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Ambient air — Automated measuring systems for the measurement of the concentration of particulate matter (PM10; PM2,5)

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National foreword

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Ambient air - Automated measuring systems for the measurement of the concentration of particulate matter (PM10; PM2,5)

Air ambiant - Systèmes automatisés de mesurage de la concentration de matière particulaire (PM10; PM2,5)

Außenluft - Automatische Messeinrichtungen zur Bestimmung der Staubkonzentration (PM10; PM2,5)

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European foreword

This document (EN 16450:2017) has been prepared by Technical Committee CEN/TC 264 “Air quality”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2017, and conflicting national standards shall be withdrawn at the latest by September 2017.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN shall not be held responsible for identifying any or all such patent rights.

This document supersedes CEN/TS 16450:2013.

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1 Scope

In order to be in compliance with EU Air Quality Directive requirements, the reference methods given in the Directive 2008/50/EC [1] for the measurement of mass concentrations of particulate matter are not commonly used for operation in routine monitoring networks. These networks usually apply automated continuous measurement systems (AMS), such as those based on the use of oscillating microbalances, ß-ray attenuation, or *in situ* optical methods. Such AMS are typically capable of producing 24-h average measurement values over a measurement range up to 1 000 µg/m^3 and 1-h average measurement values up to 10 000 µg/m^3, if applicable, where the volume of air is the volume at ambient conditions near the inlet.

The 1-h average values may be used for:

a) direct information of the public;

b) aggregation to produce daily or yearly average concentration values for regulatory reporting purposes.

NOTE National regulatory reporting purposes could require other time basis for averages (i.e. monthly).

Directive 2008/50/EC allows the use of such systems after demonstration of equivalence with the reference method, i.e. after demonstration that these systems meet the Data Quality Objectives for continuous measurements. Guidelines for the demonstration of equivalence are given in Reference [2].

This European Standard lays down the minimum performance requirements and test procedures for the type testing of appropriate AMS for particulate matter. The standard includes the evaluation of its equivalence with the reference method as laid down in Directive 2008/50/EC.

Further, this European Standard describes minimum requirements for ongoing quality assurance – quality control (QA/QC) of AMS deployed in the field. These requirements are necessary to ensure that uncertainties of measured concentrations are kept within the required limits during extended periods of continuous monitoring in the field, and include procedures for maintenance, calibration and control checks.

Additional procedures are described that determine whether an instrument's equivalence to the reference method is maintained through possible pollution climate changes, over periods longer than five years.

Lastly, this European Standard describes harmonized requirements and procedures for the treatment and validation of raw measurement data that are used for the assembly of daily or yearly average concentration values. Experience with existing methods for data treatment and validation – for similar AMS – has shown that the different ways of data treatment and validation applied may lead to significant differences in reported results for similar data sets [3].

When the European Standard is used for purposes other than measurements required by Directive 2008/50/EC, the range and uncertainty requirements may not apply.

This European Standard contains information for different groups of users.

Clauses 5 and 6 and Annex A contain general information about the principles of automated continuous measurement systems for particulate matter, and relevant equipment.

Clause 7 and Annexes B and C are specifically directed towards test houses and laboratories that perform type testing of automated continuous measurement systems for particulate matter. These clauses contain information about:

c) type testing conditions, test procedures and test requirements;

d) system performance requirements;

e) evaluation of the type testing results;

f) evaluation of the uncertainty of the measurement results of the automated continuous measurement systems for particulate matter based on the type testing results.

Clauses 8 to 11 are aimed at monitoring networks performing the practical measurements of particulate matter in ambient air. These clauses contain information about:

g) initial installation of the system in the monitoring network and acceptance testing;

h) ongoing quality assurance/quality control;

i) on-going verification of suitability;

j) treatment, validation and reporting of measurement results.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12341, *Ambient air - Standard gravimetric measurement method for the determination of the PM10 or PM2,5 mass concentration of suspended particulate matter*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
ambient air
outdoor air in the troposphere, excluding workplaces as defined by Directive 89/654/EEC [4] where provisions concerning health and safety at work apply and to which members of the public do not have regular access

[SOURCE: Directive 2008/50/EC [1]]

3.2
automated measuring system
AMS
entirety of all measuring instruments and additional devices necessary for obtaining a measurement result

3.3
availability of the AMS
fraction of the time period for which valid measuring data of the ambient air concentration is available from an AMS

[SOURCE: EN 14211 [5]]

3.4
calibration
operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

Note 1 to entry: A calibration may be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it may consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.

Note 2 to entry: Calibration should not be confused with adjustment of a measuring system, often mistakenly called "self-calibration", nor with verification of a calibration.

[SOURCE: JCGM 200:2012 (VIM) [6]]

3.5
combined standard uncertainty
standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms, the terms being the variances or covariances of these other quantities weighted according to how the measurement result varies with changes in these quantities

[SOURCE: ISO/IEC Guide 98-3:2008 [7]]

3.6
competent authority
organization which implements the requirements of EU Directives and regulates installations, which shall comply with the requirements of applicable European Standards

Note 1 to entry: In ambient air quality monitoring this is an authority that performs one or more of the tasks listed in Article 3 of Directive 2008/50/EC.

3.7
competent body
organization which can demonstrate its competence for a specific task to the competent authority in the Member State

3.8
coverage factor
numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

[SOURCE: ISO/IEC Guide 98-3:2008 [7]]

3.9
data capture
percentage of the time for which the AMS has produced valid data to the time for which the aggregated value is to be calculated, excluding periods of regular calibration or normal maintenance

[SOURCE: Directive 2008/50/EC [1]]

3.10
detection limit
smallest concentration of a measurand that can be reliably detected by a specific measurement process

3.11
equivalent method
method other than the reference method for the measurement of a specified air pollutant meeting the data quality objectives for fixed measurements specified in the relevant Air Quality Directive [1]

Note 1 to entry: Equivalence is granted for defined (regional) situations within a Member State, but may be granted for situations encompassing more than one region or Member State.

3.12
expanded uncertainty
quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

Note 1 to entry: The fraction may be viewed as the coverage probability or level of confidence of the interval.

Note 2 to entry: To associate a specific level of confidence with the interval defined by the expanded uncertainty requires explicit or implicit assumptions regarding the probability distribution characterized by the measurement result and its combined standard uncertainty. The level of confidence that may be attributed to this interval can be known only to the extent to which such assumptions may be justified.

[SOURCE: ISO/IEC Guide 98-3:2008 [7]]

3.13
interferent
component of the air sample, excluding the measured constituent, that affects the output signal

3.14
limit value
level fixed on the basis of scientific knowledge, with the aim of avoiding, preventing or reducing harmful effects on human health and/or the environment as a whole, to be attained within a given period and not to be exceeded once attained

[SOURCE: Directive 2008/50/EC [1]]

3.15
monitoring station
enclosure located in the field in which an AMS has been installed to measure particulate matter in such a way that its performance and operation comply with the prescribed requirements

3.16
parallel measurement
measurement from measuring systems, sampling from the same air over the same time period

3.17
performance characteristic
one of the parameters assigned to an AMS in order to define its performance

3.18
performance criterion
limiting quantitative numerical value assigned to a performance characteristic, to which conformance is tested

3.19
period of unattended operation
time period over which the drift is within the performance criterion for long term drift

3.20
PM_x
particulate matter suspended in air which passes through a size-selective inlet at a constant flow with a 50 % efficiency cut-off at x µm aerodynamic diameter

Note 1 to entry: By convention, the size-selective standard inlet designs prescribed in EN 12341 — used at the prescribed flow rates – possess the required characteristics to sample the relevant PM fraction suspended in ambient air.

Note 2 to entry: The efficiency of the size selectiveness of other inlets used could have a significant effect on the fraction of PM surrounding the cut-off, and, consequently on the mass concentration of PM_x determined.

3.21
reference method
RM
measurement method(ology) which, by convention, gives the accepted reference value of the measurand

3.22
sampled air
ambient air that has been sampled through the sampling inlet and sampling system

3.23
sampling inlet
entrance to the sampling system where ambient air is collected from the atmosphere

3.24
span
a means to produce an instrument response different from zero suitable to evaluate the sensitivity of the AMS

3.25
standard uncertainty
uncertainty of the result of a measurement expressed as a standard deviation

[SOURCE: ISO/IEC Guide 98-3:2008 [7]]

3.26
surrounding temperature
temperature of the air directly surrounding the AMS (temperature inside the monitoring station or laboratory)

3.27
time coverage
percentage of the reference period of the relevant limit value for which valid data for aggregation have been collected

3.28
type approval
decision taken by a competent authority that the pattern of an AMS conforms to the requirements as laid down in this document

3.29
type testing
examination of two or more AMS of the same pattern which are submitted by a manufacturer to a competent body for testing of performance requirements

3.30
uncertainty (of measurement)
parameter associated with the result of a measurement that characterizes the dispersion of the values that could reasonably be attributed to the measurand

[SOURCE: ISO/IEC Guide 98-3:2008 [7]]

3.31
zero air
air containing particulate matter at a level ≤ 1,0 µg/m^3

3.32
zero level
average of the results of a number of replicate measurements of zero air

4 Symbols and abbreviated terms

For the purposes of this document, the following symbols and abbreviated terms apply.

a, c	intercept of orthogonal regression of results of AMS vs. reference method results
A	availability of the AMS
b, d	slope of orthogonal regression of results of AMS vs. reference method results
k	coverage factor
L	limit value
ΔP	pressure difference determined for the time interval Δt (leak test)
P_0	pressure at t = 0 (leak test)
T_s	is the surrounding air temperature
$T_{s,lab}$	is the surrounding air temperature at the laboratory
Δt	time interval needed for the pressure rise (leak test)
t_{valid}	time during which valid data have been collected (field test)
$t_{cal,maint}$	time spent for scheduled calibrations and maintenance (field test)
t_{field}	total duration of the field test

V_L	volume leak rate (leak test)
V_{sys}	estimated total volume of the system (dead volume)
u	standard uncertainty
u_a	uncertainty of the intercept of the regression formula
u_b	uncertainty of the slope of the regression formula
$u_{bs,AMS}$	between-AMS uncertainty
$u_{bs,RM}$	between-RM uncertainty
u_{RM}	random uncertainty of reference method results
w	relative uncertainty
W	expanded relative uncertainty
x_i	individual measurement result of AMS
y_i	individual reference measurement result

AMS	Automated Measuring System
EU	European Union
GDE	Guide to the Demonstration of Equivalence of Ambient Air Monitoring Methods
GUM	Guide to the Expression of Uncertainty in Measurement
JCGM	Joint Committee for Guides in Metrology
PM	Particulate Matter
QA/QC	Quality Assurance / Quality Control
RM	Reference Method(ology)
RSS	Residual Sum of Squares

5 Principle

5.1 General

A number of measuring principles may be used to determine the mass concentration of particulate matter in ambient air. This European Standard is not limited to the application of a single system for the automated continuous measurement. In general (but not necessarily), the measuring system will consist of:

a) a size-selective inlet for PM_{10} or $PM_{2,5}$ (when using an optical system for size classification of particulate matter a size-selective inlet is not required);

b) a sample tube of a length needed to meet the specific sampling height requirements given in Reference [1];

c) a measuring section;

d) a vacuum pump;

e) flow meters and flow controllers;

f) temperature and pressure sensors;

g) hardware and software for data collection, storage and calculation of measurement results.

