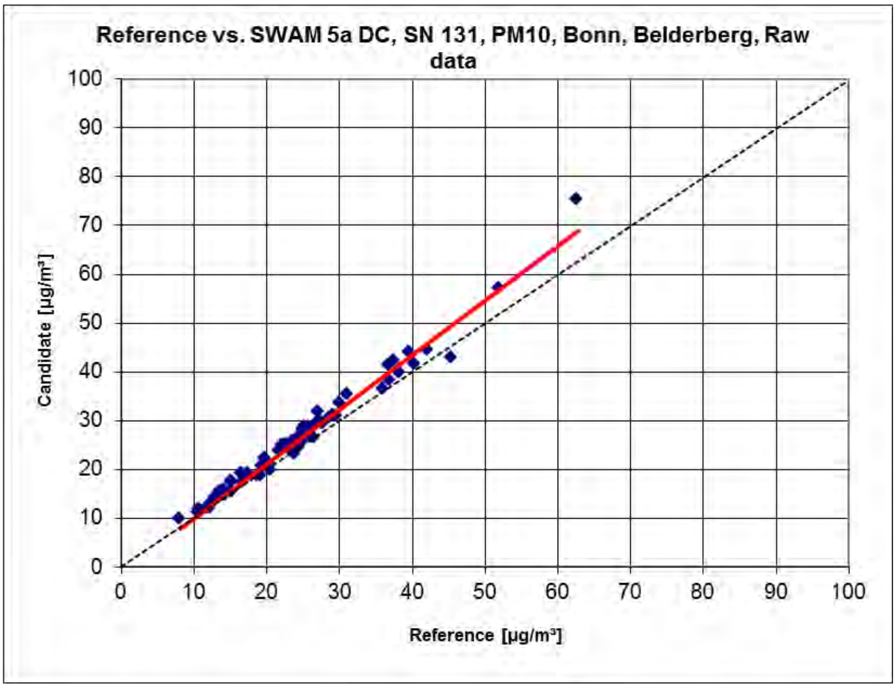


Figure 94: Reference vs. candidate system, SWAM 5a DC, SN 131, component PM_{10}, Bonn, Belderberg

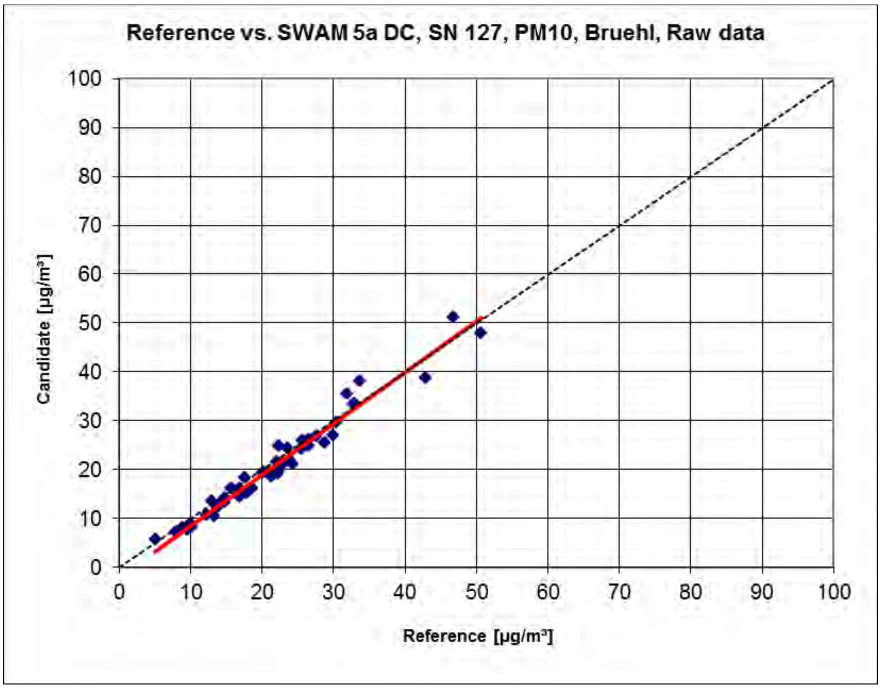


Figure 95: Reference vs. candidate system, SWAM 5a DC, SN 127, component PM_{10}, Brühl

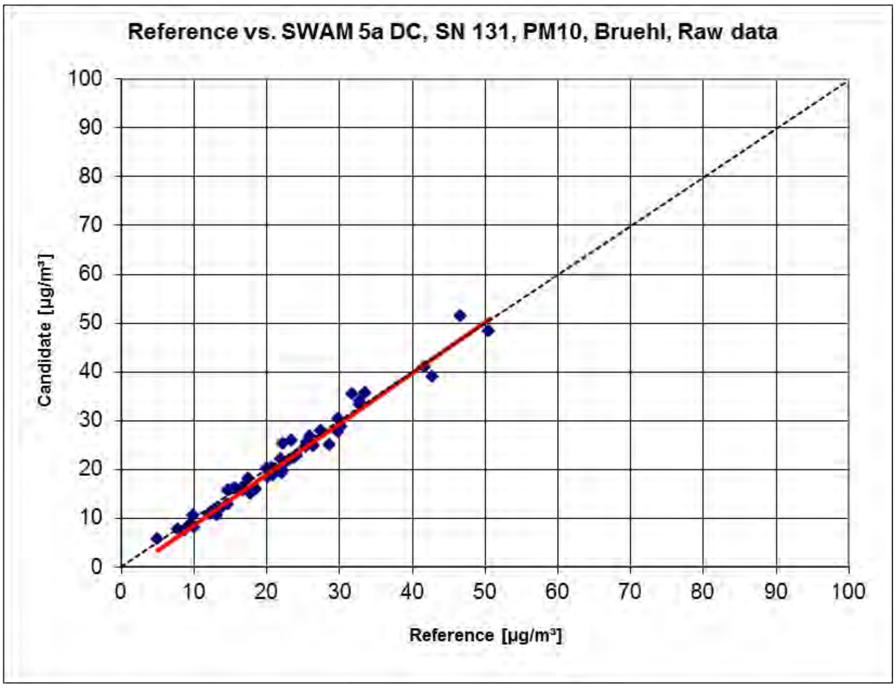


Figure 96: Reference vs. candidate system, SWAM 5a DC, SN 131, component PM_{10}, Brühl

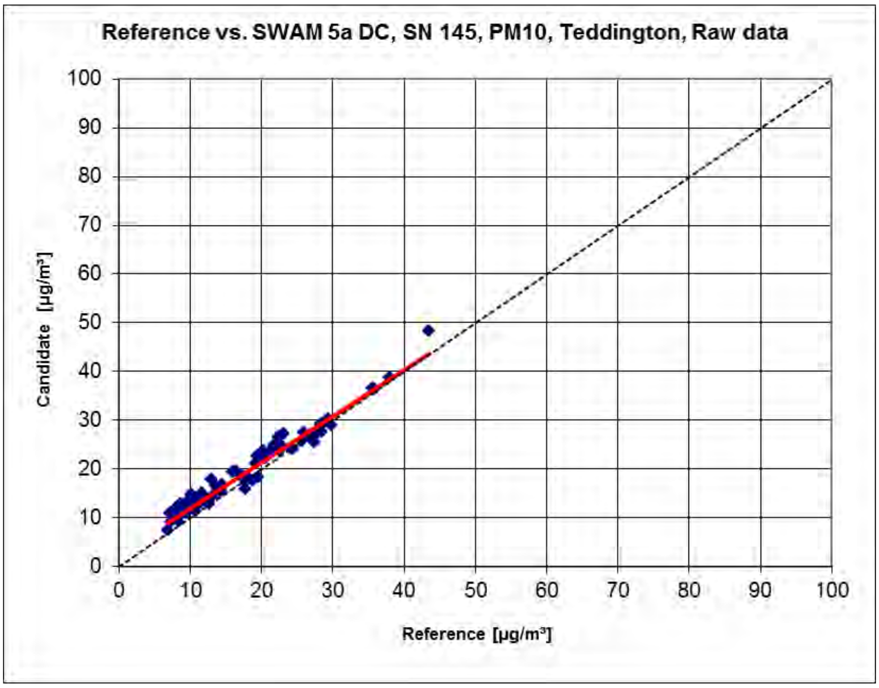


Figure 97: Reference vs. candidate system, SWAM 5a DC, SN 145, component PM_{10}, Teddington

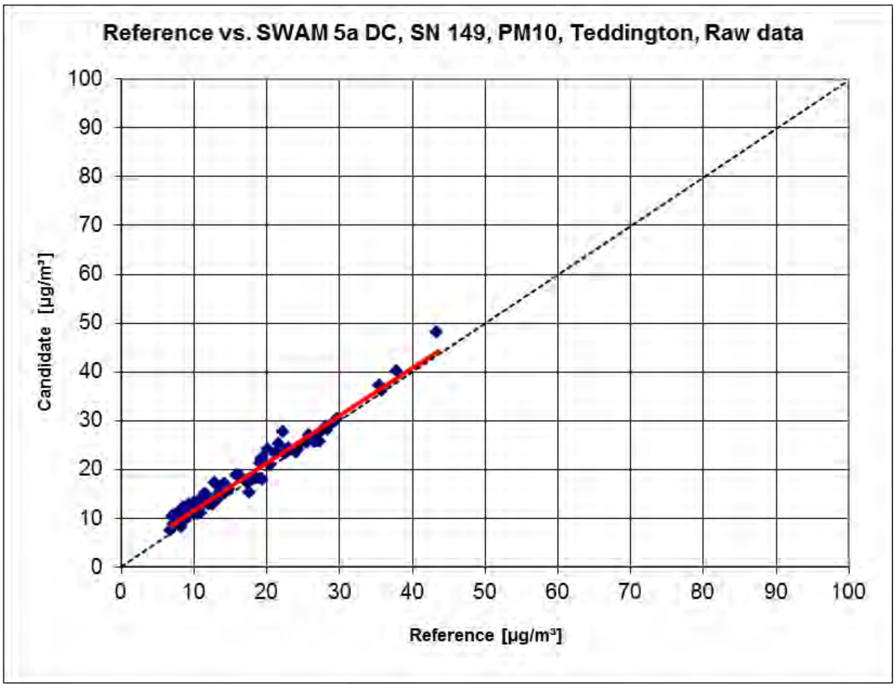


Figure 98: Reference vs. candidate system, SWAM 5a DC, SN 149, component PM_{10}, Teddington

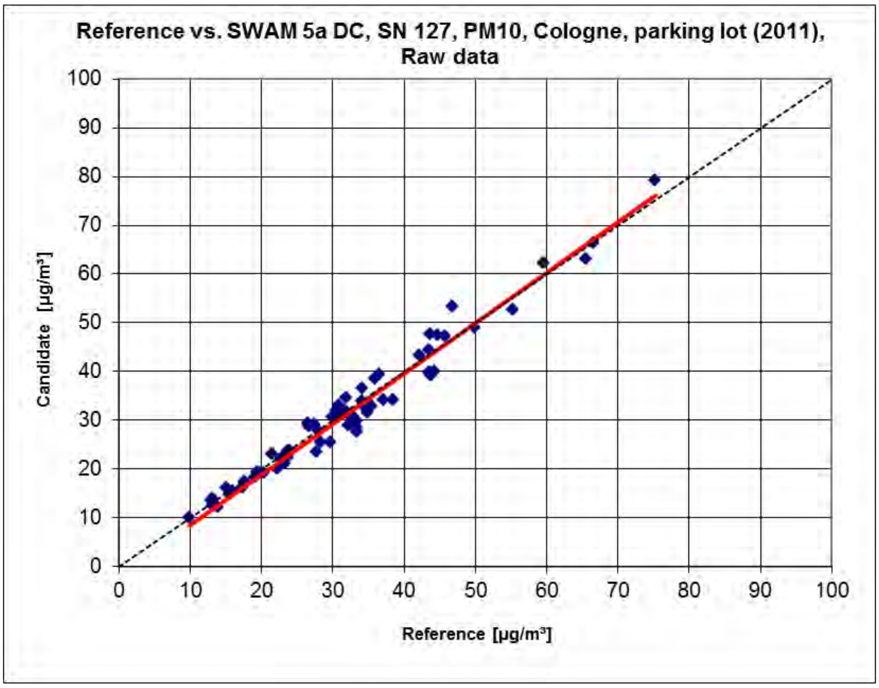


Figure 99: Reference vs. candidate system, SWAM 5a DC, SN 127, component PM_{10}, Cologne, parking lot (2011)

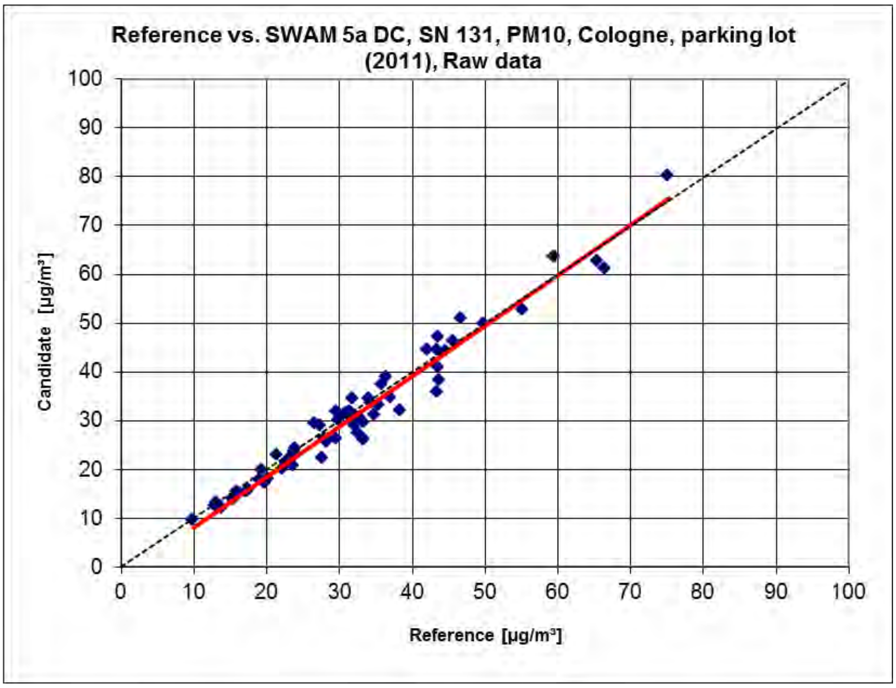


Figure 100: Reference vs. candidate system, SWAM 5a DC, SN 131, component PM_{10}, Cologne, parking lot (2011)

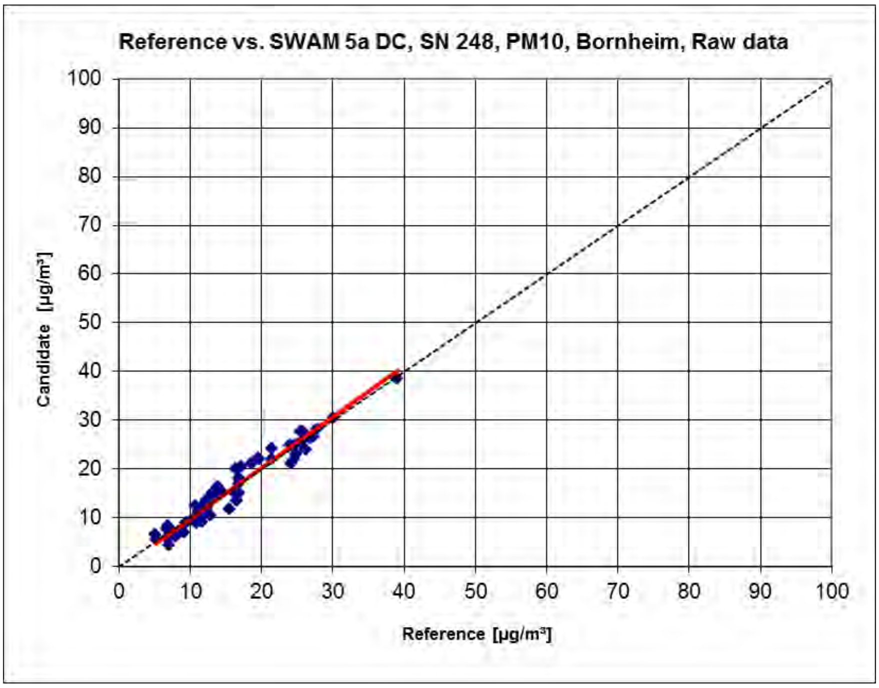


Figure 101: Reference vs. candidate system, SWAM 5a DC, SN 248, component PM_{10}, Bornheim

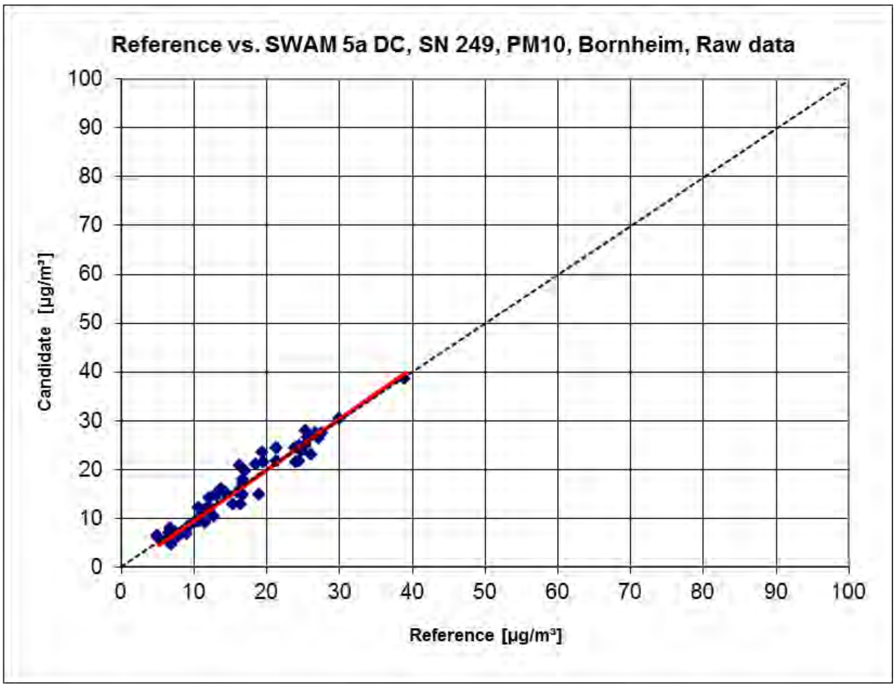


Figure 102: Reference vs. candidate system, SWAM 5a DC, SN 249, component PM_{10}, Bornheim

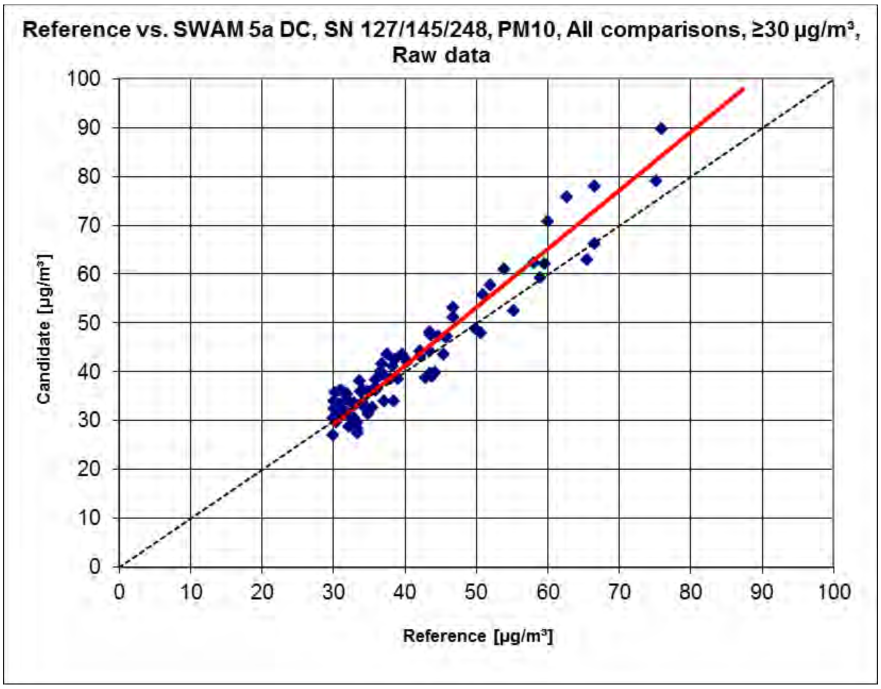


Figure 103: Reference vs. candidate system, SWAM 5a DC, SN 127/145/248, component PM_{10}, values ≥ 30 µg/m³

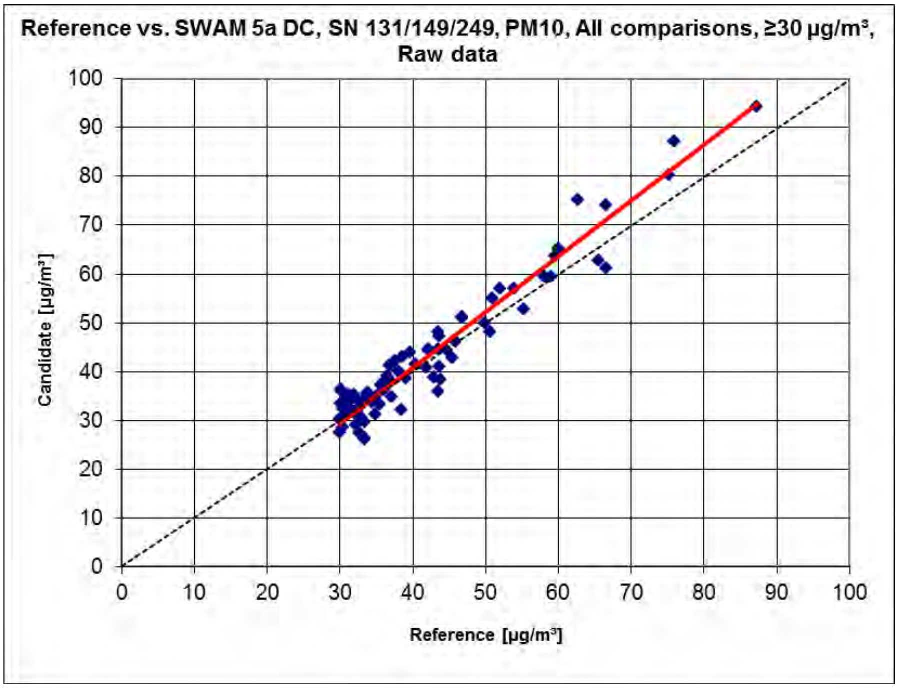


Figure 104: Reference vs. candidate system, SWAM 5a DC, SN 131/149/249, component PM_{10}, values ≥ 30 µg/m³

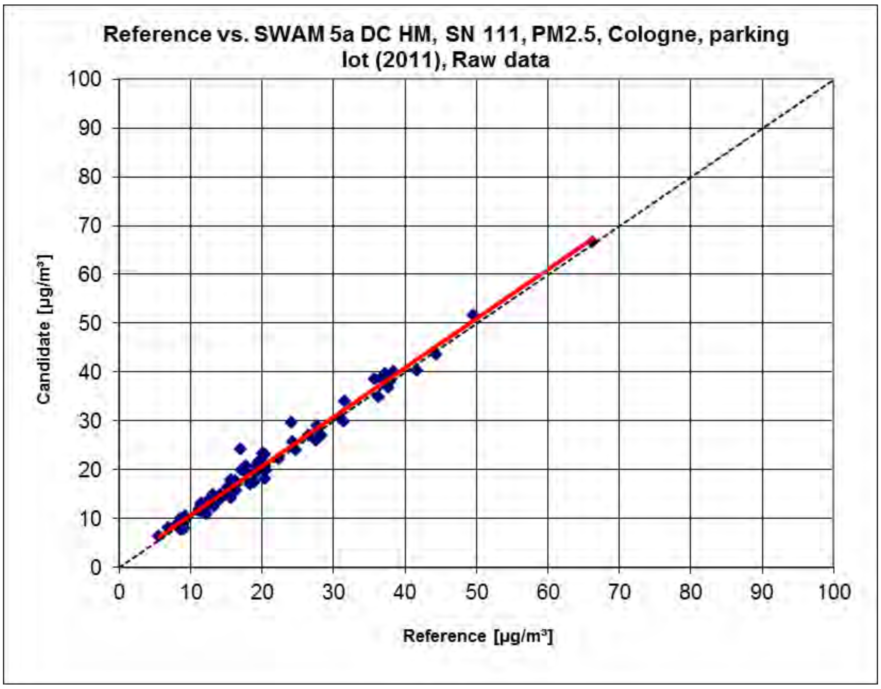


Figure 105: Reference vs. candidate system, SWAM 5a DC HM, SN 111, component $PM_{2.5}$, Cologne, parking lot (2011)

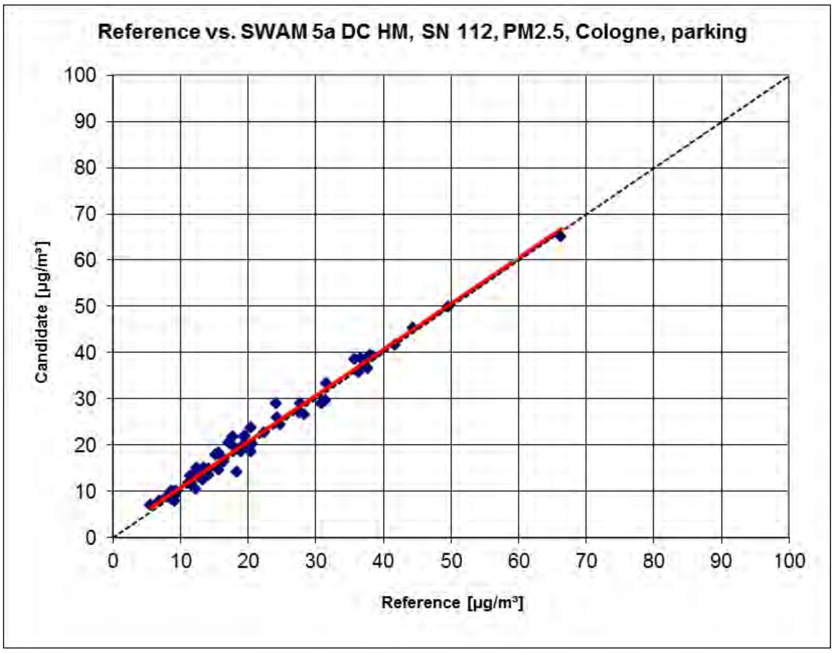


Figure 106: Reference vs. candidate system, SWAM 5a DC HM, SN 112, component $PM_{2.5}$, Cologne, parking lot (2011)

