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BSI Standards Publication

Ambient air — Standard gravimetric measurement method for the determination of the PM_{10} or $PM_{2,5}$ mass concentration of suspended particulate matter

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National foreword

This British Standard is the UK implementation of EN 12341:2014. It supersedes BS EN 12341:1999 and BS EN 14907:2005 which are withdrawn.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 secretary.

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English Version

Ambient air - Standard gravimetric measurement method for the determination of the PM_{10} or $\mathrm{PM}_{2,5}$ mass concentration of suspended particulate matter

Air ambiant - Méthode normalisée de mesurage gravimétrique pour la détermination de la concentration massique MP_{10} ou $\mathrm{MP}_{2,5}$ de matière particulaire en suspension

Außenluft - Gravimetrisches Standardmessverfahren für die Bestimmung der PM_{10}- oder $\mathrm{PM}_{2,5}$-Massenkonzentration des Schwebstaubes

This European Standard was approved by CEN on 10 April 2014.

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COMITÉ EUROPÉEN DE NORMALISATION
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Foreword

This document (EN 12341:2014) 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of an identical text or by endorsement, at the latest by November 2014 and conflicting national standards shall be withdrawn at the latest by November 2014.

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

This document supersedes EN 12341:1998 and EN 14907:2005.

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 the Council Directive 2008/50/EC [1].

EN 12341:2014 includes the following significant technical changes with respect to EN 12341:1998 and EN 14907:2005:

- this document is adapted from EN 14907:2005 due to consideration of best available technology;
- the three different standard reference methods for PM_{10} described in EN 12341:1998 and the two different standard reference methods for $PM_{2,5}$ described in EN 14907:2005 are replaced in this document by only one possible standard reference method for each of PM_{10} or $PM_{2,5}$.

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom

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 European Standard 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 European Standard may also be used for measurement of mass concentrations of other PM fractions such as PM_1. However, this European Standard does not describe standardized sampling inlets for such fractions.

This European Standard merges the earlier European Standards EN 12341:1998 [2] and EN 14907:2005 [3] with the aim of harmonizing the very similar procedures that are used to measure mass concentrations of both fractions of particulate matter in ambient air.

The European Standard method described in this European Standard is focussed 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 traceable reference standards for PM_{10} or $PM_{2,5}$ measurements. 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 European Standard 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;
- 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 European Standard method;
- (tentative) 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 European Standard were partly determined in different comparative and validation trials. The trials were sponsored by the European Commission and the European Free Trade Association.

However, for lack of appropriate criteria and protocols to test filters for fitness for purpose, considerable differences may 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 PM_{10} for concentrations around 50 % of the daily limit value [4]. This may have implications for results produced by automated measurement systems as these are calibrated by comparison of results with those obtained using reference samplers (CEN/TS 16450:2013 [5]).

In principle, 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] and EN 15549 [7]) in conformity with Directive 2004/107/EC [8],

- constituents of $PM_{2,5}$ (see CEN/TR 16243 [9] and CEN/TR 16269 [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).

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

1 Scope

This European Standard describes 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. 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 European Standard is 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 5.1.4).

This European Standard describes procedures and gives requirements for the 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 European Standard does not exclude the use of single-filter samplers.

This European Standard does not give procedures for the demonstration of equivalence of other sampler types, e.g. equipped with a different aerosol classifier and/or operating at different flow rates. Such procedures and requirements are given in detail in the *Guide to the Demonstration of Equivalence of Ambient Air Monitoring Methods* [11] and for automated continuous PM monitors (see CEN/TS 16450:2013).

The present European Standard represents an evolution of earlier European Standards (EN 12341:1998 and EN 14907:2005) through the development of the 2,3 m^3/h sampler to include constraints on the filter temperature during and after sampling and the ability to monitor temperatures at critical points in the sampling system. It is recommended that when equipment is procured it complies fully with the present European Standard. However, older versions of these 2,3 m^3/h samplers that do not employ sheath air cooling, the ability to cool filters after sampling, or the ability to monitor temperatures at critical points in the sampling system have a special status in terms of their use as reference samplers. Historical results obtained using these samplers will remain valid. These samplers can still be used for monitoring purposes and for equivalence trials, provided that a well justified additional allowance is made to their uncertainties (see Annex B).

In addition, three specific sampling systems – the “long nozzle” 2,3 m^3/h sampler and the 68 m^3/h sampler for PM_{10} in EN 12341:1998, and the 30 m^3/h $PM_{2,5}$ inlet in EN 14907:2005 – also have a special status in terms of their use as reference samplers. Historical results obtained using these samplers will remain valid. These samplers can still be used for monitoring purposes and for equivalence trials, provided that a well-justified additional allowance is made to their uncertainties (see Annex B).

Other sampling systems, as described in Annex B of this European Standard, can be used provided that a well justified additional allowance is made to their uncertainties as derived from equivalence tests.

NOTE 2 By evaluating existing data it has been shown that these samplers give results for PM_{10} and $PM_{2,5}$ that are equivalent to those obtained by application of this European Standard. