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

bsi.

National foreword

This British Standard is the UK implementation of EN 12341:2023. It supersedes BS EN 12341:2014, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EH/2/3, Ambient atmospheres.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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

Air ambiant - Méthode normalisée de mesurage gravimétrique pour la détermination de la concentration massique MP10 ou MP2,5 de matière particulaire en suspension

Außenluft - Gravimetrisches Standardmessverfahren für die Bestimmung der PM10- oder PM2,5-Massenkonzentration des Schwebstaubes

This European Standard was approved by CEN on 24 April 2023.

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European foreword

This document (EN 12341:2023) 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of an identical text or by endorsement, at the latest by February 2024, and conflicting national standards shall be withdrawn at the latest by February 2024.

This document supersedes EN 12341:2014.

Technical modifications which have been made in comparison with the previous edition are summarized in Annex I.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association and supports essential requirements of EU Directive(s).

For relationship with EU Directive(s), see the introduction.

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.

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Introduction

For air quality across the European Union to be assessed on a consistent basis, Member States need to employ standard measurement techniques and procedures. The aim of this document is to present a harmonized methodology for monitoring the mass concentrations of suspended particulate matter (PM_{10} and $PM_{2,5}$ respectively) in ambient air, following Directive 2008/50/EC on ambient air quality and cleaner air for Europe [1] which sets the parameters specific to the assessment of ambient concentration levels of particulate matter.

NOTE In principle, the methodology described in this document may also be used for measurement of mass concentrations of other PM fractions such as PM_1. However, this document does not describe standardized sampling inlets for such fractions.

The European Standard method described in this document is focused primarily on harmonization and improvement of the data quality of measurement methods used in monitoring networks with regard to avoiding unnecessary discontinuities with historical data. It is a method that is suited for practical use in routine monitoring, but not necessarily the method with the highest metrological quality.

There are no reference materials currently available to provide traceability for PM_{10} or $PM_{2,5}$ measurements in ambient air. Therefore, the standard method defines the measured quantity by convention, specifically by the sample inlet design and associated operational parameters covering the whole measurement process. This document contains:

- a description of a manual gravimetric standard measurement method for PM_{10} or $PM_{2,5}$ using sequential samplers or single-filter samplers;
- a summary of performance requirements of the method, together with associated type testing requirements for the sampler;
- requirements for suitability testing of facilities and equipment on initial application of the method;
- requirements for ongoing quality assurance / quality control when applying the method in the field;
- the assessment of measurement uncertainty of the results of this document method;
- criteria and test methods for the evaluation of the suitability of filters for application using this method.

The performance characteristics and requirements described in this document were partly determined in different comparative and validation trials. The trials were sponsored by the European Commission and the European Free Trade Association.

The requirements of this document are targeted firstly towards obtaining optimum results for the measurement of mass concentrations of PM_{10} or $PM_{2,5}$.

However, the filters collected for the purpose of determining the mass concentrations of PM_{10} or $PM_{2,5}$ can be used for further speciation, e.g. for the determination of concentrations of:

- heavy metals and polycyclic aromatic hydrocarbons (see EN 14902 [6], EN 15549 [7]) and CEN/TS 16645 [20] in conformity with Directive 2004/107/EC [8], as amended by Directive 2015/1480/EU [26].
- constituents of PM2,5 (see EN 16909 [9] and EN 16913 [10]) to be used for source apportionment as required by Directive 2008/50/EC.

Additional requirements might have to be considered for those purposes (e.g. blank values of chemical constituents).

1 Scope

This document specifies a standard method for determining the PM_{10} or $PM_{2,5}$ mass concentrations of suspended particulate matter in ambient air by sampling the particulate matter on filters and weighing them by means of a balance.

Measurements are performed with samplers with inlet designs as specified in Annex A, operating at a nominal flow rate of 2,3 m^3/h, over a nominal sampling period of 24 h. The method covers the determination of ambient air concentrations of specific fractions of suspended particulate matter in zones classified as rural areas, urban-background areas, traffic-orientated locations and locations influenced by industrial sources. Measurement results are expressed in µg/m^3, where the volume of air is the volume at ambient conditions near the inlet at the time of sampling.

The range of application of this document is for 24 h measurements from approximately 1 µg/m^3 (i.e. the limit of detection of the standard measurement method expressed as its uncertainty) up to 150 µg/m^3 for PM_{10} and 120 µg/m^3 for $PM_{2,5}$.

NOTE 1 Although the European Standard is not validated for higher concentrations, its range of application could well be extended to ambient air concentrations up to circa 200 µg/m^3 when using suitable filter materials (see 5.1.5.2).

This document specifies procedures and gives requirements for the testing and use of so-called sequential samplers, equipped with a filter changer, suitable for extended stand-alone operation. Sequential samplers are commonly used throughout the European Union for the measurement of concentrations in ambient air of PM_{10} or $PM_{2,5}$. However, this document does not exclude the use of single-filter samplers.

NOTE 2 Older versions of samplers, which conform to previous versions of EN 12341 [2 and 21], can still be used to evaluate equivalence of candidate methods, using the procedures described in EN 16450 [5] and in [11]. As newer versions of samplers tested under this document become available, discontinue the use of older reference samplers in EN 16450 and in [11]. Type testing reports of equivalent methods are still valid if they were commissioned prior to the availability of type approved reference samplers tested under this document.

This document also provides guidance for the selection and testing of filters with the aim of reducing the measurement uncertainty of the results obtained when applying this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

JCGM 100, *Evaluation of measurement data — Guide to the expression of uncertainty in measurement*

EN 15267-1:2009, *Air quality - Certification of automated measuring systems - Part 1: General principles*

EN 15267-2:2009, *Air quality - Certification of automated measuring systems - Part 2: Initial assessment of the AMS manufacturer's quality management system and post certification surveillance for the manufacturing process*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1.1
accuracy of measurement
closeness of the agreement between the result of a measurement and a true value of the measurand

NOTE 1 to entry: “Accuracy” is a qualitative concept.

NOTE 2 to entry: The term precision should not be used for “accuracy”.

[SOURCE: JCGM 100]

3.1.2
ambient air
outdoor air in the troposphere, excluding workplaces 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; Directive 89/654/EEC [12]]

3.1.3
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

[SOURCE: JCGM 200 [13]]

3.1.4
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: JCGM 100]

3.1.5
competent authority
organization which implements the requirements of EU Directives and regulates installations, which complies 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.

3.1.6
competent body
organization which can demonstrate its competence for a specific task to the competent authority in the Member State

Note 1 to entry: It is recommended 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 to entry: EN ISO/IEC 17025 is the harmonized internationally accepted standard that applies.

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

3.1.7
coverage factor
numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

[SOURCE: JCGM 100]

3.1.8
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: JCGM 100]

3.1.9
field blank
filter that undergoes the same procedures of conditioning and weighing as a sample filter, including transport to and from, and storage in the field, but is not used for sampling air

3.1.10
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: 2008/50/EC]

3.1.11
monitoring station
enclosure located in the field in which a sampler has been installed to measure particulate matter in such a way that its performance and operation comply with the prescribed requirements

3.1.12
parallel measurement
measurements from measuring systems, sampling from the same air over the same time period

3.1.13
performance characteristic
one of the parameters assigned to a sampler in order to define its performance

3.1.14
performance criterion

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

3.1.15
period of unattended operation

time period over which the sampler can be operated without requiring operator intervention

3.1.16
PM_x

particulate matter suspended in air which is small enough to pass through a size-selective inlet 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 this document – 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 may have a significant effect on the fraction of PM surrounding the cut-off, and, consequently on the mass concentration of PMx determined.

3.1.17
reference method
RM

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

3.1.18
reference sampler

sampling system which has been proved to be compliant to the requirements of the design and performance characteristics of this document

3.1.19
sampled air

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

3.1.20
sampling inlet

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

3.1.21
standard uncertainty

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

[SOURCE: JCGM 100]

3.1.22
suspended particulate matter
SPM

notion of all particles surrounded by air in a given, undisturbed volume of air

3.1.23

type testing

examination of two or more samplers of the same model (identical in hardware and firmware) which are submitted by a manufacturer to a competent body for testing of performance requirements

3.1.24

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: JCGM 100]

3.1.25

weighing room blank

filter that undergoes the same procedures of conditioning and weighing as a sample filter, but is stored in the weighing room

3.2 Symbols and abbreviations

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

—	φ	Flow rate related to standard conditions
—	φ_a	Flow rate related to ambient conditions (T_a, P_a)
—	ΔP	Pressure difference determined for the time interval Δt (leak test)
—	Δt	Time interval needed for the pressure rise (leak test)
—	C	Concentration of PM (µg/m^3) at ambient conditions
—	k	Coverage factor
—	m	Filter mass
—	m_c	Mass of blank conditioned filter
—	m_l	Mass of sampled filter
—	m_s	Mass of sampled and conditioned filter
—	m_u	Mass of unsampled filter
—	P_0	Pressure at t = 0 (leak test)
—	P_a	Ambient pressure
—	Q_l	Percentage leak rate
—	t	Sampling time
—	T_a	Ambient temperature
—	u	Standard uncertainty
—	u_{bs}	Between-sampler uncertainty
—	u_f	Uncertainty of flow
—	u_{mfb}	Uncertainty due to the effect of humidity on a blank filter
—	u_{mh}	Uncertainty due to hysteresis effects on mass of PM
—	u_m	Uncertainty of the mass of PM (ml – mu)

—	u_{mb}	Uncertainty due to buoyancy
—	u_{mba}	Uncertainty due to balance calibration
—	u_{mc}	Uncertainty due to contamination
—	u_{mfe}	Uncertainty due to lack of filter efficiency
—	u_{mg}	Uncertainty due to the interaction with gases
—	u_{mhp}	Uncertainty due to the effect of humidity on particulate matter
—	u_{mip}	Uncertainty due to inlet performance
—	u_{ml}	Uncertainty of the mass of a sampled filter
—	u_{ms}	Uncertainty due to static charging of the filter
—	u_{mtl}	Uncertainty due to losses of PM on transport and storage
—	u_{mu}	Uncertainty of the mass of an unsampled filter
—	u_{mzd}	Uncertainty due to balance zero drift
—	$u_{\mathrm{v,rel}}$	Uncertainty of the volumetric flow using the results of flow checks of the samplers from control card
—	$u_{\mathrm{v,ref}}$	Uncertainty of the flow meter (Oriflow flow meter)
—	φ_{L}	Leak flow rate (leak test)
—	$\mathrm{V_o}$	flow rate measured after the filter housing
—	$\mathrm{V_i}$	flow rate measured at the sample inlet
—	V_{sys}	Estimated total volume of the system (dead volume)
—	w	Relative uncertainty
—	W	Expanded relative uncertainty
—	x_{i}	Individual measurement result from a sampler
—	u_{fc}	Uncertainty due to flow calibration
—	u_{fd}	Uncertainty due to flow drift
—	u_{t}	Uncertainty of sample time
—	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
—	POM	Polyoxymethylene
—	PTFE	Polytetrafluoroethylene
—	QA/QC	Quality Assurance / Quality Control
—	RH	Relative Humidity
—	RM	Reference Method(ology)
—	SPM	Suspended Particulate Matter

4 Principle

4.1 Description of the standard measuring principle

Ambient air is passed through a size-selective inlet at a known, constant flow rate. The relevant PM fraction is collected on a filter for a known period of nominally 24 h. The mass of the PM material is determined by weighing the filter at pre-specified, constant conditions before and after collection of the particulate matter.

Key factors which can affect the result of the measurement, and which are addressed by the procedures prescribed within this document, include:

- (variations in) the design and construction of the size-selective inlet;
- the sampling flow rate;
- deposition losses of PM within the pipework between the inlet and the filter;
- uncontrolled losses within the pipework between the inlet and the filter, and on the filter due to volatilization of water and semi-volatile PM at any time between collection and weighing;
- changes in weight of the filters or PM due to, e.g. the behaviour of water and semi-volatile compounds on the filter and PM, spurious addition or loss of material, buoyancy, or static electricity.

In order to minimize the effects of these factors, this document gives requirements for a series of parameters that determine the magnitudes of these effects.

4.2 Initial use and procedures for ongoing QA/QC

QA/QC procedures are described for sample collection, filter transport and handling, and filter weighing.

The QA/QC procedures within this document are separated into those activities typically carried out with each measurement, and those carried out less frequently.

QA/QC procedures which are used for each measurement, including filter handling and conditioning, weighing room conditions, proper functioning of the weighing instrument, and the use of blank filters, are described in Clause 6.

It is of particular importance that the facilities used for the weighing of the filters before and after sampling fulfil the requirements of this document. Consequently, a series of tests is described through which the user may ensure the proper operation of the facilities.

Additional QA/QC procedures which are used on a less frequent basis, including flow calibration, calibration of the weighing instrument, and maintenance (inlet cleaning) and leak testing of the sampling system, are described in Clause 7.

4.3 Evaluation of measurement uncertainty

Procedures for the user to evaluate the measurement uncertainty contributions are described in Clause 9.

5 Equipment, facilities and testing

5.1 Sampling system components and programme for type testing

5.1.1 General

This document specifies the designs for the sampling systems to be used within the standard method.