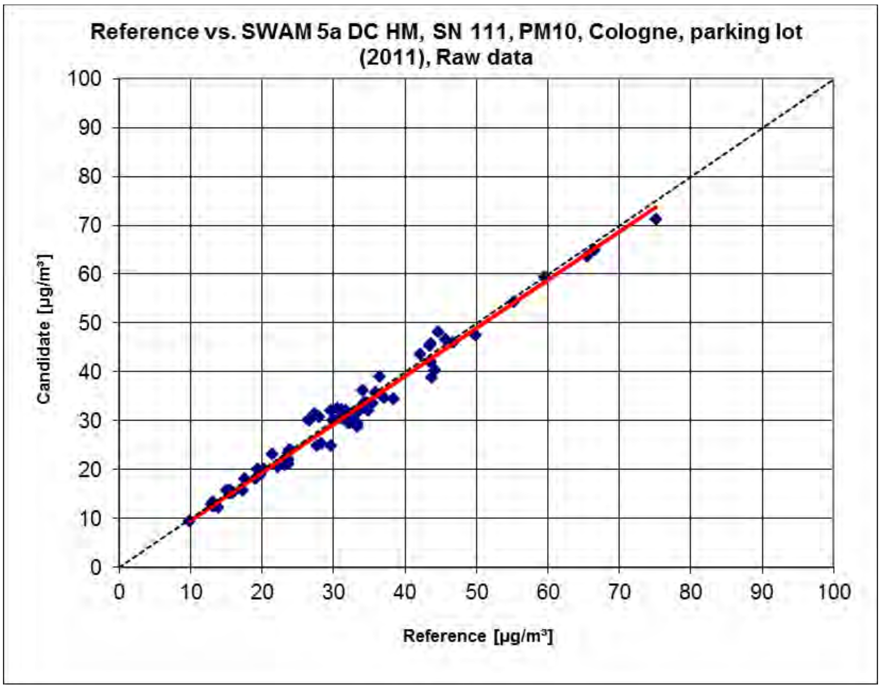


Figure 107: Reference Vs. candidate system, SWAM 5a DC HM, SN 111, component PM_{10}, Cologne, parking lot (2011)

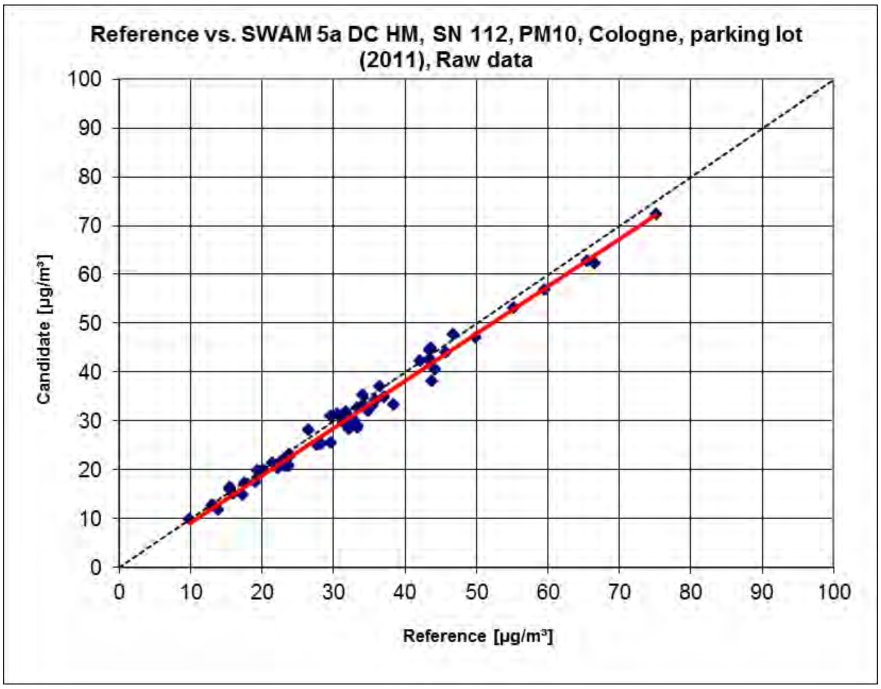


Figure 108: Reference vs. candidate system, SWAM 5a DC HM, SN 112, component PM_{10}, Cologne, parking lot (2011)

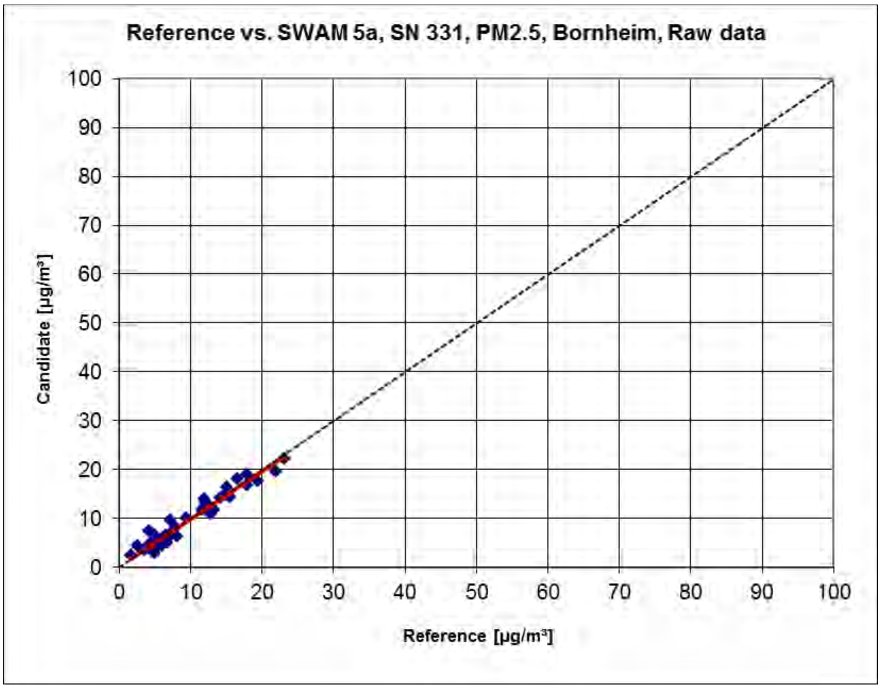


Figure 109: Reference vs. candidate system, SWAM 5a, SN 331, component $PM_{2.5}$, Bornheim

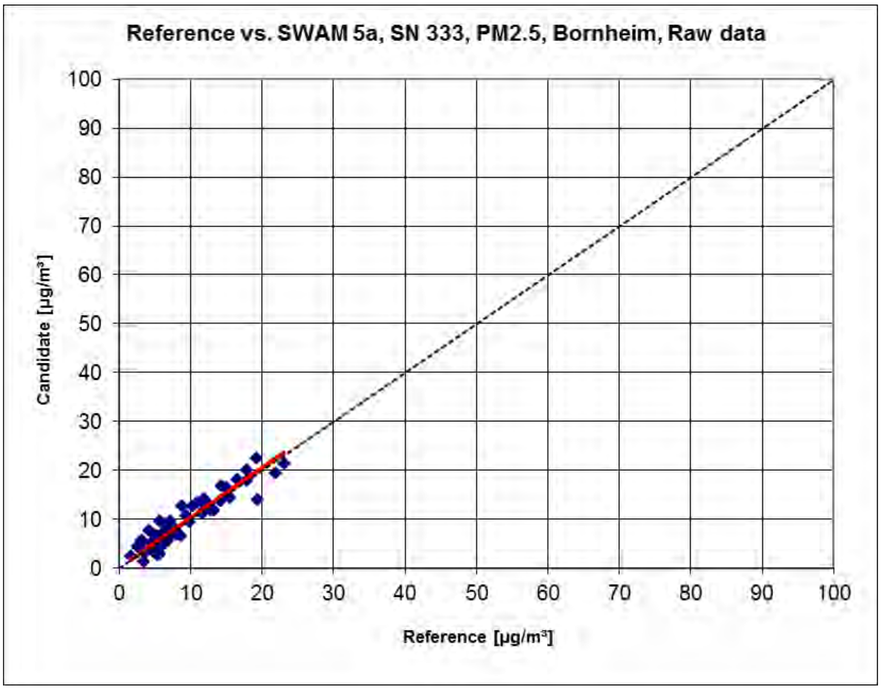


Figure 110: Reference vs. candidate system, SWAM 5a, SN 333, component $PM_{2.5}$, Bornheim

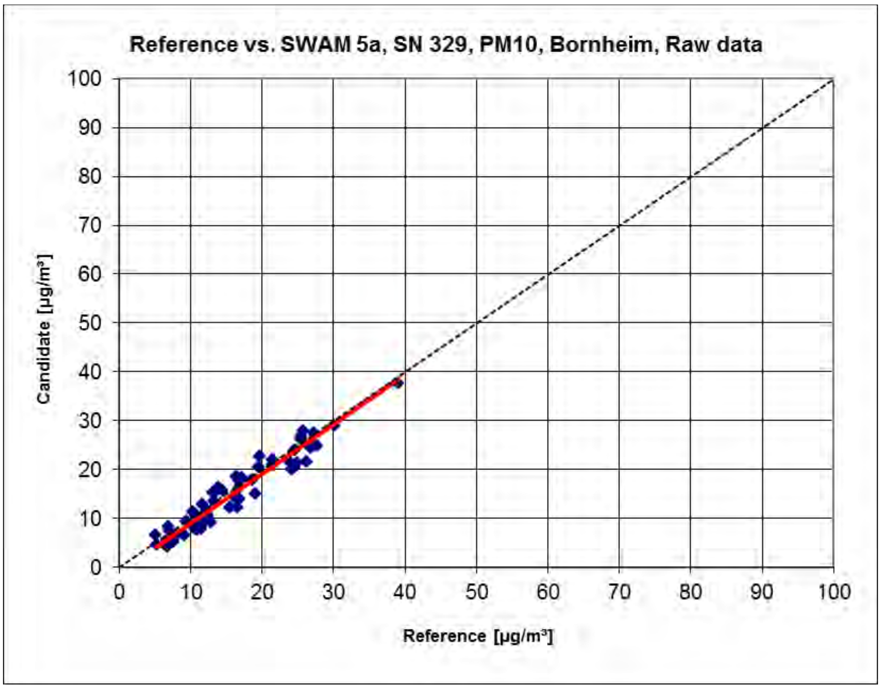


Figure 111: Reference vs. candidate system, SWAM 5a, SN 329, component PM_{10}, Bornheim

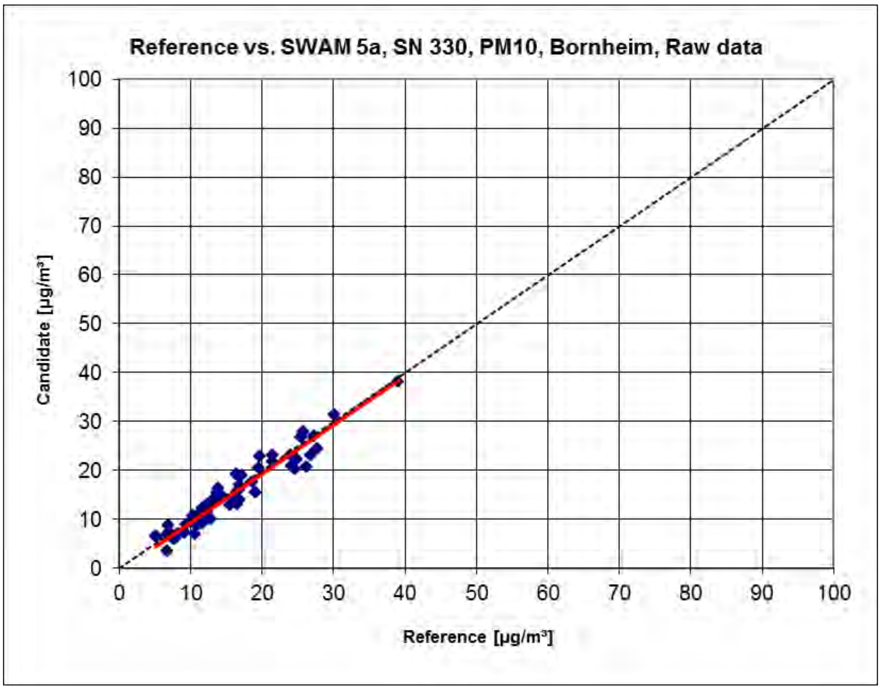


Figure 112: Reference vs. candidate system, SWAM 5a, SN 330, component PM_{10}, Bornheim

6.1 17 Use of correction factors/terms (7.5.8.5–7.5.8.8)

Correction factors/terms (=calibration) shall be applied in the event the highest expanded uncertainty calculated for the tested instruments exceeds the relative expanded uncertainty specified under requirements for data quality or the test demonstrates that the slope is significantly different from 1 and/or the ordinate intercept is significantly different from 0.

6.2 Equipment

Not required for this performance criterion.

6.3 Testing

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

6.4 Evaluation

If it emerges from the evaluation of raw data in accordance with 6.1 17 Expanded uncertainty of AMS results (7.5.8.5–7.5.8.8) that $W_{AMS} > W_{dqo}$, i.e. the tested instrument is not found to be equivalent with the reference method, then it is permissible to use a correction factor or term which results from the regression equation for the full data set. The corrected values have to meet the requirements for all data sets or sub data sets. Moreover, a correction may also be used for the case that $W_{AMS} \leq W_{dqo}$ in order to improve the accuracy of the tested instruments.

Three different situations may occur:

a) Slope be is not significantly different from 1: $|b-1| \leq 2u(b)$

Ordinate intercept a is significantly different from 0: $|a| > 2u(a)$

b) Slope be is significantly different from 1: $|b-1| > 2u(b)$

Ordinate intercept a is not significantly different from 0: $|a| \leq 2u(a)$

b) Slope be is significantly different from 1: $|b-1| > 2u(b)$

Ordinate intercept a is significantly different from 0: $|a| > 2u(a)$

concerning a)

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

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

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

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

and

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

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

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

concerning b)

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

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

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

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

and

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

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

The algorithms for calculating ordinate 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 ordinate intercept a may be used as a correction terms to correct all input values y_i according to the following equation:

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

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

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

and

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

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

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

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

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

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

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

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

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

The largest resulting uncertainty $W_{AMS,corr}$ is compared and assessed against the criteria for data quality of air quality measurements in accordance with EU Directive [8]. Two situations are conceivable:

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

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

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

6.5 Assessment

Even without the need for any correction factors, the expanded uncertainties W_{AMS} were below the expanded, relative uncertainty W_{dqo} defined for fine dust at 25% for $PM_{2.5}$ and PM_{10} for all data sets observed. After applying correction factors for instrument version SWAM 5a Dual Channel Monitor, the candidate systems continue to meet the requirements for data quality for ambient air monitoring for all data sets. A minor deterioration of the expanded uncertainty for the $PM_{2.5}$ data set was observed. However, a considerable improvement of the expanded uncertainty for the PM_{10} data set was observed at the same time.

Criterion satisfied? yes

The evaluation of the full data set resulted in a significant slope and intercept for $PM_{2.5}$ and a significant intercept for PM_{10}.

For $PM_{2.5}$:

The slope for the entire data set is 0.973. The intercept for the full data set is 0.355 (see Table 44)

For PM_{10}:

The slope for the entire data set is 1.051. The intercept for the full data set is -0.271 (see Table 45)

For the component $PM_{2.5}$, the full data set was corrected in terms of the slope and intercept. All data sets were re-evaluated using the corrected values.

For the component PM_{10}, the full data set was corrected in terms of the slope. All data sets were re-evaluated using the corrected values.

After applying the correction, all datasets comply with the requirements for data quality and measurement uncertainty improved considerably for some sites, especially for PM_{10}. As a result of the correction term applied, total uncertainty deteriorated slightly for $PM_{2.5}$.

When a measuring system is operated in the context of a measurement grid, the January 2010 version of the Guide 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 (Guide [4], Chapter 9.9.2, Table 6 and/or EN 16450 [9], Chapter 8.6.2, Table 5). It should be noted that the highest expanded uncertainty determined for $PM_{2.5}$ after applying the correction was in the range between 20–25% The highest expanded uncertainty determined for PM_{10} after applying the correction was in the range between 15–20%.

The operator of the measurement grid or the competent authority of a member state is responsible for compliant implementation of the requirements for regular tests as described above. TÜV Rheinland recommends the use of the expanded uncertainty of the full data set for this purpose: 12.22% ($PM_{2.5}$ uncorrected data set) and 12.40% ($PM_{2.5}$ data set after correcting slope/intercept). This would imply annual tests at 3 sites (corrected and uncorrected); 13.08% (PM_{10} uncorrected data set) and 9.10% (PM_{10} data set after correction of the slope). this would imply annual tests at 3 (uncorrected) or 2 (corrected) sites.

6.6 Detailed presentation of test results

Table 52 and Table 53 show the evaluation results of the equivalence test after applying the correction factor to the full data set.

Table 52: Summary of results for equivalence testing, SWAM 5a DC, component $PM_{2.5}$ after correction of slope/intercept

Comparison candidate with reference according to Standard EN 16450: 2017					
Candidate	SWAM 5a DC		SN	ı 145 / SN 248 & SN 131 / SN 149 / SN 249	
			Limit value	30	µg/m³
Status of measured values	Slope & offset corrected		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.51**	**µg/m³**			
Uncertainty between Candidates	**0.73**	**µg/m³**			
SN 127 / SN 145 / SN 248 & SN 131 / SN 149 / SN 249					
Number of data pairs	**312**				
Slope b	**1.001**	**not significant**			
Uncertainty of b	**0.011**				
Ordinate intercept a	**-0.007**	**not significant**			
Uncertainty of a	**0.189**				
Expanded meas. uncertainty W_{CM}	**12.40**	**%**			
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	**0.64**	**µg/m³**			
Uncertainty between Candidates	**0.79**	**µg/m³**			
SN 127 / SN 145 / SN 248 & SN 131 / SN 149 / SN 249					
Number of data pairs	**91**				
Slope b	**1.051**				
Uncertainty of b	**0.029**				
Ordinate intercept a	**-2.028**				
Uncertainty of a	**0.804**				
Expanded meas. uncertainty W_{CM}	**15.74**	**%**			
All comparisons, <18 µg/m³					
Uncertainty between Reference	**0.50**	**µg/m³**			
Uncertainty between Candidates	**0.45**	**µg/m³**			
SN 127 / SN 145 / SN 248 & SN 131 / SN 149 / SN 249					
Number of data pairs	**221**				
Slope b	**0.959**				
Uncertainty of b	**0.022**				
Ordinate intercept a	**0.606**				
Uncertainty of a	**0.237**				
Expanded meas. uncertainty W_{CM}	**11.04**	**%**			

Comparison candidate with reference according to Standard EN 16450: 2017					
Candidate	SWAM 5a DC		SN	√ 145 / SN 248 & SN 131 / SN 149 / SN 249	
			Limit value	30	µg/m³
Status of measured values	Slope & offset corrected		Allowed uncertainty	25	%
Cologne, parking lot (2007)					
Uncertainty between Reference	0.67	µg/m³			
Uncertainty between Candidates	0.71	µg/m³			
	SN 127			SN 131	
Number of data pairs	45			46	
Slope b	1.029			0.995	
Uncertainty of b	0.023			0.023	
Ordinate intercept a	-0.653			-0.372	
Uncertainty of a	0.393			0.391	
Expanded meas. uncertainty W_{CM}	7.89	%		8.51	%
Bonn, Belderberg					
Uncertainty between Reference	0.46	µg/m³			
Uncertainty between Candidates	0.44	µg/m³			
	SN 127			SN 131	
Number of data pairs	41			41	
Slope b	1.025			1.052	
Uncertainty of b	0.020			0.022	
Ordinate intercept a	-1.611			-2.437	
Uncertainty of a	0.456			0.504	
Expanded meas. uncertainty W_{CM}	10.17	%		10.90	%
Bruehl					
Uncertainty between Reference	0.65	µg/m³			
Uncertainty between Candidates	0.65	µg/m³			
	SN 127			SN 131	
Number of data pairs	43			45	
Slope b	1.013			1.032	
Uncertainty of b	0.033			0.033	
Ordinate intercept a	-1.357			-1.595	
Uncertainty of a	0.509			0.534	
Expanded meas. uncertainty W_{CM}	11.26	%		10.95	%
Teddington					
Uncertainty between Reference	0.33	µg/m³			
Uncertainty between Candidates	0.45	µg/m³			
	SN 145			SN 149	
Number of data pairs	74			80	
Slope b	1.005			1.002	
Uncertainty of b	0.023			0.020	
Ordinate intercept a	0.801			1.020	
Uncertainty of a	0.290			0.252	
Expanded meas. uncertainty W_{CM}	12.04	%		11.73	%
Cologne, parking lot (2011)					
Uncertainty between Reference	0.52	µg/m³			
Uncertainty between Candidates	1.37	µg/m³			
	SN 127			SN 131	
Number of data pairs	67			53	
Slope b	1.053			1.000	
Uncertainty of b	0.027			0.032	
Ordinate intercept a	-0.904			0.277	
Uncertainty of a	0.634			0.824	
Expanded meas. uncertainty W_{CM}	17.35	%		19.33	%
Bornheim					
Uncertainty between Reference	0.65	µg/m³			
Uncertainty between Candidates	0.33	µg/m³			
	SN 248			SN 249	
Number of data pairs	57			60	
Slope b	1.084			1.094	
Uncertainty of b	0.041			0.043	
Ordinate intercept a	-0.213			-0.338	
Uncertainty of a	0.441			0.456	
Expanded meas. uncertainty W_{CM}	18.79	%		20.08	%
All comparisons, ≥18 µg/m³					
Uncertainty between Reference	0.64	µg/m³			
Uncertainty between Candidates	0.79	µg/m³			
	SN 127 / SN 145 / SN 248			SN 131 / SN 149 / SN 249	
Number of data pairs	95			95	
Slope b	1.067			1.023	
Uncertainty of b	0.029			0.029	
Ordinate intercept a	-2.358			-1.408	
Uncertainty of a	0.810			0.81	
Expanded meas. uncertainty W_{CM}	16.02	%		16.40	%
All comparisons, <18 µg/m³					
Uncertainty between Reference	0.50	µg/m³			
Uncertainty between Candidates	0.45	µg/m³			
	SN 127 / SN 145 / SN 248			SN 131 / SN 149 / SN 249	
Number of data pairs	232			230	
Slope b	0.958			0.985	
Uncertainty of b	0.021			0.024	
Ordinate intercept a	0.593			0.413	
Uncertainty of a	0.226			0.252	
Expanded meas. uncertainty W_{CM}	10.75	%		11.18	%
All comparisons					
Uncertainty between Reference	0.51	µg/m³			
Uncertainty between Candidates	0.73	µg/m³			
	SN 127 / SN 145 / SN 248			SN 131 / SN 149 / SN 249	
Number of data pairs	327			325	
Slope b	1.009	not significant		0.991	not significant
Uncertainty of b	0.011			0.011	
Ordinate intercept a	-0.118	not significant		0.137	not significant
Uncertainty of a	0.187			0.193	
Expanded meas. uncertainty W_{CM}	12.42	%		13.00	%

Table 53: Summary of results for equivalence testing, SWAM 5a DC, component PM_{10} after correction of slope

Comparison candidate with reference according to Standard EN 16450: 2017					
Candidate	SWAM 5a DC		SN	ⅰ 145 / SN 248 & SN 131 / SN 149 / SN 249	
			Limit value	50	µg/m³
Status of measured values	Slope corrected		Allowed uncertainty	25	%
All comparisons					
Uncertainty between Reference	**0.75**	**µg/m³**			
Uncertainty between Candidates	**0.63**	**µg/m³**			
SN 127 / SN 145 / SN 248 & SN 131 / SN 149 / SN 249					
Number of data pairs	**404**				
Slope b	**0.999**	**not significant**			
Uncertainty of b	**0.009**				
Ordinate intercept a	**-0.240**	**not significant**			
Uncertainty of a	**0.228**				
Expanded measured uncertainty WCM	**9.10**	**%**			
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	**0.78**	**µg/m³**			
Uncertainty between Candidates	**1.14**	**µg/m³**			
SN 127 / SN 145 / SN 248 & SN 131 / SN 149 / SN 249					
Number of data pairs	**83**				
Slope b	**1.111**				
Uncertainty of b	**0.030**				
Ordinate intercept a	**-5.296**				
Uncertainty of a	**1.307**				
Expanded measured uncertainty WCM	**13.55**	**%**			
All comparisons, <30 µg/m³					
Uncertainty between Reference	**0.74**	**µg/m³**			
Uncertainty between Candidates	**0.43**	**µg/m³**			
SN 127 / SN 145 / SN 248 & SN 131 / SN 149 / SN 249					
Number of data pairs	**321**				
Slope b	**0.962**				
Uncertainty of b	**0.015**				
Ordinate intercept a	**0.527**				
Uncertainty of a	**0.276**				
Expanded measured uncertainty WCM	**8.99**	**%**			

Comparison candidate with reference according to Standard EN 16450: 2017					
Candidate	SWAM 5a DC		SN	√ 145 / SN 248 & SN 131 / SN 149 / SN 249	
			Limit value	50	µg/m³
Status of measured values	Slope corrected		Allowed uncertainty	25	%
Cologne, parking lot (2007)					
Uncertainty between Reference	1.12	µg/m³			
Uncertainty between Candidates	0.83	µg/m³			
	SN 127			**SN 131**	
Number of data pairs	98			100	
Slope b	1.070			1.021	
Uncertainty of b	0.012			0.011	
Ordinate intercept a	-0.306			0.394	
Uncertainty of a	0.321			0.295	
Expanded measured uncertainty W_{CM}	14.51	%		8.39	%
Bonn, Belderberg					
Uncertainty between Reference	0.53	µg/m³			
Uncertainty between Candidates	0.43	µg/m³			
	SN 127			**SN 131**	
Number of data pairs	62			62	
Slope b	1.076			1.060	
Uncertainty of b	0.020			0.019	
Ordinate intercept a	-1.113			-0.986	
Uncertainty of a	0.542			0.513	
Expanded measured uncertainty W_{CM}	12.73	%		10.36	%
Bruehl					
Uncertainty between Reference	0.77	µg/m³			
Uncertainty between Candidates	0.54	µg/m³			
	SN 127			**SN 131**	
Number of data pairs	51			53	
Slope b	0.996			0.985	
Uncertainty of b	0.026			0.024	
Ordinate intercept a	-1.815			-1.594	
Uncertainty of a	0.614			0.570	
Expanded measured uncertainty W_{CM}	10.65	%		11.41	%
Teddington					
Uncertainty between Reference	0.45	µg/m³			
Uncertainty between Candidates	0.50	µg/m³			
	SN 145			**SN 149**	
Number of data pairs	73			79	
Slope b	0.901			0.921	
Uncertainty of b	0.020			0.020	
Ordinate intercept a	2.370			1.927	
Uncertainty of a	0.379			0.371	
Expanded measured uncertainty W_{CM}	11.81	%		9.99	%
Cologne, parking lot (2011)					
Uncertainty between Reference	0.59	µg/m³			
Uncertainty between Candidates	0.83	µg/m³			
	SN 127			**SN 131**	
Number of data pairs	69			66	
Slope b	0.982			0.983	
Uncertainty of b	0.021			0.024	
Ordinate intercept a	-1.574			-1.966	
Uncertainty of a	0.728			0.836	
Expanded measured uncertainty W_{CM}	13.63	%		15.53	%
Bornheim					
Uncertainty between Reference	0.63	µg/m³			
Uncertainty between Candidates	0.33	µg/m³			
	SN 248			**SN 249**	
Number of data pairs	56			59	
Slope b	0.991			0.990	
Uncertainty of b	0.031			0.032	
Ordinate intercept a	-0.575			-0.723	
Uncertainty of a	0.553			0.568	
Expanded measured uncertainty W_{CM}	8.08	%		8.76	%
All comparisons, ≥30 µg/m³					
Uncertainty between Reference	0.78	µg/m³			
Uncertainty between Candidates	1.14	µg/m³			
	SN 127 / SN 145 / SN 248			**SN 131 / SN 149 / SN 249**	
Number of data pairs	86			85	
Slope b	1.137			1.085	
Uncertainty of b	0.031			0.031	
Ordinate intercept a	-6.111			-4.605	
Uncertainty of a	1.330			1.32	
Expanded measured uncertainty W_{CM}	14.24	%		13.74	%
All comparisons, <30 µg/m³					
Uncertainty between Reference	0.74	µg/m³			
Uncertainty between Candidates	0.43	µg/m³			
	SN 127 / SN 145 / SN 248			**SN 131 / SN 149 / SN 249**	
Number of data pairs	323			334	
Slope b	0.964			0.964	
Uncertainty of b	0.015			0.015	
Ordinate intercept a	0.547			0.428	
Uncertainty of a	0.281			0.272	
Expanded measured uncertainty W_{CM}	8.78	%		8.96	%
All comparisons					
Uncertainty between Reference	0.75	µg/m³			
Uncertainty between Candidates	0.63	µg/m³			
	SN 127 / SN 145 / SN 248			**SN 131 / SN 149 / SN 249**	
Number of data pairs	409			419	
Slope b	1.010	not significant		0.986	not significant
Uncertainty of b	0.009			0.009	
Ordinate intercept a	-0.376	not significant		-0.069	not significant
Uncertainty of a	0.237			0.223	
Expanded measured uncertainty W_{CM}	9.41	%		9.47	%

6.1 18 Maintenance interval (7.5.7)

The maintenance interval shall be at least 2 weeks.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

With regard to this minimum requirement, the maintenance tasks required in a specific period and the length of that period for the correct functioning of the measuring system were identified. Moreover, the results of the zero drift tests (see 6.1 12 Zero checks (7.5.3) were taken into account when determining the maintenance interval .

6.4 Evaluation

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

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

The measuring system comes with filter stocks of 36, 72 or 96 filters. Accordingly, the maximum period of operation is determined as follows:

SWAM 5a Dual Channel Monitor:

For 24h sampling when operating both lines, operating times of 18, 36 or 48 days can be realised.

SWAM 5a Dual Channel Hourly Mode Monitor:

At a 1h cycle time and 8-fold allocation for each filter (setting used during the test) 6 filters are used for each measurement day in operation. Consequently, maximum operating times of 6, 12 or 16 days can be realised.

SWAM 5a Monitor:

For 24h sampling, operating times of 36, 72 or 96 days can be realised.

Similar to the reference method specified in EN 12341:2014, Chapter 7.3, it is recommended to re-stock the filters when the sampling inlets are cleaned after 15 days ($PM_{2.5}$) or after 30 days (PM_{10}).

During operation times, maintenance is generally limited to contamination and plausibility checks and potential status/error messages.

6.5 Assessment

The maintenance interval is determined by the necessary maintenance tasks (filter replacement/cleaning the sampling head if necessary). It is 15 days for $PM_{2.5}$ and 30 days for PM_{10}.

Criterion satisfied? yes

6.6 Detailed presentation of test results

The necessary maintenance works are listed in chapter 8 of the operation manual.

6.1 19 Automatic diagnostic check (7.5.4)

Results of automated/functional checks, where available, shall be recorded.

6.2 Equipment

Not required for this performance criterion

6.3 Testing

A modem was connected to the measuring system. Among other, status signals provided by the AMS were recorded relying on remote data transmission.

Access options provided by the DR FAI Manager operating system and the Hyperterminal were checked.

The measuring system allows for comprehensive monitoring and control functions. A number of reading, writing and control commands are available; a complete overview of which is provided in the AMS operating manual.

The instrument saves the results of internal tests for the purpose of quality assurance/functional tests e.g. leak tightness of the system, flow calibration and radiometric determination of mass concentrations.

The DR FAI Manager operating software conveniently provides options to monitor the operating status and provides data saved as text files (also see Figure 13 to Figure 19 in section 3.3 AMS scope and set-up).

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

As part of the performance test, a PC was connected directly connected to the AMS via RS232 to test the transfer of data and the instrument status.

6.4 Evaluation

All instrument functions described in the operation manual are available and can be activated. The instrument saves the results of internal tests for the purpose of quality assurance/functional tests e.g. leak tightness of the system, flow calibration and radiometric determination of mass concentrations.

6.5 Assessment

The instrument saves the results of internal tests for the purpose of quality assurance/functional tests e.g. leak tightness of the system, flow calibration and radiometric determination of mass concentrations.

Criterion satisfied? yes

6.6 Detailed presentation of test results

Available automatic/functional tests are listed in chapter 7 of the operation manual.

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

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

6.2 Equipment

Not required for this performance criterion

6.3 Testing

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

6.4 Evaluation

The SWAM 5a measuring systems use various temperature, pressure and/or humidity sensors.

All relevant sensors for temperature (ambient temperature, room temperature, temperature near the mass flow meter, temperature near the filter during sampling), pressure (air pressure, pressure drop at the filter) or relative humidity (in the area of the filter during sampling) are accessible. This allows to perform comparison measurements using transfer standards.

It is possible to check the internal sensors (e.g. in the filter area during sampling or with regard to flow measurement), but requires disassembly of the installation and should therefore ideally be performed in a laboratory as part of the annual checks according to standard EN 16450, Table 4,

A user can only adjust the parameters ambient air, air pressure and flow rate. In the event of excessive deviations of all other parameters, the manufacturer has to be contacted.

.

6.5 Assessment

It is easy to check and adjust the relevant external sensors for determining ambient temperature and ambient pressure on-site. It is also possible to check the internal sensors (e.g. in the filter area during sampling or with regard to flow measurement). However, this requires disassembly of the installation and should therefore ideally be performed in a laboratory as part of the annual checks according to standard EN 16450, Table 4,

Criterion satisfied? yes

6.6 Detailed presentation of test results

Not required for this performance criterion

7. Recommendations for use in practice

7.1 Tasks performed in the maintenance interval (15 days ($PM_{2,5}$) and 30 days (PM_{10}))

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

- Verification of the instrument status incl. internal functional checks
  The instrument status can be verified by checking the AMS; alternatively it can be monitored online.
- Sampling heads have to be cleaned following the manufacturer's instruction and taking into account local concentrations of suspended particulate matter.
  These tasks should be performed when replacing the filters.

Apart from that please consider the manufacturer's instructions.

7.2 Additional maintenance tasks

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

- Checking and cleaning of the priming rod every 3 months
  Leak tightness of the AMS needs to be checked after having perfumed maintenance tasks.
- Checking the oil level and filters of the air compressor every 6 months
- Maintenance of the pump every 12 months Air throughput needs to be checked after having performed maintenance tasks with the help of a flow transfer standard, where necessary, a re-calibration has to be performed.

Further details are provided in the operation manual.

Environmental Protection/Air Pollution Control

Guido Baum

Dipl.-Ing. Guido Baum

Dipl.-Ing. Karsten Pletscher

Cologne, 07 September 2018
936/21239762/B

8. Bibliography

[1] VDI Guideline 4202, Part 1 – "Performance criteria for performance tests of automated ambient air measuring systems – Point-related measurement methods for gaseous and particulate air pollutants," dated June 2002.

[2] VDI Guideline 4203, part 3 – "Testing of automated measuring systems – Test procedures for point-related ambient air measuring systems for gaseous and particulate air pollutants", dated August 2004

[3] European standard EN 12341 "Air Quality - Determination of the PM_{10} fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods", German version EN 12341 1998

[4] European standard EN 14907, "Ambient air quality – Standard gravimetric measurement method for the determination of $PM_{2.5}$ mass fraction of suspended particulate matter", German version EN 14907: 2005

[5] Guide „Demonstration of Equivalence of Ambient Air Monitoring Methods", English version dated November 2005 (initial testing) and of January 2010

[6] Operation manual SWAM 5a Monitor, SWAM 5a Dual Channel Monitor and SWAM 5a Dual Channel Hourly Mode Monitor

[7] Operation manual LVS3 of 2000

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

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

[10] "UK Equivalence Programme for Monitoring of Particulate Matter" report, Report No.: BV/AQ/AD202209/DH/2396 dated 5 June 2006

[11] TÜV Rheinland report no. 936/21207522/A dated 23 March 2009, Report on the performance test of the SWAM 5a Dual Channel Monitor air quality monitor with PM_{10} and $PM_{2.5}$ pre-separator manufactured by FAI Instruments s.r.l for the components suspended particulate matter PM_{10}, $PM_{2.5}$)

[12] Statement issued by TÜV Rheinland Energie und Umwelt GmbH dated 11 October 2011

[13] Statement issued by TÜV Rheinland Energie und Umwelt GmbH dated 3 November 2011

2.1 SWAM 5a Dual Channel Monitor für PM_{10} und $PM_{2,5}$

Hersteller:

FAI Instruments s.r.l., Fonte Nuova (Rom), Italien

Eignung:

Zur kontinuierlichen parallelen Immissionsmessung der PM10- und der PM2,5-Fraktion im Schwebstaub im stationären Einsatz

Messbereiche bei der Eignungsprüfung:

PM10: 0-200 µg/m3
PM2,5: 0-200 µg/m3

Softwareversion: Version

Rel 04-08.01.65-30.02.00

Hinweise:

1. Die Anforderungen gemäß des Leitfadens Demonstration of Equivalence of Ambient Air Monitoring Methods werden eingehalten.
2. Es wurden Filterhalter mit einer Beaufschlagungsfläche von 5,20 cm2 eingesetzt.
3. Die Messeinrichtung ist mit dem gravimetrischen PM10-Referenzverfahren nach DIN EN 12341 regelmäßig am Standort zu kalibrieren.
4. Die Messeinrichtung ist mit dem gravimetrischen PM2,5-Referenzverfahren nach DIN EN 14907 regelmäßig am Standort zu kalibrieren.

Prüfinstitut:

TÜV Rheinland Immissionsschutz und Energiesysteme GmbH, Köln
Bericht Nr.: 936/21207522/A vom 23. März 2009

Figure 113: Original announcement in the Federal Gazette, Banz. 25 August 2009, no. 125, page 2929, chapter II no. 2.1

7. Mitteilung zur Bekanntmachung des Umweltbundesamtes vom 3. August 2009 (BAnz. S. 2929, Kapitel II Nummer 2.1)
Die Messeinrichtung SWAM 5a Dual Channel Monitor für PM10 und PM2,5 der Firma FAI Instruments s.r.l. erfüllt die Anforderungen der DIN EN 12341, der DIN EN 14907 sowie des Leitfadens zum Nachweis der Gleichwertigkeit von Immissionsmesseinrichtungen in der Version vom November 2005. Darüber hinaus erfüllt die Herstellung und das Qualitätsmanagement der Messeinrichtung SWAM 5a Dual Channel Monitor für PM10 und PM2,5 die Anforderungen der DIN EN 15267.
Der Prüfbericht über die Eignungsprüfung ist im Internet unter www.qal1.de einsehbar.
Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 26. März 2011

Figure 114: Notification published in the Federal Gazette, BAnz. 29 July 2011, no. 113, page 2725, chapter III 7th Notification

2 Mitteilung zu Bekanntmachungen des Umweltbundesamtes
vom 3. August 2009 (BAnz. S. 2929, Kapitel II Nummer 2.1) und
vom 15. Juli 2011 (BAnz. S. 2725, Kapitel III 7. Mitteilung)
Die Immissionsmesseinrichtung SWAM 5a Dual Channel Monitor für PM10 und PM2,5 der Fa. FAI Instruments s.r.l. kann auch in der Geräteversion mit 1-h-Messmodus eingesetzt werden. Die Geräteversion mit 1-h-Messmodus wird unter der Bezeichnung SWAM 5a Dual Channel Hourly Mode Monitor vertrieben.
Die Immissionsmesseinrichtung SWAM 5a Dual Channel Hourly Mode Monitor für PM10 und PM2,5 der Fa. FAI Instruments s.r.l. wird baugleich unter der Bezeichnung Model 602 BetaPlus von der Fa. Teledyne Advanced Pollution Instrumentation, San Diego/USA vertrieben.
Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 11. Oktober 2011

Figure 115: Notification published in the Federal Gazette, BAnz. 2 March 2012, no. 36, page 920, chapter V, 2nd Notification

3 Mitteilung zu Bekanntmachungen des Umweltbundesamtes
vom 3.August 2009 (BAnz. S.S2929, Kapitel II Nummer 2.1) und
vom 15.Juli 2011 (BAnz. S.B2725, Kapitel III 7. Mitteilung)
Die Bekanntgabe der Immissionsmesseinrichtung SWAM 5a Dual Channel Monitor für PM10 und PM2,5 der Fa. FAI Instruments s.r.l. umfasst auch die einkanalige Bauform der Immissionsmesseinrichtung mit der Gerätebezeichnung SWAM 5a Monitor für PM10 oder PM2,5.
Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 3. November 2011

Figure 116: Notification published in the Federal Gazette, BAnz. 2 March 2012, no. 36, page 920, chapter V, 3rd Notification

12 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 3. August 2009 (BAnz. S. 2929, Kapitel II Nummer 2.1) und vom 23. Februar 2012 (BAnz. S. 920, Kapitel V, 2. und 3. Mitteilung)

Die aktuelle Softwareversion der Staubimmissionsmesseinrichtung SWAM 5a Dual Channel Monitor für PM_{10} und $PM_{2,5}$ der Firma FAI Instruments s. r. l. lautet:

04-09.01.85-30.02.00

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 15. Oktober 2012

Figure 117: Notification published in BAnz AT 05.03.2013 B10, chapter V 12th Notification

8 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 3. August 2009 (BAnz. S. 2929, Kapitel II Nummer 2.1) und vom 12. Februar 2013 (BAnz AT 05.03.2013 B10, Kapitel V 12. Mitteilung)

Die aktuellen Softwareversionen für die Messeinrichtung SWAM 5a Dual Channel Monitor für PM_{10} und $PM_{2,5}$ lauten:

04-09.01.85-30.02.00 (alter Mikro-Controller, bis 2008)

bzw.

04-09.01.85-30.03.00 (neuer Mikro-Controller, ab 2008)

Für die Messeinrichtung SWAM 5a Dual Channel Hourly Mode Monitor für PM_{10} und $PM_{2,5}$ ist ein optionales Ethernet Board erhältlich, welches die Kommunikation mit der Messeinrichtung via LAN-Netzwerk ermöglicht. Die aktuelle Softwareversion der Messeinrichtung lautet:

05-02.08.56-30.03.00

Die aktuelle Softwareversion für die Messeinrichtung SWAM 5a Monitor für PM_{10} oder $PM_{2,5}$ lautet:

01-05.05.13-30.03.00

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 19. September 2014

Figure 118: Notification published in BAnz AT 02.04.2015 B5, chapter IV 8th Notification

44 Mitteilung zu den Bekanntmachungen des Umweltbundesamtes vom 3. August 2009 (BAnz. S. 2934, Kapitel II Nummer 2.1) und vom 25. Februar 2015 (BAnz AT 02.04.2015 B5, Kapitel IV 8. Mitteilung)

Für die Messeinrichtungen SWAM 5a Dual Channel Monitor für PM_{10} und $PM_{2,5}$, SWAM 5a Dual Channel Hourly Mode Monitor für PM_{10} und $PM_{2,5}$ und SWAM 5a Monitor für PM_{10} oder $PM_{2,5}$ der Firma FAI Instruments srl. sind auch Standard-Probeneinlässe gemäß Anhang A der Richtlinie DIN EN 12341 (Ausgabe: August 2014) unter den Bezeichnungen PM10-EN12341-2014 bzw. PM2.5-EN12341-2014 verfügbar.

Stellungnahme der TÜV Rheinland Energie und Umwelt GmbH vom 17. März 2015.

Figure 119: Notification published in BAnz AT 26.08.2015 B4, chapter V 44th Notification

9. Appendixes

Appendix 1 Measured and calculated values

- Annex 1: Zero level and detection limit
- Annex 2: Flow rate accuracy
- Annex 3: Temperature dependence of the zero point and sensitivity
- Annex 4: Dependence of span on supply voltage
- Annex 5: Measured values from the field test locations (SWAM 5a DC)
- Annex 6: Measured values from the field test locations (SWAM 5a DC HM)
- Annex 7: Measured values from the field test locations (SWAM 5a)
- Annex 8: Ambient condition at the field test locations

Appendix 2: Methods used for filter weighing

Appendix 3 Operation manuals

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

Manufacturer FAI Instruments s.r.l.

Type SWAM 5a DC

Standards ZP Measured values with zero filter

Serial-No. SN 127, Line A / SN 127, Line B

No.	Date	Measured values [µg/m³] SN 127, Line A	Date	Measured values [µg/m³] SN 127, Line B
1	6/29/2007	0.1	6/29/2007	0.3
2	6/30/2007	0.0	6/30/2007	0.1
3	7/1/2007	0.0	7/1/2007	0.2
4	7/2/2007	0.5	7/2/2007	0.0
5	7/3/2007	0.5	7/3/2007	0.5
6	7/4/2007	0.4	7/4/2007	0.2
7	7/5/2007	0.5	7/5/2007	0.6
8	7/6/2007	0.1	7/6/2007	0.4
9	7/7/2007	0.3	7/7/2007	0.5
10	7/8/2007	0.1	7/8/2007	0.5
11	7/9/2007	0.3	7/9/2007	0.6
12	7/10/2007	0.2	7/10/2007	0.5
13	7/11/2007	0.5	7/11/2007	0.4
14	7/12/2007	0.3	7/12/2007	0.4
15	7/13/2007	0.6	7/13/2007	0.5
16	7/14/2007	0.3	7/14/2007	0.6
17	7/15/2007	0.0	7/15/2007	0.5
18	7/16/2007	0.3	7/16/2007	0.2
	No. of values	18	No. of values	18
	Mean (Zero level)	0.28	Mean (Zero level)	0.39
	Standard deviation s_{x0}	0.20	Standard deviation s_{x0}	0.18
	Detection limit x	0.65	Detection limit x	0.60

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

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

Manufacturer	FAI Instruments s.r.l.			
Type	SWAM 5a DC	Standards	ZP	Measured values with zero filter
Serial-No.	SN 131, Line A / SN 131, Line B			

No.	Date	Measured values [µg/m³] SN 131, Line A	Date	Measured values [µg/m³] SN 131, Line B
1	6/29/2007	0.0	6/29/2007	0.4
2	6/30/2007	0.4	6/30/2007	0.0
3	7/1/2007	0.0	7/1/2007	0.0
4	7/2/2007	0.6	7/2/2007	0.2
5	7/3/2007	0.0	7/3/2007	0.0
6	7/4/2007	0.0	7/4/2007	0.6
7	7/5/2007	0.4	7/5/2007	0.5
8	7/6/2007	0.2	7/6/2007	0.1
9	7/7/2007	0.2	7/7/2007	0.2
10	7/8/2007	0.0	7/8/2007	0.5
11	7/9/2007	0.0	7/9/2007	0.0
12	7/10/2007	0.3	7/10/2007	0.1
13	7/11/2007	0.4	7/11/2007	0.1
14	7/12/2007	0.1	7/12/2007	0.0
15	7/13/2007	0.3	7/13/2007	0.3
16	7/14/2007	0.3	7/14/2007	0.5
17	7/15/2007	0.5	7/15/2007	0.5
18	7/16/2007	0.3	7/16/2007	0.3
	No. of values	18	No. of values	18
	Mean (Zero level)	0.22	Mean (Zero level)	0.24
	Standard deviation s_{x0}	0.20	Standard deviation s_{x0}	0.21
	Detection limit x	0.65	Detection limit x	0.71

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

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

Manufacturer FAI Instruments s.r.l.

Type SWAM5a DC

Serial-No. SN 111, Line A / SN 111, Line B

Nominal flow rate [l/min] 38.33

		SN 111, Line A			SN 111, Line B		
Temperature 1	5°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
		1	7/26/2017 10:00	38.39	1	7/26/2017 10:03	38.32
		2	7/26/2017 10:12	38.24	2	7/26/2017 10:15	38.07
		3	7/26/2017 10:24	38.10	3	7/26/2017 10:27	38.13
		4	7/26/2017 10:36	38.23	4	7/26/2017 10:39	38.04
		5	7/26/2017 10:48	37.88	5	7/26/2017 10:51	37.99
		6	7/26/2017 11:00	37.92	6	7/26/2017 11:03	38.01
		7	7/26/2017 11:12	37.94	7	7/26/2017 11:15	38.03
		8	7/26/2017 11:24	38.06	8	7/26/2017 11:27	38.05
		9	7/26/2017 11:36	38.10	9	7/26/2017 11:39	38.13
		10	7/26/2017 11:48	38.14	10	7/26/2017 11:51	38.53
			Mean	**38.10**		**Mean**	**38.13**

		SN 111, Line A			SN 111, Line B		
Temperature 2	40°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
		1	7/26/2017 16:02	38.14	1	7/26/2017 16:05	37.95
		2	7/26/2017 16:14	38.18	2	7/26/2017 16:17	37.96
		3	7/26/2017 16:26	38.60	3	7/26/2017 16:29	37.97
		4	7/26/2017 16:38	38.34	4	7/26/2017 16:41	38.00
		5	7/26/2017 16:50	38.18	5	7/26/2017 16:53	37.95
		6	7/26/2017 17:02	38.14	6	7/26/2017 17:05	38.05
		7	7/26/2017 17:14	38.17	7	7/26/2017 17:17	38.08
		8	7/26/2017 17:26	38.17	8	7/26/2017 17:29	38.09
		9	7/26/2017 17:38	38.29	9	7/26/2017 17:41	38.05
		10	7/26/2017 17:50	38.26	10	7/26/2017 17:53	38.34
			Mean	**38.25**		**Mean**	**38.04**

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

Manufacturer FAI Instruments s.r.l.

Nominal flow rate [l/min] 38.33

Type SWAM5a DC

Serial-No. SN 395, Line A / SN 395, Line B

		SN 395, Line A			SN 395, Line B		
Temperature 1	5°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
		1	7/26/2017 10:06	38.44	1	7/26/2017 10:09	38.02
		2	7/26/2017 10:18	38.42	2	7/26/2017 10:21	38.15
		3	7/26/2017 10:30	38.41	3	7/26/2017 10:33	38.19
		4	7/26/2017 10:42	38.42	4	7/26/2017 10:45	38.35
		5	7/26/2017 10:54	38.44	5	7/26/2017 10:57	38.32
		6	7/26/2017 11:06	38.41	6	7/26/2017 11:09	38.35
		7	7/26/2017 11:18	38.31	7	7/26/2017 11:21	38.35
		8	7/26/2017 11:30	38.36	8	7/26/2017 11:33	38.40
		9	7/26/2017 11:42	38.32	9	7/26/2017 11:45	38.42
		10	7/26/2017 11:54	38.31	10	7/26/2017 11:57	38.43
			Mean	**38.38**		**Mean**	**38.30**

		SN 395, Line A			SN 395, Line B		
Temperature 2	40°C	No.	Date/Time	Measured value [l/min]	No.	Date/Time	Measured value [l/min]
		1	7/26/2017 16:08	38.11	1	7/26/2017 16:11	38.48
		2	7/26/2017 16:20	38.73	2	7/26/2017 16:23	38.61
		3	7/26/2017 16:32	38.60	3	7/26/2017 16:35	38.72
		4	7/26/2017 16:44	38.60	4	7/26/2017 16:47	38.87
		5	7/26/2017 16:56	38.84	5	7/26/2017 16:59	38.87
		6	7/26/2017 17:08	38.71	6	7/26/2017 17:11	38.99
		7	7/26/2017 17:20	38.75	7	7/26/2017 17:23	39.11
		8	7/26/2017 17:32	38.40	8	7/26/2017 17:35	38.74
		9	7/26/2017 17:44	38.55	9	7/26/2017 17:47	38.71
		10	7/26/2017 17:56	38.67	10	7/26/2017 17:59	38.71
			Mean	**38.60**		**Mean**	**38.78**

Annex 3 Dependence of zero point on surrounding temperature Page 1 of 4

Manufacturer	FAI Instruments s.r.l.						
Type	SWAM 5a DC						
Serial-No.	SN 127, Line A / SN 127, Line B						
Test period	06.05.2008 - 21.05.2008		Measurement 1	Measurement 2	Measurement 3		
SN 127, Line A	No.	Temperature [°C]	Measured value [µg/m³]	Measured value [µg/m³]	Measured value [µg/m³]	Mean value of 3 measurements [µg/m³]	Mean value at 20°C [µg/m³]
Zero	1	20	0.0	0.1	0.0	0.03	0.16
	2	5	0.5	0.2	0.7	0.47	
	3	20	0.2	0.2	0.0	0.13	
	4	40	0.3	0.5	1.0	0.60	
	5	20	0.2	0.7	0.0	0.30	
SN 127, Line B	No.	Temperature [°C]	Measured value [µg/m³]	Measured value [µg/m³]	Measured value [µg/m³]	Mean value of 3 measurements [µg/m³]	Mean value at 20°C [µg/m³]
Zero	1	20	0.1	0.0	0.6	0.23	0.26
	2	5	0.3	0.0	0.5	0.27	
	3	20	0.2	0.2	0.4	0.27	
	4	40	0.5	0.7	0.7	0.63	
	5	20	0.4	0.4	0.0	0.27	

Annex 3 — Dependence of zero point on surrounding temperature — Page 2 of 4

Manufacturer	FAI Instruments s.r.l.						
Type	SWAM 5a DC						
Serial-No.	SN 131, Line A / SN 131, Line B						
Test period	06.05.2008 - 21.05.2008		Measurement 1	Measurement 2	Measurement 3		
SN 131, Line A	No.	Temperature [°C]	Measured value [µg/m³]	Measured value [µg/m³]	Measured value [µg/m³]	Mean value of 3 measurements [µg/m³]	Mean value at 20°C [µg/m³]
Zero	1	20	0.0	0.1	0.4	0.17	0.22
	2	5	0.2	0.1	0.4	0.23	
	3	20	0.0	0.3	0.0	0.10	
	4	40	0.7	0.8	0.6	0.70	
	5	20	0.3	0.4	0.5	0.40	
SN 131, Line B	No.	Temperature [°C]	Measured value [µg/m³]	Measured value [µg/m³]	Measured value [µg/m³]	Mean value of 3 measurements [µg/m³]	Mean value at 20°C [µg/m³]
Zero	1	20	0.0	0.0	0.5	0.17	0.19
	2	5	0.0	0.4	0.0	0.13	
	3	20	0.0	0.4	0.0	0.13	
	4	40	1.0	0.7	0.8	0.83	
	5	20	0.0	0.6	0.2	0.27	

Annex 3 **Dependence of span on surrounding temperature** **Page 3 of 4**

Manufacturer FAI Instruments s.r.l.

Used test standard Reference foils

Type SWAM 5a DC

Serial-No. SN 127 R1 / SN 127 R2

Test period 14.09.07 - 18.09.07

SN 127 R1	No.	Temperature [°C]	Measurement 1 Measured value [mg/cm²]	Measurement 2 Measured value [mg/cm²]	Meaurement 3 Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]	Mean value at 20°C [mg/cm²]
Span	1	20	3.457	3.455	3.451	3.454	3.451
	2	5	3.453	3.453	3.448	3.451	
	3	20	3.451	3.450	3.454	3.452	
	4	40	3.448	3.446	3.450	3.448	
	5	20	3.443	3.454	3.448	3.448	
SN 127 R2	**No.**	**Temperature [°C]**	**Measured value [mg/cm²]**	**Measured value [mg/cm²]**	**Measured value [mg/cm²]**	**Mean value of 3 measurements [mg/cm²]**	**Mean value at 20°C [mg/cm²]**
Span	1	20	6.833	6.838	6.828	6.833	6.829
	2	5	6.833	6.830	6.829	6.831	
	3	20	6.833	6.829	6.828	6.830	
	4	40	6.826	6.828	6.825	6.826	
	5	20	6.821	6.829	6.826	6.825	

Annex 3 **Dependence of span on surrounding temperature** **Page 4 of 4**

Manufacturer FAI Instruments s.r.l.

Used test standard Reference foils

Type SWAM 5a DC

Serial-No. SN 131 R1 / SN 131 R2

Test period 14.09.07 - 18.09.07

			Measurement 1	Measurement 2	Meaurement 3		
SN 131 R1	No.	Temperature [°C]	Measured value [mg/cm²]	Measured value [mg/cm²]	Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]	Mean value at 20°C [mg/cm²]
Span	1	20	3.396	3.399	3.401	3.399	3.401
	2	5	3.399	3.404	3.403	3.402	
	3	20	3.401	3.398	3.406	3.402	
	4	40	3.406	3.402	3.401	3.403	
	5	20	3.402	3.400	3.405	3.402	
SN 131 R2	No.	Temperature [°C]	Measured value [mg/cm²]	Measured value [mg/cm²]	Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]	Mean value at 20°C [mg/cm²]
Span	1	20	6.863	6.873	6.871	6.869	6.871
	2	5	6.871	6.875	6.874	6.873	
	3	20	6.874	6.875	6.873	6.874	
	4	40	6.874	6.873	6.874	6.874	
	5	20	6.870	6.870	6.867	6.869	

Annex 4 — Dependence of span on supply voltage — Page 1 of 2

Manufacturer FAI Instruments s.r.l.

Used test standard Foils

Type SWAM 5a DC

Serial-No. SN 111, R1 / SN 111, R2

Test period 31.07.2017

			Measurement 1	Measurement 2	Measurement 3	
SN 111, R1	No.	Mains voltage [V]	Measured value [mg/cm²]	Measured value [mg/cm²]	Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]
Span	1	230	3.464	3.451	3.454	3.456
	2	195	3.445	3.442	3.444	3.444
	3	230	3.442	3.441	3.444	3.442
	4	253	3.443	3.445	3.446	3.445
	5	230	3.446	3.445	3.444	3.445
SN 111, R2	No.	Mains voltage [V]	Measured value [mg/cm²]	Measured value [mg/cm²]	Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]
Span	1	230	6.807	6.799	6.797	6.801
	2	195	6.788	6.788	6.790	6.789
	3	230	6.785	6.785	6.787	6.786
	4	253	6.785	6.791	6.788	6.788
	5	230	6.788	6.786	6.788	6.787

Annex 4 **Dependence of span on supply voltage** **Page 2 of 2**

Manufacturer FAI Instruments s.r.l.

Used test standard Foils

Type SWAM 5a DC

Serial-No. SN 395, R1 / SN 395, R2

Test period 31.07.2017

SN 395, R1	No.	Mains voltage [V]	Measurement 1 Measured value [mg/cm²]	Measurement 2 Measured value [mg/cm²]	Measurement 3 Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]
Span	1	230	3.294	3.294	3.293	3.294
	2	195	3.325	3.293	3.293	3.304
	3	230	3.294	3.291	3.295	3.293
	4	253	3.295	3.293	3.293	3.294
	5	230	3.290	3.293	3.293	3.292

SN 395, R2	No.	Mains voltage [V]	Measured value [mg/cm²]	Measured value [mg/cm²]	Measured value [mg/cm²]	Mean value of 3 measurements [mg/cm²]
Span	1	230	6.604	6.609	6.605	6.606
	2	195	6.602	6.601	6.603	6.602
	3	230	6.599	6.602	6.601	6.601
	4	253	6.601	6.598	6.604	6.601
	5	230	6.598	6.602	6.603	6.601

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 1 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
1	10/20/2007			18.0	20.2		15.9	16.4	20.8	21.0	Outlier Ref. PM2,5	Cologne,
2	10/21/2007			18.1	19.8		15.8	17.1	20.2	20.1		parking lot
3	10/22/2007			21.6	22.9			18.8		23.4	Water inleakage SN127	
4	10/23/2007	23.1	20.9	24.4	26.6	86.2		20.4		26.5	Water inleakage SN127	
5	10/24/2007	27.1	29.2	30.7	32.0	89.7	26.8	26.1	34.0	32.4		
6	10/25/2007	24.2	25.8	26.7	28.3	91.0	23.2	22.4	28.6	27.7		
7	10/26/2007	21.8	24.5	27.7	28.9	81.6	22.8	22.4	30.2	29.5		
8	10/27/2007			33.9	35.9		29.5	28.8	36.0	34.7		
9	10/28/2007			34.4	35.7						Change to wintertime	
10	10/29/2007										Change to wintertime	
11	10/30/2007										ZP/RP-Check	
12	10/31/2007	22.8	24.6	26.4	28.2	87.1	23.1	23.3	31.7	32.7		
13	11/1/2007			29.1	31.3		27.3	27.2	35.6	36.0		
14	11/2/2007			29.1	31.0		21.9	22.8	34.0	36.3		
15	11/3/2007			23.7	23.8		17.9	18.0	28.5	28.1		
16	11/4/2007			16.9	19.1		11.8	11.8	21.4	21.3		
17	11/5/2007	14.5	16.1	18.4	18.9	82.2	13.5	13.6	24.0	23.7		
18	11/6/2007	10.8	11.9	15.8	16.8	69.4	9.6	9.8	20.7	19.7		
19	11/7/2007	15.0	15.0	23.1	23.0	65.3	14.7	14.4	29.1	29.2		
20	11/8/2007	9.5	10.6	13.5	14.7	71.6	10.0	9.8	15.8	15.7		
21	11/9/2007	7.1	7.1	10.0	10.6	68.6	7.0	6.8	13.4	13.7		
22	11/10/2007			9.8	10.3		7.5	7.5	13.0	12.7		
23	11/11/2007			6.3	7.8		5.4	5.8	9.6	9.3		
24	11/12/2007	8.8	9.6	15.1	16.2	58.7	10.2	10.6	19.5	19.5		
25	11/13/2007	11.7	11.7	15.8	15.7	74.5	13.2	13.5	17.9	17.6		
26	11/14/2007	12.2	12.2	14.7	14.9	82.3	14.0	13.7	17.8	17.5		
27	11/15/2007	17.6	18.5	22.4	25.8	74.8	19.7	19.5	25.3	24.3		
28	11/16/2007	27.5	27.2	35.0	38.3	74.6	28.0	27.7	40.1	38.6		
29	11/17/2007			55.7	60.5		47.3	45.4	62.4	59.4		
30	11/18/2007	16.0	16.3	17.4	21.5	83.0	16.3	17.3	18.3	18.8		

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

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
31	11/19/2007	21.6	22.3	24.5	28.3	83.1	22.6	22.1	26.3	26.2		Cologne,
32	11/20/2007			22.5	27.5		22.3	21.4	26.2	25.5		parking lot
33	11/21/2007			24.0	28.0		21.9	22.1	28.1	27.9		
34	11/22/2007	20.8	22.2	26.2	29.5	77.2	23.4	23.1	29.6	30.2		
35	11/23/2007	17.0	17.8	24.1	28.4	66.4	15.5	16.1	27.7	28.1		
36	11/24/2007			23.8	28.2		16.0	16.3	27.9	28.2		
37	11/25/2007			13.8	14.4		5.6	6.1	12.0	12.5		
38	11/26/2007			15.3	15.4		8.3	8.1	17.5	17.7		
39	11/27/2007	18.2	18.3	26.5	27.1	68.2	16.8	16.9	31.0	30.4		
40	11/28/2007	20.1	21.6	26.4	26.2	79.3	19.3	19.1	28.3	27.3		
41	11/29/2007			19.2	19.7		14.8	13.8	22.3	22.0		
42	11/30/2007			14.0	13.8		8.4	8.2	15.1	15.5		
43	12/1/2007			10.0	9.6		4.7	4.2	11.5	11.7		
44	12/2/2007			6.0	5.7		2.9	2.5	7.3	7.0		
45	12/3/2007			10.6	10.8		5.4	5.7	12.6	11.5		
46	12/4/2007	9.4	9.4	13.2	13.9	69.6	8.1	8.4	17.0	16.9		
47	12/5/2007	6.8	7.0	11.9	12.8	56.1	6.1	5.6	14.9	14.2		
48	12/6/2007			5.8	7.6						ZP/RP-Check	
49	12/7/2007	7.4	7.8	13.3	13.4	57.2	7.0	7.2	16.5	16.2		
50	12/8/2007			8.0	8.5		4.8	3.8	9.4	9.3		
51	12/9/2007			5.6	5.9		3.9	3.8	7.1	7.1		
52	12/10/2007	11.2	12.3	17.7	17.5	66.5	13.2	13.1	20.4	19.8		
53	12/11/2007			13.2	13.3		12.1	11.5	20.4	19.8		
54	12/12/2007	26.5	27.1	32.6	31.2	84.0	26.8	25.7	35.4	35.0		
55	12/13/2007	15.2	15.6	18.9	17.8	83.9	14.9	15.2	20.3	20.3		
56	12/14/2007	13.8	14.0	17.0	15.8	84.5	13.5	13.1	17.9	17.4		
57	12/15/2007			17.2	16.2		14.9	14.5	17.7	17.7		
58	12/16/2007			25.0	24.5		23.4	22.8	26.7	26.2		
59	12/17/2007	25.0	24.6	31.1	31.0	80.0	26.7	24.9	36.2	34.8		
60	12/18/2007			66.9	66.3		57.1	53.1	77.9	74.0		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 3 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
61	12/19/2007			77.0	74.9		64.8	63.0	89.6	87.3		Cologne,
62	12/20/2007			88.2	86.3		70.3	68.2	100.4	94.2		parking lot
63	12/21/2007			53.5	54.2		53.5	51.6	61.0	57.1		
64	12/22/2007			59.4	60.6		65.3	61.2	70.8	65.2		
65	12/23/2007			58.6	59.2		48.6	44.6	59.3	59.4		
66	12/24/2007			25.2	25.5		23.4	21.9	24.9	24.5		
67	12/25/2007			30.3	30.6		29.3	29.1	32.6	32.4		
68	12/26/2007			33.6	34.0		31.4	31.9	36.1	35.8		
69	12/27/2007			12.3	12.7		10.9	10.7	12.7	12.5		
70	12/28/2007			12.0	12.7		11.2	11.3	12.8	12.1		
71	12/29/2007			8.9	10.0		7.2	6.7	10.0	10.4		
72	12/30/2007			16.2	16.0		9.8	9.8	17.7	18.9		
73	12/31/2007	37.2	37.2	46.0	45.6	81.1	37.0	35.6	47.3	46.1		
74	1/1/2008			22.7	22.5		19.6	19.0	23.4	23.3		
75	1/2/2008			19.4	19.3		17.3	17.0	20.2	20.1		
76	1/3/2008	19.8	19.8	21.9	22.4	89.2	20.5	19.7	22.7	22.1		
77	1/4/2008						23.1	22.7	26.5	26.4		
78	1/5/2008						7.0	6.0	11.2	11.4		
79	1/6/2008										Filter supply ran out	
80	1/7/2008										Filter supply ran out	
81	1/8/2008										ZP/RP-Check	
82	1/9/2008	8.3	9.2	12.4	13.4	68.1	7.6	7.8	14.9	14.5		
83	1/10/2008	9.4	9.6	11.3	12.1	80.6	9.1	8.7	12.8	13.3		
84	1/11/2008	6.0	5.4	7.5	8.3	71.9	6.0	6.0	8.8	8.2		
85	1/12/2008			14.1	12.7		9.1	9.0	13.8	13.8		
86	1/13/2008			16.2	16.6		12.8	13.0	16.8	16.8		
87	1/14/2008	10.3	8.8	13.2	13.6	71.6	10.1	9.9	14.3	14.0		
88	1/15/2008	4.6	4.1	7.0	5.8	67.9	4.8	4.7	6.6	6.7		
89	1/16/2008	6.8	6.6	10.0	10.1	67.3	7.4	7.4	12.1	12.3		
90	1/17/2008	7.2	7.6	12.3	11.7	61.8	5.9	6.1	12.8	13.0		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 4 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
91	1/18/2008			12.0	11.8		5.7	4.3	14.4	14.5		Cologne, parking lot
92	1/19/2008	3.4	4.2	5.6	4.4	75.7	4.0	3.8	6.3	6.6		
93	1/20/2008			5.7	5.3		3.7	3.4	5.7	5.4		
94	1/21/2008	5.6	5.4	8.5	8.4	65.5	5.6	5.4	9.9	9.0		
95	1/22/2008			20.3	19.4		9.4	9.6	22.7	22.8		
96	1/23/2008	12.2	12.4	20.6	20.0	60.6	10.8	10.5	22.2	21.9		
97	1/24/2008	14.1	14.7	26.7	26.0	54.6	12.5	11.1	29.5	28.7		
98	1/25/2008	10.1	10.3	18.3	18.0	56.3	9.0	9.2	20.0	20.0		
99	1/26/2008			26.3	25.5		17.1	17.0	28.4	28.6		
100	1/27/2008			31.6	30.3		17.3	17.0	32.1	33.8		
101	1/28/2008	27.5	28.3	39.2	38.1	72.2	25.9	25.6	42.5	42.9		
102	1/29/2008			51.0	50.8		36.2	34.4	55.8	55.0		
103	1/30/2008	18.8	19.4	24.7	25.7	75.9	17.4	17.5	27.2	27.3		
104	1/31/2008			7.7	7.7		5.6	5.6	8.4	8.1		
105	2/1/2008			10.8	10.2		5.4	5.0	11.9	12.1		
106	2/2/2008			13.4	14.2		7.1	6.8	14.1	14.4		
107	2/3/2008			11.5	12.2		9.1	8.9	11.9	12.3		
108	2/4/2008	7.6	7.6	9.7	10.4	75.6	8.1	7.7	10.9	10.3		
109	2/5/2008			5.2	5.3		3.3	2.8	5.8	5.7		
110	2/14/2008	32.6	33.3	38.2	38.2	86.3	31.6	30.9	41.2	39.8		Bonn
111	2/15/2008			15.0	15.5		11.6	11.9	16.7	17.5		
112	2/16/2008			18.3	19.2		15.0	14.9	19.0	18.6		
113	2/17/2008	30.3	29.9	37.7	37.4	80.2	31.0	30.4	43.5	42.0		
114	2/18/2008	48.4	48.5	63.0	62.4	77.2	50.8	52.2	75.8	75.1		
115	2/19/2008	41.7	42.1	52.0	51.9	80.5	40.7	40.6	57.7	56.9		
116	2/20/2008	38.8	37.6	41.6	42.6	90.8	36.6	37.1	44.2	44.4		
117	2/21/2008	30.7	31.0	39.9	39.5	77.7	29.0	28.5	43.5	43.9		
118	2/22/2008	17.8	17.9	24.8	25.1	71.4	15.5	15.7	27.9	27.2		
119	2/23/2008			27.4	27.2		21.4	21.5	29.6	30.1		
120	2/24/2008			30.1	29.2		24.4	24.0	31.3	30.9		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 5 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
121	2/25/2008	19.0	18.8	24.1	24.6	77.5	18.6	18.3	26.1	26.1		Bonn
122	2/26/2008	12.5	13.0	23.9	23.4	53.8	11.6	11.4	25.9	25.7		
123	2/27/2008	18.8	18.6	27.6	27.8	67.5	16.2	14.5	29.0	29.3		
124	2/28/2008	20.8	21.5	28.4	30.0	72.5	19.1	19.4	30.5	31.0		
125	2/29/2008	9.8	9.8	14.7	14.0	68.1	8.2	8.5	14.7	14.5		
126	3/1/2008			15.6	14.8		7.2	6.9	15.1	15.4		
127	3/2/2008			23.3	23.1		11.2	10.9	24.1	24.5		
128	3/3/2008	12.9	13.5	20.1	19.6	66.4	13.3	11.7	22.8	22.1		
129	3/4/2008	13.9	14.4	22.2	22.2	63.7	13.4	13.0	25.9	24.8		
130	3/5/2008	16.2	15.2	26.1	25.4	61.2	16.4	16.0	28.7	28.6		
131	3/6/2008	20.8	21.1	30.0	30.2	69.7	18.7	18.8	32.5	33.5		
132	3/7/2008	16.9	15.9	25.5	24.5	65.5	15.2	15.6	28.6	27.9		
133	3/8/2008			20.7	20.1		14.4	14.6	20.6	20.7		
134	3/9/2008			11.5	9.9		6.8	6.1	12.2	11.6		
135	3/10/2008	4.1	5.4	8.6	7.6	58.6	4.5	4.5	9.4	9.8		
136	3/11/2008	7.1	7.3	13.6	13.4	53.1	6.9	6.8	15.2	15.2		
137	3/12/2008			19.1	19.2						ZP/RP-Check	
138	3/13/2008	12.0	11.6	16.5	16.9	70.7	10.9	10.2	19.1	18.9		
139	3/14/2008	20.8	20.3				19.5	19.9	30.1	29.9	Ref. PM10 not considered	
140	3/15/2008			10.7	11.1		8.0	7.6	10.8	11.0		
141	3/16/2008			16.9	18.4		11.9	11.3	18.7	18.8		
142	3/17/2008	13.5	12.9	22.0	23.3	58.5	11.4	11.0	26.0	25.1		
143	3/18/2008	14.8	13.1	21.6	22.0	64.0	12.5	11.7	24.8	23.6		
144	3/19/2008	12.8	13.7	18.7	20.0	68.6	11.7	10.2	21.1	20.6		
145	3/20/2008	8.0	7.8	10.3	10.8	74.8	6.7	6.5	11.0	11.1		
146	3/21/2008						7.5	7.8	10.7	10.9	Ref. PM10 not considered	
147	3/22/2008			24.7	26.0		22.0	21.1	26.7	26.3		
148	3/23/2008			19.8	21.1		15.3	14.9	21.6	21.1		
149	3/24/2008			12.0	12.5		7.7	7.9	12.0	11.9		
150	3/25/2008	13.0	12.4	16.6	16.7	76.1	11.5	11.7	17.5	17.3		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 6 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
151	3/26/2008	20.1	20.3	22.2	22.6	90.1					Change to summertime	Bonn
152	3/27/2008	7.6	7.6								Change to summertime	
153	3/28/2008			12.8	13.2		6.5	6.6	13.9	14.2		
154	3/29/2008			14.3	14.6		7.9	7.6	15.5	15.4		
155	3/30/2008			15.0	15.3		9.8	9.3	18.6	17.2		
156	3/31/2008	11.6	12.1	16.7	16.5	71.3	11.4	11.4	19.7	19.1		
157	4/1/2008	14.3	13.5	25.0	25.4	55.2	11.9	11.8	30.1	28.6		
158	4/2/2008	17.2	17.6	26.6	27.7	64.1	14.9	14.6	31.5	31.7		
159	4/3/2008	22.2	23.3	30.9	31.5	72.9	20.6	19.8	36.3	35.3		
160	4/4/2008	30.1	29.4	36.9	36.8	80.7	27.8	28.6	41.6	41.3		
161	4/5/2008			14.4	13.9		11.1	11.1	15.0	15.7		
162	4/6/2008			17.3	17.5		12.7	12.3	19.3	19.2		
163	4/7/2008	22.5	23.0	26.3	26.7	86.1	21.9	21.3	29.3	28.7		
164	4/8/2008	31.7	32.3	37.3	36.7	86.6	30.1	30.3	39.3	38.2		
165	4/9/2008	35.6	35.0	40.8	39.9	87.6	31.3	31.7	42.1	41.5		
166	4/10/2008			30.5	30.2						ZP/RP-Check	
167	4/11/2008	36.4	35.7	45.5	45.3	79.5	31.9	32.1	43.7	42.8		
168	4/12/2008			12.6	12.1		7.7	7.6	12.6	12.8		
169	4/13/2008			11.7	11.9		10.0	9.8	12.8	12.0		
170	4/14/2008	29.3	29.6	36.2	36.0	81.6	27.0	27.7	36.6	36.4		
171	4/15/2008	22.0	21.9	27.2	25.8	82.7	20.1	19.9	26.6	26.3		
172	4/16/2008	17.6	18.3	25.6	24.7	71.4	17.4	16.5	26.4	26.2		
173	4/17/2008	20.1	19.2	23.9	23.9	82.3	18.0	17.3	23.0	23.1		
174	4/18/2008	21.2	20.7	25.0	24.0	85.5	20.2	19.2	25.1	24.4		
175	4/19/2008			21.4	19.6		16.3	16.4	18.8	19.7		
176	4/20/2008			19.7	18.8		15.7	14.6	19.7	18.7		
177	4/21/2008	23.2	22.7	29.1	28.0	80.3	23.1	22.1	30.2	30.3		
178	9/30/2008	3.5	5.0	5.0	5.0	84.0	3.9	2.9	5.8	5.5		Brühl
179	10/1/2008	5.6	5.2	10.4	9.2	55.3	4.9	3.3	8.3	8.4		
180	10/2/2008	5.3	6.2	13.2	12.6	44.5	6.1	3.7	13.6	11.6		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 7 of 18**

Manufacturer FAI Instruments s.r.l.
Type of instrument SWAM 5a DC
Serial-No. SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
181	10/3/2008	7.8	8.0	13.8	12.6	59.6	7.0	7.2	10.5	10.5		Brühl
182	10/4/2008			13.8	13.6		5.6	4.9	12.3	11.7		
183	10/5/2008						4.7	1.7	4.8	4.9		
184	10/6/2008						6.5	6.4	11.9	12.0		
185	10/7/2008	8.3	8.5	14.7	14.8	57.0	8.6	8.8	14.2	15.5		
186	10/8/2008	11.6	10.9	22.5	22.3	50.2	12.5	13.2	24.9	25.0		
187	10/9/2008	16.2	16.6	34.1	33.2	48.8	17.4	18.0	38.1	35.6		
188	10/10/2008	15.4	15.2	25.8	26.3	58.8	14.8	16.1	25.8	26.6		
189	10/11/2008			32.4	31.4		25.1	24.8	35.6	35.3	Outlier Ref. PM2,5	
190	10/12/2008			23.7	23.4		16.5	17.4	24.3	25.7		
191	10/13/2008	18.0	17.1	33.7	32.1	53.3	19.8	20.8	33.6	33.6		
192	10/14/2008	17.5	21.2	46.6	47.0	41.4	21.7	20.4	51.2	51.2		
193	10/15/2008	9.7	9.7	15.0	16.2	61.8	9.2	8.9	16.2	16.0		
194	10/16/2008	9.4	9.1	17.8	17.5	52.3	8.1	8.7	18.3	17.9		
195	10/17/2008	12.9	13.4	25.9	25.2	51.5	11.9	10.9	25.9	25.3		
196	10/18/2008	16.1	14.5	19.7	20.5	76.2	11.4	11.8	19.3	20.0		
197	10/19/2008			16.7	17.2						Failure SN131 - cable break	
198	10/20/2008	13.9	13.3	22.6	20.3	63.4					Failure SN131 - cable break	
199	10/21/2008	9.4	9.8	16.1	15.5	60.7					Failure SN131 - cable break	
200	10/22/2008			25.8	24.3						Failure SN131 - cable break	
201	10/23/2008										Failure SN131 - cable break	
202	10/24/2008	18.9	19.3	26.3	26.6	72.3	16.2	18.2	24.8	24.6		
203	10/25/2008	15.2	14.3	16.3	17.3	87.8	12.1	12.0	14.9	15.6		
204	10/26/2008			8.0	9.7		5.7	5.2	8.1	7.4		
205	10/27/2008	11.4	11.4	19.9	20.8	56.0	10.4	9.8	19.5	18.3		
206	10/28/2008	14.0	12.7	21.9	22.9	59.5	11.5	11.4	19.9	19.6		
207	10/29/2008	31.5	31.5	42.4	43.4	73.3	27.8	27.1	38.9	38.9		
208	10/30/2008	17.6	18.1	21.6	22.7	80.7	15.1	14.5	19.2	19.0		
209	10/31/2008	15.6	16.5	21.0	21.6	75.3	14.8	15.3	18.5	19.5		
210	11/1/2008			23.8	24.8		18.0	17.9	21.2	22.6		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 8 of 18**

Manufacturer: FAI Instruments s.r.l.
Type of instrument: SWAM 5a DC
Serial-No.: SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
211	11/2/2008			22.5	23.0		16.5	16.2	21.0	21.3		Brühl
212	11/3/2008	19.9	19.4	30.3	29.7	65.6		21.5		30.2	SN127 - Filter depleted	
213	11/4/2008	29.0	29.2	41.9	41.8	69.6		29.1		40.7	SN127 - Filter depleted	
214	11/5/2008	34.5	33.8	50.1	51.3	67.4	34.9	32.3	48.0	48.1		
215	11/6/2008	22.8	23.7	36.1	36.5	64.1					Replacement TÜV-cabinet	
216	11/7/2008										Replacement TÜV-cabinet	
217	11/8/2008										Replacement TÜV-cabinet	
218	11/9/2008										Replacement TÜV-cabinet	
219	11/10/2008										Replacement TÜV-cabinet	
220	11/11/2008										ZP/RP-Check	
221	11/12/2008	10.9	11.1	20.2	22.0	52.1	8.7	8.4	19.2	18.7		
222	11/13/2008	17.9	18.5	31.2	28.8	60.7	16.0	15.9	27.0	27.4		
223	11/14/2008	14.3	14.5	20.9	21.8	67.5	12.7	13.0	19.3	19.4		
224	11/15/2008			17.4	16.4		11.1	10.8	14.3	16.0		
225	11/16/2008	8.9	9.8				8.2	8.1	16.0	15.3	Outlier Ref. PM10	
226	11/17/2008	13.8	14.0	30.8	29.9	45.7	12.5	12.8	29.6	28.5		
227	11/18/2008	12.5	13.2	25.1	22.7	53.8	11.4	11.9	22.1	22.2		
228	11/19/2008	12.8	14.1				12.7	12.8	25.3	24.6	Outlier Ref. PM10	
229	11/20/2008			19.3	17.9		8.5	8.0	16.1	15.7	Ref PM2,5 not considered	
230	11/21/2008	5.8	3.4	10.8	9.5	45.5	3.8	3.6	8.3	8.0		
231	11/22/2008			12.2	12.1		7.0	6.7	10.8	10.6		
232	11/23/2008	6.4	6.8	10.9	8.1	69.6	5.0	5.3	7.7	8.5		
233	11/24/2008	17.7	17.5	22.2	21.9	79.8	16.1	16.8	21.5	21.9		
234	11/25/2008	17.7	17.9	28.9	28.7	61.9	14.7	15.4	25.5	24.8		
235	11/26/2008	9.6	10.4	18.0	17.9	55.9	9.0	8.1	15.3	14.9		
236	11/27/2008	13.4	13.0	16.5	17.1	78.8	12.6	12.2	16.1	16.2		
237	11/28/2008	23.1	23.2	26.3	26.6	87.5	22.0	21.6	26.2	24.9		
238	11/29/2008	24.3	25.4	27.1	28.0	90.2	22.9	22.9	26.8	27.7		
239	11/30/2008			24.8	26.2		21.4	21.2	24.2	24.4		
240	12/1/2008	27.2	26.8	32.4	33.3	82.2	24.9	24.7	33.2	33.0		

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

Manufacturer: FAI Instruments s.r.l.

Type of instrument: SWAM 5a DC

Serial-No.: SN 127 / SN 131
SN 145 / SN 149 (Teddington)

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 / SN 145 PM2,5 [µg/m³]	SN 131 / SN 149 PM2,5 [µg/m³]	SN 127 / SN 145 PM10 [µg/m³]	SN 131 / SN 149 PM10 [µg/m³]	Remark	Test site
241	12/2/2008	10.9	11.1	14.5	14.9	74.7	9.6	9.6	13.3	12.6		Brühl
242	12/3/2008	13.6	13.6	15.2	16.6	85.6	11.4	11.8	16.0	15.7		
243	12/4/2008	6.0	6.4	7.1	8.8	77.6	5.6	4.9	7.3	7.5		
244	12/5/2008	7.5	8.1	9.8	10.1	78.4	6.2	6.3	9.1	10.5		
245	12/6/2008	14.5	15.8	20.6	21.3	72.3	12.6	13.5	19.2	20.3		
246	7/24/2008			32.9	32.0						ZP/RP-Check	Teddington
247	7/25/2008	15.4	15.1	22.5	23.6	65.9	13.9	13.2	27.1	24.4		
248	7/26/2008			21.0	21.6		14.1	14.2	23.3	23.3	Outlier Ref. PM2,5	
249	7/27/2008	13.1	13.2	19.0	19.9	67.8	15.3	15.0	22.4	22.0		
250	7/28/2008	13.5	13.6	20.3	20.3	66.9	15.7	15.8	23.5	24.1		
251	7/29/2008	4.2	4.7	11.8	12.1	37.4	6.0	6.4	14.0	14.7		
252	7/30/2008	9.6	9.5	16.2	16.5	58.4	11.3	10.9	19.4	18.8		
253	7/31/2008	10.8	11.0	22.2	22.4	49.0	14.0	14.0	26.4	27.8		
254	8/1/2008	4.2	5.5	16.3	15.5	30.3	6.8	7.5	19.3	18.9		
255	8/2/2008	2.4	2.2	8.5	6.0	31.6	4.8	4.5	8.9	8.9		
256	8/3/2008	2.0	2.5	8.2	8.4	26.8	3.9	3.6	10.2	10.8		
257	8/4/2008	3.4	4.4	9.4	9.6	41.1	6.0	5.6	13.2	12.5		
258	8/5/2008	3.1	3.6	7.5	7.3	45.1	5.8	6.0	10.8	10.6		
259	8/6/2008										Power loss	
260	8/7/2008	5.4	6.2	11.9	11.4	50.2	7.7	7.5	15.0	15.0		
261	8/8/2008	5.2	6.2	9.9	9.6	58.5	7.5	6.9	12.5	11.9		
262	8/9/2008	2.3	3.3	7.1	7.3	39.3	4.9	4.5	10.7	10.4		
263	8/10/2008	3.9	4.1	11.7	11.2	34.7	4.8	5.4	13.8	13.0		
264	8/11/2008	5.6	6.0	13.7	13.5	42.7	6.5	7.1	16.3	15.0		
265	8/12/2008	3.5	3.5	10.6	10.5	33.2	4.5	4.6	12.8	12.6		
266	8/13/2008	3.5	3.8	11.8	11.4	31.7	4.7	5.0	13.1	13.4		
267	8/14/2008	6.1	6.5	11.0	11.1	56.9	7.0	6.6	12.3	11.0		
268	8/15/2008	5.6	6.3	10.0	11.6	55.4	5.5	5.3	11.2	10.9		
269	8/16/2008	5.5	5.5				4.7	5.1	9.1	9.0	Outlier Ref. PM10	
270	8/17/2008	2.7	2.7	8.7	8.5	31.2	3.9	4.5	12.7	12.2		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 10 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 145 / SN 149

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 145 PM2,5 [µg/m³]	SN 149 PM2,5 [µg/m³]	SN 145 PM10 [µg/m³]	SN 149 PM10 [µg/m³]	Remark	Test site
271	8/18/2008										ZP/RP-Check	Teddington
272	8/19/2008	4.6	4.7	12.5	13.0	36.6	5.7	5.7	12.6	12.8		
273	8/20/2008	3.9	4.1	10.2	10.1	39.6	5.3	5.6	14.6	13.2		
274	8/21/2008	6.5	6.8	13.2	13.5	50.2	7.3	7.7	14.3	13.8		
275	8/22/2008	5.2	4.9	9.5	9.3	53.6	6.1	5.9	10.7	10.8		
276	8/23/2008	4.5	4.4	9.2	9.5	47.4	6.2	6.5	11.4	12.9		
277	8/24/2008	3.5	3.5	8.6	8.7	40.3	4.7	5.6	11.7	11.4		
278	8/25/2008	6.5	6.5	12.9	13.0	50.0	9.2	9.1	17.6	17.4		
279	8/26/2008	4.8	4.9	10.7	9.5	47.9	7.3	7.0	13.3	13.3		
280	8/27/2008	7.4	7.0	13.4	13.6	53.2		9.0		16.7	SN145 Sensor defective	
281	8/28/2008	9.6	9.3	14.1	14.2	66.8		12.4		16.5	SN145 Sensor defective	
282	8/29/2008	13.7	12.8	20.1	19.1	67.8		17.1		22.4	SN145 Sensor defective	
283	8/30/2008	31.6	30.5	43.8	43.2	71.4	39.3	36.8	48.2	48.2		
284	8/31/2008	13.3	12.1	22.0	21.6	58.5	15.7	16.6	24.6	25.3		
285	9/1/2008	2.9	2.6	8.1	8.1	33.9	4.3	4.5	11.7	11.2		
286	9/2/2008	3.0	2.4	11.8	12.4	22.3	3.8	4.7	13.3	12.8		
287	9/3/2008	3.6	3.3	14.2	14.3	24.2	5.0	5.1	16.4	15.4		
288	9/4/2008	4.1	3.7				5.7	5.4	12.7	12.8	Outlier Ref. PM10	
289	9/5/2008	2.6	2.7	7.5	7.6	35.0	4.8	4.5	10.4	10.0		
290	9/6/2008	3.4	3.6	8.0	7.6	44.9	4.1	4.8	9.9	9.2		
291	9/7/2008	3.1	2.7	8.4	8.2	34.8	5.0	4.6	9.7	9.8		
292	9/8/2008	6.4	6.6	14.7	14.2	45.0	8.4	8.1	16.5	16.8		
293	9/9/2008	6.0	5.2	14.4	14.2	39.1	6.8	7.4	15.3	17.2		
294	9/10/2008	4.3	4.1	11.0	10.6	38.6	5.8	7.2	13.5	13.6		
295	9/11/2008	6.5	5.4	17.2	17.5	34.2	6.6	6.3	18.4	17.4		
296	9/12/2008	5.5	5.1	9.4	9.1	57.3	6.8	6.7	11.4	10.5		
297	9/13/2008	15.5	15.4	20.4	20.7	75.5	16.8	16.5	22.0	20.9		
298	9/14/2008	10.9	10.3	18.1	17.4	60.0	11.6	11.3	18.0	17.7		
299	9/15/2008	11.8	12.3	17.5	17.5	68.6	12.1	12.5	17.7	17.2		
300	9/16/2008	17.7	17.4	24.6	24.2	72.0	17.3	17.5	23.9	24.1		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 11 of 18**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC

Serial-No. SN 145 / SN 149

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 145 PM2,5 [µg/m³]	SN 149 PM2,5 [µg/m³]	SN 145 PM10 [µg/m³]	SN 149 PM10 [µg/m³]	Remark	Test site
301	9/17/2008	19.4	19.2	26.9	28.1	70.3	18.0	17.6	25.4	25.8		Teddington
302	9/18/2008	17.0	17.2	24.5	23.6	71.3	16.3	16.6	23.9	23.5		
303	9/19/2008	20.7	20.9	29.3	29.4	70.9	20.4	20.6	30.0	29.7		
304	9/20/2008	21.7	21.4	26.9	26.6	80.6	20.7	21.2	26.8	25.7		
305	9/21/2008	21.6	22.0	28.6	28.1	76.9	22.3	23.2	29.0	28.9		
306	9/22/2008	14.8	15.0	22.3	22.6	66.3	15.8	17.0	23.5	23.5		
307	9/23/2008	6.3	6.1	18.0	17.8	34.5					ZP/RP-Check	
308	9/24/2008	11.4	11.4	18.8	19.7	59.1	12.3	11.8	21.0	21.3		
309	9/25/2008	16.1	16.5	26.7	26.4	61.2	16.1	16.2	26.5	25.8		
310	9/26/2008	17.5	17.4	29.9	29.7	58.5	17.5	18.4	28.9	30.4		
311	9/27/2008	27.2	27.2	35.7	35.6	76.4	29.1	28.7	36.4	37.2		
312	9/28/2008						16.9	16.8	24.7	25.1		
313	9/29/2008	4.3	4.4	7.4	8.5	54.9	4.8	4.6	9.7	10.1		
314	9/30/2008	3.2	3.3	6.9	6.7	48.3	3.3	3.5	7.3	7.6		
315	10/1/2008						3.5	3.7	8.8	8.4		
316	10/2/2008						4.5	4.3	8.0	7.8		
317	10/3/2008						5.2	6.0	9.4	9.8		
318	10/4/2008						2.1	2.9	6.2	6.3		
319	10/5/2008										Not in operation	
320	10/6/2008										Not in operation	
321	10/7/2008										Not in operation	
322	10/8/2008						10.4	11.1	17.3	16.5		
323	10/9/2008	8.9	10.1	18.4	18.0	52.2	8.9	9.3	17.8	18.0		
324	10/10/2008	10.5	10.6	19.5	19.6	54.1	9.0	9.8	18.1	18.0		
325	10/11/2008	15.6	15.8	22.6	22.6	69.5	15.5	17.9	24.8	23.4		
326	10/12/2008	20.4	21.1	25.9	25.9	80.1	21.6	21.7	27.2	27.0		
327	10/13/2008	8.3	8.4	14.6	14.4	57.6	9.2	9.3	16.2	15.3		
328	10/14/2008	6.1	6.4	11.4	12.2	52.7	7.2	7.5	14.1	13.6		
329	10/15/2008	3.9	3.8	8.2	8.6	46.0	3.7	4.5	9.0	8.3		
330	10/16/2008										ZP-Check	

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 12 of 18**

Manufacturer	FAI Instruments s.r.l.	PM10 & PM2.5
Type of instrument	SWAM 5a DC	Measured values in µg/m³ (ACT)
Serial-No.	SN 145 / SN 149 SN 127 / SN 131 (Cologne, parking lot)	

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 145 / SN 127 PM2,5 [µg/m³]	SN 149 / SN 131 PM2,5 [µg/m³]	SN 145 / SN 127 PM10 [µg/m³]	SN 149 / SN 131 PM10 [µg/m³]	Remark	Test site
331	10/17/2008										ZP-Check	Teddington
332	10/18/2008										ZP-Check	
333	10/19/2008										Not in operation	
334	10/20/2008										Not in operation	
335	10/21/2008										Not in operation	
336	10/22/2008										Not in operation	
337	10/23/2008										Not in operation	
338	10/24/2008										Not in operation	
339	10/25/2008										Not in operation	
340	10/26/2008										Not in operation	
341	10/27/2008										Not in operation	
342	10/28/2008										Not in operation	
343	10/29/2008						16.3	16.1	22.1	21.2		
344	10/30/2008						10.2	10.5	13.9	13.8		
345	10/31/2008	11.7	12.0	16.9	18.5	66.9	10.2	10.3	15.8	15.2		
346	11/1/2008	14.8	15.1	18.3	19.2	79.9	14.1	14.3	17.6	18.2		
347	11/2/2008	20.4	20.0	25.5	25.8	78.7	20.0	19.7	25.6	25.5		
348	11/3/2008	20.7	20.9	27.0	27.8	76.0	19.2	20.4	26.7	27.4		
349	11/4/2008	31.1	30.9	37.5	38.4	81.7	31.1	31.5	38.7	40.2		
350	11/5/2008	29.7	29.6	35.5	36.2	82.8	28.3	28.4	36.2	36.2		
351	11/6/2008	23.5	23.8	28.2	28.6	83.2	21.7	22.3	27.5	28.2		
352	11/7/2008	6.8	6.7	15.2	14.7	45.4		6.5		15.9	SN 145, Filter supply ran out	
353	11/8/2008	3.5	3.5	8.6	9.4	39.1		3.7		9.8	SN 145, Filter supply ran out	
354	11/9/2008	4.1	4.0	11.5	11.9	34.8		4.3		13.7	SN 145, Filter supply ran out	
355	2/14/2011	21.1	19.5	23.8	24.2	84.5	19.4	19.6	23.6	24.4		Cologne, parking lot
356	2/15/2011	16.4	16.0	19.0	19.7	83.7	16.3	16.2	19.2	19.9		
357	2/16/2011	24.5	24.0	34.0	34.2	71.1	23.1	23.4	33.8	34.7		
358	2/17/2011	36.0	35.5	42.2	42.1	84.8	38.3	38.5	43.2	44.6		
359	2/18/2011	36.5	36.7	43.4	43.5	84.3	37.2	36.7	44.2	44.6		
360	2/19/2011						51.4	50.1	58.4	58.2		

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

Manufacturer: FAI Instruments s.r.l.

Type of instrument: SWAM 5a DC

Serial-No.: SN 127 / SN 131

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
361	2/20/2011	27.6	27.8	29.5	29.8	93.5	26.7	28.6	0.0	31.9		Cologne, parking lot
362	2/21/2011	31.3	31.8	36.6	36.2	86.6	33.9	33.0	39.3	39.0		
363	2/22/2011	36.5	37.9	43.3	43.8	85.4	39.5	39.3	47.6	47.3		
364	2/23/2011	38.0	37.9	45.7	45.7	83.0	37.8	38.5	47.1	46.3		
365	2/24/2011	30.3	31.4	36.0	35.8	85.9	29.7	28.2	38.4	37.4		
366	2/25/2011	26.4	26.7	30.4	29.6	88.6	27.1	25.9	30.6	30.2		
367	2/26/2011						14.4	14.7	17.6	17.9		
368	2/27/2011	13.5	13.3	15.4	14.8	88.5	13.8		15.9		SN 131 in Ending Mode, Filter supply depleted	
369	2/28/2011	36.7	36.0	44.7	43.7	82.3	33.0		39.8		SN 131 in Ending Mode, Filter supply depleted	
370	3/1/2011	66.6	66.0	75.6	74.7	88.2	70.1	65.6	79.1	80.4		
371	3/2/2011	49.4	49.7	60.6	58.5	83.1	54.3	51.5	62.0	63.6		
372	3/3/2011	39.4	37.5	50.8	48.9	77.1	41.0	38.8	48.8	49.9		
373	3/4/2011	76.3	76.5								Maintenance / Flow checks - Values discarded	
374	3/5/2011						26.4	26.6	35.9	37.2		
375	3/6/2011	8.9	9.2	13.6	14.1	65.1	6.4	7.6	12.0	12.3		
376	3/7/2011	8.3	9.0	13.8	12.4	66.2	8.0	8.6	12.2	12.6		
377	3/8/2011	31.1	31.8	43.9	43.8	71.7	26.9	28.4	38.9	38.4		
378	3/9/2011	19.1	18.8	30.5	28.7	63.9	16.6	16.3	25.3	26.3		
379	3/10/2011						8.0	7.9	14.5	14.6		
380	3/11/2011	16.7	16.1	33.5	33.1	49.2	13.5	14.0	29.6	29.8		
381	3/12/2011						16.0	18.2	28.9	30.7		
382	3/13/2011	13.3	13.1	16.2	15.6	83.1	11.4	11.7	15.4	15.5		
383	3/14/2011	18.2	20.0	27.7	25.6	71.5					Power loss due to AC SN127	
384	3/15/2011	37.4	37.9	44.1	43.1	86.3		33.0		41.0	SN127 no value after power loss	
385	3/16/2011			67.3	65.8		49.8	48.7	66.1	61.2	Outlier Ref PM2,5	
386	3/17/2011	50.7	49.6	68.0	67.1	74.1					Geiger instabilities on both systems, cause unknown	
387	3/18/2011	28.4	28.1	38.4	38.4	73.5	21.9	21.6	34.0	32.2		
388	3/19/2011						10.9	11.6	16.6	17.3		
389	3/20/2011	20.4	20.4	28.6	28.0	72.0	17.5	17.0	25.2	25.7		
390	3/21/2011	22.4	22.3	34.7	34.3	64.8	21.3	21.0	32.7	33.7		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 14 of 18**

Manufacturer	FAI Instruments s.r.l.	PM10 & PM2.5
Type of instrument	SWAM 5a DC	Measured values in µg/m³ (ACT)
Serial-No.	SN 127 / SN 131	

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 127 PM2,5 [µg/m³]	SN 131 PM2,5 [µg/m³]	SN 127 PM10 [µg/m³]	SN 131 PM10 [µg/m³]	Remark	Test site
391	3/22/2011	41.7	41.6	55.7	54.8	75.4	36.6	37.4	52.6	52.8		Cologne, parking lot
392	3/23/2011	20.3	20.4	33.1	31.6	63.0	19.1	19.3	31.0	31.0		
393	3/24/2011	18.6	20.2	33.3	32.7	58.8	17.6	17.9	30.6	30.7		
394	3/25/2011	27.6	27.5	36.9	37.2	74.2	25.1	25.9	34.1	34.9		
395	3/26/2011						12.6	12.9	18.1	18.8		
396	3/27/2011	24.6	24.8	35.6	35.4	69.5	22.7	22.4	32.7	33.2		
397	3/28/2011	20.5	20.7	32.4	31.9	64.2	17.9	18.8	28.8	29.1		
398	3/29/2011	44.7	44.2	65.4	65.6	67.8	39.7	39.5	62.9	62.7		
399	3/30/2011	15.6	15.6	24.0	23.4	65.8	14.6	14.6	22.6	22.9		
400	3/31/2011	6.0	5.1	10.5	9.3	56.2	6.1	6.0	9.9	9.8		
401	4/1/2011	8.5	7.7	13.3	13.0	61.7	8.3	7.3	13.7	13.3		
402	4/2/2011						20.7	22.4	35.2	36.2		
403	4/3/2011	14.6	13.7	22.1	22.4	63.6	13.0	13.7	19.9	20.2		
404	4/4/2011	8.8	9.0	17.9	16.6	51.6	8.4	8.6	15.9	15.5		
405	4/5/2011	11.0	11.4	19.2	19.0	58.7	10.1		18.2	17.9	SN131, Pump Line A defective	
406	4/6/2011	13.0	12.9	23.6	23.8	54.6	12.8		23.5	22.7	SN131, Pump Line A defective	
407	4/7/2011	13.7	13.1	23.2	24.2	56.7	12.1		22.3	20.9	SN131, Pump Line A defective	
408	4/8/2011	19.0	19.8	34.9	34.8	55.7	17.8		31.5	31.2	SN131, Pump Line A defective	
409	4/9/2011						14.1		29.5	31.2	SN131, Pump Line A defective	
410	4/10/2011	11.1	11.8	23.4	22.3	50.1	11.2		22.0	21.6	SN131, Pump Line A defective	
411	4/11/2011	15.2	15.1	31.3	31.5	48.2	15.2		31.3	31.9	SN131, Pump Line A defective	
412	4/12/2011	9.0	8.2	18.0	17.1	49.0	8.4		17.2	15.9	SN131, Pump Line A defective	
413	4/13/2011	12.5	12.2	24.4	23.2	51.9	12.4		23.2	23.7	SN131, Pump Line A defective	
414	4/14/2011	19.6	19.5	32.0	31.5	61.5	19.7		31.9	31.8	SN131, Pump Line A defective	
415	4/15/2011	13.3	11.5	31.9	31.9	38.8	14.7		34.4	34.6	SN131, Pump Line A defective	
416	4/16/2011						23.3		46.9	48.2	SN131, Pump Line A defective	
417	4/17/2011						14.3		21.9	21.4	SN131, Pump Line A defective	
418	4/18/2011	17.0	17.3	26.4	26.6	64.6	20.1		29.3		SN131, Pump Line A defective, Line B lost due to cycle interruption	
419	4/19/2011	17.5	17.9	30.3	30.7	58.0	20.3		31.9			
420	4/20/2011	20.0	20.8	33.9	34.2	59.8	22.8		36.5			

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 15 of 18**

Manufacturer	FAI Instruments s.r.l.
Type of instrument	SWAM 5a DC
Serial-No.	SN 127 / SN 131 SN 248 / SN 249 (Bornheim)

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 127 / SN 248 PM2,5 [µg/m³]	SN 131 / SN 249 PM2,5 [µg/m³]	SN 127 / SN 248 PM10 [µg/m³]	SN 131 / SN 249 PM10 [µg/m³]	Remark	Test site
421	4/21/2011						21.7		33.1	33.6	SN131, Repair of pump Line A	Cologne, parking lot
422	4/22/2011						21.1	22.9	28.2	28.6		
423	4/23/2011						30.5	23.4	38.7	38.4		
424	4/24/2011						23.3	31.9	28.5	31.5		
425	4/25/2011	19.6	20.7	27.4	27.4	73.6	21.6	22.9	29.1	29.1		
426	4/26/2011	17.1	17.6	31.0	31.3	55.7	18.9	20.9	31.8	31.6		
427	4/27/2011			44.3	45.1		27.6	28.4	47.2	44.3		
428	4/28/2011	16.2	17.8	28.0	28.0	60.8	20.1	19.6	27.6	26.4		
429	4/29/2011	19.0	19.4	25.9	27.3	72.0	21.5	22.5	28.5	29.5		
430	4/30/2011	12.9	13.3	21.0	22.0	61.0	14.8	17.2	23.0	23.1		
431	5/1/2011	6.7	7.0	13.0	12.9	52.9	8.6	8.5	13.3	12.7		
432	5/2/2011	9.3	9.2	16.1	14.9	59.8	9.8	10.8	14.6	14.0		
433	5/3/2011	9.1	9.3	15.9	15.1	59.2	9.5	9.4	15.4	14.2		
434	5/4/2011	11.4	11.5	20.5	20.2	56.1	11.9	12.0	18.9	18.1		
435	5/5/2011			20.1	19.5		12.6	11.7	19.0	17.4	Outlier Ref. PM2.5	
436	5/6/2011	13.7	13.6	30.7	31.1	44.2	16.7	18.2	33.0	31.6		
437	5/7/2011	19.1	17.6	46.1	47.5	39.2	25.8	29.7	53.2	51.0		
438	5/8/2011	12.3	12.2	23.4	23.0	53.0	13.7	15.9	20.9	22.4		
439	5/9/2011	17.9	17.9	32.4	32.8	54.9	18.9	19.7	30.2	27.6		
440	5/10/2011	24.4	23.9	43.8	43.2	55.5	27.2	24.9	39.6	35.9		
441	5/11/2011	15.6	15.8	33.1	33.6	47.1	15.6	15.4	27.4	26.5		
442	5/12/2011	11.4	11.7	28.1	27.4	41.4	11.0	11.7	23.4	22.3		
443	5/13/2011	13.5	14.7	32.6	34.0	42.4	13.1	14.3	28.3	26.2		
444	5/14/2011						10.1	12.0	20.6	19.5		
445	8/11/2011	5.5	5.2	11.4	11.1	47.3	5.0	4.7	11.2	10.9		Bornheim
446	8/12/2011	3.0	3.8	6.4	7.0	50.2	4.4	3.7	7.6	7.0		
447	8/13/2011						5.4	5.4	8.6	8.2		
448	8/14/2011	2.6	3.7	7.0	6.7	45.9	4.8	4.4	8.4	8.0		
449	8/15/2011	6.0	5.4	13.5	13.9	41.6	7.9	8.3	15.2	15.7		
450	8/16/2011	6.0	6.0	13.7	12.9	45.1	8.2	8.5	14.8	14.6		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 16 of 18**

Manufacturer: FAI Instruments s.r.l.

Type of instrument: SWAM 5a DC

Serial-No.: SN 248 / SN 249

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 248 PM2,5 [µg/m³]	SN 249 PM2,5 [µg/m³]	SN 248 PM10 [µg/m³]	SN 249 PM10 [µg/m³]	Remark	Test site
451	8/17/2011	14.7	14.0	25.8	25.0	56.3	17.0	18.0	27.8	27.9		Bornheim
452	8/18/2011	9.0	8.7	16.8	15.9	54.1	13.0	13.5	20.0	20.8		
453	8/19/2011	6.6	6.2	13.3	12.8	48.8	9.1	9.3	15.0	14.9		
454	8/20/2011						10.7	10.7	17.5	16.3		
455	8/21/2011	10.4	10.3	17.1	17.2	60.4	13.3	14.2	20.6	19.7		
456	8/22/2011	10.9	10.8	19.7	19.3	55.8	15.2	15.6	22.3	23.6		
457	8/23/2011	19.2	19.1	29.9	30.1	63.7	17.9	17.9	30.5	30.4		
458	8/24/2011	6.7	7.4	16.9	16.7	41.9	7.8	7.9	17.0	17.0		
459	8/25/2011	11.5	12.1	18.8	18.6	63.4	14.2	14.3	21.2	21.0		
460	8/26/2011	4.9	5.5	10.7	10.7	48.7	7.4	6.9	12.4	12.3		
461	8/27/2011						3.1	3.7	5.4	5.5		
462	8/28/2011			7.7	7.6		3.3	3.8	7.1	7.1		
463	8/29/2011	6.0	6.2	11.4	11.5	53.0	4.9	5.6	10.0	10.2		
464	8/30/2011	9.1	8.2	17.1	16.6	51.1	7.5	7.2	15.0	14.8		
465	8/31/2011	14.5	13.9	26.0	23.6	57.2	13.6	14.0	23.2	23.8		
466	9/1/2011	17.7	18.2	27.5	26.1	66.9	18.1	17.5	26.5	27.4		
467	9/2/2011	14.9	15.0	25.1	24.1	60.6	16.8	16.5	24.9	24.8		
468	9/3/2011						16.3	17.0	26.1	25.9		
469	9/4/2011	8.2	8.0	12.7	12.1	65.3	7.3	6.4	12.2	12.2		
470	9/5/2011	4.9	5.0	9.2	9.1	53.8	3.1	3.5	7.0	6.8		
471	9/6/2011	5.2	5.6	11.1	10.6	49.8	4.1	4.2	9.0	9.5		
472	9/7/2011	6.1	5.8	12.5	13.2	46.1	4.1	4.4	10.5	10.5		
473	9/8/2011						4.2	3.8	8.8	8.2		
474	9/9/2011	6.8	7.1	12.1	11.8	58.0	6.4	6.7	12.1	12.0		
475	9/10/2011						9.2	9.3	13.3	13.1		
476	9/11/2011	5.7	5.5	9.4	9.3	59.5	5.2	4.5	8.9	8.4		
477	9/12/2011	5.2	6.1	11.6	11.6	48.6	4.7	4.8	9.3	9.0		
478	9/13/2011	6.3	7.2	16.3	16.8	40.6	5.4	6.0	13.5	12.8		
479	9/14/2011	6.7	7.2	15.3	15.6	44.9	5.1	5.1	11.9	12.8		
480	9/15/2011	11.1	12.2	24.3	24.9	47.3	11.4	10.6	22.1	21.8		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 17 of 18**

Manufacturer: FAI Instruments s.r.l.

Type of instrument: SWAM 5a DC

Serial-No.: SN 248 / SN 249

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 248 PM2,5 [µg/m³]	SN 249 PM2,5 [µg/m³]	SN 248 PM10 [µg/m³]	SN 249 PM10 [µg/m³]	Remark	Test site
481	9/16/2011	13.0	13.7	23.0	25.1	55.4	12.5	12.1	21.1	21.6		Bornheim
482	9/17/2011						6.1	5.6	9.6	9.3		
483	9/18/2011	3.2	3.9	7.0	7.1	50.4	2.5	2.9	4.5	4.7		
484	9/19/2011	7.8	8.2	12.5	11.6	66.2	6.6	6.9	10.8	11.2		
485	9/20/2011	6.2	6.2	12.3	12.3	50.6		4.9		11.6	SN 248 main board defective	
486	9/21/2011	6.6	6.6	12.4	12.3	53.6		6.4		10.7	SN 248 main board defective	
487	9/22/2011	6.4	7.8	19.2	18.9	37.3		6.9		14.8	SN 248 main board defective	
488	9/23/2011	12.2	13.4	26.1	26.2	49.1	13.1	13.4	23.9	23.1		
489	9/24/2011							14.3		20.7	SN 248 wrong sampled volume - cause unknown	
490	9/25/2011	15.7	14.5	21.3	21.7	70.0	15.9	16.1	22.0	21.8		
491	9/26/2011	12.0	12.0	18.8	20.6	60.8	13.8	13.5	22.1	21.5		
492	9/27/2011	21.9	21.9	38.3	39.8	56.0	19.9	20.3	38.5	38.6		
493	9/28/2011	15.5	15.5	25.7	25.7	60.2	18.3	18.7	27.7	26.6		
494	9/29/2011	17.1	16.0	25.4	25.4	65.1	18.3	17.5	25.6	25.0		
495	9/30/2011	12.4	11.8	23.4	24.5	50.6	13.4	13.6	24.8	24.3		
496	10/1/2011						13.7	13.2	21.2	21.4		
497	10/2/2011						28.8	28.9	37.1	37.7		
498	10/3/2011	13.5	14.8	21.4	21.4	66.2	14.5	14.4	24.2	24.5		
499	10/4/2011	9.9	9.8	15.9	16.3	60.9	10.4	9.7	15.3	15.3		
500	10/5/2011	4.5	2.5	7.0	6.5	51.7	4.1	3.6	6.0	6.0		
501	10/6/2011	5.5	4.1	10.8	10.4	45.6	4.4	4.3	9.6	9.4		
502	10/7/2011	3.6	3.1	8.1	7.6	42.9	3.4	3.3	6.2	6.3		
503	10/8/2011						4.4	5.5	7.9	8.0		
504	10/9/2011	6.0	6.4	10.1	10.4	60.7	5.5	5.7	9.7	9.4		
505	10/10/2011	4.7	5.2	11.9	12.5	40.9	7.1	7.2	13.6	14.1		
506	10/11/2011	1.3	2.0	5.5	5.0	31.2	3.4	3.7	5.5	6.0		
507	10/12/2011	1.9	3.2	5.3	5.0	49.3	4.5	5.2	6.5	6.5		
508	10/13/2011	4.2	4.2	11.5	11.7	36.3	6.3	6.2	12.3	11.8		
509	10/14/2011	5.9	8.5	14.8	14.0	50.2	9.1	8.8	15.3	15.2		
510	10/15/2011						10.6	10.5	14.3	14.4		

Annex 5 **Measured values from field test sites, related to actual conditions** **Page 18 of 18**

Manufacturer	FAI Instruments s.r.l.
Type of instrument	SWAM 5a DC
Serial-No.	SN 248 / SN 249

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 248 PM2,5 [µg/m³]	SN 249 PM2,5 [µg/m³]	SN 248 PM10 [µg/m³]	SN 249 PM10 [µg/m³]	Remark	Test site
511	10/16/2011	11.1	13.8	17.0	16.7	73.7	14.1	14.3	18.1	17.9		Bornheim
512	10/17/2011	18.6	20.2	28.0	27.3	70.0	20.8	20.1	28.2	27.5		
513	10/18/2011	4.3	6.7	11.6	11.5	47.7	6.4	6.8	11.8	11.5		
514	10/19/2011	3.8	5.2				5.6	5.6	10.5	9.9	Outlier Ref. PM10	
515	10/20/2011	9.3	9.5	11.9	15.8	67.9	10.7	10.3	16.4	16.0		
516	10/21/2011	17.6	18.1	28.0	26.4	65.5	18.4	18.6	26.7	26.5		
517	10/22/2011						20.0	20.3	23.6	23.7		
518	10/23/2011	23.0	23.2				23.7	23.8	28.2	27.8	Outlier Ref. PM10	
519	10/24/2011						16.2	15.9	22.1	21.2		
520	10/25/2011						12.2	12.3	16.1	17.2		
521	10/26/2011						7.2	7.1	12.5	12.3		

Annex 6 **Measured values from field test sites, related to actual conditions** **Page 1 of 3**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a DC HM

Serial-No. SN 111 / SN 112

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 111 PM2,5 [µg/m³]	SN 112 PM2,5 [µg/m³]	SN 111 PM10 [µg/m³]	SN 112 PM10 [µg/m³]	Remark	Test site
1	2/14/2011	21.1	19.5	23.8	24.2	84.5	21.2	19.7	24.0	22.9		Cologne, parking lot
2	2/15/2011	16.4	16.0	19.0	19.7	83.7	17.6	17.3	20.0	19.9		
3	2/16/2011	24.5	24.0	34.0	34.2	71.1	25.8	26.0	33.2	33.0		
4	2/17/2011	36.0	35.5	42.2	42.1	84.8	38.7	38.6	43.5	42.3		
5	2/18/2011	36.5	36.7	43.4	43.5	84.3	38.6	38.9	45.4	44.4		
6	2/19/2011						51.2	51.3	56.2	56.0		
7	2/20/2011	27.6	27.8	29.5	29.8	93.5	29.1	29.1	32.1	31.0		
8	2/21/2011	31.3	31.8	36.6	36.2	86.6	34.0	33.3	39.0	37.0		
9	2/22/2011	36.5	37.9	43.3	43.8	85.4	39.6	38.2	45.7	44.9		
10	2/23/2011	38.0	37.9	45.7	45.7	83.0	38.2	39.5	46.6	44.0		
11	2/24/2011	30.3	31.4	36.0	35.8	85.9	30.7	29.1	35.7	34.3		
12	2/25/2011	26.4	26.7	30.4	29.6	88.6	27.0		30.0		SN 112 error 26 (Filter-loader not properly inserted)	
13	2/26/2011						14.8	15.2	17.9	17.5		
14	2/27/2011	13.5	13.3	15.4	14.8	88.5	14.2		15.7		SN 112 no data available	
15	2/28/2011	36.7	36.0	44.7	43.7	82.3	34.8	35.8	40.2	40.5		
16	3/1/2011	66.6	66.0	75.6	74.7	88.2	66.6	65.1	71.2	72.4		
17	3/2/2011	49.4	49.7	60.6	58.5	83.1	51.6	49.8	59.4	56.9		
18	3/3/2011	39.4	37.5	50.8	48.9	77.1	40.1	39.2	47.4	47.0		
19	3/4/2011	76.3	76.5								Maintenance / Flow checks - Values discarded	
20	3/5/2011						29.1	29.8	37.1	37.3		
21	3/6/2011	8.9	9.2	13.6	14.1	65.1	7.8	7.9	12.2	11.8		
22	3/7/2011	8.3	9.0	13.8	12.4	66.2	7.6	8.4	12.5	12.6		
23	3/8/2011	31.1	31.8	43.9	43.8	71.7	29.8	29.6	38.8	38.1		
24	3/9/2011	19.1	18.8	30.5	28.7	63.9	17.5	18.6	24.9	25.6		
25	3/10/2011										Power loss	
26	3/11/2011	16.7	16.1	33.5	33.1	49.2	15.8	16.5	29.4	28.9		
27	3/12/2011						16.0	17.0	27.8	28.1		
28	3/13/2011	13.3	13.1	16.2	15.6	83.0	12.4	12.5	15.2	15.1		
29	3/14/2011	18.2	20.0	27.8	25.6	71.5					Power loss	
30	3/15/2011	37.4	37.9	44.1	43.1	86.3	36.9	36.7	42.0	42.0		

Annex 6 **Measured values from field test sites, related to actual conditions** **Page 2 of 3**

Manufacturer	FAI Instruments s.r.l.
Type of instrument	SWAM 5a DC HM
Serial-No.	SN 111 / SN 112

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 111 PM2,5 [µg/m³]	SN 112 PM2,5 [µg/m³]	SN 111 PM10 [µg/m³]	SN 112 PM10 [µg/m³]	Remark	Test site
31	3/16/2011			67.3	65.8		53.3	55.7	64.9	62.2		Cologne,
32	3/17/2011	50.7	49.6	68.0	67.1	74.1					Geiger instabilities on all systems, cause unknown	parking lot
33	3/18/2011	28.4	28.1	38.4	38.4	73.5	27.0	26.6	34.5	33.4		
34	3/19/2011						12.7	12.3	17.7	16.9		
35	3/20/2011	20.4	20.4	28.6	28.0	72.0	18.2	18.6	25.4	25.3		
36	3/21/2011	22.4	22.3	34.7	34.3	64.8	22.4	22.7	33.8	32.8		
37	3/22/2011	41.7	41.6	55.7	54.8	75.4	40.4	41.6	54.3	53.2		
38	3/23/2011	20.3	20.4	33.1	31.6	63.0	20.7		31.3		SN112 filter blocked	
39	3/24/2011	18.6	20.2	33.3	32.7	58.8	19.8	20.1	31.7	30.2		
40	3/25/2011	27.6	27.5	36.9	37.2	74.2	25.9	27.0	34.7	34.8		
41	3/26/2011						12.6	13.5	18.3	18.2		
42	3/27/2011	24.6	24.8	35.6	35.4	69.5	24.0	24.5	33.6	33.1		
43	3/28/2011	20.5	20.7	32.4	31.9	64.2	19.9	20.3	29.4	28.3		
44	3/29/2011	44.7	44.2	65.5	65.6	67.8	43.6	45.4	63.6	62.6		
45	3/30/2011	15.6	15.6	24.0	23.4	65.8	14.2	14.7	21.2	20.7		
46	3/31/2011	6.0	5.1	10.5	9.3	56.2	6.4	7.0	9.5	10.0		
47	4/1/2011	8.5	7.7	13.3	13.1	61.7	8.8	9.0	13.2	12.7		
48	4/2/2011						17.6	19.8	31.4	31.9		
49	4/3/2011	14.6	13.7	22.1	22.4	63.6	15.0	14.9	20.5	20.2		
50	4/4/2011	8.8	9.0	17.9	16.6	51.6	8.9	9.4	15.7	14.8		
51	4/5/2011	11.0	11.4	19.2	19.0	58.7	11.7	11.8	18.2	17.6		
52	4/6/2011	13.0	12.9	23.6	23.8	54.6	13.5	13.9	23.3	23.0		
53	4/7/2011	13.7	13.1	23.2	24.2	56.7	14.4	15.1	22.1	21.0		
54	4/8/2011	19.0	19.8	34.9	34.8	55.7	19.6	21.8	32.1	32.0		
55	4/9/2011						15.9	16.5	30.1	29.6		
56	4/10/2011	11.1	11.8	23.4	22.3	50.1	12.6	13.3	21.7	21.9		
57	4/11/2011	15.2	15.1	31.3	31.5	48.2	16.4	18.0	31.8	29.7		
58	4/12/2011	9.0	8.2	18.0	17.1	49.0	10.1	10.2	18.0	17.3		
59	4/13/2011	12.5	12.2	24.4	23.2	51.9	13.6	14.1	23.9	23.1		
60	4/14/2011	19.6	19.5	32.0	31.5	61.5	21.5	22.1	32.1	31.8		

Annex 6 **Measured values from field test sites, related to actual conditions** **Page 3 of 3**

Manufacturer: FAI Instruments s.r.l.

Type of instrument: SWAM 5a DC HM

Serial-No.: SN 111 / SN 112

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 111 PM2,5 [µg/m³]	SN 112 PM2,5 [µg/m³]	SN 111 PM10 [µg/m³]	SN 112 PM10 [µg/m³]	Remark	Test site
61	4/15/2011	13.3	11.5	31.9	31.9	38.8	12.8	15.0	29.8	31.3		Cologne, parking lot
62	4/16/2011						18.0	21.6	41.0	40.1		
63	4/17/2011						14.6	15.6	21.8	21.5		
64	4/18/2011	17.0	17.3	26.4	26.6	64.6	19.9	20.6	30.0	28.1		
65	4/19/2011	17.5	17.9	30.3	30.7	58.0	20.7	21.9	32.4	31.4		
66	4/20/2011	20.0	20.8	33.9	34.2	59.8	23.2	23.7	36.1	35.4		
67	4/21/2011						23.6	24.6	34.5	34.0		
68	4/22/2011						21.8	23.2	30.2	29.6		
69	4/23/2011						33.5	34.6	40.7	40.7		
70	4/24/2011						25.6		32.6		SN 112 filter blocked	
71	4/25/2011	19.6	20.7	27.4	27.4	73.6	23.4		31.3		SN 112 filter blocked	
72	4/26/2011	17.1	17.6	31.0	31.3	55.7	20.0		32.2		No measurement SN112 due to wrong set-up	
73	4/27/2011			44.4	45.1		33.4		48.2		No measurement SN112 due to wrong set-up	
74	4/28/2011	16.2	17.8	28.0	28.0	60.8	24.2		30.8		No measurement SN112 due to wrong set-up	
75	4/29/2011	19.0	19.4	25.9	27.3	72.0	20.8		30.1		No measurement SN112 due to wrong set-up	
76	4/30/2011	12.9	13.3	21.0	22.0	61.0	14.8	14.7	23.2	21.4		
77	5/1/2011	6.7	7.0	13.0	12.9	52.9	8.2	7.9	13.0	12.6		
78	5/2/2011	9.3	9.2	16.1	14.9	59.8	10.5	10.1	15.6	16.3		
79	5/3/2011	9.1	9.3	15.9	15.1	59.2	9.7	9.3	15.2	16.1		
80	5/4/2011	11.4	11.5	20.5	20.2	56.1	13.0	13.3	20.0	19.9		
81	5/5/2011			20.1	19.5		12.2	12.2	19.0	19.6	Outlier Ref. PM2.5	
82	5/6/2011	13.7	13.6	30.7	31.1	44.2	14.4	13.5	30.5	30.9		
83	5/7/2011	19.1	17.6	46.1	47.5	39.2	17.0	14.3	46.1	47.8		
84	5/8/2011	12.3	12.2	23.4	23.0	53.0	10.8	10.5	21.0	20.7		
85	5/9/2011	17.9	17.9	32.4	32.8	54.9	19.4	19.6	30.4	29.7		
86	5/10/2011	24.4	23.9	43.8	43.2	55.5	29.6	29.1	42.0	42.7		
87	5/11/2011	15.6	15.8	33.1	33.6	47.1	17.8	18.4	31.6	32.8		
88	5/12/2011	11.4	11.7	28.1	27.4	41.4	11.5	11.5	24.9	25.1		
89	5/13/2011	13.5	14.7	32.6	34.0	42.4	14.0	13.6	28.8	28.6		
90	5/14/2011						9.9	9.2	20.6	17.7		

Annex 7 **Measured values from field test sites, related to actual conditions** **Page 1 of 3**

Manufacturer	FAI Instruments s.r.l.
Type of instrument	SWAM 5a
Serial-No.	SN 331 & SN 333 (PM2.5) SN 329 & SN 330 (PM10)

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 331 PM2,5 [µg/m³]	SN 333 PM2,5 [µg/m³]	SN 329 PM10 [µg/m³]	SN 330 PM10 [µg/m³]	Remark	Test site
1	8/11/2011	5.5	5.2	11.4	11.1	47.3		2.6	9.7	10.9	SN 331 Instability power supply of Geiger counter	Bornheim
2	8/12/2011	3.0	3.8	6.4	7.0	50.2		3.4	5.6	7.1	SN 331 Instability power supply of Geiger counter	
3	8/13/2011							3.1	5.8	6.5	SN 331 Instability power supply of Geiger counter	
4	8/14/2011	2.6	3.6	7.0	6.7	45.9		5.7	8.4	8.8	SN 331 Instability power supply of Geiger counter	
5	8/15/2011	6.0	5.4	13.5	13.9	41.7		9.7	15.8	15.5	SN 331 Instability power supply of Geiger counter	
6	8/16/2011	6.0	6.0	13.7	12.9	45.1		7.0	13.5	13.8	SN 331 Instability power supply of Geiger counter	
7	8/17/2011	14.7	14.0	25.8	25.0	56.3		16.8	26.2	26.8	SN 331 Instability power supply of Geiger counter	
8	8/18/2011	9.0	8.7	16.8	15.9	54.1		12.6	18.5	19.2	SN 331 Instability power supply of Geiger counter	
9	8/19/2011	6.6	6.2	13.3	12.8	48.8		8.9	15.2	13.9	SN 331 Instability power supply of Geiger counter	
10	8/20/2011							10.2	16.2	16.9	SN 331 Instability power supply of Geiger counter	
11	8/21/2011	10.4	10.3	17.1	17.2	60.4		12.7	18.3	19.0	SN 331 Instability power supply of Geiger counter	
12	8/22/2011	10.9	10.8	19.7	19.3	55.8		13.3	20.5	20.5	SN 331 Instability power supply of Geiger counter	
13	8/23/2011	19.2	19.1	29.9	30.1	63.7		22.5	29.0	31.4	SN 331 Instability power supply of Geiger counter	
14	8/24/2011	6.7	7.4	16.9	16.7	41.9		8.3	16.4	17.0	SN 331 Instability power supply of Geiger counter	
15	8/25/2011	11.5	12.1	18.8	18.6	63.4		11.6	17.9	17.8	SN 331 Instability power supply of Geiger counter	
16	8/26/2011	4.9	5.5	10.7	10.7	48.8		6.5	10.8	10.6	SN 331 Instability power supply of Geiger counter	
17	8/27/2011							2.9	3.3	5.2	SN 331 Instability power supply of Geiger counter	
18	8/28/2011	1.8		7.7	7.6			2.4	5.4	6.0	SN 331 Instability power supply of Geiger counter	
19	8/29/2011	5.9	6.2	11.4	11.5	53.0		5.1	7.8	9.9	SN 331 Instability power supply of Geiger counter	
20	8/30/2011	9.1	8.1	17.1	16.6	51.1		6.5	13.9	13.9	SN 331 Instability power supply of Geiger counter	
21	8/31/2011	14.5	13.9	26.0	23.6	57.2		13.8	21.3	22.2	SN 331 problem solved (cable break)	
22	9/1/2011	17.7	18.2	27.5	26.1	66.9	16.9	17.9	24.5	23.1		
23	9/2/2011	14.9	15.0	25.1	24.1	60.6	14.8	16.4	23.9	22.6		
24	9/3/2011						14.8	15.5	23.3	22.6		
25	9/4/2011	8.2	8.0	12.7	12.1	65.3	6.4	6.8	10.3	10.4		
26	9/5/2011	4.8	5.0	9.2	9.1	53.8	2.9	4.0	6.7	7.2		
27	9/6/2011	5.2	5.6	11.1	10.6	49.8	4.1	3.7	7.7	8.7		
28	9/7/2011	6.1	5.8	12.5	13.2	46.1	4.5	4.4	9.1	10.0		
29	9/8/2011						3.6	3.7	8.1	8.2		
30	9/9/2011	6.8	7.1	12.1	11.8	57.9	6.4	6.7	10.6	11.0		

Annex 7 **Measured values from field test sites, related to actual conditions** **Page 2 of 3**

Manufacturer FAI Instruments s.r.l.

Type of instrument SWAM 5a

Serial-No. SN 331 & SN 333 (PM2.5)
SN 329 & SN 330 (PM10)

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 331 PM2,5 [µg/m³]	SN 333 PM2,5 [µg/m³]	SN 329 PM10 [µg/m³]	SN 330 PM10 [µg/m³]	Remark	Test site
31	9/10/2011						8.5	7.9	11.5	11.2		Bornheim
32	9/11/2011	5.7	5.5	9.4	9.3	59.5	4.8	4.6	9.4	9.0		
33	9/12/2011	5.2	6.1	11.6	11.6	48.5	4.8	3.0	8.9	9.3		
34	9/13/2011	6.3	7.2	16.3	16.8	40.6	5.1	5.5	12.2	13.1		
35	9/14/2011	6.7	7.2	15.3	15.6	44.9	6.2	5.7	12.2	12.9		
36	9/15/2011	11.1	12.2	24.3	24.9	47.4	11.9	11.2	20.6	20.2		
37	9/16/2011	13.0	13.7	23.0	25.1	55.4	11.8	11.9	20.0	21.0		
38	9/17/2011						4.2	4.3	6.9	7.5		
39	9/18/2011	3.2	3.9	7.0	7.1	50.4	3.7	3.2	7.5	7.5		
40	9/19/2011	7.8	8.2	12.5	11.6	66.2	8.2	7.8	10.8	10.8		
41	9/20/2011	6.2	6.2	12.3	12.3	50.6	5.7	7.0	11.8	12.3		
42	9/21/2011	6.6	6.6	12.4	12.3	53.6	6.6	6.9	10.8	11.8		
43	9/22/2011	6.4	7.8	19.2	18.9	37.3	6.9	7.2	15.0	15.6		
44	9/23/2011	12.2	13.4	26.1	26.2	49.1	11.0	11.9	21.5	20.7		
45	9/24/2011						14.5	14.1	19.9	21.1		
46	9/25/2011	15.7	14.5	21.3	21.7	70.0	16.3	16.3	20.9	21.9		
47	9/26/2011	12.0	12.0	18.8	20.6	60.8	13.9	14.3	22.6	23.0		
48	9/27/2011	21.9	21.9	38.3	39.8	56.0	19.6	19.4	37.8	38.2		
49	9/28/2011	15.5	15.5	25.7	25.7	60.2	14.5	14.5	28.0	28.0		
50	9/29/2011	17.1	16.0	25.4	25.4	65.1	18.2	18.2	26.9	26.8		
51	9/30/2011	12.4	11.8	23.4	24.5	50.6	13.1	13.2	21.3	23.2		
52	10/1/2011						12.3	12.5	18.7	19.7		
53	10/2/2011						28.1	28.2	34.9	36.5		
54	10/3/2011	13.5	14.8	21.4	21.4	66.2	14.2	13.8	22.1	23.2		
55	10/4/2011	9.8	9.8	15.9	16.3	60.9		9.4	14.4	14.7	SN 331 carousel blocked by filter	
56	10/5/2011	4.5	2.5	7.0	6.5	51.8		1.4	4.1	3.6	SN 331 carousel blocked by filter	
57	10/6/2011	5.5	4.1	10.8	10.4	45.6		3.4	8.0	7.1	SN 331 carousel blocked by filter	
58	10/7/2011	3.6	3.1	8.1	7.6	42.9	3.5	3.6	6.6	6.1		
59	10/8/2011						5.8	5.1	9.2	8.3		
60	10/9/2011	6.0	6.4	10.1	10.4	60.7	6.1	7.3	11.3	10.7		

Annex 7 **Measured values from field test sites, related to actual conditions** **Page 3 of 3**

Manufacturer: FAI Instruments s.r.l.

Type of instrument: SWAM 5a

Serial-No.: SN 331 & SN 333 (PM2.5)
SN 329 & SN 330 (PM10)

PM10 & PM2.5
Measured values in µg/m³ (ACT)

No.	Date	Ref. 1 PM2,5 [µg/m³]	Ref. 2 PM2,5 [µg/m³]	Ref. 1 PM10 [µg/m³]	Ref 2. PM10 [µg/m³]	Ratio PM2,5/PM10 [%]	SN 331 PM2,5 [µg/m³]	SN 333 PM2,5 [µg/m³]	SN 329 PM10 [µg/m³]	SN 330 PM10 [µg/m³]	Remark	Test site
61	10/10/2011	4.7	5.2	11.9	12.5	40.9	6.7	6.9	11.7	12.9		Bornheim
62	10/11/2011	1.3	2.0	5.5	5.0	31.2	2.4	2.4	4.7	6.4		
63	10/12/2011	1.9	3.2	5.3	5.0	49.3	4.5	4.4	6.5	6.6		
64	10/13/2011	4.2	4.2	11.5	11.7	36.3	7.5	7.6	12.9	12.3		
65	10/14/2011	5.9	8.5	14.8	14.0	50.2	9.7	9.7	15.7	14.7		
66	10/15/2011						10.7	10.9	15.1	13.9		
67	10/16/2011	11.1	13.7	17.0	16.7	73.7	13.0	13.3	17.7	16.1		
68	10/17/2011	18.6	20.1	28.0	27.3	70.0	17.6	14.0	24.9	24.5		
69	10/18/2011	4.3	6.7	11.6	11.5	47.7	5.1	5.0	9.4	10.3		
70	10/19/2011	3.8	5.2				5.0	5.1	9.4	10.0	Outlier Ref. PM10	
71	10/20/2011	9.3	9.5	11.9	15.8	67.9	10.1	10.7	16.3	16.3		
72	10/21/2011	17.6	18.1	28.0	26.4	65.5	18.9	20.0	27.4	27.1		
73	10/22/2011						19.2	19.7	23.4	22.8		
74	10/23/2011	23.0	23.2				22.2	21.4	25.9	26.0	Outlier Ref. PM10	
75	10/24/2011						13.2	13.2	18.7	18.2		
76	10/25/2011						12.3	11.1	15.4	15.7		
77	10/26/2011						6.8	6.4	11.6	11.7		

Annex 8 **Ambient conditions at the field test sites** **Page 1 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
1	10/20/2007	Cologne,	6.6	1027	65.3	0.0	153	0.3
2	10/21/2007	parking lot	5.4	1020	81.5	0.0	197	3.0
3	10/22/2007		3.1	1020	71.8	0.5	155	0.0
4	10/23/2007		4.5	1018	68.1	0.0	99	0.0
5	10/24/2007		7.6	1017	70.7	0.0	66	0.3
6	10/25/2007		9.2	1015	68.3	0.3	110	0.0
7	10/26/2007		8.7	1016	69.3	0.0	201	0.0
8	10/27/2007		8.7	1020	69.9	0.2	182	0.0
9	10/28/2007		8.7	1012	68.4	2.3	154	0.0
10	10/29/2007		8.9	1005	82.0	0.9	208	31.0
11	10/30/2007		7.1	1015	76.7	0.3	235	0.3
12	10/31/2007		5.8	1023	80.8	0.1	136	0.0
13	11/1/2007		9.0	1024	79.5	0.0	168	0.0
14	11/2/2007		12.0	1023	86.9	0.0	262	5.7
15	11/3/2007		11.5	1019	80.2	0.0	291	0.9
16	11/4/2007		9.3	1021	70.6	0.0	153	0.0
17	11/5/2007		9.3	1016	70.1	1.0	228	3.0
18	11/6/2007		7.7	1019	71.7	1.9	261	2.7
19	11/7/2007		9.2	1012	78.2	2.6	254	5.9
20	11/8/2007		8.7	1003	73.8	2.4	260	9.8
21	11/9/2007		5.5	1009	73.7	5.4	266	5.0
22	11/10/2007		8.6	1003	76.6	3.8	254	17.4
23	11/11/2007		6.2	1005	73.7	4.0	289	3.6
24	11/12/2007		5.7	1011	71.4	3.0	272	1.5
25	11/13/2007		3.6	999	79.0	1.1	184	10.9
26	11/14/2007		2.0	1010	69.8	1.5	173	0.0
27	11/15/2007		1.7	1019	69.5	0.6	101	0.0
28	11/16/2007		3.6	1021	67.4	0.0	217	0.0
29	11/17/2007		2.5	1016	78.6	0.0	175	0.0
30	11/18/2007		4.0	1002	70.1	5.2	133	0.0

Annex 8 **Ambient conditions at the field test sites** **Page 2 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
31	11/19/2007	Cologne,	3.8	1004	74.7	4.1	136	6.2
32	11/20/2007	parking lot	6.9	1002	62.0	4.9	128	0.3
34	11/21/2007		7.9	1001	76.6	1.4	133	0.9
34	11/22/2007		8.5	1000	79.4	1.2	155	0.0
35	11/23/2007		4.8	1013	78.4	0.6	209	1.2
36	11/24/2007		4.4	1014	75.1	0.5	216	2.1
37	11/25/2007		5.4	1013	74.9	4.3	284	6.2
38	11/26/2007		4.4	1019	73.2	2.6	273	2.4
39	11/27/2007		3.6	1020	76.2	0.4	196	0.0
40	11/28/2007		2.2	1010	73.9	2.7	143	0.0
41	11/29/2007		4.8	1002	79.5	1.3	203	4.7
42	11/30/2007		7.7	1000	76.4	1.6	188	5.1
43	12/1/2007		8.1	999	69.4	1.9	217	3.2
44	12/2/2007		9.2	984	70.4	3.8	226	7.1
45	12/3/2007		6.2	996	71.4	3.6	271	11.8
46	12/4/2007		7.8	1010	75.8	1.3	202	0.6
47	12/5/2007		10.9	1007	70.3	3.1	191	0.9
48	12/6/2007		11.1	997	76.7	2.4	209	21.0
49	12/7/2007		7.9	995	67.5	3.4	251	1.8
50	12/8/2007		6.7	991	69.5	4.0	192	6.5
51	12/9/2007		7.2	982	71.3	2.9	187	6.5
52	12/10/2007		6.1	1001	81.4	2.0	271	5.4
53	12/11/2007		4.6	1021	76.7	1.9	292	0.6
54	12/12/2007		4.8	1031	72.7	0.4	126	0.0
55	12/13/2007		3.8	1033	68.6	0.0	83	0.0
56	12/14/2007		1.1	1030	63.2	0.9	56	0.0
57	12/15/2007		-0.5	1029	64.1	1.2	59	0.0
58	12/16/2007		-0.8	1030	68.3	0.2	69	0.0
59	12/17/2007		-1.7	1028	68.8	0.8	81	0.0
60	12/18/2007		-2.4	1030	74.3	0.0	118	0.0

Annex 8 **Ambient conditions at the field test sites** **Page 3 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
61	12/19/2007	Cologne, parking lot	-1.9	1031	74.8	0.0	104	0.0
62	12/20/2007		-3.4	1026	81.5	0.0	121	0.0
63	12/21/2007		-0.9	1020	71.0	0.7	133	0.0
64	12/22/2007		-2.2	1020	70.5	1.5	151	0.0
65	12/23/2007		-0.4	1022	76.7	0.6	142	0.0
66	12/24/2007		-0.5	1020	78.2	2.5	124	0.0
67	12/25/2007		-0.9	1014	71.0	3.6	133	0.3
68	12/26/2007		1.2	1023	80.3	1.2	143	0.6
69	12/27/2007		3.9	1024	76.0	3.8	150	0.3
70	12/28/2007		4.1	1016	75.0	4.8	154	0.6
71	12/29/2007		4.9	1009	76.1	1.7	198	5.0
72	12/30/2007		5.1	1018	75.3	1.9	248	1.5
73	12/31/2007		3.3	1021	81.8	0.0	150	0.6
74	1/1/2008		-1.5	1017	79.6	0.5	115	0.0
75	1/2/2008		-0.7	1008	65.4	3.5	106	0.0
76	1/3/2008		1.2	1001	59.9	4.9	142	0.0
77	1/4/2008		3.3	1001	62.8	5.9	139	0.9
78	1/5/2008		6.3	997	75.6	1.3	183	4.8
79	1/6/2008		4.4	1005	74.0	1.5	192	4.1
80	1/7/2008		6.8	1008	67.5	3.0	243	1.8
81	1/8/2008		5.4	1010	72.8	3.6	155	0.0
82	1/9/2008		4.8	1008	76.2	0.6	186	3.8
83	1/10/2008		8.7	1003	68.5	4.5	173	0.0
84	1/11/2008		10.4	993	64.5	5.5	164	2.4
85	1/12/2008		4.0	1006	72.1	1.8	190	0.3
86	1/13/2008		3.6	1005	69.1	4.7	138	0.0
87	1/14/2008		7.4	1000	68.7	4.7	162	0.9
88	1/15/2008		9.2	988	63.6	6.8	173	0.0
89	1/16/2008		6.8	995	76.5	0.6	188	7.4
90	1/17/2008		8.3	1000	70.6	3.9	199	5.6

Annex 8 **Ambient conditions at the field test sites** **Page 4 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
91	1/18/2008	Cologne, parking lot	11.1	1008	72.2	2.7	217	3.6
92	1/19/2008		12.4	1014	75.8	2.9	235	4.5
93	1/20/2008		11.7	1013	72.3	4.5	239	0.0
94	1/21/2008		9.0	1003	70.6	4.3	233	6.5
95	1/22/2008		3.3	1020	71.0	1.6	220	0.0
96	1/23/2008		6.0	1021	68.9	2.7	153	0.0
97	1/24/2008		5.9	1024	74.4	1.0	225	2.7
98	1/25/2008		7.1	1029	62.7	1.7	233	0.0
99	1/26/2008		7.5	1024	64.8	3.5	244	0.0
100	1/27/2008		7.5	1025	73.7	2.0	246	0.0
101	1/28/2008		7.4	1025	65.8	0.0	230	0.0
102	1/29/2008		3.4	1018	71.6	0.1	220	0.0
103	1/30/2008		2.2	1017	80.7	0.6	224	3.9
104	1/31/2008		4.7	999	67.7	5.6	190	2.4
105	2/1/2008		4.1	994	70.1	3.0	227	6.5
106	2/2/2008		1.3	1011	69.1	1.9	195	1.2
107	2/3/2008		3.8	1001	55.2	5.9	131	0.0
108	2/4/2008		4.0	1002	77.0	2.1	171	5.6
109	2/5/2008		8.2	1003	73.8	4.0	175	19.2
110	2/14/2008	Bonn	2.5	1028	70.7	1.0	187	0.0
111	2/15/2008		0.6	1033	54.3	1.9	188	0.0
112	2/16/2008		0.8	1034	46.4	0.7	187	0.0
113	2/17/2008		1.7	1028	54.8	0.2	197	0.0
114	2/18/2008		2.0	1021	53.1	0.2	161	0.0
115	2/19/2008		4.6	1013	63.9	0.6	157	0.9
116	2/20/2008		4.9	1013	77.5	0.2	160	0.9
117	2/21/2008		10.1	1015	66.3	0.4	179	0.6
118	2/22/2008		11.1	1017	65.5	1.7	127	0.0
119	2/23/2008		8.6	1015	69.4	0.3	134	0.0
120	2/24/2008		9.7	1011	70.3	0.4	188	0.3

Annex 8 **Ambient conditions at the field test sites** **Page 5 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
121	2/25/2008	Bonn	11.3	1006	65.2	0.8	153	0.0
122	2/26/2008		9.3	1004	65.5	2.2	72	2.4
123	2/27/2008		7.9	1012	60.6	0.7	150	0.0
124	2/28/2008		8.9	1009	72.4	0.5	117	7.7
125	2/29/2008		9.7	994	66.8	4.7	132	9.2
126	3/1/2008		10.5	999	63.7	4.8	121	0.6
127	3/2/2008		9.6	1001	66.1	1.8	124	2.1
128	3/3/2008		4.4	1004	64.3	1.0	150	9.1
129	3/4/2008		2.9	1017	65.8	2.2	147	0.9
130	3/5/2008		2.8	1019	59.1	0.3	131	0.0
131	3/6/2008		7.1	1010	66.9	0.3	131	0.0
132	3/7/2008		7.7	1004	63.4	0.3	139	0.0
134	3/8/2008		8.1	998	59.4	0.4	153	0.0
134	3/9/2008		8.6	989	58.8	0.8	120	0.0
135	3/10/2008		8.2	979	63.2	2.8	159	2.1
136	3/11/2008		9.7	984	63.5	4.0	122	4.8
137	3/12/2008		7.7	1001	59.9	4.3	122	0.0
138	3/13/2008		9.0	1002	69.2	1.7	134	10.3
139	3/14/2008		8.1	1005	67.8	1.0	173	0.0
140	3/15/2008		11.6	993	66.7	0.4	148	7.7
141	3/16/2008		7.3	998	72.8	2.1	183	16.5
142	3/17/2008		4.3	1005	62.6	2.0	123	0.0
143	3/18/2008		4.7	1005	65.6	2.3	164	0.9
144	3/19/2008		3.6	1007	72.5	1.7	105	5.1
145	3/20/2008		5.5	983	69.0	3.4	133	5.6
146	3/21/2008		2.5	975	75.2	1.2	123	6.8
147	3/22/2008		1.7	989	63.9	3.1	233	1.8
148	3/23/2008		0.7	988	60.3	0.4	171	2.1
149	3/24/2008		1.2	990	74.2	2.5	126	2.7
150	3/25/2008		1.1	995	74.4	0.7	141	7.7

Annex 8 **Ambient conditions at the field test sites** **Page 6 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
151	3/26/2008	Bonn	3.8	991	81.0	0.3	178	4.2
152	3/27/2008		6.8	997	69.5	0.5	131	0.0
153	3/28/2008		9.5	1002	55.4	2.7	124	0.3
154	3/29/2008		11.4	1003	45.3	1.4	107	0.0
155	3/30/2008		12.3	1002	56.5	0.6	181	0.0
156	3/31/2008		10.8	1012	58.3	0.6	171	0.0
157	4/1/2008		10.6	1011	62.8	2.2	184	2.7
158	4/2/2008		8.0	1014	70.2	2.6	194	1.5
159	4/3/2008		7.7	1019	70.3	0.7	160	2.1
160	4/4/2008		9.4	1009	70.8	0.0	125	3.9
161	4/5/2008		4.9	996	76.8	0.6	136	13.6
162	4/6/2008		4.3	991	67.7	0.9	241	2.1
163	4/7/2008		4.1	997	65.3	1.0	150	0.3
164	4/8/2008		6.5	993	61.7	0.6	220	0.0
165	4/9/2008		7.1	990	68.4	0.3	219	2.4
166	4/10/2008		8.8	990	58.1	0.7	224	0.0
167	4/11/2008		9.8	996	52.9	0.7	129	0.0
168	4/12/2008		10.3	1002	61.9	1.0	110	1.5
169	4/13/2008		8.6	1002	77.7	0.5	163	20.4
170	4/14/2008		7.0	1009	75.7	0.5	112	8.6
171	4/15/2008		4.7	1013	75.0	0.3	188	5.9
172	4/16/2008		5.6	1006	57.7	0.8	214	0.0
173	4/17/2008		8.5	995	51.2	2.2	171	0.0
174	4/18/2008		10.2	989	55.6	1.5	190	0.0
175	4/19/2008		9.0	996	73.0	1.7	175	0.0
176	4/20/2008		12.1	995	60.9	2.0	211	0.0
177	4/21/2008		13.6	995	56.0	1.5	259	0.0
178	9/30/2008	Brühl	11.4	996	74.2	2.0	214	16.5
179	10/1/2008		12.4	992	68.9	6.6	241	5.0
180	10/2/2008		9.4	996	67.4	4.6	217	0.6

Annex 8 **Ambient conditions at the field test sites**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
181	10/3/2008	Brühl	8.7	1001	72.6	3.4	216	2.1
182	10/4/2008		9.6	1006	61.6	6.1	225	0.0
183	10/5/2008		12.6	997	71.2	8.3	213	9.8
184	10/6/2008		13.4	1007	79.7	0.8	200	2.7
185	10/7/2008		15.4	1005	75.3	2.3	144	0.3
186	10/8/2008		12.5	1012	82.0	1.2	254	5.3
187	10/9/2008		10.1	1024	78.8	0.5	246	0.0
188	10/10/2008		11.6	1024	77.6	0.2	185	0.3
189	10/11/2008		13.0	1020	78.0	0.8	145	0.0
190	10/12/2008		12.9	1017	79.4	1.0	163	0.3
191	10/13/2008		16.2	1011	74.4	1.5	174	0.3
192	10/14/2008		14.1	1012	72.5	1.9	206	0.0
193	10/15/2008		14.3	1006	72.8	4.4	203	4.1
194	10/16/2008		9.3	1005	75.9	3.2	246	6.2
195	10/17/2008		8.3	1012	71.4	2.3	228	0.0
196	10/18/2008		8.7	1012	71.0	0.2	199	0.0
197	10/19/2008		9.5	1013	70.0	1.8	196	0.0
198	10/20/2008		14.2	1004	68.9	3.6	171	0.0
199	10/21/2008		10.3	1006	76.2	1.7	228	2.1
200	10/22/2008		7.8	1017	72.7	1.3	208	0.0
201	10/23/2008		7.5	1019	73.0	2.6	151	0.0
202	10/24/2008		9.7	1018	73.3	1.3	158	0.3
203	10/25/2008		9.9	1021	78.6	1.2	161	0.3
204	10/26/2008		12.6	1007	70.2	3.5	191	7.4
205	10/27/2008		8.0	1000	76.8	1.4	249	3.9
206	10/28/2008		4.5	1002	74.9	0.9	209	0.0
207	10/29/2008		4.7	996	76.8	0.0	212	0.0
208	10/30/2008		4.4	992	77.9	1.5	109	1.8
209	10/31/2008		6.5	998	78.3	1.6	122	4.2
210	11/1/2008		8.4	1001	80.1	0.7	139	1.8

Annex 8 **Ambient conditions at the field test sites** **Page 8 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
211	11/2/2008	Brühl	8.9	1006	79.3	0.2	194	0.0
212	11/3/2008							
213	11/4/2008							
214	11/5/2008							
215	11/6/2008							
216	11/7/2008							
217	11/8/2008							
218	11/9/2008							
219	11/20/2008							
220	11/21/2008							
221	11/22/2008							
222	11/23/2008							
223	11/24/2008							
224	11/25/2008							
225	11/26/2008							
226	11/27/2008		No weather data available					
227	11/28/2008							
228	11/29/2008							
229	11/20/2008							
230	11/21/2008							
231	11/22/2008							
232	11/23/2008							
234	11/24/2008							
234	11/25/2008							
235	11/26/2008							
236	11/27/2008							
237	11/28/2008							
238	11/29/2008							
239	11/30/2008							
240	12/1/2008							

Annex 8 **Ambient conditions at the field test sites**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
241	12/2/2008	Brühl	No weather data available					
242	12/3/2008							
243	12/4/2008							
244	12/5/2008							
245	12/6/2008							
246	7/24/2008	Teddington	No weather data available					
247	7/25/2008							
248	7/26/2008							
249	7/27/2008							
250	7/28/2008							
251	7/29/2008							
252	7/30/2008							
253	7/31/2008							
254	8/1/2008							
255	8/2/2008							
256	8/3/2008							
257	8/4/2008							
258	8/5/2008							
259	8/6/2008							
260	8/7/2008							
261	8/8/2008							
262	8/9/2008							
263	8/10/2008							
264	8/11/2008							
265	8/12/2008							
266	8/13/2008							
267	8/14/2008							
268	8/15/2008							
269	8/16/2008							
270	8/17/2008							

Annex 8 **Ambient conditions at the field test sites** **Page 10 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
271	8/18/2008	Teddington	No weather data available					
272	8/19/2008							
273	8/20/2008							
274	8/21/2008							
275	8/22/2008							
276	8/23/2008							
277	8/24/2008							
278	8/25/2008							
279	8/26/2008							
280	8/27/2008							
281	8/28/2008							
282	8/29/2008							
283	8/30/2008							
284	8/31/2008							
285	9/1/2008							
286	9/2/2008							
287	9/3/2008							
288	9/4/2008							
289	9/5/2008							
290	9/6/2008							
291	9/7/2008							
292	9/8/2008							
293	9/9/2008							
294	9/10/2008							
295	9/11/2008							
296	9/12/2008							
297	9/13/2008							
298	9/14/2008							
299	9/15/2008							
300	9/16/2008							

Annex 8 **Ambient conditions at the field test sites** **Page 11 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
301	9/17/2008	Teddington	14.5	1005	68.1	0.6	153	
302	9/18/2008		11.6	1007	72.0	0.5	195	
303	9/19/2008		12.8	1012	70.1	0.3	170	
304	9/20/2008		13.1	1011	70.5	0.5	116	
305	9/21/2008		13.2	1008	70.0	0.6	168	
306	9/22/2008		14.8	1006	76.5	1.1	211	
307	9/23/2008		14.4	1006	76.0	1.8	228	
308	9/24/2008		14.8	1010	81.9	0.8	168	
309	9/25/2008		13.3	1016	74.7	0.7	89	
310	9/26/2008		13.4	1016	75.6	0.7	146	
311	9/27/2008		12.0	1011	80.6	0.1	206	
312	9/28/2008		13.9	1005	70.7	0.2	300	
313	9/29/2008		14.0	997	71.7	0.3	235	
314	9/30/2008		13.7	984	83.8	0.4	210	
315	10/1/2008		10.4	985	71.9	0.4	232	
316	10/2/2008		9.5	988	69.7	0.7	272	
317	10/3/2008		9.3	999	64.0	0.6	279	
318	10/4/2008		14.1	985	87.0	1.1	179	
319	10/5/2008		10.1	987	88.7	0.6	259	
320	10/6/2008		14.8	991	87.0	0.9	161	
321	10/7/2008		12.7	991	89.6	0.6	219	
322	10/8/2008		9.6	1008	80.6	0.2	276	
323	10/9/2008		13.3	1013	80.2	0.3	184	
324	10/10/2008		12.0	1009	84.4	0.4	210	
325	10/11/2008		12.8	1007	85.9	0.2	198	
326	10/12/2008		15.4	1001	86.5	0.3	206	
327	10/13/2008		12.5	1001	90.9	0.1	209	
328	10/14/2008		14.4	998	90.5	0.3	192	
329	10/15/2008		12.1	994	86.8	0.3	255	
330	10/16/2008		8.2	1001	78.7	0.4	241	

Annex 8 **Ambient conditions at the field test sites** **Page 12 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
331	10/17/2008	Teddington	9.0	1002.0	83.8	0.0	228.9	
332	10/18/2008		10.6	1001	83.3	0.1	213	
333	10/19/2008		14.0	995	76.3	0.8	192	
334	10/20/2008		11.2	989	90.2	0.4	203	
335	10/21/2008		6.7	999	80.5	0.2	214	
336	10/22/2008		9.4	1006	80.9	0.2	226	
337	10/23/2008		13.6	1000	79.8	1.0	195	
338	10/24/2008		6.5	1011	85.1	0.2	250	
339	10/25/2008		14.1	1002	81.8	0.9	194	
340	10/26/2008		9.2	995	95.0	0.0	227	
341	10/27/2008		4.2	994	85.6	0.1	285	
342	10/28/2008		4.3	994	81.7	0.5	253	
343	10/29/2008		4.3	984	77.8	0.4	153	
344	10/30/2008		5.3	985	79.6	1.1	161	
345	10/31/2008		5.7	992	80.1	0.9	245	
346	11/1/2008		8.8	989	91.5	1.2	233	
347	11/2/2008		10.1	997	88.9	0.8	224	
348	11/3/2008		10.6	998	93.6	0.9	151	
349	11/4/2008		11.4	1001	86.2	0.8	179	
350	11/5/2008		10.5	998	92.6	0.5	284	
351	11/6/2008		10.5	992	90.7	0.4	161	
352	11/7/2008		No weather data available					
353	11/8/2008							
354	11/9/2008							
355	2/14/2011	Cologne, parking lot	6.0	998	87.5	2.5	143	5.1
356	2/15/2011		5.4	992	86.9	3.5	110	1.8
357	2/16/2011		4.0	994	86.7	1.4	125	0.0
358	2/17/2011		4.1	1002	76.8	1.7	124	0.0
359	2/18/2011		2.7	1009	78.4	1.5	104	0.0
360	2/19/2011		2.7	1010	73.6	4.5	95	0.0

Annex 8 **Ambient conditions at the field test sites** **Page 13 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
361	2/20/2011	Cologne, parking lot	-0.5	1011	67.1	4.1	77	0.0
362	2/21/2011		-2.7	1011	65.5	3.1	94	0.0
363	2/22/2011		-1.6	1015	56.2	3.0	124	0.0
364	2/23/2011		1.2	1016	59.6	5.0	132	0.0
365	2/24/2011		2.2	1019	94.2	2.6	102	5.7
366	2/25/2011		5.3	1018	87.1	3.4	111	0.0
367	2/26/2011		6.3	1005	86.0	4.3	196	10.5
368	2/27/2011		4.2	1010	86.0	3.9	251	1.5
369	2/28/2011		3.8	1022	83.3	0.9	202	0.0
370	3/1/2011		5.2	1026	69.9	2.1	139	0.3
371	3/2/2011		4.8	1024	54.7	2.2	137	0.0
372	3/3/2011		3.7	1024	50.4	1.4	90	0.0
373	3/4/2011		3.4	1021	67.8	1.2	222	0.0
374	3/5/2011		2.7	1021	73.4	2.2	206	0.0
375	3/6/2011		3.0	1024	52.4	1.9	84	0.0
376	3/7/2011		4.0	1023	34.2	5.1	101	0.0
377	3/8/2011		7.9	1013	54.0	2.3	147	0.0
378	3/9/2011		7.1	1010	75.8	3.5	232	0.9
379	3/10/2011		9.2	1008	68.9	5.3	231	0.0
380	3/11/2011		8.1	1008	69.5	3.8	197	0.3
381	3/12/2011		12.1	998	61.6	3.3	147	0.3
382	3/13/2011		11.2	1001	77.3	2.0	156	1.5
383	3/14/2011		9.8	1010	81.2	0.3	114	0.0
384	3/15/2011		12.3	1006	66.2	2.2	96	0.0
385	3/16/2011		9.5	1000	71.9	2.5	126	0.0
386	3/17/2011		5.7	1009	86.9	4.7	267	0.0
387	3/18/2011		6.0	1018	89.1	1.1	135	11.1
388	3/19/2011		5.0	1027	59.5	1.2	123	0.0
389	3/20/2011		5.3	1027	57.7	0.9	150	0.0
390	3/21/2011		6.9	1029	56.5	1.0	166	0.0

Annex 8 **Ambient conditions at the field test sites** **Page 14 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
391	3/22/2011	Cologne, parking lot	9.4	1031	62.7	1.1	184	0.0
392	3/23/2011		10.7	1030	66.8	1.2	161	0.0
393	3/24/2011		10.9	1021	67.2	1.0	174	0.0
394	3/25/2011		11.8	1010	59.4	1.6	183	0.0
395	3/26/2011		7.7	1010	64.8	1.5	105	0.0
396	3/27/2011		9.3	1006	60.9	1.1	196	0.0
397	3/28/2011		7.2	1009	60.2	1.9	172	0.0
398	3/29/2011		9.6	1007	62.1	1.1	168	0.0
399	3/30/2011		12.6	1008	66.7	2.4	170	0.0
400	3/31/2011		13.8	1011	78.2	3.7	230	6.5
401	4/1/2011		13.9	1014	78.1	2.3	175	0.0
402	4/2/2011		17.6	1006	62.2	2.6	159	0.0
403	4/3/2011		10.9	1009	85.3	2.0	251	8.7
404	4/4/2011		10.0	1017	65.3	2.7	214	0.0
405	4/5/2011		11.8	1020	71.9	2.1	173	0.9
406	4/6/2011		16.2	1019	73.9	1.8	196	0.0
407	4/7/2011		13.8	1019	67.2	3.0	245	0.0
408	4/8/2011		12.9	1018	64.7	2.9	255	0.0
409	4/9/2011		11.3	1018	59.8	1.3	183	0.0
410	4/10/2011		14.0	1016	60.2	1.1	191	0.0
411	4/11/2011		16.0	1012	58.8	3.9	244	2.7
412	4/12/2011		7.7	1018	66.7	4.1	257	0.9
413	4/13/2011		10.1	1013	57.1	2.0	203	0.0
414	4/14/2011		8.0	1013	65.4	0.6	159	0.0
415	4/15/2011		10.4	1014	53.6	1.2	169	0.0
416	4/16/2011		11.9	1017	51.7	0.9	166	0.0
417	4/17/2011		11.4	1017	53.7	1.2	139	0.0
418	4/18/2011		14.3	1011	48.6	1.9	149	0.0
419	4/19/2011		15.5	1009	52.4	1.2	146	0.0
420	4/20/2011		16.6	1008	51.3	1.1	154	0.0

Annex 8 **Ambient conditions at the field test sites**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
421	4/21/2011	Cologne, parking lot	17.8	1006	54.1	0.7	180	0.0
422	4/22/2011		20.0	1003	51.8	1.3	146	8.3
423	4/23/2011		18.0	1005	58.0	0.7	152	0.0
424	4/24/2011		18.1	1011	51.7	1.0	172	0.0
425	4/25/2011		16.8	1013	50.3	1.2	153	0.0
426	4/26/2011		16.7	1011	51.5	1.8	166	2.1
427	4/27/2011		10.8	1010	90.4	0.7	213	8.9
428	4/28/2011		14.2	1005	77.6	0.7	176	0.3
429	4/29/2011		17.2	1002	56.8	1.7	112	3.0
430	4/30/2011		16.9	1002	47.4	1.7	141	0.0
431	5/1/2011		14.8	1002	44.5	1.6	111	0.0
432	5/2/2011		11.0	1004	53.3	2.0	116	0.0
433	5/3/2011		10.0	1011	49.4	1.0	164	0.0
434	5/4/2011		9.7	1016	61.5	1.3	168	0.0
435	5/5/2011		14.1	1015	46.9	2.2	119	0.0
436	5/6/2011		18.6	1012	41.1	2.5	110	0.0
437	5/7/2011		21.9	1011	37.0	3.4	109	0.0
438	5/8/2011		22.1	1013	34.7	4.1	97	0.0
439	5/9/2011		19.5	1016	48.6	2.1	131	0.0
440	5/10/2011		19.2	1017	66.8	1.6	221	2.1
441	5/11/2011		18.1	1013	55.0	1.6	247	0.0
442	5/12/2011		14.0	1013	58.9	2.6	206	0.0
443	5/13/2011		15.0	1011	56.4	1.2	199	0.0
444	5/14/2011		12.6	1011	60.6	3.1	240	9.8
445	8/11/2011	Bornheim	20.9	1004	53.8	1.2	220	0.3
446	8/12/2011		18.5	1003	78.9	1.1	228	2.1
447	8/13/2011		20.1	1001	77.0	0.7	185	0.0
448	8/14/2011		17.4	1000	86.2	1.1	219	17.4
449	8/15/2011		17.9	1009	71.8	1.2	230	0.0
450	8/16/2011		19.1	1010	69.0	0.7	190	0.6

Annex 8 **Ambient conditions at the field test sites**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
451	8/17/2011	Bornheim	21.1	1007	73.8	0.7	206	4.7
452	8/18/2011		22.5	1004	76.6	1.2	174	20.9
453	8/19/2011		16.8	1011	80.0	1.5	235	3.3
454	8/20/2011		20.7	1011	66.6	0.8	157	0.0
455	8/21/2011		23.2	1007	74.8	1.0	184	0.3
456	8/22/2011		20.4	1009	76.5	1.2	253	0.0
457	8/23/2011		22.6	1005	78.4	0.9	206	0.0
458	8/24/2011		20.1	1007	76.6	0.7	192	0.6
459	8/25/2011		20.8	1003	83.4	1.0	176	2.1
460	8/26/2011		19.4	999	83.7	1.5	195	29.1
461	8/27/2011		15.3	1007	77.0	1.1	207	0.3
462	8/28/2011		15.6	1009	69.2	1.3	212	0.0
463	8/29/2011		14.5	1008	66.7	2.0	243	0.0
464	8/30/2011		13.6	1008	73.6	0.8	236	0.0
465	8/31/2011		14.8	1007	72.0	0.7	225	0.0
466	9/1/2011		16.4	1006	71.6	0.6	182	0.0
467	9/2/2011		21.2	1004	72.2	0.8	160	0.0
468	9/3/2011		24.5	1002	67.0	1.3	132	3.6
469	9/4/2011		20.2	1002	79.5	1.1	223	0.6
470	9/5/2011		16.6	1009	62.9	1.9	217	0.0
471	9/6/2011		17.4	1005	66.8	2.6	219	4.8
472	9/7/2011		14.9	1004	73.1	2.2	246	5.7
473	9/8/2011		14.7	1003	84.7	1.1	209	3.3
474	9/9/2011		19.0	1004	86.9	0.4	167	0.0
475	9/10/2011		23.8	1001	73.0	1.5	155	0.0
476	9/11/2011		16.2	1003	86.0	0.7	165	16.2
477	9/12/2011		19.4	1004	71.1	1.7	204	0.0
478	9/13/2011		16.7	1006	67.3	1.6	219	0.0
479	9/14/2011		15.2	1011	65.1	1.5	224	0.0
480	9/15/2011		14.1	1013	75.3	0.6	207	0.0

Annex 8 **Ambient conditions at the field test sites** **Page 17 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
481	9/16/2011	Bornheim	17.1	1006	72.6	1.4	145	0.0
482	9/17/2011		16.8	1001	70.6	1.0	207	3.6
483	9/18/2011		13.3	998	76.4	1.0	200	4.5
484	9/19/2011		13.6	1008	75.8	1.4	231	0.9
485	9/20/2011		15.6	1014	78.0	0.5	196	0.0
486	9/21/2011		16.9	1011	69.5	0.8	204	0.0
487	9/22/2011		15.2	1011	72.2	1.2	231	0.0
488	9/23/2011		Outage of weather station					
489	9/24/2011							
490	9/25/2011							
491	9/26/2011							
492	9/27/2011							
493	9/28/2011							
494	9/29/2011							
495	9/30/2011		18.4	1017	68.3	1.2	155	0.0
496	10/1/2011		18.1	1018	70.6	0.5	176	0.0
497	10/2/2011		17.8	1016	75.4	0.3	213	0.0
498	10/3/2011		18.8	1013	65.9	0.8	168	0.0
499	10/4/2011		17.8	1013	72.4	1.6	214	0.0
500	10/5/2011		17.5	1011	70.8	1.2	199	0.0
501	10/6/2011		13.2	1001	71.2	2.3	213	0.3
502	10/7/2011		9.9	1005	81.6	3.6	272	5.7
503	10/8/2011		8.7	1009	85.5	2.1	258	6.0
504	10/9/2011		12.2	1011	84.5	1.4	190	5.4
505	10/10/2011		17.7	1009	74.4	3.2	261	0.3
506	10/11/2011		16.3	1010	77.4	3.6	251	0.0
507	10/12/2011		12.5	1012	91.1	0.9	226	17.9
508	10/13/2011		9.9	1022	76.3	0.6	209	0.0
509	10/14/2011		8.7	1024	69.6	1.0	151	0.0
510	10/15/2011		7.8	1020	68.8	1.2	162	0.0

Annex 8 **Ambient conditions at the field test sites** **Page 18 of 18**

No.	Date	Test site	Amb. temperature (avg) [°C]	Amb. pressure [hPa]	Rel. humidity [%]	Wind velocity [m/s]	Wind direction [°]	Precipitation [mm]
511	10/16/2011	Bornheim	8.5	1016	73.8	1.5	157	0.0
512	10/17/2011		10.5	1011	78.5	0.8	163	0.0
513	10/18/2011		9.2	1003	82.0	1.2	197	3.0
514	10/19/2011		8.1	1010	74.4	1.5	225	0.0
515	10/20/2011		5.6	1018	79.8	1.0	223	0.0
516	10/21/2011		5.2	1019	79.3	1.1	154	0.0
517	10/22/2011		6.8	1013	69.3	3.9	128	0.0
518	10/23/2011		7.4	1007	71.6	2.3	138	0.0
519	10/24/2011		9.8	999	67.2	3.8	132	0.0
520	10/25/2011		10.9	997	68.8	1.9	132	0.0
521	10/26/2011		9.4	1006	74.9	0.9	171	0.0

Appendix 2:

Methods used for filter weighing

A) Locations in Germany (Cologne, Bonn, Brühl, Bornheim)

A.1 Performance of weighing

Weighing takes place in an air-conditioned weighing chamber. Conditions are as follows: 20 °C ±1 °C and 50% ±5% rel. humidity and thus meet the requirements of EN 14907.

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

Before sampling = initial weighing	After sampling = back weighing
Processing 48 hours + 2 hours	Processing 48 hours + 2 hours
Filter weighing	Filter weighing
additional processing 24 hours + 2 hours	additional processing 24 hours + 2 hours
Filter weighing and immediate packaging	Filter weighing

The balance is available ready for operation at all times. The balance is calibrated before every weighing series. If everything turns out to be okay, the reference with is weighed against the calibration weight of 200 mg and peripheral parameters are recorded. Deviations from the previous weighing meet the standard's requirements and do not exceed 20 µg (see Figure 120). The six control filters are weighed this way. For control filters deviating by more than 40 µg a warning is displayed on the evaluation page. This filters are not used for back weighing. The first three flawless control filters are used for back weighing, remaining filters remain safely stored in their can to be used in the event the first three filters are damaged or experience excessive deviations. Figure 121 presents the exemplary trend over a period of four weeks.

Filters, for which there is a difference or more than 40 µg between the first and the second weighing, are not used for initial weighing. For back weighing, filters with differences exceeding 60 µg are removed from the evaluation as required by the standard.

Weighed filters are separately kept in polystyrene boxes for transports to and from the measurement site and for storage. The box is not opened until the filter is inserted in the filter cartridge. Virgin filters can be stored in the weighing chamber up to 28 days until sampling. Should this period be exceeded, initial weighing will be repeated.

Deposited filters can be stored for a maximum of 15 days at temperatures up to 23°C. Filters are stored in a fridge at 7°C.

A2 Evaluation of the filters

Filters are evaluated using a correction term. The purpose of this corrective calculation is to minimise changes in the mass as a result of conditions in the weighing chamber.

Equation:

$$\text{Dust} = MF_{rück} - (M_{Tara} \times (MKon_{rück} / MKon_{hin})) \qquad \text{(F1)}$$

$MKon_{hin}$ = mean mass of the 3 control filters determined on 48 h and 72h initial weighing

$MKon_{rück}$ = mean mass of the 3 control filters determined on 48 h and 72 h back weighing

M_{Tara} = mean mass of the filter determined on 48 h and 72 h initial weighing

$MF_{rück}$ =mean mass of the filter determined on 48 h and 72 h back weighing

Dust = corrected dust load on the filter

The corrective calculation proved to render the method independent of the conditions in the weighing chamber. This way, the influence of water contents on the filter mass comparing virgin and deposited filters can be controlled and do not influence the dust concentrations deposited on the used filters. This is sufficient to meet the requirements of EN 14907, chapter 9.3.2.5.

The exemplary trend for the calibration weight for Nov 2008 to Feb 2009 shows that the permissible difference of 20 µg compared to the previous measurement is not exceeded.

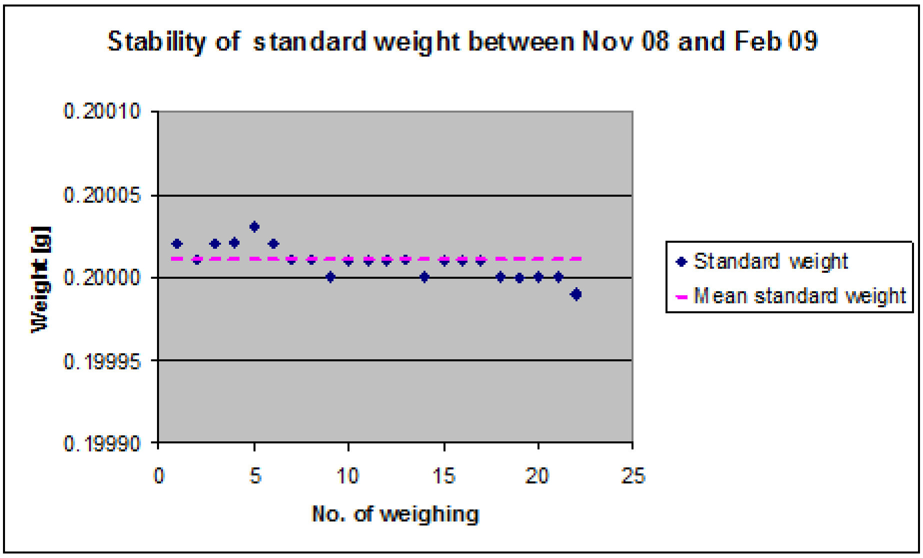


Figure 120: Stability of the calibration weight

Table 54: Stability of the calibration weight

Date	Weighing no.	Standard weight	Difference compared to previous weighing
		g	µg
12.11.2008	1	0.20002	
13.11.2008	2	0.20001	-10
10.12.2008	3	0.20002	10
11.12.2008	4	0.20002	0
17.12.2008	5	0.20003	10
18.12.2008	6	0.20002	-10
07.01.2009	7	0.20001	-10
08.01.2009	8	0.20001	0
14.01.2009	9	0.20000	-10
15.01.2009	10	0.20001	10
21.01.2009	11	0.20001	0
22.01.2009	12	0.20001	0
29.01.2009	13	0.20001	0
30.01.2009	14	0.20000	-10
04.02.2008	15	0.20001	10
05.02.2009	16	0.20001	0
11.02.2009	17	0.20001	0
12.02.2009	18	0.20000	-10
18.02.2009	19	0.20000	0
19.02.2009	20	0.20000	0
26.02.2009	21	0.20000	0
27.02.2009	22	0.19999	-10

Marked yellow = mean
Marked green = lowest value
Marked blue = highest value

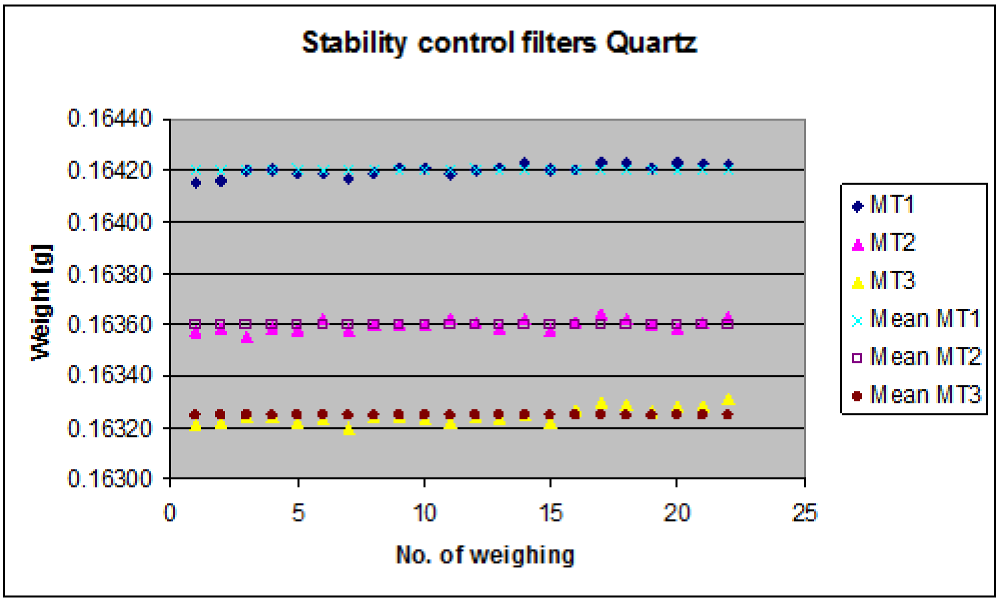


Figure 121: Stability of the control filter

Table 55: Stability of the control filter

Weighing no.	MT1 [g]	MT2 [g]	MT3 [g]
1	0.16415	0.16357	0.16321
2	0.16416	0.16359	0.16322
3	0.16420	0.16355	0.16324
4	0.16420	0.16359	0.16324
5	0.16419	0.16358	0.16322
6	0.16419	0.16362	0.16323
7	0.16417	0.16358	0.16320
8	0.16419	0.16360	0.16324
9	0.16421	0.16360	0.16324
10	0.16421	0.16360	0.16323
11	0.16419	0.16362	0.16322
12	0.16420	0.16361	0.16324
13	0.16421	0.16359	0.16323
14	0.16423	0.16362	0.16325
15	0.16420	0.16358	0.16322
16	0.16420	0.16361	0.16327
17	0.16423	0.16364	0.16330
18	0.16423	0.16362	0.16329
19	0.16421	0.16360	0.16326
20	0.16423	0.16359	0.16328
21	0.16422	0.16361	0.16328
22	0.16422	0.16363	0.16331
Average	0.16420	0.16360	0.16325
Standard dev.	2,19602E-05	2,1157E-05	3,0165E-05
rel. std. dev.	0.013	0.013	0.018
Median	0.16420	0.16360	0.16324
lowest value	0.16415	0.16355	0.16320
highest value	0.16423	0.16364	0.16331

Marked yellow = mean

Marked green = lowest value

Marked blue = highest value

B) Site in the United Kingdom (Teddington)

B.1 Implementation of weighing protocols

NPL (National Physical Laboratory) was commissioned to weigh filters for the field test manually. In compliance with EN EN14907, the filter was stored in the weighing chamber for less than 28 days. The plexiglas chamber used for weighing was kept at 20 ± 1°C and 50 ± 5 %. Filters were weighed twice each before and after sampling. Table 56 summarises weighing conditions and weighing times.

Table 56: Weighing conditions and weighing times

Pre Sampling	Post Sampling
Condition minimum of 48 hours Weigh Filters Condition 24 hours Weigh Filters	Condition 48 hours Weigh Filters Condition 24 hours Weigh Filters

The beam balance was checked before every weighing series in order to remove mechanical rigidity. Calibration took place after that. At the beginning and the end of every filter lot, a 50 mg and a 200 mg reference weight were weighed. In accordance with the UK PM Equivalence Report [11], the filter was weighed against a 100 mg reference weight rather than against a zero filter since the latter experiences weight loss over time. Four filters each were weighed between the reference weights, since the weighing drift over this period is small.

The **mass of the reference weight (CM)** for the filters was calculated for each weighing series according to equation **E A.1**.

$$CM = \frac{\left(m_{check,Beg} + m_{check,End}\right)}{2}$$ **E A.1**

Where:

$M_{check,Beg}$ = mass of the reference weight, weighed just upstream of of the sampling filter.

$M_{check,End}$ = mass of the reference filter, weighed just downstream of the sampling filter.

The **relative mass (RM)** of the filters was determined for every weighing series in accordance with equation **E A.2**. $RM = m_{filter} - CM$ **E A.2**

Where:

m_{filter} = mass of the sampling filter

EN 14907 defines the **particle mass (PM)** as calculated in accordance with the following equation:

$$PM = \left(\frac{RM_{End1} + RM_{End2}}{2}\right) - \left(\frac{RM_{Beg1} + RM_{Beg2}}{2}\right)$$ **E A.3**

Where:

Beg1 marks weighing series 1 before sampling

Beg2 marks weighing series 2 before sampling

End1 marks weighing series 2 after sampling

End2 marks weighing series 2 after sampling

End scattering range (S_{Pre}), Beg scattering range (S_{Post}) and reference weight scattering range (S_{Blank}) were calculated according to the following equation:

$$S_{Pre} = RM_{Anf1} - RM_{Anf2}$$ **E A.4**

$$S_{Post} = RM_{End1} - RM_{End2}$$ **E A.5**

$$S_{Blank} = \left(\frac{CM_{End2} + CM_{End1}}{2}\right) - \left(\frac{CM_{Anf2} + CM_{Anf1}}{2}\right)$$ **E A.6**

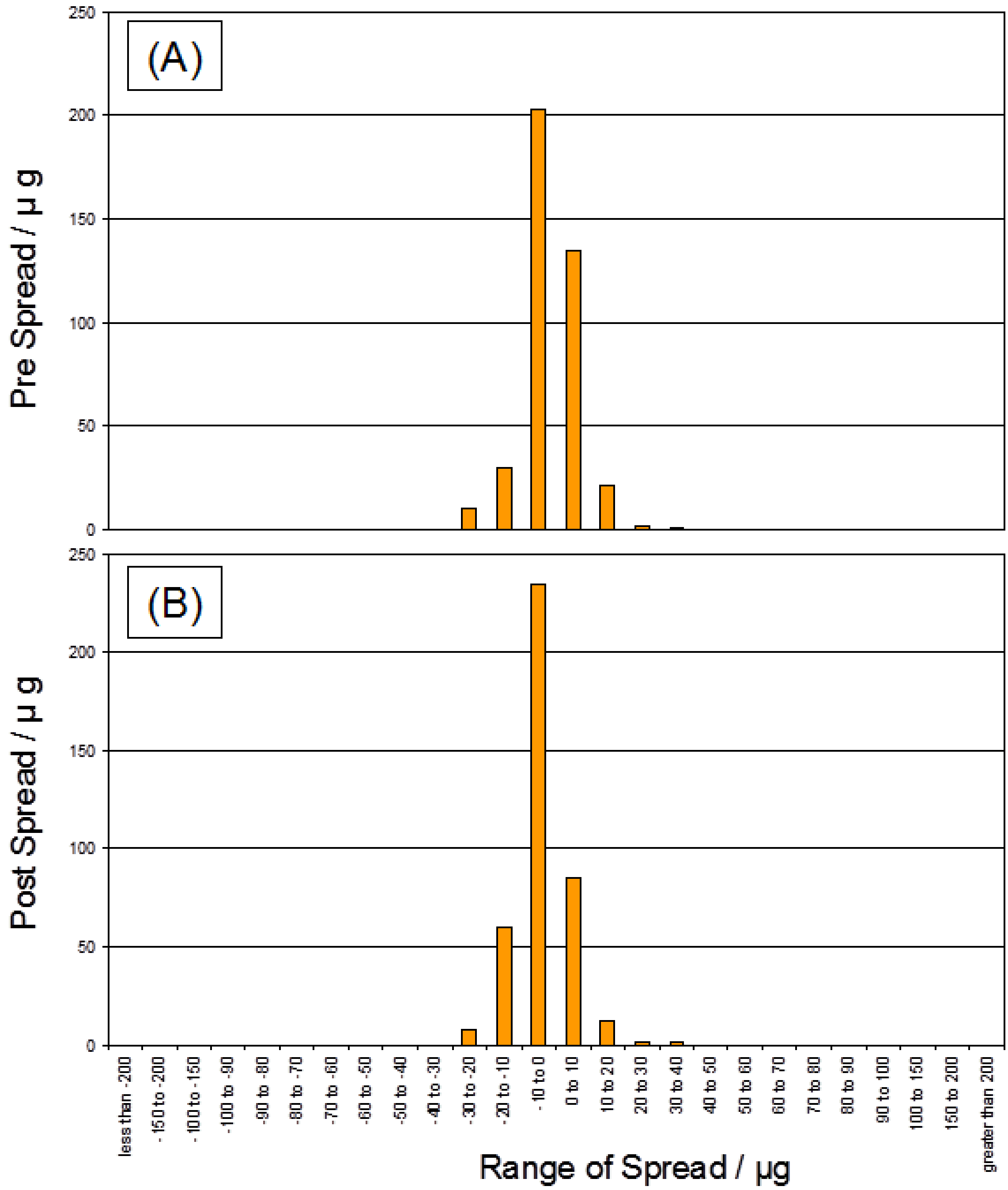
As described in the UK PM Equivalence Report [11], it was not possible to weigh all filters within the 15-day period as required by EN 14907.

However, the filters were immediately taken from the reference sampler to be put in the fridge which is why it was unnecessary to establish whether $T_{Umgebung}$ exceeded 23°C. 15 days appear unfeasible for a relatively small field test scope. The method is unlikely to be copied in national or regional grids. The method used here is representative for the operation of the reference sampler in practice

A.2 Analysis of the weighing protocol used

Figure 122 presents the scattering behaviour of the initial and back weighing for all EMFAB filters collected referred to the carrying weight and the reference weight. If all filters lose relative weight , scattering shifts to the right. Conversely, scattering will shift left if the filters increase in mass. Standard EN EN14907 requires undeposited filters to be discarded if the mass difference between the two initial weighings exceeds 40 µg. By the same token, EN 14907 requires filters to be discarded if the difference between the two back weighings exceeds 60 µg. This criterion did not result in any filters being discarded. It is considered unlikely that the defined scattering of repeated mass determinations significantly affect the results.

Figure 122: Scattering of the EMFAB filter for (**A**) initial weighing compared to the reference weight and (**B**) back weighing compared to the reference weight.



Appendix 3:

Manual