Auxiliary equipment may include:

h) sample tube heaters;

i) systems for (partial) drying of the sampled air;

j) humidity sensors;

k) hardware/software for performing compensation measurements, i.e. measurements to compensate for unwanted effects of interferents or random variations in the PM mass determination.

5.2 Measurement principles

Several measurement principles are currently applied in routine monitoring practice. Descriptions of the most common principles – which do not preclude other principles – are given in Annex A.

5.3 Type testing

The type testing of an AMS according to Clause 7 and subsequent QA/QC and verification procedures according to Clause 8 provide evidence that the defined requirements concerning data quality objectives laid out in relevant EU Directives can be satisfied. A competent body shall perform the type testing. The type testing shall be awarded by, or on behalf of, the competent authority of a Member State.

The type testing is based on the evaluation of performance characteristics determined under a prescribed series of tests. In this European Standard, test procedures are described for the determination of the actual values of the performance characteristics for at least two AMS in a laboratory and the same two AMS in the field. The evaluation for type testing of an AMS includes the calculation of the expanded uncertainty of the measuring result based on the numerical values of the tested performance characteristics and comparison with a prescribed maximum uncertainty.

Appropriate experimental evidence shall be provided by:

a) type testing performed under conditions of intended use of the specified method of measurement, and

b) calculation of expanded uncertainty of results of measurement.

5.4 Suitability testing

Before putting a type-approved AMS into operation, the body responsible for the field operation shall test its suitability for its specific field conditions. If the specific conditions have already been covered by the type testing, then the suitability test is not necessary. If these conditions have not been covered by the type testing field tests, suitability tests shall be performed at locations representative of these specific field conditions.

5.5 Field operation and quality control

After the initial installation of the AMS at the monitoring station its correct functioning shall be tested.

Requirements for quality assurance and quality control are given for the operation and maintenance of the AMS, to ensure that the uncertainty of subsequent measurement results obtained in the field is not compromised.

5.6 Data handling and validation

Practical experience with existing methods for data handling and validation – for similar AMS – has shown that the different ways of data treatment and validation applied may lead to significant differences in reported results for similar data sets [3].

Hence, requirements and recommendations are given for the treatment and validation of raw measurement data collected by the AMS (see Clause 9).

6 Sampling

6.1 General

Conditions and layout of the sampling equipment will contribute to the uncertainty of the measurement; to minimize this contribution to the measurement uncertainty, performance criteria for the sampling equipment are given in the following subclauses.

NOTE In Annex A, examples of equipment are schematically presented.

6.2 Sampling location

The location where the ambient air shall be sampled and analysed is not specified as this depends strongly on the category of a monitoring station (such as measurements in, e.g. a traffic or urban background area).

NOTE For guidance on sampling points on a micro scale, see reference [1].

6.3 Sample inlet and sampling line

Each AMS is equipped with its own sample inlet and sampling line. Sampling inlets may be – but are not restricted to – size-selective inlets for PM_{10} or $PM_{2,5}$.

NOTE Examples of designs of size-selective inlets for PM_{10} or $PM_{2,5}$ can be found in EN 12341.

The manufacturer should provide information on the design of the sample inlet and the sampling line.

The sample inlet and sampling line shall be made of an inert, non-corroding, electrically conducting material, preferably stainless steel, or anodized aluminium or aluminium alloy. The inlet shall be constructed in such a way that ingress of rainwater into the sampling line (or system) is prevented.

The construction of the sampling line shall be such that deposition losses of particulate matter by kinetic processes as well as losses due to thermal, chemical or electrostatic processes are minimized. Contact of the sampled air with cold surfaces may cause condensation and shall be avoided. If heating of surfaces is applied, the instrument shall be tested with this facility in operation as part of the type testing.

The air flow velocity in the sampling line shall be such that significant losses of particulate matter due to diffusion or turbulent inertial impaction are minimized.

6.4 Control and regulation of sample flow rate

Correct operation of the AMS requires calibration and control of sampling flow rate, and measurement of ambient temperature and pressure.

The sample flow rate into the AMS shall be maintained within the specifications as laid down in Table 1.

6.5 Expression of concentrations

Results shall be reported in units of mass per unit volume expressed at ambient conditions. The air temperature needed for the conversion to ambient conditions shall be measured close to the sampling inlet. The air pressure needed for the conversion shall be obtained from on-site measurements, or from measurements at a representative meteorological site nearby.

When using data from meteorological sites, care shall be taken to convert these to the correct altitude of the sampling site, if relevant.

It is essential that any conversion to ambient conditions is clearly and unambiguously identified by the manufacturer. The manufacturer shall inform the test laboratory or test house whether any built-in corrections are applied. Where no internal corrections are applied, the manufacturer shall provide the test laboratory or test house with any algorithms that are required for the conversion of the AMS readings to different temperatures and/or pressures.

7 Type testing

7.1 Performance requirements

This test programme describes a procedure for determining whether an AMS is suitable to be considered equivalent to the EU Reference Methods for the measurement of particulate matter in ambient air. Tested AMS will have to meet the Data Quality Objectives of Reference [1]. This test programme is suitable to evaluate AMS for monitoring different fractions – PM_{10} or $PM_{2,5}$ – of suspended particulate matter in ambient air.

This process of evaluation of the values of the performance characteristics comprises laboratory and field tests, and the calculation of the expanded uncertainty. Two AMS of the same pattern shall be included in the full test programme. Both of the AMS submitted for type testing are required to pass all of the tests listed under Clause 7.

A competent body shall perform the type testing. The type testing shall be awarded by or on behalf of the competent authority. The competent body performing the required tests shall be able to demonstrate that it works in conformity with the requirements of internationally accepted standards for test laboratories.

NOTE 1 EN ISO/IEC 17025 [9] is the harmonized internationally accepted standard that applies.

NOTE 2 A formal accreditation by a member body of the European Accreditation Organization to EN ISO/IEC 17025 is a demonstration of conformity.

7.2 Relevant performance characteristics and performance criteria

The performance characteristics which shall be determined during a laboratory and field test, and their related performance criteria, are given in Table 1.

Table 1 — Relevant performance characteristics and criteria

	Performance characteristic	Requirement	Location (Lab/Field)	Clause
1	Measuring ranges	0 µg/m³ to 1 000 µg/m³ as a 24-h average value 0 µg/m³ to 10 000 µg/m³ as a 1-h average value, if applicable	L	
2	Negative signals	Shall not be suppressed	L	
3	Zero level and detection limit	Zero level: ≤ 2,0 µg/m³ Detection limit: ≤ 2,0 µg/m³	L	7.4.3
4	Flow rate accuracy [a]	≤ 2,0 % – at 5 °C and 40 °C by default for installation in a temperature-controlled environment or – at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures.	L	7.4.4
5	Constancy of sample volumetric flow	≤ 2,0 % sampling flow (averaged flow) ≤ 5 % rated flow (instantaneous flow)	F	7.4.5
6	Leak tightness of the sampling system	≤ 2,0 % of sample flow rate	L	7.4.6
7	Dependence of zero on surrounding temperature[a]	≤ 2,0 µg/m³ – from 5 °C to 40 °C by default for installation in a temperature-controlled environment or – at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures.	L	7.4.7
8	Dependence of measured value on surrounding temperature[a]	≤ 5 % from the value at the nominal test temperature – from 5 °C to 40 °C by default for installation in a temperature-controlled environment or – at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures.	L	7.4.7
9	Influence of mains voltage on measured signal	≤ 5 % from the value at the nominal test voltage	L	7.4.8

	Performance characteristic	**Requirement**	**Location (Lab/Field)**	**Clause**
10	Effect of failure of mains voltage	Instrument parameters shall be secured against loss. On return of mains voltage the instrument shall automatically resume functioning.	L	
11	Effect of humidity on measured value	≤ 2,0 µg/m³ in zero air when cycling relative humidity from 40 % to 90 % and back	L	7.4.9
12	Zero checks	Absolute value ≤ 3,0 µg/m³	F	7.5.3
13	Recording of operational parameters	Measuring systems shall be able to provide data of operational states for telemetric transmission of – at minimum – the following parameters: – flow rate; – pressure drop over sample filter (if relevant); – sampling time; – sample 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.	F	7.5.4
14	Daily averages or values	The AMS shall allow for the formation of daily averages or values.	F	7.5.5
15	Availability	At least 90 %	F	7.5.6
16	Between-AMS uncertainty	≤ 2,5 µg/m³	F	7.5.8.4
17	Expanded uncertainty	≤ 25 % at the level of the relevant limit value related to 24-h average results (if required, after calibration, see 7.5.8.5)	F	7.5.8.8
18	Maintenance interval/period of unattended operation	At least 14 d	F	7.5.7
19	Automatic diagnostic check	Shall be possible for the AMS	F	7.5.4

	Performance characteristic	Requirement	Location (Lab/Field)	Clause
20	Checks of temperature sensors, pressure and/or humidity sensors[b]	Shall be checked for the AMS to be within the following criteria ±2 °C ±1 kPa ±5 % RH	F	7.5.2

[a] Limitations, e.g. operation below or above a certain temperature, shall be specified in the type testing report.

[b] For some instruments such checks are not possible *in situ* because of the positioning of the sensors within the AMS. Therefore, these checks are restricted to sensors that are accessible in the field (typically in the sampling head). If checks are not possible this shall be documented.

7.3 Design changes

When the manufacturer makes design changes (software and/or hardware) to a type-approved AMS it should follow the requirements of e.g. [14 and 15].

7.4 Laboratory test procedures

7.4.1 General

A competent body shall perform the determination of the performance characteristics in the laboratory as a part of the type testing. The quality of the materials and equipment used in the described test procedures shall be in accordance with the requirements given in this European Standard. Manufacturers shall submit the following items:

a) two AMS of the same pattern;

b) calibration devices;

c) all necessary components for operation under field conditions, e.g. sample inlet, sampling line; temperature sensors; pressure and/or humidity sensors;

d) provisions for acquisition of digital (e.g. RS232) or analogue (e.g. 4-20 mA) signals;

e) provisions for formation of daily averages.

7.4.2 Test conditions

7.4.2.1 General

Before operating the AMS, the operating instructions of the manufacturer shall be followed particularly with regard to the set-up of equipment (e.g. checks of critical parameters) and the quality and quantity of the consumable products necessary.

Manufacturers shall make available suitable instructions for checks and/or calibrations of critical parameters that affect the measurement. The instructions of the manufacturer for the control of performance characteristics should be taken into account if relevant.

The AMS shall be allowed to warm up during the time specified by the manufacturer before undertaking any tests. If the warm-up time is not specified, a minimum of 4 h is recommended.

The auto rescaling function and self-correction for drift shall be disabled during the laboratory tests. The possibility of calibration of temperature sensors, pressure and/or humidity sensors shall be checked and documented.

For optical instruments, these functions may be a part of the compensation for contamination of optical surfaces.

When applying zero air to the AMS, the zero air generation system shall be operated sufficiently long before starting the tests in order to ensure the input of zero air to the AMS.

Most AMS are able to give an output signal as a moving average over an adjustable period of time and some systems automatically change this integration time as a function of the frequency of the fluctuations in concentration in the PM concentrations. These options are typically used in order to smooth output data. During laboratory and field tests for the type testing the settings of the monitor shall be as specified by the manufacturer, apart from the auto zeroing and auto-scaling capabilities, which shall be disabled during the lab tests. All settings shall be noted down in the test report.

7.4.2.2 Parameters

During the laboratory tests for each individual performance characteristic, the values of the following parameters shall be stable within the specified range given in Table 2.

Table 2 — Set points and stability of test parameters

Parameter	Set points	Stability
Surrounding air temperature	20 °C to 23 °C (except for the flow rate accuracy test, see 7.4.4, and the surrounding air temperature test, see 7.4.7)	±2 °C
Electrical voltage	At nominal line voltage and within manufacturer's specifications (except for the voltage dependence test, see 7.4.8)	±1 %
Sample flow to the AMS	Manufacturer's specification	±1 %

7.4.2.3 Zero air

For the determination of some performance characteristics, zero air is used. The zero air shall contain particulate matter at a level ≤ 1,0 µg/m^3.

NOTE Zero air can be generated by passing ambient air or indoor air through a HEPA filter provided by the manufacturer of the AMS or by dedicated zero-air generation systems.

7.4.3 Zero level and detection limit

The zero level and detection limit of the AMS shall be determined by measurement of 15 24-h average readings obtained by sampling from zero air (no rolling or overlapped averages are permitted). The mean of these 15 readings is used as the zero level. The detection limit is calculated as 3,3 times the standard deviation of the 15 readings [9]. Both shall fulfil the requirements in Table 1.

7.4.4 Flow rate accuracy

The mean flow rate shall be measured at two temperatures of surrounding air:

— 5 °C and 40 °C by default or

— at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures; these temperatures shall then be specified in the type testing report.

The measurements shall be performed using a reference flow meter having a relative expanded uncertainty (95 % confidence) of ≤ 1,0 % of the controlled flow rate.

It is recommended to use a low pressure-drop flow meter.

At each temperature, at least 10 measurements shall be taken over a minimum period of one hour at the operational flow rate specified by the manufacturer. The measurements shall be performed at equal intervals over the measurement period. For each temperature, the mean of the measurement results shall be compared with the operational flow rate.

The relative difference between the two values shall fulfil the performance requirement in Table 1.

7.4.5 Constancy of sample flow rate

This test requires the use of a continuous reading flow meter, e.g. a mass flow meter.

It is recommended to use a low pressure-drop flow meter.

The test is based on the sampling of ambient air during the test period. During a period of at least 24 h the sample flow, temperature and pressure are monitored continuously and recorded as a one minute average.

During actual sampling the instantaneous flow rate and the flow rate averaged over the sampling period shall fulfil the performance requirements in Table 1.

7.4.6 Leak tightness of the sampling system

The leak tightness (leak rate) of the complete air flow path of the AMS (sample inlet, sampling line, measuring system) shall be tested according to the manufacturer's specification. A leak test integrated in an AMS can be used, provided that the stringency of such a test is suitable for a proper assessment of the instrument's leak tightness.

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

This test may require the use of either a pressure measuring device, or a volumetric flow meter.

The leak tightness shall fulfil the performance requirement in Table 1 or shall be within the specifications of the manufacturer of the AMS with fulfilment of required DQO.

7.4.7 Dependence of zero and span on surrounding temperature

These tests require the use of zero and span calibration devices.

If an AMS is not providing a span calibration device or the provided device is not suitable, this shall be explicitly pointed out in the type testing report. For this case, suitable additional QA actions are to be considered.

The dependence of the zero reading and span value, measured by applying a calibration artefact on the surrounding temperature, shall be determined at the following temperatures:

— at a nominal temperature $T_{S,n}$ = 20 °C;

— at a default minimum temperature $T_{S,1}$ = 5 °C;

— at a default maximum temperature $T_{S,2}$ = 40 °C;

— at minimum and maximum temperatures specified by the manufacturer if these deviate from the default temperatures.

At each temperature setting three individual measurement results at zero and at span shall be recorded.

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

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

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

The differences between readings at both extreme temperatures and $T_{S,n}$ shall be determined.

The differences found shall comply with the performance criteria given in Table 1.

7.4.8 Dependence of span on supply voltage

The dependence of the value measured by applying a calibration artefact on the supply voltage shall be determined at the following voltages (see EN 50160 [10]; within the specifications of the manufacturer):

— at the nominal voltage Vs,*n* = 230 V;

— at a minimum voltage Vs,1 = 195 V;

— at a maximum voltage Vs,2 = 253 V.

These tests require the use of span calibration devices.

At each voltage setting three individual measurement results at span shall be recorded.

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

The tests are performed in the voltage sequence $V_{S,n}$ - $V_{S,1}$ - $V_{S,n}$ - $V_{S,2}$ - $V_{S,n}$.

In order to exclude any possible drift due to factors other than voltage, the measurements at $V_{S,n}$ are averaged.

The differences between readings at both extreme voltages and $V_{S,n}$ shall be determined.

The differences found shall comply with the performance criteria given in Table 1.

For reporting the dependence on voltage the highest value of the result at span level shall be taken.

For an AMS operating on direct current the testing of voltage variation shall be carried out over the range of ± 10 % of the nominal voltage.

7.4.9 Dependence of reading on water vapour concentration

The dependence of the AMS concentration readings on the level of water vapour in the sampled air shall be determined by supplying humidified zero air to the AMS in excess of the sample flow rate. Tests shall be performed by changing the relative humidity of the sampled air between 40 % and 90 %.

The test can be performed with two general methods:

a) Sampling humidified air (preferred option)

These tests require the provision of zero air and an air humidification system. The supply flow rate of humidified air shall be ≥ 10 % in excess of the AMS sample flow rate with excess flow being vented.

b) Complete surrounding atmosphere humidified

These tests require a climate chamber in order to provide an atmosphere with varying relative humidities. The AMS shall be completely installed in the chamber and will sample zero air.

For both methods:

After stabilization of relative humidity and AMS concentration reading, a reading over the lowest averaging period of the AMS at 40 % relative humidity is recorded. The relative humidity is then raised to 90 % at a rate of 25 % per hour. The equilibration time and the average concentration reading are recorded. The humidity is then lowered to 40 % at a rate of 25 % per hour. Again, the equilibration time and the average concentration reading are recorded.

If an instrument provides readings only every 24 h, the rates of changes of humidity shall be adapted proportionally.

The largest difference in readings between 40 % and 90 % relative humidity shall fulfil the performance criterion in Table 1.

7.5 Field test procedures

7.5.1 General

The AMS shall be tested in a way that is representative of its practical use; practical frequencies of calibrations and checks shall be applied in the different trials.

In the field test two AMS of the same pattern (model, hardware, firmware and software configuration and version) are tested for:

a) their ability to record a minimum number of operational parameters (see Table 1);

b) their ability to produce daily average PM concentration values;

c) their availability and period of unattended operation [1)]

d) between-AMS uncertainty [1)];

e) equivalence with the reference method by meeting the expanded measurement uncertainty requirement [1)].

Both AMS shall pass the field tests.

In order to determine the latter two characteristics the AMS shall be operated side-by-side with an approved implementation of the reference method. In order to ensure proper functioning of the reference method, two reference instruments shall be used.

The competent body shall ensure that the requirements of the manufacturer regarding the installation of the AMS are met. The AMS shall be installed in such a way that unauthorized tampering or adjustments are prevented. Before (re)installation in the field, the critical parameters that affect the measurement results of the AMS shall be checked.

The competent body shall verify that the reference method is operated in accordance with EN 12341 and that the required data quality objectives are met. The uncertainty of the results obtained by application of the reference method shall be fully known.

Manufacturers shall make available suitable procedures for checks of instruments, particularly for calibrations and checks of parameters that affect the PM mass measurement (e.g. flow rate, ambient pressure and temperature).

1) Table 1 contains quantitative criteria for these characteristics.

7.5.2 Experimental conditions

Test sites shall be representative for typical conditions for which equivalence will be claimed, including possible episodes of high concentrations. A total of at least 4 comparisons shall be performed. These shall cover at least 2 sites, and different climatic seasons, with particular emphasis on the following variables, if appropriate:

a) composition of the PM fraction, notably high and low fractions of semi-volatile particles, to cover the maximum impact of losses of semi-volatiles;

b) air humidity and temperature (high and low) to cover any conditioning losses of semi-volatiles during the sampling process;

c) wind speed (high and low) to cover any dependency of inlet performance due to deviations from ideal behaviour as dictated by mechanical design, or deviations from the nominal (or assigned) sampling flow rate.

The comparisons may be performed in the form of short campaigns, in which case these campaigns shall be performed in different climatic seasons. Alternatively, the comparisons may be organized in a way that measurements are performed over a longer period, e.g. one year. In that case, the results may be split over summer and winter seasons, provided that:

d) measurements are performed uninterruptedly at regular intervals, e.g. every second day;

e) sufficient valid results are obtained for each season;

f) no data are selectively removed from the data sets, unless it can be demonstrated that there is a technical or plausible reason for doing so.

The Competent Authority may require to perform tests at more locations in order to satisfy its own requirements for granting a type testing.

It is strongly recommended that the manufacturer assumes responsibility for performing tests that cover – as much as possible – a wide range of European conditions, so as to facilitate the type testing. Such conditions may include the site types mentioned specifically in Reference [1]:

g) a traffic site;

h) an urban background site;

i) a rural site;

j) an industrial site.

At each site, facilities for remote or local data acquisition and instrument surveillance shall be available. A full description of the sites' characteristics shall be included in the type testing report.

During each comparison a minimum of 40 valid measurement results, each averaged over 24 h, shall be collected.

Samplers and instruments shall be positioned in such a way that the effects of spatial inhomogeneity of the compound concentration in the sampled air are negligible in comparison to other uncertainty contributions.

Both methods shall be operated under conditions reflecting practical application in the field, e.g. calibration intervals, flow checks, analysis of blank samples. Calibration and checks should be at least performed before and after each comparison.

During each test, the following information shall be collected and recorded:

k) calibration procedures, equipment, sensors (see Table 1) and intervals;

l) (results of) quality checks;

m) particular events/situations that may be of influence on measurement results;

n) site-specific conditions during the tests (composition of PM, air humidity and temperature, wind speed).

7.5.3 Zero checks

Regular checks of the AMS reading at zero point shall be performed in the field during normal operation over a sufficient time period by using an appropriate method to provide zero air to the AMS. Instructions of the manufacturer shall be taken into account. An appropriate method to generate zero air is the sampling of ambient air through a zero filter (HEPA) installed at the inlet of the AMS instead of the regular sampling inlet. The zero check shall be performed for at least 24 h.

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

During the checks, the absolute value of the AMS zero reading shall not exceed the criterion in Table 1.