This document represents an evolution of earlier European Standards (EN 12341 [2] and [21], EN 14907 [3]). New reference sampler procured shall comply fully with this document. Older versions of these samplers, including those described in EN 12341:2014 Annex B [21], have a special status in terms of their use. These samplers can still be used for monitoring purposes and for ongoing quality control, provided that a well justified additional allowance is made to their uncertainties. An appropriate procedure for calculating the additional uncertainty allowance is provided in EN 12341:2014 Annex B [21].

The determination of the concentration of PM_{10} or $PM_{2,5}$ in ambient air shall fulfil the requirement within the maximum uncertainty of the measured values, which is prescribed by Directive 2008/50/EC. In order to achieve an uncertainty less than (or equal to) this required uncertainty, the sampler shall fulfil all the criteria for a number of performance characteristics which are given in this standard. The values of the selected performance characteristics shall be evaluated by means of laboratory tests and field tests. By combining uncertainties derived from the values of the selected performance characteristics in the expanded uncertainty calculation, a judgement shall be made as to whether or not the sampler meets the criterion of maximum uncertainty prescribed by Directive 2008/50/EC.

This process of assessment of the values of the performance characteristics comprises laboratory tests and field tests and the calculation of the expanded uncertainty. Two samplers of the same model shall be tested in the laboratory and in the field tests. All samplers tested are required to pass their respective tests.

It is permitted for testing in the laboratory and field to use two samplers of the same model consecutively or separately with four samplers of the same model.

The type testing according to Clause 7 and subsequent QA/QC and verification procedures according to Clause 9 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 approval shall be awarded by, or on behalf of, the competent authority of a Member State. The type testing report shall be publicly available.

The type testing is based on the evaluation of performance characteristics determined under a prescribed series of tests. In this document, test procedures are described for the determination of the actual values of the performance characteristics for two samplers of the same model in a laboratory and in the field. The evaluation for type testing of the sampler includes the calculation of the expanded uncertainty of the measuring result based on the numerical values of the tested performance characteristics and then by comparison of this result 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.

In order to assess the performance of single or sequential samplers, it is necessary to undergo a series of laboratory and field tests. The requirements of these tests are given in Table 1, described further in the accompanying clauses. The requirements shall be assessed via a combination of laboratory and field tests, as prescribed in Table 1.

Table 1 — Requirements for sampling equipment

	Design/performance characteristic	**Requirement**	**Type Test (Lab (L)/Field(F))**	**Clause**
1	Sampler design	The sampler design shall be as prescribed.	L	5.1.2, 5.1.4, 5.1.5
2	Inlet design	The design of the inlet shall be as prescribed.	L	5.1.3, normative Annex A
3	Temperature of air through the sample filter during sampling	Within ± 5 °K of climate chamber temperature at 20 °C.	L	5.1.5
4	Nominal flow rate	2,3 m^3/h at ambient conditions. ≤ 2,0 % of nominal flow rate at −20 °C, 20 °C and 50 °C by default for outdoor environments under lab tests. Ambient conditions under field trials.	L/F	5.1.6
5	Constancy of sample volumetric flow	2,3 m^3/h at ambient conditions. ≤ 2,0 % of rated flow over sampling time ≤ 5,0 % rated flow (instantaneous flow) at −20 °C, 20 °C and 50 °C by default for outdoor environments.	L	5.1.6
6	Leak tightness of the sampling system	$\varphi_L \leq 1,0$ % of sample flow rate	L/F	5.1.10
7	Single-filter cycle time	24 h	L	5.1.9
8	Maximum bias of sampler clock	±5 min (in 30 d)	F	5.1.9
9	Maximum bias of sensor for ambient temperature measurement or, if applicable, the sensor for measurement of temperature in the flow measuring device	≤ 2 K at −20 °C, 20 °C and 50 °C by default for outdoor environments.	L	5.1.7

	Design/performance characteristic	**Requirement**	**Type Test (Lab (L)/Field(F))**	**Clause**
10	Maximum bias of sensor for ambient pressure measurement or, if applicable, the sensor for measurement of pressure in the flow measuring device	≤ 1 kPa	L	5.1.8
11	Maximum bias of sensors for internal temperatures (filter during sampling; filter during storage)	≤ 2 K	L	5.1.7
12	Minimum hourly recording and transmission of operational parameters	The sampler shall be able to record at a minimum hourly rate and transmit – at minimum – the following parameters: • Average flow rate • Sampling time and sample volume • Average air temperature in filter section • Average ambient temperature • Average temperature of filter storage • Average ambient pressure The sampler shall continue to record these operational parameters while in standby mode, i.e. when the sampler is not actively sampling but exposed sampler filters remain in storage.	L/F	5.1.12
13	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	5.1.13
14	Ending of sampling due to filter overloading	Instruments with filter changers shall have the ability to restart automatically with a new filter if the previous filter sample was ended due to a high pressure drop across the filter.	L	5.1.14

	Design/performance characteristic	Requirement	Type Test (Lab (L)/Field(F))	Clause
15	Between-sampler uncertainty	≤ 2,0 µg/m³.	F	5.3.2
16	Availability	At least 95 %	F	5.3.2
17	Firmware / Software / Manuals versions	Shall be documented in the report. Firmware and software versions shall be recorded on the instrument	L/F	5.1.15

When the manufacturer makes design changes (software and/or hardware) to a type-tested sampler it shall follow the requirements of EN 15267-1 and EN 15267-2.

5.1.2 Sampler design

Sampling systems for the standard measurement methods for PM_{10} and $PM_{2,5}$ typically consist of the following elements, an example of which is illustrated schematically in Annex B:

- size-selective inlets, whose designs are prescribed in 5.1.3;
- connecting pipe-work between the inlet and the filter holder, described in 5.1.4;
- filter holder and filter, described in 5.1.5;
- flow control system, given by performance specifications in 5.1.6;
- sample changer (for sequential samplers);
- storage facility for filters in the sampler (for sequential samplers).

NOTE 1 Different filter storage configurations are possible. An example is provided in Annex B.

The sampler shall be designed in a way that it is possible to check and calibrate all sensors that are important to ensure the correct performance of the sampler. The manual of the sampler shall contain instructions on how to access and test the sensors, together with any specific tools required to achieve this.

It is recommended to design the sampling device to minimize the effect of high temperatures as a result of solar gain.

5.1.3 Standard inlet design

A standard drawing of the inlet design for the sampling of PM_{10} and $PM_{2,5}$ is given in Annex A.

The inlet shall be made of an inert, non-corroding, electrically conducting material such as stainless steel, aluminium alloy or anodized aluminium.

For a correct size-selective sampling of PM_{10} and $PM_{2,5}$ the sampling flow shall be kept at a nominal flow rate of 2,3 m³/h (see 5.1.5 and Annex F).

The design of the inlet shall be checked with standards for dimensional measurements traceable to Internationally accepted standards with uncertainties according to: ISO 2768-1 [18] tolerance class m, tolerance H7 (for critical components) and EN ISO 286-2 [19] (for all other measurements). The manufacturer shall also provide a disassembled sample nozzle of each type for type testing in order for the internal dimensions to be assessed for compliance.

5.1.4 Connecting pipe work

The requirements for the connecting pipe work between the inlet and the filter holder are to minimize deposition losses of particulate matter by kinetic processes, as well as losses due to thermal, chemical or electrostatic processes.

- The pipe work shall be made of an inert, non-corroding, electrically conducting material such as stainless steel, aluminium alloy or anodized aluminium.
- The pipe work shall have no bends and be vertical.
- The length of the connecting pipe work between the inlet and the filter holder shall be no more than 3 m.
- The pipe work shall be designed to minimize the effect of solar heating so that the air sample is kept as close as possible to ambient temperature.
- The temperature of the connecting pipe work shall be kept as close to the ambient temperature as possible in order to avoid contact of the sampled air with cold surfaces which could cause condensation, for instance by flowing a sheath of ambient air around the pipe work (see Annex B, Figure B.1).

5.1.5 Filter holder and filter

5.1.5.1 Filter holder

The filter holder shall be made of an inert, non-corroding material such as stainless steel, aluminium alloy or anodized aluminium. Plastic material such as polycarbonate, POM (polyoxymethylene) or PTFE (polytetrafluoroethylene) can also be used.

The filter holder shall be suitable for insertion of circular filters, such that the diameter of the exposed area through which the sampled air passes is between 34 mm and 44 mm.

The filter support shall be made either of stainless steel, anodized aluminium, aluminium alloy, polycarbonate, POM or PTFE grid material.

The filter holder shall securely hold the filter in place, creating a leak-free seal, without causing damage to the structure of the filter. The filter holders shall be evaluated by sampling two filters (one of membrane material and one of fibre-based material) over a period of 24 h. After exposure, the filters shall be inspected to ensure a clearly defined line between the sampled and unsampled areas, with no damage to the filters. Photographic evidence shall be provided.

The filter holder arrangement shall be designed in such a way that the temperature of the filter holder and the filter are kept as close as possible to ambient temperature. The effect of heating sources, such as electrical apparatus (e.g. the sampling pump), and cooling elements such as air conditioning shall be minimized. Laboratory climate chamber tests shall be performed at 20 °C and the temperature of the air through the sample filter shall differ by less than 5 °K from the temperature of the air being sampled. This shall be checked by incorporating temperature measurements in the sampled air immediately after the filter, which shall be compared with ambient air temperature measurements.

The output of the sampler temperature sensors shall be recorded at a frequency of at least once per hour. These hourly measurements shall be used to assess compliance against this test requirement.

5.1.5.2 Filter

The filters shall be made of glass fibre, quartz fibre, PTFE or PTFE coated glass fibre. The suitability of specific types and brands of filters may depend on:

- (variations in) the filter composition, e.g. (variations in) the fraction of binder used;
- the integrity of the filter at filter handling;
- the capacity of the sampler pump;
- the maximum pressure drop over the filter at which the flow rate can be maintained at its nominal level;
- the period(s) and relative humidity(ies) used for filter conditioning before sampling. See Annex C.5 for details of the effect of humidity on different filter types.

The filter material(s) used for type testing shall be reported. The end user shall satisfy themselves that the filter they choose is fit for purpose.

NOTE 1 Due to the lack of appropriate criteria and protocols to test filters for fitness for purpose, considerable differences can exist between results obtained when using different filter types, and even filters of the same type. For example, differences of up to 15 % have been found when applying different brands of quartz-fibre filters in parallel measurements of PM10 for concentrations around 50 % of the daily limit value [4]. This can have implications for results produced by automated measurement systems as these are calibrated by comparison of results with those obtained using reference samplers (EN 16450 [5]).

The filters shall have a separation efficiency of at least 99,5 % for particles with an aerodynamic diameter of 0,3 µm.

Annex C provides a number of tests and criteria for the evaluation of the fitness-for-purpose of specific filter types and brands. These range from simple tests that may be performed by monitoring networks themselves to more sophisticated tests that require specialized test facilities.

NOTE 2 PTFE-based filter materials are known to have a lesser capacity for PM under specific conditions (e.g. high concentrations of water vapour) under which clogging of filters dan occur, reducing the sampling time to below 24 h.

NOTE 3 Filters that are exposed and stored in samplers that cool after exposure can provide different results to samplers that do not have this capability, especially when ambient temperatures are above 20 °C. This will need to be considered when reviewing results from cooled and uncooled samplers in co-location studies.

5.1.6 Flow control system

The flow system for sample collection shall provide the flow rate necessary for the correct size selection at the inlet, and also a known sampled volume for calculation of the PM concentration.

As the sampled volume shall be expressed at ambient air conditions near the PM inlet, the flow control shall be such that the sampled volume of air at ambient conditions per unit time is kept constant by incorporating temperature and pressure measurements at a representative location in ambient air. The flow rate measured by the flow control system installed downstream of the filter being sampled shall be converted to ambient conditions according to the ideal gas law.

This conversion requires the measurement of ambient temperature and pressure. In the case of an internal volumetric flow control, measurements of temperature and pressure in the flow controlling device are required. The sensors used for this purpose shall be of such quality that they meet the requirements given in Table 1.

Volumetric flow through the inlet shall be controllable to a nominal value of 2,3 m^3/h at ambient conditions. The instantaneous value of the flow rate shall be kept within 5 % of the nominal value at ambient conditions.

The performance of the sampler shall be evaluated according to the procedures below:

Measurements for instantaneous volumetric flow shall be taken at least every 10 s for a period of not less than 30 min.

Measurements for averaged volumetric flow shall be taken at least every 6 min for a period of not less than 24 h.

The volumetric flow averaged over the sampling period shall be within 2 % of the nominal value.

The sample flow is calibrated at the beginning of the lab test sequence (at +20 °C) and at the beginning of the field tests with a logging flow meter, with readings traceable to Internationally Accepted Standards with an uncertainty ≤ 1,0 %. The calibration of the sample flow is then evaluated at the end of the field test sequences.

The nominal flow rate shall be calibrated in the laboratory at +20 °C and then measured in the laboratory at two temperatures:

- −20 °C and 50 °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.

The flow meter shall be located within the test chamber during testing.

At each temperature, at least 10 measurements shall be taken over a minimum period of 1 h at the specified flow rate. 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 specified flow rate.