7.5.4 Recording of operational parameters

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

a) flow rate;

b) pressure drop over sample filter (if relevant);

c) sampling time;

d) sample volume (if relevant);

e) mass concentration of relevant PM fraction(s);

f) ambient temperature;

g) ambient pressure;

h) air temperature in measuring section;

i) temperature of the sampling inlet if a heated inlet is used.

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

7.5.5 Daily averages

The AMS shall allow for the formation of daily averages. When a 24-h average value is based on aggregated results with a lower averaging time, the percentage of these values available for calculating the 24-h average shall be at least 75 %.

7.5.6 Availability

The correct operation of the instruments shall be checked at least once every workday. This daily check consists 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 shall be recorded.

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

Availability is calculated as

$$A = \frac{t_{\text{valid}} + t_{\text{cal,maint}}}{t_{\text{field}}} \quad (1)$$

where

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

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

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

The availability shall fulfil the relevant performance criterion in Table 1.

7.5.7 Maintenance interval

The maintenance interval is the longest time period without intervention as recommended by the manufacturer. The competent body shall ensure that during this period the AMS does not need any maintenance or adjustment. When the maintenance period is found to be shorter than that recommended, the manufacturer's recommendations shall be revised.

7.5.8 Data evaluation

7.5.8.1 General

A flow scheme for the evaluation procedure is given in Figure 1, explaining the subsequent steps.

7.5.8.2 Data suitability

Data shall only be removed from the reference or AMS data sets when technical or plausible reasons can be found for doing so. The data removed and reasons for removal shall be documented.

When applying the reference method, errors are known to occur occasionally due to the manual handling of the filters. Therefore, it is permitted to remove up to 2,5 % of data pairs that qualify as outliers of reference results as long as the number of valid data pairs per comparison is ≥ 40. The data removed and reasons for removal shall be documented.

Of the full data set at least 20 % of the results obtained using the reference method shall be greater than:

— 28 µg/m^3 for PM_{10};

— 17 µg/m^3 for $PM_{2,5}$.

NOTE When due to low concentration levels, the criteria for 20 % of results to be greater than 28 µg/m^3 for PM_{10}, or to be greater than 17 µg/m^3 for $PM_{2,5}$ cannot be obtained, a minimum of 32 data points higher than these thresholds is considered sufficient.

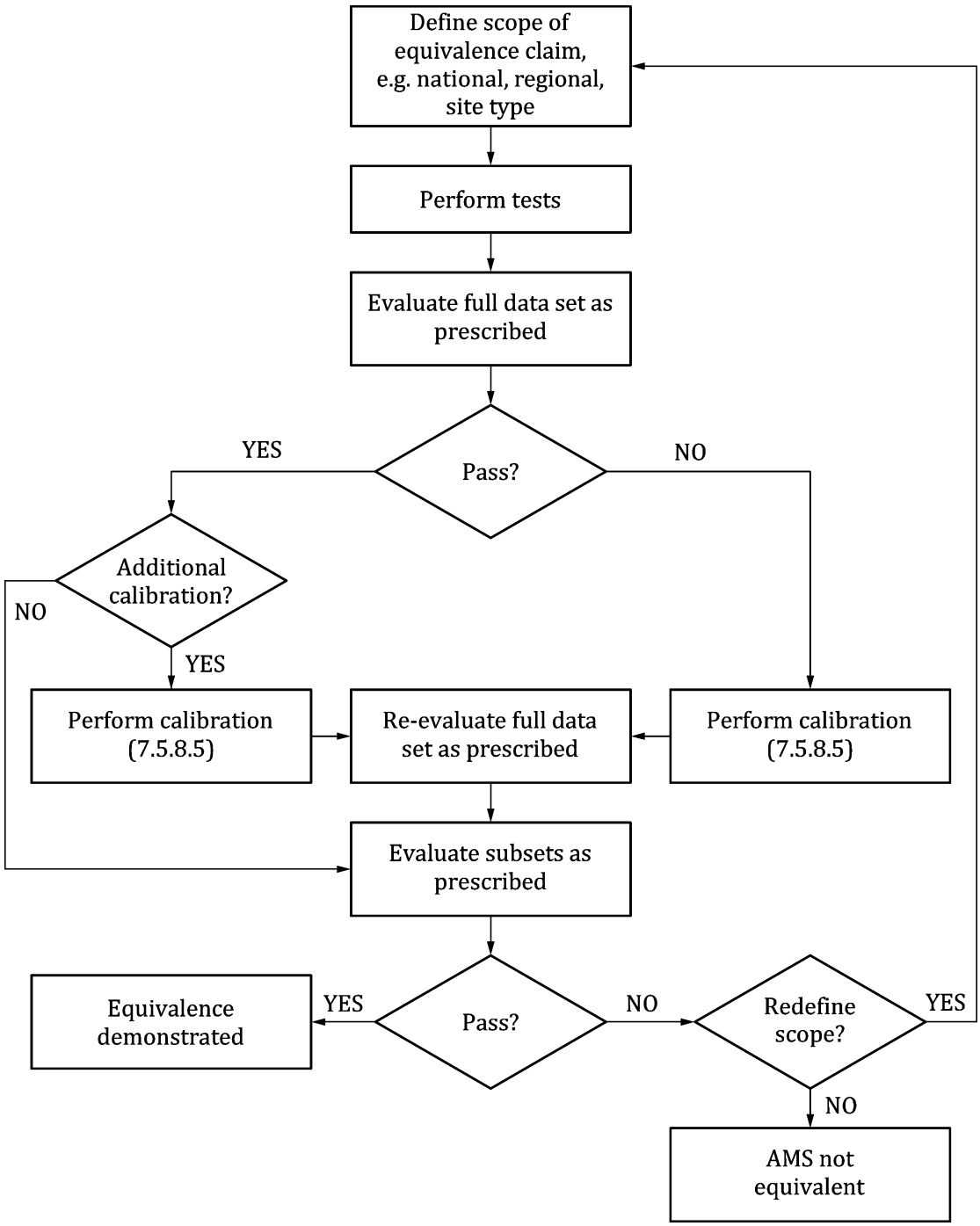


Figure 1 — Flow scheme for evaluation procedure of field test data

7.5.8.3 Between-RM uncertainty

The between-RM uncertainty, $u_{\mathrm{bs,RM}}$, is calculated from the differences of all 24-h results of the reference instruments operated in parallel as:

$$u_{\mathrm{bs,RM}}^2 = \frac{\sum_{i=1}^{n}\left(x_{\mathrm{i},1} - x_{\mathrm{i},2}\right)^2}{2n} \tag{2}$$

where

$x_{i,1}$, $x_{\mathrm{i},2}$ are the results of parallel reference measurements for a single 24-h period i;

n is the number of 24-h measurement results.

A between-RM uncertainty > 2,0 µg/m³ is an indication of unsuitable performance of one or both instruments. As a consequence, the data set cannot be used as reference data set.

7.5.8.4 Between-AMS uncertainty

The between-AMS uncertainty, $u_{\mathrm{bs,AMS}}$, is calculated from the differences of all 24-h results of the AMS operated in parallel as:

$$u_{\mathrm{bs,AMS}}^2 = \frac{\sum_{i=1}^{n}\left(y_{\mathrm{i},1} - y_{\mathrm{i},2}\right)^2}{2n} \tag{3}$$

where

$y_{\mathrm{i},1}$, $y_{\mathrm{i},2}$ are the results of parallel AMS measurements for a single 24-h period i;

n is the number of 24-h measurement results.

The between-AMS uncertainty shall be determined

— for all results together;

— for a dataset obtained by splitting the full data set according to PM concentrations: greater than or equal to 30 µg/m³ for PM_{10}, or concentrations greater than or equal to 18 µg/m³ for $PM_{2,5}$;

A between-AMS uncertainty > 2,5 µg/m³ is an evidence of unsuitable performance of one or both instruments.

7.5.8.5 Calibration function (lack-of-fit)

Theoretically, if AMS and reference method are fully equivalent, the relationship between the results of both methods can be described by a linear relation $y_{\mathrm{i}} = x_{\mathrm{i}}$. However, since the measurands of both methods are usually different, it is assumed that the relationship between measurement results of the AMS and the reference method can be described by a linear relation of the form:

$$y_{\mathrm{i}} = a + bx_{\mathrm{i}} \tag{4}$$

where

y_{i} is the result of an AMS for an individual 24-h period i (in µg/m³ at ambient conditions);

x_{i} is the (average) result of the reference method for an individual 24-h period i (in µg/m³ at ambient conditions);

a is the intercept of the calibration function;

b is the slope of the calibration function.

In practice, the actual relationship between measurement results of AMS and reference method may not always be linear.

The relation between the results of the AMS and the (average) results of the reference method is established for each of the AMS individually using a regression technique leading to symmetrical treatment of both variables. A commonly applied technique is orthogonal regression. Algorithms for the calculation of the regression coefficients and their variances are given in Annex B.

The relation is established separately:

a) for all results together;

b) for a reduced data set only taking into account concentrations greater than or equal to 30 µg/m^3 for PM10, or concentrations greater than or equal to 18 µg/m^3 for PM2,5 provided that the subset contains 40 or more valid data pairs;

c) for data sets for each individual site.

For $PM_{2,5}$ a concentration of 30 µg/m^3 shall be used as a substitute value for the daily limit value.

NOTE The Competent Authority may require the use of a lower value instead of this "substitute" daily limit value.

Preconditions for acceptance of the full AMS data set are that:

d) the slope b is insignificantly different from 1; test criterion $|b-1| \leq 2u_b$;

e) the intercept a is insignificantly different from 0; test criterion $|a| \leq 2u_a$.

where

u_b is the standard uncertainty of the slope b, calculated as the square root of its variance;

u_a is the standard uncertainty of the intercept a, calculated as the square root of its variance.

When the test results show that the slope differs significantly from 1 and/or the intercept differs significantly from 0, the candidate method shall be calibrated using the values obtained for slope and/or intercept of all paired data together. The calibration shall be applied to the full AMS data set, and to each of the subsets specified above. Annex C explains how to perform the calibration.

Calibration needs not to be performed when:

f) the value of the slope is 0,980 ≤ b ≤ 1,020; and/or

g) the value of the intercept is −1,0 µg/m^3 ≤ a ≤ 1,0 µg/m^3; or

h) the introduction of additional uncertainty terms leads to an insignificant change of the combined uncertainty of the AMS (see 7.5.8.6.2 – 7.5.8.6.4); or

i) when overlap occurs between the uncertainty domains of the reference method (RM) and the AMS.

7.5.8.6 Uncertainty of the results of the AMS

7.5.8.6.1 No correction for slope and intercept

For evaluation of the uncertainty of the results of the AMS the following relationship is used:

$$u_{yi}^2 = \frac{RSS}{(n-2)} - u_{RM}^2 + \left[a + (b-1)L\right]^2 \quad (5)$$

where

u_{yi} is the uncertainty of the AMS measurement result y_i;

RSS is the residual sum of squares resulting from the orthogonal regression;

n is the number of data pairs used for the regression;

u_{RM} is random uncertainty of the reference method; u_{RM} is calculated as $u_{bs,RM} / \sqrt{2}$ where $u_{bs,RM}$ is the reference between-sampler/instrument uncertainty calculated using Formula (3) using the duplicate reference results as input;

L is the daily limit value for PM_{10} (50 µg/m³) or substitute daily limit value for $PM_{2,5}$ (30 µg/m³).

NOTE The Competent Authority may require the use of a lower value instead of this "substitute" daily limit value for $PM_{2,5}$.

The residual sum of squares RSS is calculated as:

$$RSS = \sum_{i=1}^{n} \left(y_i - a - bx_i\right)^2 \quad (6)$$

The term $\frac{RSS}{(n-2)} - u_{RM}^2$ represents the random uncertainty of the results of the AMS. The term $\left[a + (b-1)L\right]$ is the bias at the limit value of the results of the AMS.

7.5.8.6.2 Correction for intercept required

When the calibration function needs to be corrected for an intercept being significantly different from 0, the following relationship is used for the evaluation of the uncertainty of the results of the AMS:

$$u_{yi,corr}^2 = \frac{RSS}{(n-2)} - u_{RM}^2 + \left[c + (d-1)L\right]^2 + u_a^2 \quad (7)$$

where

$u_{yi,corr}$ is the uncertainty of the AMS measurement result y_i obtained after correction (see Annex C);

c, d are the new regression coefficients obtained after correction (see Annex C).

RSS is now calculated as:

$$RSS = \sum_{i=1}^{n} \left(y_i - c - dx_i\right)^2 \quad (8)$$

7.5.8.6.3 Correction for slope required

When the calibration function needs to be corrected for a slope being significantly different from 1, the following relationship is used for the evaluation of the uncertainty of the results of the AMS:

$$u_{\mathrm{yi,corr}}^2 = \frac{RSS}{(n-2)} - u_{\mathrm{RM}}^2 + \left[c + (d-1)L\right]^2 + L^2 u_{\mathrm{b}}^2 \quad (9)$$

with RSS being calculated using Formula (8).

7.5.8.6.4 Correction for slope and intercept required

When the calibration function needs to be corrected for a slope being significantly different from 1 and an intercept being significantly different from 0, the following relationship is used for the evaluation of the uncertainty of the results of the AMS:

$$u_{\mathrm{yi,corr}}^2 = \frac{RSS}{(n-2)} - u_{\mathrm{RM}}^2 + \left[c + (d-1)L\right]^2 + u_{\mathrm{a}}^2 + L^2 u_{\mathrm{b}}^2 \quad (10)$$

with RSS being calculated using Formula (8).

Formula (10) is a simplification because it does not include covariance between slope and intercept. The resulting uncertainty may be higher than when a covariance term is included.

7.5.8.7 Relative standard uncertainty

For the data sets specified in 7.5.8.5 the combined relative uncertainty of the AMS at the relevant limit value is calculated:

$$w_{\mathrm{AMS}}^2 = \frac{u_{\mathrm{y_i=L}}^2}{L^2} \quad (11)$$

where

$u_{\mathrm{y_i=L}}$ is the uncertainty at the relevant PM limit value (in µg/m³);

L is the relevant PM limit value (in µg/m³).

For PM_{10} the value of the daily limit value shall be used in Formula (11). For $PM_{2,5}$ a substitute value of 30 µg/m³ shall be used.

NOTE The Competent Authority may require the use of a lower value instead of this “substitute” daily limit value for $PM_{2,5}$.

The appropriate value of $u_{\mathrm{y_i=L}}$ depends on the requirement for applying corrections for slope and/or intercept values being significantly different from 1, or 0, respectively. Subclauses 7.5.8.6.1 to 7.5.8.6.4 give the appropriate formulas for each situation.

7.5.8.8 Expanded uncertainty

For each of the AMS data sets the expanded relative uncertainty of the results of the AMS is calculated by multiplying w_{AMS} by a coverage factor k reflecting the appropriate number of degrees of freedom resulting from the determination of w_{AMS}:

$$W_{\mathrm{AMS}} = k \cdot w_{\mathrm{AMS}} \quad (12)$$

In view of the large number of experimental results available, a coverage factor k = 2 shall be used.

7.6 Requirements for type testing

Evaluation of the type testing results of the AMS consists of the following steps:

a) the value of each individual performance characteristic tested in the laboratory shall fulfil the criterion stated in Table 1 (see 7.2);

b) the value of each of the individual performance characteristics tested in the field shall fulfil the criterion stated in Table 1 (see 7.2);

c) the expanded uncertainty calculated from the results of the field tests shall fulfil the criterion as stated in 2008/50/EC and other EU Directives where applicable;

These are the minimum requirements that shall be met for the granting of type approval by the competent authority.

7.7 Type testing report

Requirements for type testing reports are given in Annex D.

Results of field tests shall be available as a spreadsheet, or text file with delimitations suitable for importing into spreadsheets.

8 Field operation and ongoing quality control

8.1 General

When a type-approved AMS has been selected for a particular measuring task, then the suitability of this AMS shall be evaluated for specific conditions that may exist within the monitoring network. This evaluation is aimed at demonstrating that the type-approved instrument will also meet the data quality objectives as stated in 2008/50/EC and other EU Directives where applicable under these site-specific conditions. If the specific conditions have already been covered by the type testing tests, then the suitability test is not necessary.

The evaluation is in the form of an equivalence test as described in 7.5, which contains elements of the field test described above and is described in 8.2. For this suitability testing, only one implementation of the Reference Method and one AMS are needed.

After installation in the field (see 8.3), quality assurance and quality control procedures for ongoing monitoring shall be followed (as described in 8.4) in order to ascertain that the measured data comply with the uncertainty requirements as stated in 2008/50/EC and other EU Directives where applicable.

8.2 Suitability testing

8.2.1 General

The site-specific conditions to be considered in the suitability evaluation are given in Table 3.

Table 3 — Site specific conditions

Parameter	Remarks
Composition of the PM fraction	High and low fractions of semi-volatile particles, to cover the maximum impact of losses of semi-volatiles Substantial fraction of coarse particulates when the inlet design, if any, of the AMS differs from that of the reference sampler
Air humidity and temperature	High and low temperatures and relative air humidities to account for loss of semi-volatile constituents of PM or particle growth
Wind speed	High and low wind speed to cover any dependency of inlet performance due to deviations from ideal behaviour as dictated by mechanical design, or deviations from the nominal (or assigned) sampling flow rate.

The suitability evaluation shall be performed using the procedures described in 7.5 but may be limited to testing of:

a) calibration function;

b) equivalence with the reference method by meeting the expanded measurement uncertainty criterion.

Tests shall be performed at locations representative for extreme conditions with particular emphasis on the following variables, if appropriate:

c) composition of the PM fraction, notably high and low fractions of semi-volatile particles, to cover the maximum impact of losses of semi-volatiles;

d) air humidity and temperature (high and low) to cover any conditioning losses of semi-volatiles during the sampling process.

These test conditions shall be different from those used in type testing.

The results of the tests shall fulfil the requirements given in 7.5.7 to 7.5.8.

NOTE 1 When due to low concentration levels, the criteria for 20 % of results to be greater than 28 µg/m^3 for PM_{10}, or to be greater than 17 µg/m^3 for $PM_{2,5}$ cannot be obtained, a minimum of 32 data points higher than these thresholds is considered sufficient.

NOTE 2 When no information about the uncertainty of the results of the reference method is available from other (previous) parallel measurements, a value for u_{RM} of 0,67 µg.m^{-3} (from [2]) is used by default.

NOTE 3 When no information about the uncertainty of the results of the candidate method is available from other (previous) parallel measurements, it is advised to use the value for u_{CM} from the equivalence demonstration (7.5.8.6.1).

For further evaluation of the AMS suitability, the results of these tests may be combined with the results available from the type testing tests and evaluated in accordance with 7.5.8. The resulting uncertainty for the full data set (after calibration, if necessary) is used further for the establishment of the regime for ongoing verification of equivalence (see 8.6).

8.2.2 Evaluation

The results of the tests shall fulfil the requirements given in 7.5.7 and 7.5.8.

In the case where the intercept of the regression formula obtained for a predefined scope of application is insignificantly different from zero, the calibration function may be simplified by forcing the orthogonal regression function through the origin (0,0): $y_i = bx_i$.

This will result in one calibration factor for the defined scope of application. Algorithms for the calculation of the relevant regression parameters and uncertainties are given in the second part of Annex B.

The uncertainty obtained is usually higher than that obtained when using a function of the form $y_i = a + bx_i$. It is therefore important to check that the use of the simplified formula does not lead to a violation of the uncertainty criterion.

8.3 Initial installation

The AMS shall be installed at a monitoring station in accordance with the manufacturer's requirements in such a way that its normal operation is not compromised. This implies that the AMS is sheltered and shielded from dust, rain and snow, direct solar radiation, strong temperature fluctuations etc. At some locations voltage stabilizers for the power supply may be considered, when voltage fluctuations are expected. After installation of the AMS at the measuring station the AMS shall be tested for proper operation.

When the AMS has been set up at the monitoring station, the proper functioning of the AMS shall be checked. The results of these checks shall fulfil the requirements and limitations as set out by the manufacturer of the AMS as well as the requirements given in this standard. The compliance with the requirements of the manufacturer and requirements set out in this standard shall be documented.

When the concentrations measured by an AMS at a monitoring station are collected by a data-logger/computer system, then the proper functioning of the data collection system shall be checked. When the measured data are transmitted to a central computer system, the transmission process shall be checked as well. Checks shall be performed to an extent ensuring that the actual concentrations measured by the AMS are properly recorded in any data collection system.

Each time parts of the data registration/transmission process are changed, the proper function of the complete process shall be rechecked.

All checks on the proper function of the data collection/transmission system(s) shall be documented.

8.4 Ongoing quality control

8.4.1 General

Quality control is essential to ensure that the uncertainties of the measured values for particulate matter in ambient air are kept within the stated limits during extended continuous monitoring periods in the field. This requires that maintenance, test and calibration procedures shall be followed which are essential for obtaining accurate air quality data. In this section, procedures for maintenance, checks and calibration are given. These procedures are regarded as a minimum necessary for maintaining the required quality level.

The quality of the materials and equipment used in the described test procedures shall be in accordance with the manufacturer's requirements and the requirements given in this standard and shall not significantly influence the results of these procedures. Requirements for quality checks and calibrations have been determined on the basis of the identification of sources contributing to measurement uncertainty of AMS for measurement of PM in general. For specific methods other contributions may exist that have to be taken into account in quality control programmes when applying these methods in practice.

NOTE 1 It is advised that the competent body performing the required tests be able to demonstrate that it works in conformity with the requirements of internationally accepted standards for test laboratories.

NOTE 2 EN ISO/IEC 17025 is the harmonized internationally accepted standard that applies.

NOTE 3 A formal accreditation by a member body of the European Accreditation Organization to EN ISO/IEC 17025 is a demonstration of conformity.

8.4.2 Frequency of calibrations, checks and maintenance

The checks and calibrations together with their frequency are summarized in Table 4. Criteria are also given for readjustment, calibration or maintenance of the AMS.

Table 4 — Required frequency of calibration, checks and maintenance

Calibration, checks and maintenance	**Clause**	**Minimum Frequency**[a]	**Lab/ field**	**Action criteria**[b]	**Uncertainty requirements for transfer standards**
Checks of status values of operational parameters (see 7.5.4)	8.4.3	Daily (on working days)	L / F	See below	
Checks of sensors for temperatures, pressure and/or humidity[c]	8.4.4	Every 3 months	F	±2 °C ±1 kPa ±5 % RH	
Calibration of sensors for temperatures, pressure and/or humidity[c]	8.4.5	Every year	L / F		1,5 °C 0,5 kPa 3 % RH
Check of the AMS flow rate(s)	8.4.6	Every 3 months	F	±5 %	2 %
Calibration of the AMS flow rate(s)	8.4.7	Every year	L / F		1 %
Leak check of the sampling system	8.4.8	Every year	F	±2 %	
Zero check of the AMS reading	8.4.9	Every year	L / F	±3 µg/m^3	
Check of the AMS mass measuring system	8.4.10	As recommended by the manufacturer and after repair, but at least every year	L / F	as set out by manufacturer, or ± 3 % if necessary	
Regular maintenance of components of the AMS	8.5	As required by the manufacturer	L / F	as set out by manufacturer	

[a] Frequencies of checks and calibrations may be relaxed when sufficient history exists demonstrating that drifts of sensor readings and flow rates remain within the specified requirements.

[b] With reference to nominal values.

[c] For some instruments such checks and calibrations are not possible *in situ* because of the positioning of the sensors within the AMS. Therefore, these checks and calibrations are restricted to sensors that are accessible in the field (typically in the sampling head). As a part of the annual checks, the checks may be performed in a laboratory room with constant temperature and relative humidity by comparing sensor readings (after stabilization) with those of reference standards.

8.4.3 Checks of operational parameters

During operation, as a minimum, AMS status signals for the following parameters shall be acquired and measurement data flagged, if necessary:

a) flow rate, and pressure drop over sample filter (if relevant);

b) sampling time;

c) sample volume (if relevant);

d) mass concentration of relevant PM fraction(s);

e) ambient temperature (see 6.5);

f) ambient pressure (see 6.5);

g) air temperature in measuring section;

h) temperature of the sampling inlet if a heated inlet is used;

i) any critical parameter affecting the measurement.

In addition, the instrument status shall be checked for warning and alarm messages.

8.4.4 Checks of AMS sensors

Where temperature, pressure (difference) and/or relative humidity sensors are essential to ensure the accuracy of the PM mass concentration measurement made by the instrument, these shall be checked using appropriate transfer standards with readings traceable to (inter)nationally accepted standards. These checks shall be performed before the flow rate check.

If the sensor values determined using the transfer standards differ by more than the criteria given in Table 4, the sensors shall be recalibrated and adjusted according to the manufacturer's instructions (see 8.4.5).

In the case of temperature sensors, these may be sensors giving actual temperatures of, e.g. ambient air, sample inlet heating and measuring compartments.

NOTE For some instruments, such checks are not possible because of the positioning of the sensors within the AMS. In these cases, if the manufacturer does not provide any procedure checks may be performed by putting the AMS in a laboratory room with constant temperature and relative humidity, and then by comparison of the sensor readings (after stabilization) with those of reference standards.

8.4.5 Calibration of AMS sensors

Where temperature, pressure (difference) and/or relative humidity sensors are essential for controlling the proper functioning of the instrument, these shall be calibrated at least once per year using appropriate transfer standards with readings traceable to (inter)nationally accepted standards. These transfer standards shall fulfil the following uncertainty specifications (95 % confidence):

a) temperature: 1,5 °C;

b) pressure: 0,5 kPa;

c) relative humidity: 3 %.

In the case of temperature sensors, these may be sensors giving actual temperatures of, e.g. ambient air, sample inlet heating and measuring compartments.

NOTE For some instruments, such calibrations are not possible because of the positioning of the sensors within the AMS. In these cases, if the manufacturer does not provide any procedure checks can be performed in a laboratory room with constant temperature and relative humidity by comparing sensor readings (after stabilization) with those of reference standards.

8.4.6 Checks of the AMS flow rates

Checks of instantaneous flow rates shall be performed using an appropriate flow meter with readings traceable to (inter)nationally accepted standards. The expanded relative uncertainty of the flow meter (95 % confidence) shall be ≤ 2 % at laboratory conditions. Flow checks shall include the AMS sample line, unless this consists of a straight tube without joints or connections other than to a size separator or the measurement section of the AMS. All sensors shall be in operation during the flow check.

It is recommended to use a low pressure-drop flow meter. If the flow rate determined using the flow meter differs by more than 5 % from the value required for its proper operation, the flow controller shall be recalibrated and adjusted according to the manufacturer's instructions.

When validating data collected where the flow rate differs by greater than 5 % from the default flow, the user shall take any action it judges to be appropriate for the specific situation (see 8.4.11).

8.4.7 Calibration of the AMS flow rates

Calibration shall be performed every year using an appropriate transfer standard flow meter with readings traceable to (inter)nationally accepted standards. The expanded relative uncertainty of the transfer standard flow meter (95 % confidence) shall be ≤ 1 % at laboratory conditions.

NOTE The uncertainty requirement for the transfer standard flow meter may be different if the final Data Quality Objectives are met.

Flow calibrations shall include the AMS sample line unless this consists of a straight tube without joints or connections other than to a size separator or the measurement section of the AMS. All sensors shall be in operation during the flow calibration.

It is recommended to use a low pressure-drop flow meter.

8.4.8 Leak check of the sampling system

A yearly leak test of the sampling system shall be performed as described in 7.4.6. If the test reveals a leak rate of > 2 %, the sampling system shall be maintained and retested for leaks.

When validating data collected where the leak rate exceeds 2 % or if the tolerance limit prescribed by the manufacturer is exceeded, the user shall take any action it judges to be appropriate for the specific situation (see 8.4.11).

8.4.9 Zero check of the AMS reading

Checks of the AMS reading at zero point shall be performed every year during normal operation over a sufficient time period by using an appropriate method to produce a zero reading of the AMS. Instructions of the manufacturer have to be taken into account. A zero reading may be obtained by:

a) application of a zero-reading artefact, e.g. a zero calibration foil or

b) application of zero air to the AMS during a minimum period and using an appropriate method recommended by the manufacturer.

One example of an appropriate method to provide zero air is the installation of a zero filter (HEPA) at the inlet of the AMS instead of the regular sampling inlet and sampling ambient air for the period required to obtain a constant signal.

If the zero values determined exceed the criterion given in Table 4, the user shall take any action it judges to be appropriate for the specific situation.

8.4.10 Checks and calibrations of AMS mass measuring system

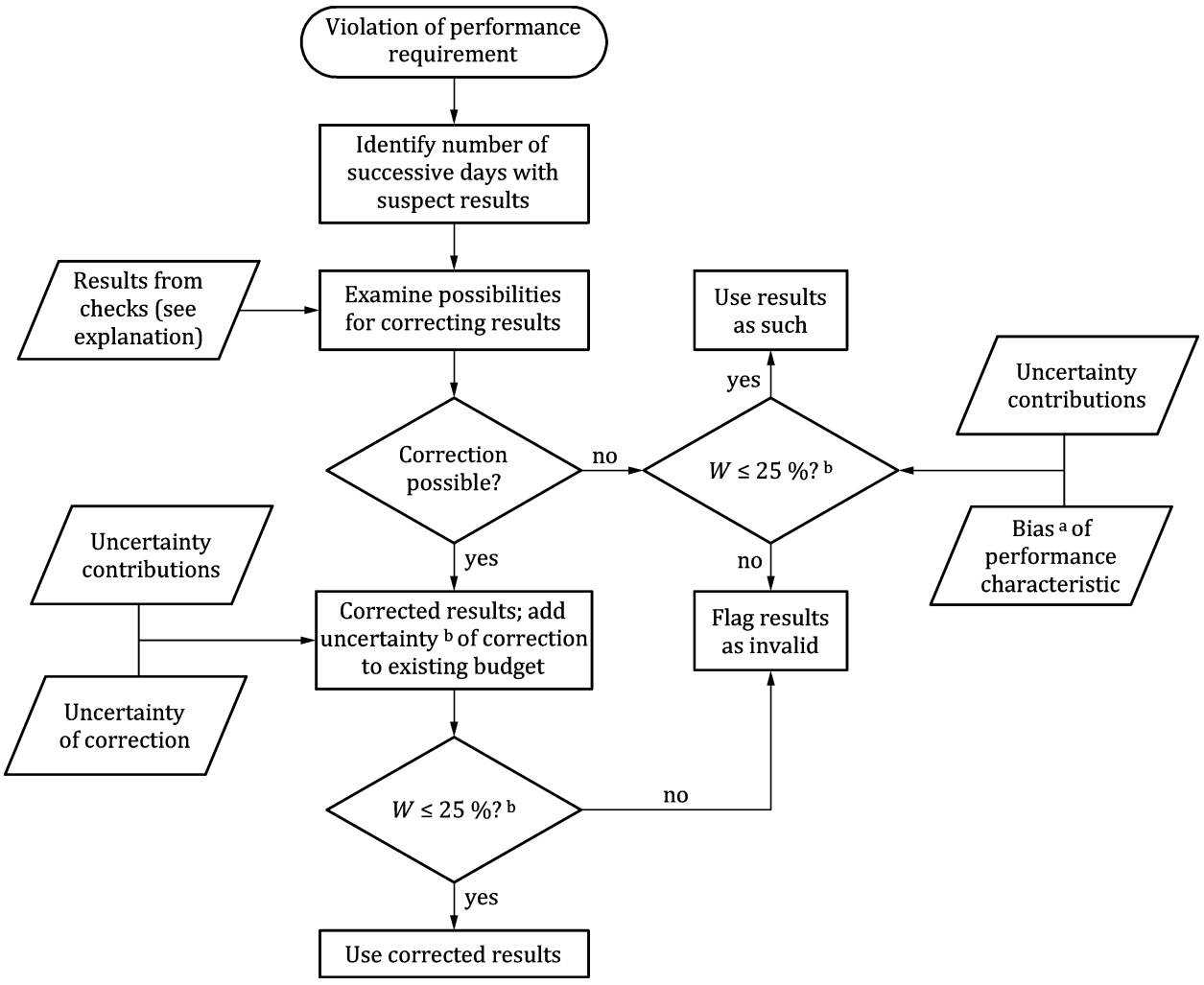
The AMS measuring system shall be calibrated with a frequency and using the procedure required by the manufacturer, to ensure proper operation of the AMS. The performance of calibrations differs between types of AMS, and may consist of applications of zero and span filters or foils.

For optical AMS that do not measure mass directly, but produce mass readings based on particle sizes and numbers, the calibration of the physical parameters used to derive mass concentrations is generally performed using aerosols generated from mono-disperse particles or well-characterized aerosols.

8.4.11 Treatment of data after exceedance of performance criteria

If in one of the above checks a violation of a performance criterion has occurred, the effect of this violation on the measurement results obtained between the previous and the current check shall be evaluated. The aim of this evaluation is to attempt to optimize the time coverage and data capture. In principle, the first shall be 100 %; the second shall be ≥ 90 % of measurement time including periods of calibration and normal maintenance.

A flow scheme for the performance of this evaluation and for the evaluation of possibilities for correcting data are given below in Figure 2.



Key

[a] Deviation of the value of the performance characteristic from its requirement.

[b] At the level of the daily limit value.

Figure 2 — Flow scheme for performance of evaluation of effects of violation of performance requirements and possibilities for data correction

EXAMPLE Exceedances that would in principle permit application of corrections include:

— exceedances during checks of ambient pressure and/or temperature sensors (8.4.4);

— exceedances during flow rate checks (8.4.6), as long as these are ≤ 10 % (a higher deviation may affect the size-selectivity of the sampling technique);

— exceedances during leak checks (8.4.8).

8.5 Maintenance

8.5.1 Consumables

The life of all AMS consumables shall be determined at the initial installation. Site-specific maintenance periods shall be devised for the replacement of such consumables taking into account the recommendations of the manufacturer.

8.5.2 Regular maintenance of components of the AMS

Initially, the manufacturer's recommendations shall be followed for the routine maintenance of the AMS.

For highly polluted sites or in the case of occurrence of episodes of high PM levels, the frequency shall be increased. As a rule of thumb, a highly polluted site is one in which the annual average level of PM exceeds the annual limit value.

8.6 Ongoing verification of suitability

8.6.1 General

The absence of traceable standards or reference materials for the measurement of particulate matter in ambient air necessitates the performance of quality checks by ongoing comparisons with the relevant reference method. The extent of the comparisons depends on:

a) the extent of the monitoring network;

b) differences between the characteristics of the sites covered by the monitoring network;

c) the uncertainty determined for the AMS as a part of the suitability evaluation.

If neighbouring networks use the same types of AMS, then the suitability verification may be combined under the auspices of the Competent Authority and the National Reference Laboratory.

8.6.2 Number, duration and frequency of comparisons

There is a requirement for ensuring the ongoing quality of the particulate measurement results obtained using the AMS. This is particularly important because the type testing procedure depends only on field tests between the reference method and AMS, and there is limited QA/QC that can be carried out on a routine basis (flow calibration, calibration of temperature and pressure sensors).

In addition, the type testing tests and suitability evaluation have been performed under a limited range of particulate compositions, which may not continue to be representative for the actual conditions. Therefore, it is necessary that periodic parallel measurements are performed with the reference method to confirm that the equivalence claims are still valid. For these measurements only one implementation of the reference method and one AMS are needed. The fraction of sites to be tested under this regime (with a minimum) will depend on the relative expanded uncertainty found by evaluating the combined data of the type testing and suitability tests (see 8.2.1). The minimum requirements are given in Table 5.

Table 5 — Requirements for ongoing comparisons with the reference method

W_{AMS}, in %	≤ 10	> 10 to ≤ 15	> 15 to ≤ 20	> 20 to ≤ 25
% of sites for on-going equivalence[a]	10	10	15	20
Number of sites for on-going equivalence[a]	2	3	4	5
[a] The smaller of the two resulting numbers may be applied. The minimum number of on-going equivalence test sites is 2 for each type of AMS.				

For example, when the relative expanded uncertainty for the AMS measurement results from the type testing and suitability test results (see 8.2.1) is between 10 % and 15 %, comparisons shall be performed at a minimum of 2 or 3 sites – depending on the number of AMS operated – during a full year. During this year a minimum of 80 valid data pairs shall be obtained. This may be achieved, e.g. by

having the reference method sample every 4 days. One of the sites may be a location at which tests have been performed as a part of the initial suitability tests. Other sites shall be different from the initial test locations and may be changed each year to increase the coverage of the comparison. The sites shall be representative of all conditions where the AMS are operated.

8.6.3 Evaluation of test results

The results of these tests shall be evaluated yearly using data collected over the previous 3-year period, when available, using the approach described from 7.5.8 onwards. When the resulting uncertainty falls into a different category, the extent of tests for the next year shall be changed accordingly.

NOTE When no information about the uncertainty of the results of the reference method is available from other (previous) parallel measurements, a value for u_{RM} of 0,67 $\mu g.m^{-3}$ (see [2]) is used by default.

For instruments where it was shown during the original equivalence tests that slope and or intercept correction are required, the uncertainties of the slope and/or intercept of the ongoing equivalence tests shall be used as terms c and/or d in Formulae (7), (9) or (10).

When the uncertainty is > 25 %, corrective actions shall be taken. These may include a recalibration of the method.

It may be favourable at a certain stage to use the data obtained to voluntarily recalibrate the method in order to reduce uncertainty, and, consequently, the extent of verification testing. The data used shall then fulfil the requirements given in 7.5.

The investigations and actions shall be fully documented.

9 Data handling, validation and data reports

9.1 Data handling and validation

The competent body for QA/QC of the monitoring network has the responsibility to validate acquired raw measurement data. These usually consist of hourly average measurement results. The following data shall be flagged in the raw data set:

a) data collected during calibrations;

b) data collected during maintenance;

c) data collected directly after a sample (filter) change;

d) data that can be marked as suspect for reasons of plausibility;

e) data that are below minus the detection limit of the AMS.

Plausibility checks shall include, but are not limited to:

f) checks of operational status parameters (see 7.5.3);

g) checks of readings for subsequent calibrations;

h) checks for (too) large variations of hourly results;

i) comparisons with data of pollutants for which concentrations are correlated with those of PM;

j) comparisons of data with those collected at nearby monitoring stations.

Generally, values that are below minus the detection limit specified for the AMS for the specific averaging period can be considered as too negative values and, in principle, shall not be considered for aggregations and calculations. However, it is known for example that AMS that operate by sampling PM

onto filters may produce negative measurement values far beyond the lower detection limit as a result of rapid changes in air humidity. Care shall be taken not to eliminate these data. Such data can be detected by studying the temporal changes in concentrations and in total mass collected. Usually a strongly negative value is preceded by a high positive value.

Correction for a shift in the baseline shall occur before deletion of negative data.

When a value larger than the maximum of the type-testing range is reported, this value shall be used in the calculation of averages but these averages shall be flagged in the data report to indicate that this average may have exceeded the uncertainty requirement as specified in reference [1].

Rounding of results shall be the last step of any calculation, i.e. immediately before comparing the result with the limit value. For rounding the so-called "commercial rounding" shall be used [11].

9.2 Data aggregation and reporting

All valid data – including negative data – shall be used for assembling longer-term average concentrations for reporting purposes. Minimum requirements for data aggregation are given in reference [11].

The uncertainty of measurement shall be determined and reported every year during operation in accordance with the requirements given in [11].

10 Reporting of AMS data

The readings from the AMS shall be expressed in micrograms per cubic metre of air. The sampling volume refers to ambient conditions in terms of temperature and atmospheric pressure at the time of measurements.

11 Test reports and documentation – Field operation

11.1 Suitability evaluation

When applicable, the user and/or operator of an AMS or monitoring network shall prepare a report on the suitability evaluation of the AMS.

NOTE Guidance to the contents of the suitability test report can be found in Annex E.

11.2 Documentation

The user and/or operator shall document all maintenance, repairs, calibrations, malfunctionings, etc. for each individual AMS, and monitoring site.

11.3 Ambient air quality data reports

Ambient air data reports for particulate matter shall be prepared according to relevant legal requirements. The report shall contain at least the following information:

a) reference to this document;

b) air quality data presented in the required form;

c) a statement on the measurement uncertainty of the data reported;

d) percentage of data capture;

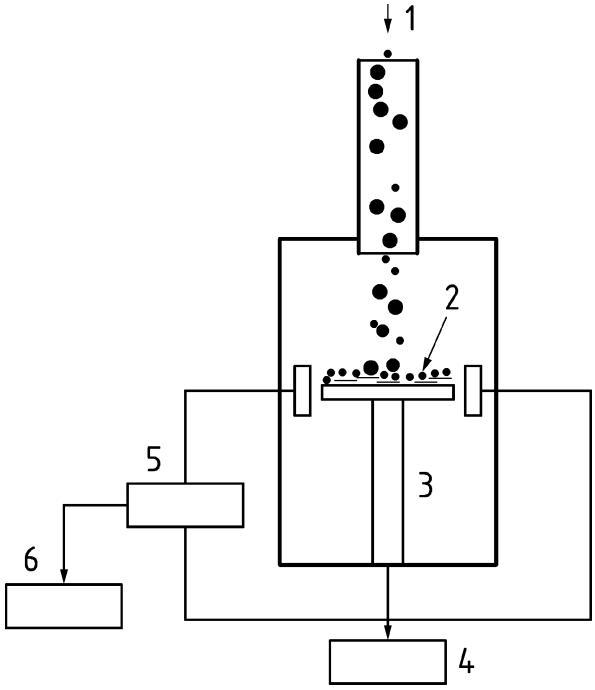
e) data collected during calibrations;

f) data that can be marked as suspect for reasons of plausibility.

Annex A
(informative)

Examples of principles of AMS for monitoring particulate matter

A.1 Oscillating microbalance



Key

1 sampled air
2 sample filter
3 oscillating element
4 pump
5 signal amplifier
6 frequency counter

Figure A.1 — Operation principle of oscillating microbalance

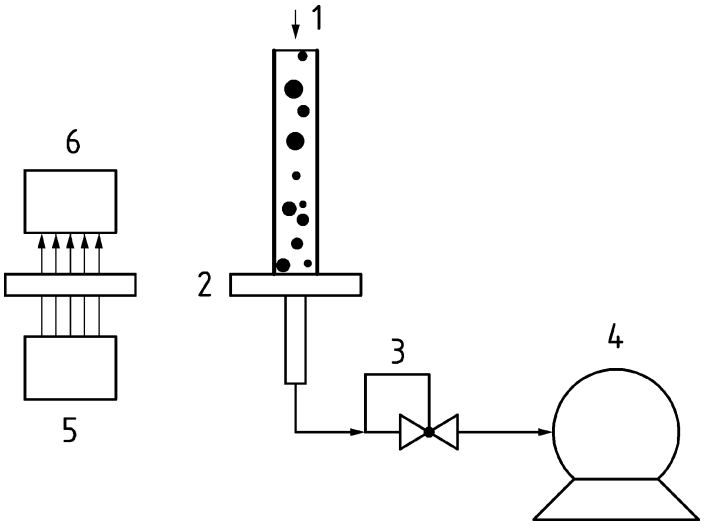
An oscillating microbalance continuously measures the mass of PM collected on a filter due to the reduction of the oscillation frequency of the oscillating element positioned underneath the filter. The microbalance is calibrated using special preweighed filters with accurately known masses. The monitor is equipped with a size-specific inlet operated at a constant flow. The concentration of PM is derived from the change of mass per unit time and the sample flow.

Zero measurements are usually obtained by sampling ambient air through a zero (HEPA) filter.

The measurement averaging period is usually 1 h or less.

Understanding of critical parameters that affect the measurement is necessary to ensure optimal instrumental use.

A.2 ß-ray attenuation



Key

1 sampled air
2 sample support
3 flow regulator
4 vacuum pump
5 ß-ray source
6 detector

Figure A.2 — Operation principle of ß-ray attenuation monitor

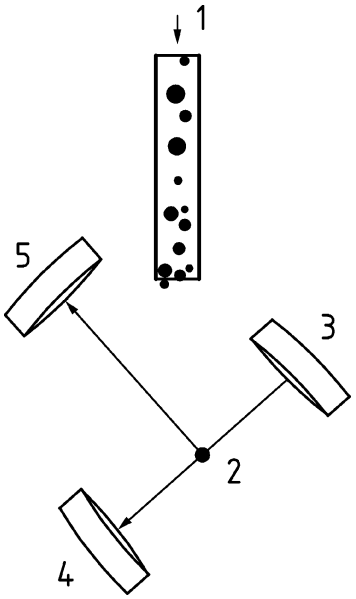
The sampled air passes through a size-selective inlet at a controlled flow rate. The relevant PM fraction is collected on a sample support (filter or filter tape). A low level of beta radiation is passed through the sample support. The increase in PM load causes a decrease in the radiation level measured by the detector. The decrease is approximately proportional to the increase in the mass of PM. The monitor is equipped with a size-specific inlet operated at a constant flow. The concentration of PM is derived from the change of mass per unit time and the sample flow. The monitor is calibrated using special calibration foils with accurately known masses.

Zero measurements are obtained using a clean sample support.

The measurement averaging period is usually between 1 h and 24 h.

Understanding of critical parameters that affect the measurement is necessary to ensure optimal instrumental use.

A.3 Light scattering



Key
1 sampled air
2 particle
3 light source
4 light trap
5 detector

Figure A.3 — Operation principle of light-scattering monitor

A light-scattering monitor measures pulses from light scattered in a particular direction (i.e. forward, side, or backward) and outputs a signal determined by the size and the concentration of airborne particles in the sample stream. The instrument is calibrated by sampling known concentrations of particles of accurately known sizes while controlling all other critical parameters (as described, e.g. in [12]). The PM mass concentration is calculated by conversion of particle numbers measured per unit time into mass per unit volume using dedicated multi-regression analysis or with preset particle densities.

Zero measurements are usually obtained by sampling ambient air through a zero (HEPA) filter.

The measurement averaging period is usually 1 min or less.

Understanding of critical parameters that affect the measurement is necessary to ensure optimal instrumental use.

A.4 System consisting of a central instrument and an array of regional instruments

The operation of the system is based on applying a correction for the losses of (semi-)volatile constituents of particulate matter, measured at a central monitoring site, to regional sites located at a certain maximum distance from the central site. The AMS at the regional sites are considered not to measure (semi-)volatile constituents. This is effected by heating the sampling line to a temperature above which components of the particulate matter are known to volatilize. The losses measured at the central site are considered to be representative for the area covered by the system [13]. It is recommended to verify if data quality objectives are fulfilled and to document this verification.

NOTE The maximum distance between local and regional instruments is largely dependent upon geographical conditions.

Annex B
(normative)

Orthogonal regression algorithms

Regression formula: $y = a + bx$

Slope b :

$$b = \frac{S_{yy} - S_{xx} + \sqrt{\left(S_{yy} - S_{xx}\right)^2 + 4\left(S_{xy}\right)^2}}{2S_{xy}} \quad \text{(B.1)}$$

where

$$S_{xx} = \sum \left(x_i - \overline{x}\right)^2 \quad \text{(B.2)}$$

$$S_{yy} = \sum \left(y_i - \overline{y}\right)^2 \quad \text{(B.3)}$$

$$S_{xy} = \sum \left(x_i - \overline{x}\right)\left(y_i - \overline{y}\right) \quad \text{(B.4)}$$

$$\overline{x} = \frac{1}{n}\sum x_i \quad \text{(B.5)}$$

$$\overline{y} = \frac{1}{n}\sum y_i \quad \text{(B.6)}$$

Intercept a :

$$a = \overline{y} - b\overline{x} \quad \text{(B.7)}$$

Variances of the slope and intercept:

$$u_b^2 = \frac{S_{yy} - \left(\left(S_{xy}\right)^2 / S_{xx}\right)}{\left(n-2\right)S_{xx}} \quad \text{(B.8)}$$

$$u_a^2 = u_b^2 \frac{\sum x_i^{\,2}}{n} \quad \text{(B.9)}$$

Regression formula: $y = bx$ (forced through 0,0). It is not considered appropriate to force the intercept through the origin when performing the initial type testing process (Clause 7), but it may be considered appropriate when performing suitability testing or ongoing equivalence verification (Clause 8)

$$b = \frac{S_{yy} - S_{xx} + \sqrt{\left(S_{yy} - S_{xx}\right)^2 + 4\left(S_{xy}\right)^2}}{2S_{xy}} \quad \text{(B.10)}$$

$$S_{xx} = \sum x_i^2 \tag{B.11}$$

$$S_{yy} = \sum y_i^2 \tag{B.12}$$

$$S_{xy} = \sum x_i y_i \tag{B.13}$$

Variance of the slope:

$$u_b^2 = \frac{S_{yy} - \left(\left(S_{xy} \right)^2 / S_{xx} \right)}{\left(n - 1 \right) S_{xx}}$$

Annex C
(normative)

Performing calibrations of the AMS

When results obtained applying regression analysis (7.5.8) indicate that

— the slope of the regression formula differs significantly from 1; and/or

— the intercept of the regression formula differs significantly from 0,

the AMS shall therefore be calibrated using the values obtained for slope and/or intercept.

Calibration needs not to be performed when:

— the value of the slope is 0,980 ≤ b ≤ 1,020; and/or

— the value of the intercept is −1,0 µg/m³ ≤ a ≤ 1,0 µg/m³; or

— the introduction of additional uncertainty terms leads to an increase or no significant decrease of the combined uncertainty of the AMS (see 7.5.8.6.2 – 7.5.8.6.4).

With reference to 7.5.8, three distinct situations may arise.

a) The slope b is not significantly different from 1, the intercept a is significantly different from 0:

In this case, the value of intercept a is used to calibrate input values y_i for the complete data set as follows:

$$y_{i,corr} = y_i - a \quad \text{(C.1)}$$

The resulting values of $y_{i,corr}$ are then used to calculate by orthogonal regression a new relationship:

$$y_{i,corr} = c + dx_i \quad \text{(C.2)}$$

and its associated parameters (RSS ; u_a) needed as input in Formula (8).

b) The slope b is significantly different from 1, the intercept a is not significantly different from 0:

In this case, the value of the slope b is used to calibrate input values y_i for the complete data set as follows:

$$y_{i,corr} = \frac{y_i}{b} \quad \text{(C.3)}$$

The resulting values of $y_{i,corr}$ are then used to calculate by orthogonal regression a new relationship:

$$y_{i,corr} = c + dx_i \quad \text{(C.4)}$$

and its associated parameters (RSS ; u_b) needed as input in Formula (10).

c) The slope b is significantly different from 1, and the intercept a is significantly different from 0:

In this case, the values of the slope b and the intercept a are used to calibrate input values y_i for the complete data set as follows:

$$y_{i,corr} = \frac{y_i - a}{b} \quad \text{(C.5)}$$

The resulting values of $y_{i,corr}$ are then used to calculate by orthogonal regression a new relationship:

$$y_{i,corr} = c + dx_i \quad \text{(C.6)}$$

and its associated parameters (RSS ; u_a ; u_b) needed as input in Formula (10).

Annex D
(normative)

Elements of type testing report

The competent body shall prepare a type testing report, which shall contain at least the following information:

a) executive summary;

b) general:

   1) type-testing proposal;

   2) unambiguous AMS designation;

   3) measured component(s);

   4) device manufacturer together with full address;

   5) field of application;

   6) measuring range for suitability test;

   7) firmware version of the AMS and software;

   8) restrictions: restrictions shall be formulated if testing shows that the AMS does not cover the full scope of possible application fields;

   9) notes: in the event of supplementary or extended testing, reference shall be made to all preceding test reports; attention shall be drawn to main equipment peculiarities;

   10) test laboratory;

   11) test report number and date of compilation.

c) task definition:

   1) nature of test: first test or supplementary testing;

   2) objective: specification of which performance criteria were tested; bibliography; scope of any supplementary tests.

d) description of the AMS tested:

   1) measuring principle: description of metrological and scientific relationships;

   2) AMS scope and set-up: description of all parts of the AMS covered in the scope of testing, including the sampling system, if possible including a copy of an illustration or flow diagram showing the AMS; statement of technical specifications, if appropriate in tabular form;

   3) operational parameters, preferably in a tabular form;

4) firmware version of the AMS and software.

e) test program: details shall be provided on the test program, in relation to the AMS under test; in the case of supplementary or extended testing, the additional scope of testing shall be detailed and substantiated; particularities of the test shall be documented:

1) laboratory tests: statement of test steps involved;

2) field tests: details on: test steps involved; site types at which the field test examinations were carried out; operating conditions for the AMS under test; frequencies of calibrations and checks;

3) any deviations from test steps and/or conditions prescribed in this European Standard; these shall also be reported on the approval certificate summary page.

f) reference method of measurement:

1) method description: it is necessary to specify the standard reference method employed. The between-sampler uncertainty of the standard reference method shall be stated, details on the sampling inlet (length, material);

2) test stand set-up: full description of the test locations, test periods and conditions (temperature; humidity; wind velocity; precipitation; estimates of the levels of semi-volatile compounds, if available).

g) Test results: comparison of the performance criteria placed on the AMS in the performance test with the results attained. The information below shall be stated for each individual test point in the following order of sequence.

1) citation of performance criterion;

2) equipment;

3) method;

4) evaluation;

5) assessment of measurement uncertainty;

6) detailed presentation of test results allowing for the respective section of the documentation.

Annex A. Values measured and computed.

Annex B. Operating instructions: the operating manual shall also be enclosed with the report in electronic form (e.g. as a PDF file).

The type testing report shall be available to users and potential users.

Annex E
(informative)

Elements of suitability evaluation report

A suitability evaluation report should contain at least the following information.

a) executive summary.

b) general:

   1) measured PM fraction;

   2) organisations performing the testing and evaluation;

   3) evaluation report identification and date of compilation.

c) task definition:

   1) nature of test: suitability evaluation additional to type testing.

d) description of the AMS tested:

   1) unambiguous AMS designation;

   2) firmware version of the AMS and software;

   3) operational parameters, preferably in a tabular form;

   4) identification of the approved type testing report.

e) test program: details shall be provided on the test program, in relation to the AMS under test; test steps involved; site types at which the field test examinations were carried out; operating conditions for the AMS under test; frequencies of calibrations and checks; particularities of the test should be documented;

f) reference method of measurement:

   1) method description: it is necessary to specify the standard reference method employed; the between-sampler uncertainty of the standard reference method should be known, details on the sampling inlet (length, material);

   2) test stand set-up: full description of the test locations, test periods and conditions (temperature; humidity; wind velocity; precipitation; estimates of the levels of semi-volatile compounds, if available).

g) test results: comparison of the performance criteria placed on the AMS in the suitability tests with the results attained:

   1) evaluation, including calibration function, if appropriate;

   2) assessment of measurement uncertainty;

   3) detailed presentation of test results allowing for the respective section of the documentation.

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