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

The constancy of flow rate 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. The nominal flow rate shall be calibrated at +20 °C and the constancy of flow rate measured at three temperatures:

- +20 °C, −20 °C and 50 °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.

During a period of at least 24 h the sample flow, temperature and pressure shall be monitored continuously and recorded at least every six minutes.

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

5.1.7 Temperature sensors

The ambient temperature sensor shall be tested by comparison with a temperature measurement device with readings traceable to Internationally Accepted Standards and an uncertainty ≤ 0,5 K. Tests shall be undertaken during the evaluation of flow measurement at - 20 °C, + 20 °C and 50 °C. A logged spot measurement every hour from the sampler shall be compared against an identical measurement from the reference measurement device.

The sample filter air temperature and filter storage temperature sensors shall be tested by comparison with a temperature measurement device with readings traceable to Internationally Accepted Standards and an uncertainty ≤ 0,5 K. Where possible tests shall be undertaken during the evaluation of flow measurement at - 20 °C, + 20 °C and 50 °C. Where this is not possible, tests shall be undertaken under controlled laboratory conditions. A logged spot measurement every hour from the sampler shall be compared against an identical measurement from the reference measurement device.

The results of these tests shall meet the requirements in Table 1.

5.1.8 Ambient pressure sensor

The ambient pressure sensor shall be tested by comparison with a pressure measurement device with readings traceable to Internationally Accepted Standards and an uncertainty ≤ 0,5 kPa. The comparison shall be undertaken over the pressure range observed during the laboratory tests. A logged spot measurement every hour from the sampler shall be compared against an identical measurement from the reference measurement device.

The results of this test shall meet the requirements of Table 1

5.1.9 Sampling period

The sampling period shall be tested over a 24 h cycle in the laboratory, by comparison with a time measurement device with readings traceable to Internationally Accepted Standards and an uncertainty ≤ 1 min. The accuracy of the sampling start and stop times programmed in the sampler shall be assessed. The precision of this sampling period shall be within 1 min.

For single filter samplers, the sampling time will be reduced to allow for the changeover of a new filter. For sequential samplers, the automatic changeover time will be significantly reduced. The sampling time for all sampler types is 24 h. The changeover times shall be documented in the report. The sampler shall create a status flag if the sample time for a filter is less than the required sampling time.

The long-term precision of the sampler clock shall be less than 5 min over a period of 30 d.

The sampler shall be able to provide information on start and stop times and duration of sampling for each individual filter.

5.1.10 Leak tightness of the sampling system

5.1.10.1 General

The leak tightness (leak rate) of the flow path of the sampler shall be tested. The test house shall ensure that the sample line used during the leak test are accounted for in the calculation process and is leak tight. 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 case proper sealing of the sample inlet is impossible, the inlet may be excluded from the test.

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

The leak rate shall fulfil the performance requirement in Table 1.

NOTE A leak test integrated in a sampler by the manufacturer can be used, provided that the stringency of such a test is equivalent to the leak test described in 5.1.10.2 and 5.1.10.3

5.1.10.2 Low pressure method

In the case of a determination of the leak rate by the low pressure method, the volume of the whole system shall be provided by the manufacturer. A threshold time, Δt, is calculated, then the pressure change during this time is measured and shall be below 100 mbar.

The time, Δt, for a 100 mbar pressure change is calculated according to Formula (1) assuming the maximum allowable leak rate from Table 1 is present:

$$\Delta t = \frac{\Delta P \cdot V_{sys}}{P_o \cdot \Phi_l} \tag{1}$$

where:

Δt	is the time taken for the pressure change ΔP assuming a 1 % leak rate;
ΔP	is pressure difference used for the leak test, 100 mbar;
V_{sys}	is the total volume of the system (dead volume);
ϕ_l	is maximum allowable leak rate from Table 1, 1 % of sample flow rate;
P_o	is pressure in the system at the start of the test (measured ambient air pressure, less 150 mbar).

The threshold time for the test will be 2 min or *Δt*, whichever is the shortest.

NOTE 1 Example calculation of *Δt* for theoretical system:

ΔP	100 mbar;
V_{sys}	1,5 l;
ϕ_l	0,383 l/min (1 % of 38,3 l per minute, equivalent to 2,3 m^3 / hour);
P_o	800 mbar.

The threshold time *Δt* calculated with Formula (1) in this case is 30 s.

The test shall be performed according to the following procedure: the system shall be closed at the inlet and the pressure be lowered by a built-in or separate pump by up to a pressure of 150 mbar below ambient air pressure. After switching off the pump, the pressure difference caused by the increasing pressure in comparison with the low pressure previously set shall be determined over the threshold time. If the pressure change is less than 100 mbar over the threshold time then the leak rate, ϕ_l, will be less than the value stated in Table 1.

The test shall be repeated 3 times and the maximum leak rate reported.

5.1.10.3 Volumetric method

Compared to the low-pressure method, this method gives rise to higher uncertainties. Consequently, its use is restricted to exceptional cases. Only if it is technically impossible to measure the low pressure, the percentage leak rate is determined by measuring flow rates at the inlet and outlet of the flow path according to Formula (2):

$$Q_l = \frac{V_o - V_i}{V_o} \cdot 100 \qquad (2)$$

where:

Q_l is percentage leak rate;

V_o is flow rate measured after the filter housing;

V_i is flow rate measured at the sample inlet.

The percentage leak rate shall be compared to the value quoted in Table 1.

5.1.11 Storage conditions

Users of this document shall carefully consider and implement suitable temperature conditions for storage of sampled filters, such that loss of volatile and semi-volatile materials is minimized over the storage period. Storage conditions shall also ensure the prevention of condensation on the filters (see 6.4.3).

The temperature of the storage chamber shall be recorded. If the sampler contains a system for cooling filters, this shall be tested.

NOTE One option is to keep sampled filters at or below a temperature of 23°C. The temperature of 23 °C is chosen to be the weighing room temperature (20 °C) with a 3 °C allowance, to take into account practical considerations. A filter cooling system can impact on the quantity of PM and water retained by a filter, depending on the choice of filters used for sampling. The effect is only likely to be observed when the cooling is active and leads to an increased relative humidity.

5.1.12 Recording of operational parameters

The sampler shall be able to record at a minimum hourly rate and transmit – at minimum – the following parameters:

- Average flow rate
- Sampling time and sample volume
- Average air temperature in filter section
- Average ambient temperature
- Average temperature of filter storage
- Average ambient pressure

The sampler shall continue to record these operational parameters while in standby mode, i.e. when the sampler is not actively sampling, but exposed sampler filters remain in storage.

NOTE Optionally, other operational parameters can be recorded, including:

- pressure drop over sample filter
- ambient humidity

In addition, an operational status shall be recorded to assist with fault diagnosis.

The sampler shall be able to transmit this data either by direct communication with a computer / external data logging / storage device, and / or via remote communication by Ethernet / telephony.

5.1.13 Effect of failure of mains power

The sampler memory shall be protected against the effect of power failure. Historic operational data collected prior to a power failure, up to and including the filter currently loaded, shall be retained in non-volatile memory.

The sampler shall include a back up real time clock, capable of keeping time during extended power failure for a minimum of 30 d. This time shall be used when power is restored to the sampler. Time synchronisation is permitted.

The sampler shall take appropriate action when power is restored:

- If power is restored within the current 24 h period, the sampler shall resume sampling on the current filter.

- If power is restored after a 24 h sampling period has elapsed, the sampler shall move on to a new filter (either the next in the cassette, or the appropriate programmed filter for the day) and begin sampling.

In both cases, the measured parameters, including the actual sampling time of the affected filters and times of power interruption and restoration shall be recorded for any affected filters.

5.1.14 Effect of ending sampling early due to filter clogging

In the event that the correct flow through the filter cannot be maintained due to clogging as a result of high concentrations / high humidity, the sampler shall have the ability to end sampling early. The user shall be able to decide on the appropriate course of action following cessation of sampling, either:

- suspend sampling until the beginning of the next 24 h period or

- begin sampling immediately with the next filter. It is recommended that the minimum sampling time for a valid daily concentration is greater than 18 h.

The instrument shall be tested by either:

- placing a filter of high enough pressure drop to reduce the sampler’s flow below the set point and evaluate the response of the sampler compared against the performance criteria in Table 1.

- operating the sampler continuously for an indefinite period in an environment of elevated PM concentrations, until the filter becomes blocked, to test that the sampler does what was programmed by the operator (stop, switch filters, etc)

The measured parameters and times of interruption and restoration shall be recorded for any affected filters.

5.1.15 Firmware, software and manual versions

To identify changes in firmware and software these version numbers shall be available to the user within the sampler menus.

The version number of the sampler’s manual supplied during type testing shall be recorded in the test report.

When the manufacturer makes design changes (software and/or hardware) to type-tested samplers it shall follow the requirements of EN 15267-1 and EN 15267-2.

5.2 Sampling system components and programme for type testing

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 document. The following specifications shall be adhered to:

- Manufacturers shall submit two samplers of the same model.
- Checking of the sample inlet dimensions shall be performed at any time before tests involving the use of the inlet head. The manufacturer shall provide details of the dimensions and tolerances of the inlet for verification against the requirements of Annex A. The manufacturer shall also provide a disassembled sample nozzle of each type for type testing, in order for the internal dimensions to be assessed for compliance.
- The samplers shall be equipped with the same type of filters throughout test. The filters shall conform with parameters defined in the scope (Clause 1), described in Clause 5.1.5.2 and with reference to Annex C of this standard. The type and manufacturer of the filters used for the tests shall be recorded in the report.

The instruments shall be located within a climate-controlled chamber. Tests are undertaken at three temperatures: 20 °C, +50 °C and −20 °C (unless specified otherwise by the manufacturer and then fully documented in the test certificate). The allowed tolerances are ± 2 °C for all three temperatures. A number of tests shall be undertaken at each of the three temperature settings. The following test sequence shall be followed:

Table 2 — Test schedule

	Tests to be performed	**Clause**
1	Sampler design, inlet design	5.1.2, 5.1.3, 5.1.4
2	Setting of climate chamber to 20°C, leak tests, calibration of sampling flow, and temperature and pressure sensors (not all sensors may be open to calibration, but at least the ambient parameter sensors shall be calibrated.)	5.1.6 to 5.1.7
3	Measurement of all parameters indicated in Table 1 with instruments with specifications given (over a period of at least 24 h).	5.1.4 to 5.1.9
4	Change of temperature to +50°C, once the set point is achieved wait for at least 4 h for stabilization.	
5	Measurement of all parameters indicated in Table 1 with instruments with specifications given (over a period of at least 24 h).	5.1.4 to 5.1.9
6	Change of temperature to −20°C, once the set point is achieved wait for at least 4 h for stabilization.	
7	Measurement of all parameters indicated in Table 1 with instruments with specifications given (over a period of at least 24 h).	5.1.4 to 5.1.9

	Tests to be performed	Clause
8	Change of temperature to 20°C and wait for at least 4 h for stabilization.	
9	Leak test.	5.1.7
10	Measurement of the parameters indicated in Table 1 (over a period of at least 24 h).	5.1.4 to 5.1.9
11	Test of operation of the sampler to operator configuration options, to include use of a second filter if specific conditions are not met (e.g. filter overloading, etc.)	5.1.14

5.3 Field tests for type testing

5.3.1 General

A competent body shall undertake the field tests of the performance characteristics 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 document. The following specifications shall be adhered to:

- The manufacturer shall submit two samplers of the same type. It is recommended that these be the same instruments as those used in the laboratory tests. Regardless, the samplers shall be re-commissioned and recalibrated for flow and other parameters to be ready for field testing.

- The samplers shall be equipped with identical filters throughout test. It is recommended that these shall be of the same manufacturer and material as those used in the laboratory tests. Regardless, the filters shall conform with parameters defined in the scope (Clause 1), described in Clause 5.1.5.2 and with reference to Annex C of this standard.

5.3.2 Performance tests

The performance of the samplers shall be evaluated at the start and end of the field trial. The following tests described in Table 1 shall be performed:

Nominal flow rate at ambient conditions, 5.1.6

Leak tightness, 5.1.10

Recording of operational parameters, 5.1.12

Between sampler uncertainty

Two samplers shall be operated concurrently for a period of at least 20 days using the same filter material. This test has to be performed for each PM fraction; this could be performed either in parallel or sequentially. For PM_{10}, recorded concentration on at least three of these days shall be higher than 28 µg/m^3. For $PM_{2,5}$, 3 days shall be higher than 17 µg/m^3. Filter weighing to be performed by a laboratory accredited to the relevant harmonized standard following the procedures in section 6.

The correct operation of the instruments shall be checked at least once every workday. This daily check consists of plausibility checks on successful filter exchanges, status signals and other relevant parameters. Time, duration and nature of any error in functioning shall be recorded. In order to facilitate the observation of the filter exchanges, then the instruments need not be programmed to exchange filters at midnight.

The total time during the field test in which valid measurement data are obtained is used for calculating availability.

Availability is calculated with Formula (3) as

$$A = \frac{t_{\text{valid}} + t_{\text{cal,maint}}}{t_{\text{field}}} \tag{3}$$

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 of 95 % as given in Table 1.

The filters shall be conditioned and weighed as set out in Clause 6 of this standard. The between-RM uncertainty, $u_{\text{bs,RM}}$, is calculated with Formula (4) from the differences of all 24 h results of the reference instruments operated in parallel as:

$$u_{\text{bs,RM}}^2 = \frac{\sum_{i=1}^{n} \left(x_{\text{i,1}} - x_{\text{i,2}} \right)^2}{2n} \tag{4}$$

where

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

n is the number of 24 h measurement results.

Where both PM_{10} and $PM_{2,5}$ heads have been tested then the between-RM uncertainty shall be calculated separately for PM_{10} and $PM_{2,5}$. A between reference method uncertainty $< 2,0$ µg/m^3 shall be achieved in order to ensure the suitable performance of both instruments.

5.4 Type testing report

Requirements for type testing report are given in Annex G.

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

6 Filter conditioning, sampling, weighing facilities and weighing procedures

6.1 General

This document specifies the requirements for the weighing facilities to be used within the standard method. These requirements are specified in Table 3.

Table 3 — Requirements for weighing facilities

	Performance characteristic	**Requirement**	**Clause**
1	Weighing room temperature	19 °C to 21 °C measured as hourly mean value [a])	6.2.1
2	Weighing room relative humidity	45 % RH to 50 % RH measured as hourly mean value [a])	6.2.1
3	Uncertainty (95 % confidence) of sensors for temperature measurement	≤ 0,5 K	6.2.1
4	Uncertainty (95 % confidence) of sensors for relative humidity measurement	≤ 2 % RH	6.2.1
5	Balance resolution	≤ 10 µg	6.2.2
6	Uncertainty (95 % confidence) of balance calibration	≤ 25 µg for a range of 0 mg to 200 mg	6.2.2
7	Recording of operational parameters	The following parameters shall be recorded to demonstrate fulfilment of the above requirements: – results of weighing room temperature measurements; – results of weighing room relative humidity measurements.	6.2.1

[a]) The ranges given for weighing room temperature and relative humidity need not to be reduced for the calibration uncertainties of the sensors used for their control.

Filters shall always be handled with tweezers (stainless steel or PTFE-coated).

Storage periods shall be kept as short as possible. Table 4 gives guidance for maximum storage periods.

Table 4 — Filter storage periods

Filter	**Maximum storage period**
Unsampled filters after weighing	2 months (total storage time in weighing room and sampler) or longer if blank measurement remains within specified limits (see 6.7.2)
Sampled filters and field blanks in the sampler	1 month
Sampled filters and field blanks in the weighing room before weighing	1 month

Further details on permitted filter materials can be found in 5.1.5.2.

6.2 Weighing Facilities

6.2.1 Weighing room

A climate-controlled facility shall be used for conditioning and weighing the filters. This facility will be referred to within this document as the “weighing room”, although it may be either a suitable room or cabinet. The temperature and the relative humidity shall be continuously monitored and controlled according to the requirements in Table 3.

The sensors used to measure the weighing room temperature and relative humidity shall fulfil the requirements given in Table 3.

The parameters listed in Table 3 under item 7 shall be recorded and made available for the demonstration of proper operation. For both parameters at minimum hourly averages shall be available.

Before the weighing room is used for routine work its proper operation shall be checked by applying the procedures described in Annex D.

6.2.2 Balance

The balance used shall be installed and operated within the weighing room and have a resolution ≤ 10 µg.

The balance used shall be of such quality that an uncertainty (95 % confidence) for calibration of ≤ 25 µg for a range of 0 mg to 200 mg can be achieved.

6.3 Filter conditioning and weighing prior to sampling

All filters shall be uniquely identified either by marking the filter directly or the filter holder. In cases where the filter is marked directly, the effect of the method for identifying filters shall be tested over a period of 1 month with repeated weighing to see if there is a significant effect upon mass.

Prior to sampling the filter shall be conditioned in the weighing room at 19 °C to 21 °C and 45 % RH to 50 % RH for ≥ 48 h followed by a first weighing (result $m_{c,1}$), and then a second weighing after further conditioning for ≥ 12 h (result $m_{c,2}$).

The difference between the two results shall fulfil the requirement, see Formula (5):

$$\left| m_{\mathrm{c},1} - m_{\mathrm{c},2} \right| \leq 40\ \mu\mathrm{g} \tag{5}$$

NOTE The above difference in mass is equivalent to a difference in measured concentration of 0,7 µg/m³ (at nominal flow and 24 h of sampling).

If this condition is not fulfilled, the filter shall be:

— either discarded,

— or further conditioned for a period ≥ 24 h, reweighed: result $m_{c,3}$.

The difference between the last two results shall fulfil the requirement, see Formula (6):

$$\left| m_{\mathrm{c},2} - m_{\mathrm{c},3} \right| \leq 40\ \mu\mathrm{g} \tag{6}$$

If this condition is not fulfilled, the filter shall be discarded.

The unsampled filter mass shall be taken as the average of the last two consecutive weighings.

A comprehensive field study [14] showed that in most cases the results of the first weighing differ only slightly from the average of the first and second weighing. As a consequence, the second weighing may be waived if the additionally resulting uncertainty was calculated and included in the uncertainty budget of the method. However, it is up to individual laboratory to demonstrate that this situation is appropriate to its own situation.

When the preconditioning test described in Annex C shows that the mass difference for a filter after preconditioning and subsequent regular conditioning is > 40 µg, it is recommended that the above procedure be preceded by a preconditioning at high relative humidity (air saturated with water vapour at 19 °C to 21 °C).

A minimum of two weighing room filter blanks of the same size and material as those used for the sampling shall be kept in the weighing room.

It is recommended that the weighing room filter blanks are from the same batch as those used for sampling.

6.4 Sampling procedure

6.4.1 Filter cassette loading

The filter cassette holds the batch of filters in a sequential sampling device. Depending on the configuration of the sampling device, separate cassettes may exist for fresh and exposed filters. Filter holders shall be loaded with conditioned blank filters in a clean environment, e.g. the weighing room. The filter and its position in the sequential sampler filter cassette shall be documented.

6.4.2 Filter sampling

Filters in a cassette shall subsequently be sampled for the required sampling period, after which it is restored into the filter cassette.

At minimum one filter shall not be sampled but shall remain in the cassette to serve as a field blank.

6.4.3 Sample storage and transport procedures

All sampled filters and field blanks shall be left protected from external contamination during storage and transport, for example in the filter holder, in clean glass petri dishes, or similar containers.

Transport of sampled filters shall be in covered and insulated containers to avoid external contamination and excessive heating. Filters shall be handled with care.

Users of this document shall carefully consider and implement suitable temperature conditions for storage of sampled filters, such that loss of volatile and semi-volatile materials is minimized over the storage period. Storage conditions shall also ensure the prevention of condensation on the filters.

NOTE This can be achieved by transport in cool boxes. Effects of condensation within the cool box on the filters can be avoided by packing the cassettes in plastic bags or by sealing them.

For gravimetric analysis filters shall be introduced into the weighing room within 1 month after sampling.

6.5 Filter conditioning and weighing after sampling

Sampled filters shall be conditioned in the weighing room for ≥ 48 h followed by a first weighing: result $m_{s,1}$, and then after an additional conditioning for 24 h to 72 h: result $m_{s,2}$.

It is recommended to ensure that both sides of the filters are exposed to the conditioning atmosphere.

The difference between the two results shall fulfil the requirement, see Formula (7):

$$\left| m_{s,1} - m_{s,2} \right| \leq 60\ \mu g \qquad (7)$$

NOTE The above difference in mass of is equivalent to a difference in measured concentration of 1 µg/m^3 (at nominal flow and 24 h of sampling).

If this condition is not fulfilled, the result shall be declared invalid, or the filter shall be further conditioned for a period ≥ 24 h and reweighed: result $m_{s,3}$.

The difference between the last two results shall fulfil the requirement, see Formula (8):

$$\left| m_{\mathrm{s},2} - m_{\mathrm{s},3} \right| \leq 60\ \mu\mathrm{g} \tag{8}$$

If this condition is not fulfilled, the result shall be declared invalid.

The sampled filter mass shall be taken as the average of the last two consecutive weighings.

A comprehensive field study [14] showed that in most cases the results of the first weighing differ only slightly from the average of the first and second weighing. As a consequence, the second weighing may be waived if the additionally resulting uncertainty was calculated and included in the uncertainty budget of the method. However, it is up to individual laboratories to demonstrate that this situation is appropriate to its own situation.

6.6 Weighing room procedures

The following procedures shall be applied at every weighing session.

- Weighing room conditions shall be monitored and documented.
- All filters shall be visually checked prior to use for defects such as holes or loose material and discarded if defects are found.
- At the beginning of each weighing session the proper functioning of the balance shall be checked with reference masses with similar mass to the filters, as a measure of accuracy and drift of the balance. If the reading of the balance differs by more than 25 µg from the reference mass, the situation shall be investigated and resolved before proceeding.
- A static discharger shall be used on filters prior to weighing unless it can be demonstrated that there is no need for this (see Annex C).

NOTE 1 For some filter materials a static discharger is normally not necessary. However, it has been found that in some cases static discharging may improve weighing results.

NOTE 2 The need for using a static discharger can be evaluated by performing 40 consecutive weighings with and without static discharger (see also Annex C).

6.7 Filter blanks for ongoing quality control

6.7.1 General

The use of blank filters is an important part of the ongoing quality control concept. For the monitoring of the weighing process including the influence of the filter conditioning, weighing room blank filters are used. Additional effects on the filter mass such as handling the filters, loading and unloading of the sampler, transport, loss of material or de-/absorption of water onto the filter material are considered by the investigation of the mass of field blanks.

6.7.2 Weighing room blanks

The masses of the individual weighing room blank filters (see 6.3) shall be recorded at each weighing session, to check and to ensure constant conditions in the weighing room and to estimate any effects affecting the mass of the filters. If the masses of the blank filters have changed by less than or equal than 40 µg since the last weighing session, the weighing of the filters can proceed. If not, the reason for the deviation shall be investigated and resolved before proceeding.

NOTE The above change in mass of 40 µg for blank filters is equivalent to a change in measured concentration of about 0,7 µg/m³ (at nominal flow and 24 h of sampling).

6.7.3 Field blanks

For effective quality control, field blanks shall be obtained for all sampling sites (see 6.4.2). The field blanks are conditioned alongside filters used for sampling and shall be weighed like all unsampled filters before transportation and storage during filter sampling at the monitoring site. After sampling, the field blanks shall again be conditioned as sampled filters (see 6.5) in the weighing room. The mass difference of the field blank after and before the sampling period is the field blank mass.

The absolute value of the field blank mass shall be less than or equal to 60 µg.

NOTE 1 The detailed procedures for dealing with exceedances of this criterion are left to the local operator.

NOTE 2 The above difference in mass is equivalent to a difference in measured concentration of 1 µg/m³ (at nominal flow and 24 h of sampling).

NOTE 3 A systematic exceedance of the field blank criterion can be an indicator for an insufficient suitability of the filter material.

Individual field blanks shall not be used for the correction of measured masses of PM on filters because the assumption that the processes affecting the field blank and the sample filter are the same is unlikely to be valid due to the flow of air passing through the sampled filter.

7 Ongoing quality control

7.1 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 monitoring periods in the field. This requires that maintenance, test and calibration procedures shall be followed which are essential for obtaining accurate and traceable air quality data. In this subclause, procedures for maintenance, checks and calibration are given. These procedures are regarded as a minimum necessary for maintaining the required quality level.

Requirements for quality checks and calibrations have been determined on the basis of the identification of sources contributing to measurement uncertainty of PM in general.

It is recommended that the organisations performing the ongoing quality control procedures are accredited according to an internationally accepted standard. EN ISO/IEC 17025 [15] is the usual harmonized international standard that applies.

NOTE A formal accreditation by a member body of the European Accreditation Organization to EN ISO/IEC 17025 [15] is a demonstration of conformity.

7.2 Frequency of calibrations, checks and maintenance

The checks and calibrations together with their frequency are summarized in Table 5. Criteria are also given for adjustment, calibration or maintenance of the equipment used. The transfer standards for the checks shall be sufficiently accurate to determine whether the action criteria in Table 5 are met.

Table 5 — Required frequency of calibration, checks and maintenance

Calibration, checks and maintenance	**Subclause**	**Frequency [b])**	**Lab (L)/ Field (F)**	**Action criteria [a])**	**Uncertainty requirements for transfer standards**
Regular maintenance of components of the sampler	7.4	As required by manufacturer	L / F		
Checks of sensors for temperatures and pressure in the sampler	7.5	Every 3 months	F	±3 K ±1 kPa	±1,5 K ±0,5 kPa
Calibration of sensors for temperatures and pressure in the sampler	7.6	Every year	L / F	±3 K ±1 kPa	≤ ± 1,0 K ≤ ± 0,5 kPa
Check of the accuracy of sampler clock	7.13	Every 3 months	F	±15 min	
Check of the sampler flow rate	7.7	Every 3 months	F	5 %	2 %
Calibration of the sampler flow rate	7.8	Every year	L / F	3 %	≤ 1 %
Leak check of the sampling system	7.9	Every year	F	1 %	
Checks of the weighing facility sensors for temperature and relative humidity	7.10	Every 6 months	L	±1 K ±3 % RH	≤ 0,4 K ≤ 3,0 % RH
Calibration of the weighing facility sensors for temperature and relative humidity	7.11	Every year	L	±1 K ±3 % RH	≤ 0,2 K ≤ 2 % RH
Calibration of the balance	7.12	Every year	L		
[a]) With reference to nominal values. Calibrations shall be performed, and adjustment shall be undertaken, if action criteria are exceeded. [b]) The frequency of the checks may be relaxed when sufficient history exists demonstrating that drifts of sensor readings and flow rates remain within the specified requirements. If the check fails a traceable calibration shall be performed.					

7.3 Recording of operational parameters

The user shall periodically collect and evaluate the following parameters:

- Flow rate (Maximum and minimum flow during sampling and average over the sampling period)
- Sampling time and sample volume
- Air temperature in filter section

- Ambient temperature
- Temperature of filter storage;
- Ambient pressure

NOTE Optionally, other operational parameters can be recorded, including:

- pressure drop over sample filter;
- ambient humidity

In addition, an operational status shall be recorded to assist with fault diagnosis.

The user shall be able to retrieve the data either by direct communication with a computer / external data logging / storage device, and / or via remote communication by Ethernet / telephony.

7.4 Maintenance of the sampling system

Leak checks shall be performed as described in 5.1.7.

Sample inlets shall be cleaned and impaction plates cleaned and greased according to the manufacturer's requirements, taking into account local particulate concentrations. If no instructions on cleaning/greasing intervals are given by the manufacturer, the impaction plates shall be greased and nozzles shall be checked - and cleaned if necessary - at least every:

- 30th sample for PM_{10};
- 15th sample for $PM_{2,5}$;

depending on the PM concentration.

NOTE 1 The optimum frequency for cleaning and re-greasing the impaction plate will be strongly site-dependent.

NOTE 2 Another option is to rotate the impaction plate in order to expose the outlets of the impactor nozzles to clean spots on the plate.

7.5 Checks of sampler sensors

Where temperature and pressure (difference) sensors are essential for controlling the proper functioning of the instrument, such as for flow control and/or otherwise defined by the manufacturer, 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 5, the sensors shall be recalibrated and adjusted according to the manufacturer's instructions.

7.6 Calibration of sampler sensors

Where temperature and pressure (difference) sensors are essential for controlling the proper functioning of the instrument, such as for flow control and/or otherwise defined by the manufacturer, these shall be calibrated at least once per year taking into account the action criteria in Table 5 using appropriate transfer standards with readings traceable to (inter)nationally accepted standards. These transfer standards shall fulfil the following uncertainty specifications (95 % confidence):

- temperature: 1,0 K,
- pressure: 0,5 kPa.

7.7 Checks of the sampler flow rate

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 sample line.

All sensors shall be in operation during the flow check. The readings of the sensors shall be used to convert the flow rate to ambient conditions of temperature and pressure.

Check that the temperature range specified by the manufacturer for proper operation of the flow measurement device is appropriate to their own practical conditions.

Flow meters shall be allowed sufficient time to condition to the actual temperatures at which measurements are performed.

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.

7.8 Calibration of the sampler flow rate

Calibration shall be performed every year taking into account the action criteria in Table 5 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 ≤ 1 % at laboratory conditions. Flow calibrations shall include the sample line. All sensors shall be in operation during the flow calibration.

7.9 Leak check of the sampling system

The leak test of the sampling system shall be checked yearly as described in 5.1.7 and shall be performed upon relocation or installation at a monitoring station.

If the test reveals a leak rate of > 1 %, the sampling system shall be maintained and retested for leaks.

7.10 Checks of weighing facility sensors

The sensors shall be checked every 6 months against appropriate transfer standards with readings traceable to (inter)nationally accepted standards. The uncertainty (95 % confidence) of the temperature measurement of the transfer standard shall be better than 0,4 K, the uncertainty (95 % confidence) of the transfer standard for relative humidity measurements shall be better than 3,0 % RH.

If the sensor values determined using the transfer standards differ by more than the criteria given in Table 5, the sensors shall be recalibrated and adjusted according to the manufacturer's instructions.

7.11 Calibration of weighing facility sensors

The sensors shall be calibrated at least once per year taking into account the action criteria in Table 5 using appropriate calibration standards with readings traceable to (inter)nationally accepted standards. The uncertainty (95 % confidence) of the temperature measurement of the calibration standard shall be better than 0,2 K, the uncertainty (95 % confidence) of the relative humidity measurements of the calibration standard shall be better than 2 % RH.

7.12 Balance

The balance shall be calibrated against appropriate masses traceable to national or international standards at least once a year. The uncertainty (95 % confidence) of the mass measurement shall be better than 25 µg for a range of 0 mg to 200 mg.

7.13 Check of the accuracy of sampler clock

The accuracy of the sampler clock shall be tested every three months. Maximum drift of the clock shall be less than ± 15 min over a three months period.

8 Expression of results

Measurement results shall be expressed as μg/m³, where the volume of air is that at the ambient conditions near the inlet during sampling.

The result is calculated as the difference in mass between the sampled and unsampled filter, divided by the sample volume, determined as the flow rate multiplied by the sampling time (see Formula (9)).

$$c = \frac{m_\mathrm{l} - m_\mathrm{u}}{\varphi_\mathrm{a} \cdot t} \qquad (9)$$

where

c is the concentration, in micrograms per cubic metre (μg/m³);

m_l is the sampled filter mass, in micrograms (μg);

m_u is the unsampled filter mass, in micrograms (μg);

φ_a is the flow rate at ambient conditions, in cubic metres per hour (m³/h);

t is the sampling time, in hours (h).

9 Performance characteristics of the method

9.1 General

The performance characteristics of the standard measurement method are covered in the following three subclauses:

- Subclause 9.2 outlines the GUM approach for determining the measurement uncertainty made using the standard method;
- Subclause 9.3 lists the individual sources of uncertainty and whether they are determined by field tests or otherwise; the individual sources of uncertainty are combined to give the combined uncertainty of the standard measurement method;
- Subclause 9.4 compares the uncertainty with the data quality objectives from Directive 2008/50/EC.

9.2 GUM concept

Following Directive 2008/50/EC, the assessment of measurement uncertainty of the standard measurement method shall be based on the approach described in the Guide to the expression of uncertainty in measurement (GUM), published as JCGM 100. The uncertainty shall be expressed at the region of the PM limit value. The approach requires the establishment of a model equation which represents the procedure for obtaining the desired output quantity from the input quantities (see Clause 8 and Formula (9)).

The output quantity c is the PM mass concentration; the input quantities are the masses m_l and m_u of the sampled and unsampled filter respectively, the flow rate φ, and the sampling time t:

- identification and quantification of all individual sources of uncertainty related to the input quantities, expressed as standard deviations, u_i;
- combination of the individual uncertainties to obtain a combined standard uncertainty, according to the dependence of the output quantity on the respective input quantity in the model equation; where the individual sources of uncertainty are independent and all contribute linearly to the output quantity, the square of the combined standard uncertainty u_c is defined by Formula (10):

$$u_c^{\,2} = \Sigma\,(u_i)^2 \qquad (10)$$

- calculation of the expanded uncertainty U, by multiplying u_c by the coverage factor k, see Formula (11):

$$U = k \cdot u_{\mathrm{C}} \qquad (11)$$

The quantity U is such that there is a 95 % probability that the true value lies within ± U of the measured value. Where a sufficient number of degrees of freedom apply, k is taken to be 2.

The expanded uncertainty shall then be compared with the measurement uncertainty required in the relevant data quality objectives.

Unlike the situation for most other air pollutants, the lack of representative reference materials means that it is not possible to evaluate the effect of individual sources of uncertainty on the measurement result by systematically varying each one in laboratory tests.

However, the combined effect of many sources of uncertainty can be evaluated using field measurements from pairs of collocated samplers simultaneously measuring the same atmosphere, and whose filters are handled in parallel. Specifically, the standard deviation u_{bs} of differences between identical samplers, further described in 5.3.1 serves as a measure of these combined effects according to Formula (12):

$$u_{\mathrm{bs}}^2 = \frac{\sum (x_{\mathrm{i},1} - x_{\mathrm{i},2})^2}{2n} \qquad (12)$$

where

$x_{i,1}$ and $x_{i,2}$ are the simultaneous concentration data from the nominally identical samplers 1 and 2;

n is the number of paired values.

The determination of the measurement uncertainty then depends on deciding whether individual sources of uncertainty will be included within the between-sampler uncertainty u_{bs}, and where they are not, quantifying and combining them appropriately.

In general, it is considered that the majority of random contribution to the measurement uncertainty will be incorporated within the between-sampler uncertainty u_{bs}.

NOTE Alternatively, the measurement uncertainty can be determined using the direct approach according to EN ISO 20988 [27] (i.e. based on co-located measurements).

9.3 Individual uncertainty sources

9.3.1 General

From the model Formula (9) in Clause 8, there are three input measurements which contribute to the output quantity, namely collected particulate mass, flow rate and time.

Individual uncertainty sources within each of these input measurements are given below.

9.3.2 Collected particulate mass

9.3.2.1 Deviation of size selection performance from designated characteristic

The designated particulate size selection characteristic for the PM fraction of suspended particulate matter is defined by the design in Annex A, when used at the correct flow rate. Deviations in transmitted size fraction will therefore depend on:

— deviations from the ideal mechanical design due to dimensional tolerances, build-up of dust, or failure to follow manufacturer`s requirement for impactor plate greasing (see 7.4);

— deviations from the required flow rate.

These deviations are limited by the design tolerances and the procedures set out in Clauses 6 and 7, and can be considered as negligible.

Also, deviations in transmitted size fraction will depend on the ambient temperature, because of the temperature dependence of the viscosity of the ambient air. In principle this variation is an intrinsic part of the standard method, and therefore does not contribute to the uncertainty of the result.

9.3.2.2 Deposition losses in the connecting pipe work

There are several different mechanisms which can potentially lead to losses of particulate matter in the pipe work between the inlet and the filter [16].

Losses due to gravitational settling and inertial deposition are considered to be negligible by using vertical sampling lines, and by avoiding flow restrictions (such as bends) in the sampling line. Losses due to electrostatic deposition are made negligible by using electrically conducting pipe work.

Another factor influencing the transport losses in the connecting pipe work is thermophoretic deposition, which is kept negligible by avoiding a large temperature drop between the connecting pipe work and the sampled air. These factors are limited by the requirements in Clause 5.

Finally, particle diffusion is only significant for very small particles (less than around 30 nm), which have a negligible contribution to the observed PM mass.

For PM the loss within pipe work as specified in Clause 5 is considered to have an insignificant contribution to the measurement uncertainty.

9.3.2.3 Filter collection efficiency

Losses of particulate matter due to transmission through the filter are expected to be very small, and are limited by the requirement on filters in Clause 5.

It is considered that any contribution to the measurement uncertainty will be negligible.

9.3.2.4 Loss of semi-volatile particulate matter between collection and weighing

It is known that substantial fractions of PM mass may be composed of semi-volatile components, such as ammonium nitrate, which can volatilize at any time between entry to the sample inlet and weighing of the sampled filter. Key factors in the rate of volatilization are the temperatures of the sampling system and the filter, relative humidity, filter material, and the flow rate. Hence, some loss of semi-volatile material is possible when this document is followed and the loss will vary with time and location.

This volatilization loss is limited within the standard measurement method by the constraints on the sampling system components set out in 5.1, and on sample storage, transport and conditioning set out in Clauses 5 and 6.

In principle, the definition of PM for the purpose of this document incorporates these losses of semi-volatile material. Therefore, the average effect of volatilization losses on the measurement of PM is considered to be zero by convention, when the constraints set out in this document are followed.

The effect on uncertainty of variations in losses of material from similar samples experiencing similar storage, transport and conditioning will be included in the variation within the between-sampler uncertainty, u_{bs}.

Variations in loss of semi-volatile material due to variations in sample storage, transport and conditioning permitted within the constraints set out within Clause 6 will not have been evaluated within the between-sampler uncertainty and are assessed separately.

9.3.2.5 Change in filter mass due to water content

It is known that the mass of filters, without any collected particulate matter, varies with humidity in a way which varies between filter materials, and also between filters nominally of the same material.

For the purpose of this document only changes in the effect of humidity between the unsampled and sampled weighings are relevant. This effect is controlled by the conditioning requirements for unsampled and sampled filters set out in Clause 6.

The contribution to measurement uncertainty due to variations of humidity on the filter will be partially included in the variation determined within the field parameter, u_{bs}. However, a change in average relative humidity from 45 % to 50 % between the unsampled and sampled filter weighing sessions would be permissible according to the standard but will not have been accounted for in the u_{bs} parameter, as the individual filters will have experienced the same conditions. The maximum effect is quantified by the constraints on mass change on unsampled filters (field blanks) at separate weighing sessions (6.7.3).

9.3.2.6 Variation in mass of particulate matter due to water content

A second function of the conditioning constraints is to bring the collected particulate matter to a standard level of water content by prescribing the temperature and relative humidity before and during weighing. Hygroscopic constituents of PM, e.g. ammonium salts and sodium chloride, will sorb amounts of water that will vary with air relative humidity [17]. The effect of this on the measurement uncertainty is partly quantified by the constraint on mass change at the separate weighings of sampled filters given in 6.5. Experimental work performed by CEN/TC 264/WG 15 has shown that for samples expected to represent worst-case scenarios the difference in mass measured is in the order of 100 µg (see Annex E).

In addition, the water content of the sampled PM may also depend on the “history” of the sample, i.e. the ambient air conditions at sampling. The water content will depend on whether the relative humidity at sampling is above the so-called deliquescence relative humidity, or below the so-called efflorescence relative humidity of the hygroscopic constituents of PM. For the above constituents these points lie roughly at 75 % RH and 35 % RH, respectively. The potential hysteresis, e.g. the difference in mass of PM measured when approaching the conditioning relative humidity from above the deliquescence RH or from below the efflorescence RH has been estimated in a limited number of experiments using samples assumed to represent worst-case conditions (see Annex E). The maximum difference observed between masses measured at 45 % RH and 50 % RH is in the order of 80 µg. Assuming a uniform distribution, a contribution of about 46 µg results.

9.3.2.7 Changes in buoyancy effects between the unsampled and sampled weighings

The density of the surrounding air, which causes a buoyancy effect on the weight of the filters, is predominantly determined by the air pressure and temperature. Of these only the temperature is controlled as part of Clause 6. The effects of changing conditions between weighing sessions would not be assessed by the field tests.

However, the expected effects of buoyancy changes can be calculated from physical principles to be less than 3 µg.

9.3.2.8 Balance uncertainty, span and zero drift

Balances shall have an uncertainty, when calibrated, of less than 25 µg (see 6.2.2). Due to the fact that the difference between weighings is used to calculate mass concentrations, this only contributes to the uncertainty budget if balance adjustment or calibration are carried out between the two weighings.

Uncorrected span and zero drift of a well calibrated balance can lead to errors of tens of µg. These errors are random and limited by the procedures for use of weighing room blank filters set out in Clause 6.

The contribution to uncertainty will be determined by the criteria in Clause 6.

9.3.2.9 Effects of static electrical forces during weighing

Static electrical charge is known to have a potentially significant effect on the weighing of some filter materials (e.g. PTFE). However, the correct use of a static discharger as required in Clause 6 is considered to control this. Any effect is considered to be included in the variation determined within the field test, u_{bs}.

9.3.2.10 Contamination or loss of filter material between unsampled and sampled weighings

It is possible to introduce significant errors in the weight of collected particulate matter because of the loss of filter or particulate material during handling and transport, or the addition of matter not collected during sampling. The procedures for handling, storage and transport in Clause 6 are designed to control these factors. The contribution to the uncertainty in normal use of the standard is considered to be included in the variation determined within the field parameter, u_{bs}.

9.3.2.11 Artefacts due to interactions between the filter material and gases

In addition to water, filter materials may adsorb volatile compounds present in the sampled air. Examples are ammonia, nitrogen dioxide and organic gases. Contributions to the filter mass will vary with concentrations of the gases and the chemical nature of the filter material. Adsorption may even lead to a reduction of losses of semi-volatile constituents of PM (9.3.2.4).For the purpose of application of this document the effect of adsorption gases on samples is recognized but not considered in the uncertainty budget.

9.3.2.12 Flow rate (φa)

The flow measurement can be based on several different physical principles, which have different influencing factors. However, the uncertainty is controlled by the requirements on the flow system set out in 5.1 and the parameters needing to be controlled shall be established by the operator in each case.

There will be two components of the flow uncertainty, firstly arising from the accuracy of the transfer standard used for calibration, and secondly from any net deviation from the required flow rate from the calibrated value over the period of the measurement. As set out in 5.1, the average flow is controlled to within ± 2 %, while the flow meter is calibrated against a transfer standard with an uncertainty of ≤ 1 %

(with 95 % confidence). These figures have been combined in quadrature to give an effective contribution in Table 1, for the uncertainty contribution to flow not covered by the field parameter, of 2 %.

Flow measurement can also be influenced by differences in flow rate between the sampling head and the flow meter, pressure drop over the filter, wind, temperature and pressure influences on the flow meter, and leakage in pipe work or around the filter holder. These factors are controlled by the QA/QC procedures in Clause 7, and any residual contribution to the uncertainty is considered to be included in the variation determined within the field parameter, u_{bs}.

9.3.3 Time (t)

There are two elements which may contribute to the uncertainty of the time measurement.

Firstly, the measurement inaccuracy of any modern timing device will be a negligible effect for the purpose of this document.

Secondly, there will be some difference between the measured time and the actual time during which the filter was sampling at the required flow rate. Following 5.1.9 the maximum difference is required to be 1 min over the sampling period of 24 h, i.e. a variation of 0,07 %. Any effect on the uncertainty is negligible.

9.3.4 Uncertainty budget

The individual sources of uncertainty are summarized in Table 6. The majority of random contributions to the measurement uncertainty (e.g. balance mass reading and zero drift) are incorporated within the between-sampler uncertainty (u_{bs}), as stated before. The value for the performance characteristic of u_{bs} is given in Table 6 with 2 µg/m³ in accordance with chapter 5.3.1. This figure shall not be lowered due to differing results in the type testing report. Sampling material, weighing room conditions and many other factors that vary from laboratory to laboratory have an effect on this figure. Therefore, this figure shall only be altered based on extensive field tests according to chapter 9.2 by the laboratory carrying out the PM-measurements.

For the uncertainty contributions, effecting the mass difference and the flow Table 6 represents the maximum allowable contribution for each uncertainty source (referring to Table 3 and 5). Results lower than these maximum permitted values obtained during type testing and ongoing quality control may be substituted to calculate specific performance for individual instruments.

Table 6 does not list contributions that are either negligible (e.g. inlet performance, transport loss, filter efficiency) or zero by convention e.g. loss of semi-volatiles. The user needs to be aware that some systematic differences e.g. filter materials are also not included in the uncertainty budget here and that these can only be seen in a proficiency exercise with other users [14].

Table 6 — Individual sources of uncertainty

Component	**Symbol**	**Performance characteristic**	**Distribution type**	**Contribution**
Between-sampler uncertainty u_{bs}	u_{bs}	2	normal	2 µg/m³
Uncertainty contributions affecting the mass difference (u_m): Weighing and hysteresis				
Balance: calibration	u_{mba}	25	rectangular	$0,5\frac{25}{\sqrt{3}}$ µg
Hysteresis effects due to sorption of water vapour includes all effects due to humidity	u_{mh}	80	rectangular	$\frac{80}{\sqrt{3}}$ µg
Sum of filter mass uncertainties	u_m			47 µg
Uncertainty contributions affecting flow (u_f):				
volumetric flow	u_{fc}	2	rectangular	$\frac{2}{\sqrt{3}}$ %
Calibration certificate	u_{cert}	0,5 % (1 %/k)	normal	0,5 %
Sum of flow uncertainties	u_f			1,3 %

In the following the overall standard measurement uncertainty u_c is calculated according to Formula (13):

— for a nominal sample volume of 55,2 m³ (2,3 m³/h x 24 h)

— at the levels of the limit values for PM_{10} and $PM_{2,5}$.

$$u_c^2 = \left(\frac{u_m}{m_1 - m_2}\right)^2 + \left(u_f\right)^2 + \left(\frac{u_{bs}}{L}\right)^2 \qquad (13)$$

with

$(m_l - m_2)$ calculated at the level of the limit value;

L daily limit value of 50 µg/m³ for PM_{10}.

NOTE For $PM_{2,5}$ a limit value is only defined with a reference period of 1 year. Therefore a substitute daily limit value for $PM_{2,5}$ of 30 µg/m³ is used.

From the specified values in Table 6, the combined relative uncertainties are then

- PM_{10}: 4,5 %
- $PM_{2,5}$: 7,4 % for a level of 30 µg/m³.

An exemplar uncertainty budget calculation is given in Annex H.1.

9.4 Expanded uncertainty vs. EU Data Quality Objectives

The uncertainties of 9.3 are to be compared with the data quality objectives described in Directive 2008/50/EC [1], notably for the daily limit values (see 9.3). However, also the uncertainties at the level of the annual limit values have been calculated.

For all limit values, the expanded uncertainty at a 95 % level of confidence is given by Formula (14):

$$U = 2u_c \tag{14}$$

The average annual concentration of PM is obtained by averaging a minimum of 0,9 × 365 daily values, taking into account that components of uncertainty which contribute randomly will have a reduced impact. For the purpose of this document it is assumed that the u_{bs} parameter represents random contributions, while other contributions remain as they were for the daily values.

The annual combined relative uncertainty is given by Formula (15):

$$u_c^2 = \left(\frac{u_m}{m_1 - m_2}\right)^2 + \left(u_f\right)^2 + \left(\left(\frac{u_{bs}}{L}\right)^2 \cdot \frac{1}{365 \times 0,9}\right) \tag{15}$$

with

L limit value; here the annual limit value of 40 µg/m³ for PM_{10} and 25 µg/m³ for $PM_{2,5}$.

NOTE An exemplar uncertainty budget calculation is given in Annex H, referring to Limit Values in Directive 2008/50/EC [1] . In the event that the air quality standards are updated in future iterations of Directive 2008/50/EC [1], the user can use these new values to calculate measurement uncertainties.

Table 7 summarizes the expanded uncertainty of the standard measurement method at the daily and annual limit values, together with the EU uncertainty requirements.

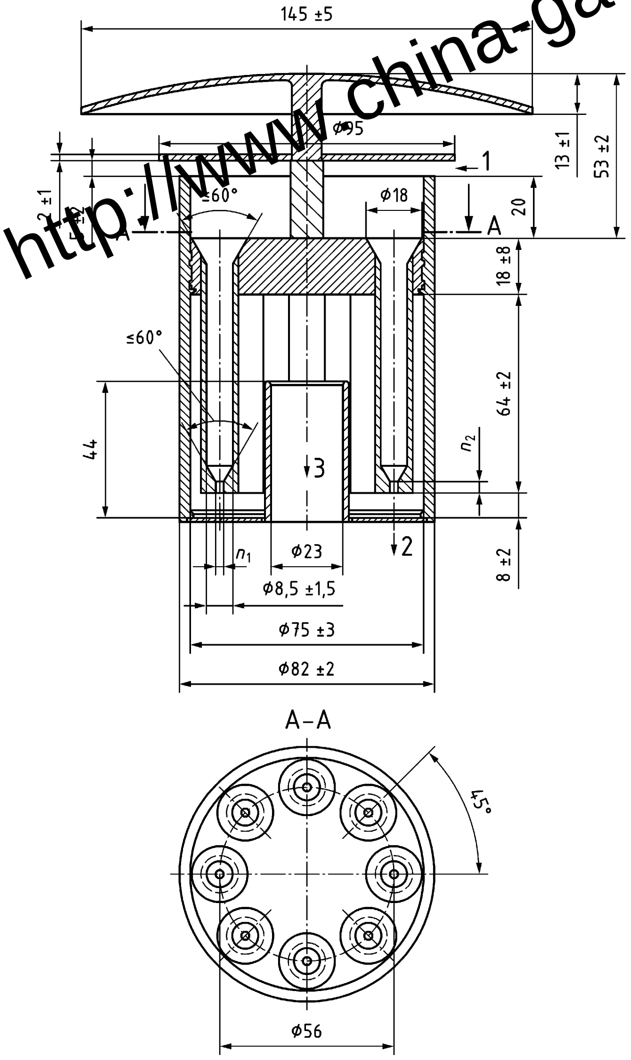
Table 7 — Expanded uncertainties of the standard method

Limit value	EU uncertainty requirement %	Expanded relative uncertainty %
PM_{10}		
– daily: 50 µg/m³	25	9,0
– annual: 40 µg/m³	25	5,0
$PM_{2,5}$		
– daily: 30 µg/m³ [a]	25	14,8
– annual: 25 µg/m³	25	7,4
[a] substitute daily limit value for $PM_{2,5}$ of 30 µg/m³, see Note above		

Annex A
(normative)

Design drawing of standard inlet for the sampling of PM$_{10}$ and PM$_{2,5}$

Dimensions in millimetres



Key

Tolerance of all measures unless otherwise specified: ± 0,2 mm, or ± 0,5°, respectively.

1 air sample
2 drainage for impacted water
3 to filter
n1 nozzle inner diameter
  for PM$_{2,5}$: 2,6 + 0,01 mm / - 0 mm (H7 manufacturing tolerance according ISO 286-2 [28])
  for PM$_{10}$: 6,5 + 0,015 mm / - 0 mm (H7 manufacturing tolerance according ISO 286-2 [28])
n2 nozzle length
  for PM$_{2,5}$: 3,7 ± 0,1 mm
  for PM$_{10}$: 7,0 ± 0,1 mm

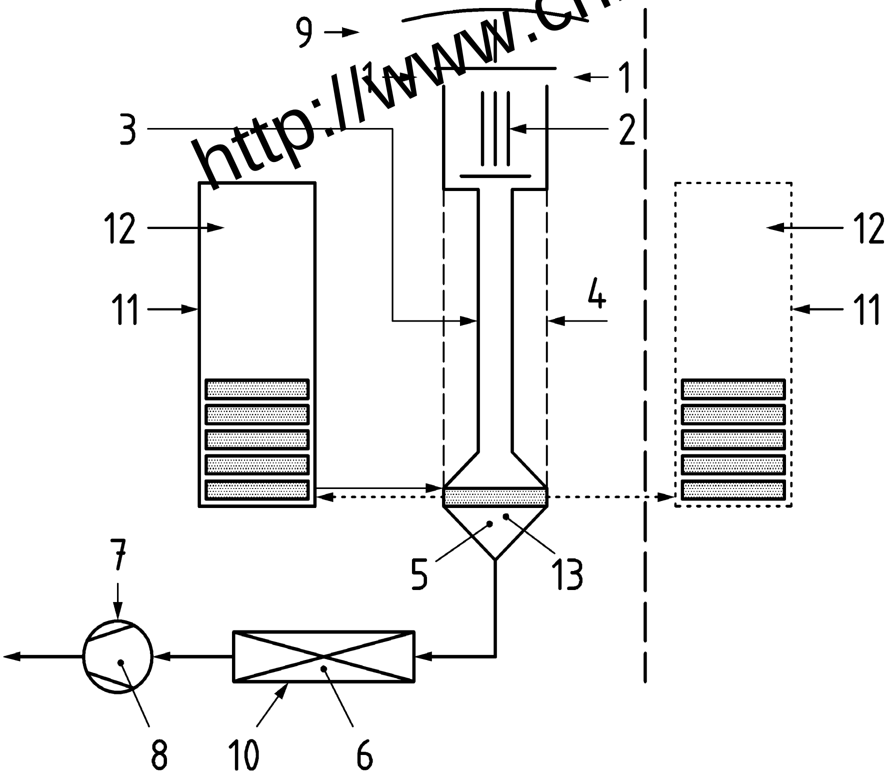
Figure A.1 — Schematic design of PM$_{10}$ and PM$_{2,5}$ inlet, flow rate 2,3 m^3/h

The design shall not be patented.

Annex B
(informative)

Scheme of PM standard sampler

The figure below provides an illustration of a possible flow schematic for a sequential sampler. Alternative designs to fulfil the requirements of this document are also possible and permitted.



Key

	sheath air inlet and container/tube system (optional)	8	flow control system
◄--►	systematic path of blank/sampled filter	9	measurement of temperature T_a and pressure P_a
1	air sample (T_a, P_a)	10	measurement of temperature T and pressure P (if required for flow control)
2	impactor inlet	11	sample changer and filter storage
3	connecting pipework	12	measurement of storage temperature
4	sheath air inlet (optional)	13	measurement of air temperature near to the filter
5	filter holder		
6	flow measuring device		
7	pump		

Figure B.1 — Scheme of PM standard sampler

Annex C
(informative)

Suitability tests for filters

C.1 Particle retention test

It is recommended that filter manufacturers determine the filter separation efficiency according to standard methods such as EN 13274-7 [23] or EN 1822-1 [24]. The filter shall be able to retain particles of a nominal aerodynamic size of 0,3 µm with an efficiency ≥ 99,5 %.

C.2 Filter material integrity test

It is essential that the integrity of a filter is maintained during regular handling, e.g. insertion into and removal from a filter holder, insertion into and removal from a petri dish, weighing, etc.

The integrity of a particular filter type may be tested as follows:

- randomly select 10 filters from a batch of ≥ 100;
- condition the filters as described in 6.3 and weigh;
- insert the filters in filter holders in the weighing room;
- remove the filters from the filter holders after 1 h;
- reweigh the filters.

The maximum loss of mass permitted for each filter is 40 µg.

C.3 Base mass reproducibility test

For filters consisting of a base material with binder, e.g. certain quartz- or glass fibre filter types, the fraction of the binder present may affect the filter behaviour considerably. The variation in the base mass of a series of filters from the same batch or different batches of such filters may be an indication of a lack of consistency in manufacturing. The variation, expressed as the relative standard deviation of the filter mass, shall be below 20 %.

C.4 Static charging test

To evaluate the necessity for filters to remove static charges before weighing the following test may be conducted:

- randomly select 10 filters from a batch of ≥ 100;
- condition the filters as described in 6.3 and weigh without static discharging;
- reweigh the filters after static discharging;
- the maximum acceptable difference for individual results is 40 µg.

C.5 Water sorption test

A more complex test for evaluation of the suitability of a filter type consists of a test in which a series of filters is based on a simulation of the actual process a field blank may go through under relative worst-case conditions:

a) a first conditioning and weighing as described in 6.3,

b) a subsequent exposure to high relative humidity (close to 100 %),

c) a subsequent conditioning as described in (6.3), followed by a series of weighings to establish the mass change of the filter.

   The test may be conducted as follows.

   - randomly select 10 filters from a batch of ≥ 100;
   - condition and weigh each filter as prescribed in 6.3;
   - expose the filters to air with a relative humidity close to 100 % at a temperature of 20 °C ± 1 °C for a period of 15 d;
   - recondition the filters as prescribed in 6.3, and weigh them after 2 d, 3 d and 7 d of conditioning; the mass after 2 d is $m_{i,2}$, the mass after 3 d is $m_{i,3}$, the mass after 7 d is $m_{i,7}$.

The following criteria apply:

- $m_{i,2} - m_{i,3} \leq 40\ \mu g$,
- $m_{i,3} - m_{i,7} \leq 40\ \mu g$.

If one of these criteria is not fulfilled this is an indication of a slow process of irreversible sorption of water and a lack of suitability of the filter type.

NOTE 1 Instruments for the performance of such tests ("dynamic vapour sorption systems") are commercially available.

NOTE 2 By considering results for individual filters rather than averages this test is also a measure of "between-filter" variability.

NOTE 3 Other suitability tests can be required for filters used for analytical purposes e.g. heavy metals or PAHs.

Annex D
(normative)

Initial suitability testing of weighing facilities

D.1 Accuracy and stability of temperature and relative humidity

In order to establish the spatial and temporal variations of the temperature and relative humidity in the weighing room, measurements of both parameters shall be performed using calibrated sensors according to 6.3.

Measurements shall be performed at minimum at the following locations:

- at/in the filter conditioning site or compartment,
- at a point representative for the conditions around the balance.

Measurements shall be performed for a minimum of 24 h during which 1-h average values shall be recorded. These shall fulfil the requirements of 6.3 at each individual location.

The tests shall first be performed in the weighing room without activities. It shall then be repeated when the activities prescribed in D.3 are performed.

D.2 Accuracy and stability of balance

Accuracy and precision of the balance shall be established by replicate weighings of a mass piece of 100 mg or 200 mg. Weighings shall be performed every 30 min during a period of 4 h. The criteria for acceptance of the balance are as follows.

- the precision of the weighings, expressed as the standard deviation of individual results, shall be ≤ 10 µg;
- the drift of the balance readings during the 4-h period shall be ≤ 10 µg/h.

D.3 Accuracy and precision of the weighing procedure

Accuracy and precision of the total weighing procedure shall be established by replicate weighings of one blank and one sampled filter. The procedure shall include static discharging if required (see including static discharging, if any; see 6.6). Weighings shall be performed every 30 min during a period of 4 h. The criteria for acceptance of the full weighing procedure are as follows.

- the precision of the weighings, expressed as the standard deviation of individual results, shall be ≤ 10 µg;
- the drift of the filter masses during the 4-h period shall be ≤ 10 µg/h.

Annex E
(informative)

Results of experimental work

A limited number of experiments have been performed to address some of the major sources of uncertainty associated with the application of the procedure:

i) the effect of exposure of blank filters to high relative humidities followed by regular conditioning;

ii) the behaviour of field blanks with and without prior exposure to high relative humidities;

iii) the effect of varying relative humidities on the masses of blank and sampled filters (including hysteresis, see 9.3.2.6.).

The following filter types were tested:

1) quartz fibre without and with binder,

2) glass fibre without and with binder,

3) Polytetrafluoroethylene (PTFE),

4) Polytetrafluoroethylene (PTFE)-coated glass fibre.

Three brands of quartz fibre filter without binder were evaluated in the tests.

The results of the tests are summarized as follows.

a) The mass change upon exposure of filters to high relative humidities depends strongly on the filter type. Quartz- and glass-fibre filters have a high susceptibility for water, with increases in mass over a 5-week period of 150 µg or more. Masses of Polytetrafluoroethylene (PTFE) and Polytetrafluoroethylene (PTFE)-coated glass fibre are hardly affected by exposure to high relative humidities.

b) Considerable differences in behaviour are observed between different brands of filters of the same type.

c) Regular conditioning after exposure to high relative humidities reduces filter masses usually to a constant level (within ± 30 µg) within 2 d to 3 d. For some filters, the mass after regular conditioning is approximately at the level before exposure to high relative humidities. For other filters, the adsorption of water is partly irreversible and/or incomplete. These filters would need exposure to high relative humidities (preconditioning) prior to regular exposure.

d) Preconditioning generally reduces the level of field blanks of quartz- and glass-fibre filters upon storage for 15 d in a sequential sampler. However, under ambient conditions of low temperature and low relative humidity, strongly negative field blank values may result for field blanks preconditioned at high humidity due to desorption of water. Preconditioning has no marked effect on the behaviour of Polytetrafluoroethylene (PTFE) and Polytetrafluoroethylene (PTFE)-coated glass fibre filters.

e) Exposure of filters to varying relative humidities reveals:

   1) the potential of the particulate matter collected on the filter to adsorb large quantities of water (up to several mg) when exposed to a relative humidity of about 90 % RH;

   2) a clear difference in the mass of sorbed water when approaching regular conditioning RH (50 %) from below the efflorescence RH or above the deliquescence RH (hysteresis); the hysteresis is found predominantly in the region of 50 % RH to 80 % RH.

Annex F
(informative)

Impactor efficiency

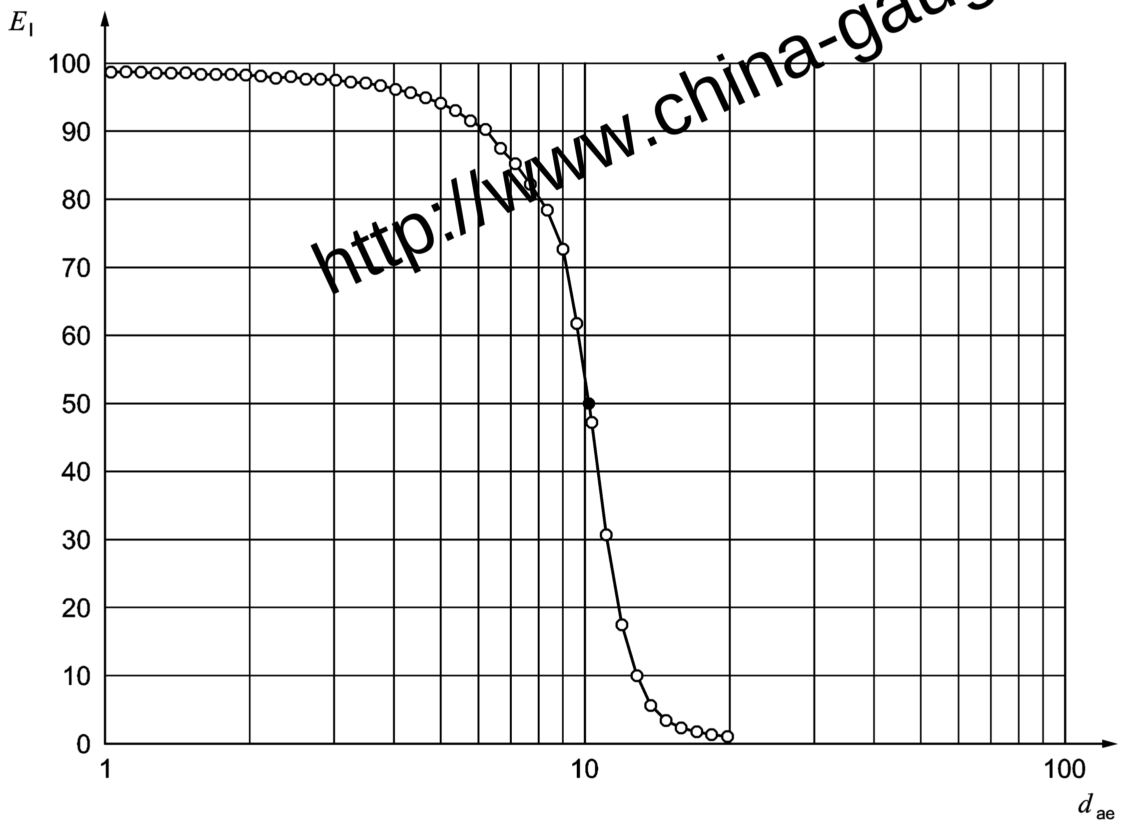


Figure F.1 — Impactor efficiency E_I in %,, in relation to the particle aerodynamic diameter d_{ae}, µm, of the standard inlet for the sampling of PM_{10} [25]

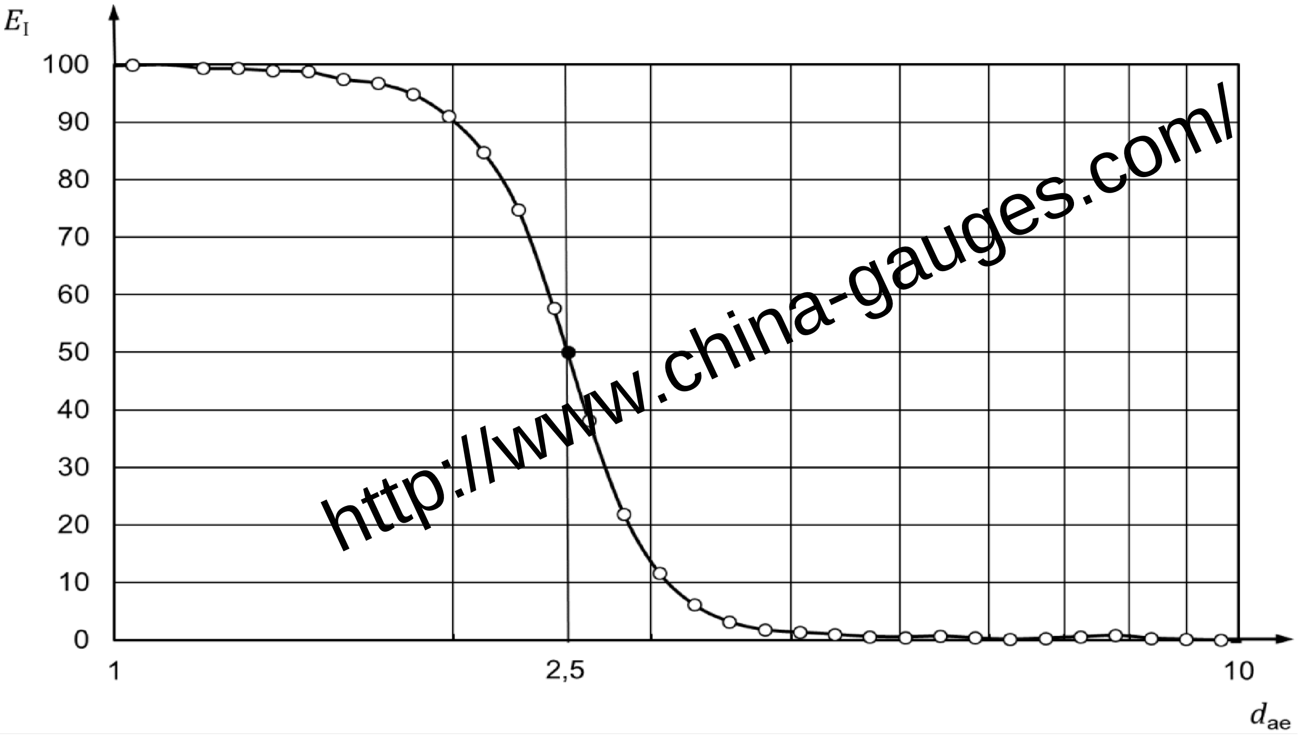


Figure F.2 — Impactor efficiency E_I, in %, in relation to the particle aerodynamic diameter d_{ae}, in µm, of the standard inlet for the sampling of $PM_{2,5}$ [22]

Annex G
(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 sampler designation (model and version);

   3) measured component(s);

   4) device manufacturer together with full address;

   5) field of application;

   6) firmware version of the sampler and software;

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

   8) 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;

   9) test laboratory;

   10) 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 sampler tested:

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

   2) operational parameters, preferably in a tabular form;

e) test program: details shall be provided on the test program, in relation to the sampler 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 sampler under test; frequencies of calibrations and checks. 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);

   3) filter media;

   4) any deviations from test steps and/or conditions prescribed in this document; these shall also be reported in the type testing report.

f) Test results: comparison of the performance criteria placed on the sampler 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 publicly available.

Annex H
(informative)

Example for uncertainty budget calculation

H.1 General

In this annex two examples are given for the calculation of the expanded uncertainty based on the approach described in section 9.3.4. and the corresponding Table 6 (Individual sources of uncertainty).

NOTE For all calculations, conventional rounding rules apply; no rounding of results is permitted until the final calculation of measurement uncertainty is undertaken

H.2 Calculation using data from prescribed type testing

This calculation makes use of the calculations and results from the uncertainty contributions given in Table 6 of Clause 9.3.4. The calculation therefore comprises the following three main uncertainty contributions:

Table H1 — Main uncertainty contributions from Clause 9.3.4

1	Sum of all effects concerning the "between-sampler uncertainty"	2 µg/m³
2	Sum of "balance calibration" and "hysteresis effects" (comprising all effect due to humidity)	47 µg
3	Sum of effects concerning flow	1,3 %

PM$_{10}$

Based on Formula 13, the combined relative uncertainty related to a **daily average** PM$_{10}$-concentration of 50 µg/m^3 is calculated to be:

$$u_c = \sqrt{(\frac{47}{2760})^2 + (\frac{1,3}{100})^2 + (\frac{2}{50})^2} = 0,045 = 4,5\% \quad \text{(H.1)}$$

According to Formula 14, the relative expanded uncertainty is calculated to be 4,5 multiplied by 2 = 9,0 %.

2760 µg corresponds to the mass sampled on a filter within 24 h at a sampling rate of 2,3 m^3/h, assuming a concentration of 50 µg/m^3.

From Formula 15, the combined relative uncertainty related to an **annual average** PM$_{10}$-concentration of 40 µg/m^3 is calculated to be:

$$u_c = \sqrt{(\frac{47}{2208})^2 + (\frac{1,3}{100})^2 + ((\frac{2}{40})^2 \cdot (\frac{1}{365 \cdot 0,9}))} = 0,025 = 2,5\% \quad \text{(H.2)}$$

According to Formula 14, the relative expanded uncertainty therefore is 2,5 multiplied by 2 = 5,0 %.

2208 µg corresponds to the mass sampled on a filter within 24 h at a sampling rate of 2,3 m^3/h, assuming a concentration of 40 µg/m^3.

$PM_{2,5}$

Based on Formula 13, the combined relative uncertainty related to a daily average $PM_{2,5}$-concentration of 30 µg/m^3 is calculated to be:

$$u_c = \sqrt{(\frac{47}{1656})^2 + (\frac{1,3}{100})^2 + (\frac{2}{30})^2} = 0,074 = 7,4\% \qquad \text{(H.3)}$$

From Formula 14, the relative expanded uncertainty therefore is calculated to be 7,4 multiplied by 2 = 14,8 %.

1656 µg corresponds to the mass sampled on a filter within 24 h at a sampling rate of 2,3 m^3/h, assuming a concentration of 30 µg/m^3.

Based on Formula 15, the combined relative uncertainty related to an **annual average** $PM_{2,5}$-concentration of 25 µg/m^3 is calculated to be:

$$u_c = \sqrt{(\frac{47}{1380})^2 + (\frac{1,3}{100})^2 + ((\frac{2}{25})^2 \cdot (\frac{1}{365 \cdot 0,9}))} = 0,037 = 3,7\% \qquad \text{(H.4)}$$

From Formula 14, the relative expanded uncertainty therefore is calculated to be 3,7 multiplied by 2 = 7,4 %.

1380 µg corresponds to the mass sampled on a filter within 24 h at a sampling rate of 2,3 m^3/h, assuming a concentration of 25 µg/m^3.

H.3 Measurement uncertainty derived from ongoing field Quality Control

It is still possible to evaluate measurement uncertainty even when the range of operating parameters and concentration ranges are not completely fulfilled. This is especially important where assessment of compliance with the performance objectives could be affected by a restricted measurement range. The example presented below is based on data derived from a field experiment carried out by the environment agency of the state of Rhineland-Palatinate, Germany in 2018. The calculation model used is very close to the strategy described in 9.3.4. The calculation is based on real data that did not cover the concentration range of the daily and annual limit values. Therefore the uncertainties derived cannot be related to those limit values. However, the outline below is a realistic representation of the uncertainties that can be achieved in field experiments and in everyday work.

The approach comprises five contributions that cover the total uncertainty of the method:

a. Parallel sampling with two identical PM_{10} – samplers (SEQ – Low Volume Samplers) and subsequent determination of the mass concentration (between sampler uncertainty)

b. Uncertainty contribution of the balance calibration

c. Determination of the hysteresis effect using the results of field blank measurement

d. Uncertainty of the volumetric flow using the results of flow checks from control card

e. Uncertainty of the flow meter

These items correspond to the uncertainty contributions given in Table 6 of Clause 9.3.4. Each contribution is now considered in turn:

1. Parallel sampling with two identical samplers

Over a time period of 4 months from Feb 2018 to May 2018 daily sampling with two LVS was performed. Quartz fibre filters with 50 mm diameter were used for sampling. Sampling and analysis were performed strictly according to the given procedures in this standard.

The between-sampler uncertainty (u_{bs}) is based on *n* = 146 paired samples. The concentration range was 3,1 to 48,1 µg/m³ with a mean concentration of 14,7 µg/m³. The calculation according to Formula (12) led to:

$u_{bs} = 0{,}43\ \mu g/m^3$

The relative random standard uncertainty was determined accordingly

$U_{bs,rel} = u_{bs} / c_{mean} = 0{,}43\ \mu g/m^3 / 14{,}7\ \mu g/m^3 = \mathbf{0{,}0293 = 2{,}93\ \%.}$

2. Uncertainty contribution of the balance calibration

The balance used was a micro filter balance. The uncertainty of the balance according to the calibration certificate is 8 µg in the range that is used for filter weighing. The standard uncertainty was determined as follows:

$u_{mba} = 0{,}5 \cdot 8\ \mu g / 55{,}2\ m^3 = 0{,}07\ \mu g/m^3$

$u_{mba,\ rel} = 0{,}07\ \mu g/m^3 / 50\ \mu g/m^3 = \mathbf{0{,}0014} = \mathbf{0{,}14\ \%}$ (related to the limit value of 50 µg/m³)

3. Uncertainty contribution of the hysteresis effect

For the determination of the hysteresis effect, field filter blanks of each filter lot have been used for calculation. This is possible because of the fact that the filter blank is mainly influenced by humidity.

The mean mass difference derived from a number of *n* = 122 filter blanks was used for calculation. The mean field blank was 42,6 µg.

The corresponding standard uncertainty therefore was calculated to

$u_{mh} = 42{,}6\ \mu g / 55{,}2\ m^3 = 0{,}77\ \mu g/m^3$

$u_{mh,rel} = 0{,}77\ \mu g/m^3 / 50\ \mu g/m^3 = \mathbf{0{,}0154} = \mathbf{1{,}54\ \%.}$ (related to the limit value of 50 µg/m³)

4. Uncertainty of the volumetric flow using the results of flow checks of the samplers from control card

For the calculation of the uncertainty of the volume flow, data from a control card were used. The volume flow was checked every time when filters were changed in the field. The values are stored in a control card. The standard uncertainty was calculated from the results of these flow checks and leads to

$u_{v,rel} = \mathbf{1{,}24\ \%}$ (related to the mean flowrate derived from the same data)

5. Uncertainty of the flow meter (Oriflow flow meter)

The uncertainty of the flow meter was taken over from the manufacturer’s documentation.

The expanded uncertainty was documented to be 1 %, leading to the standard uncertainty:

$u_{v,ref} = 1\ \% / 2 = \mathbf{0{,}50\ \%.}$

The calculated combined and expanded uncertainty using the Formulae (10), (11) and (12) are presented in Table H2 below..

Table H2 — Main uncertainty contributions from this example

Contribution	Source	Rel. uncertainty (%)
Between sampler uncertainty, $u_{bs,rel}$	Parallel sampling and subsequent weighing	2,93
Balance calibration, $u_{mba,rel}$	Calibration certificate	0,14
Hysteresis effect, $u_{mh,rel}$	Field blanks	1,34
Volumetric flow, $u_{v,rel}$	Flow check control card	1,24
Flow meter, u_{vref}	Manufacturer	0,50
Combined uncertainty		3,5
Coverage factor	k = 2 (P = 95 %)	
Expanded uncertainty	**P = 95 %**	**7,1**
Uncertainty of the yearly mean	**P = 95 %**	**4,1**

According to the results shown in the table above, the requirements are met.

Annex I
(informative)

Technical changes in EN 12341 with respect to version 2014 [21]

Details of significant technical changes between this document and the previous edition are:

Table I.1 Technical changes in EN 12341 with respect to version 2014 [21]

Clause	**Technical change**
Table 5 and 6	Updated
5	Type testing added
5.1	new procedure added how the sampler needs to store meta data; new procedures for assessing leak tightness of the sampling system added
Annex A	Clearer definitions of critical measurement requirements for inlet designs
Annex B	The former Annex B “Other samplers” of the version EN 12341:2014 [21] was deleted
Annex F	New Figure F.2
Annex H	Uncertainty budget example added
Bibliography	Bibliography updated

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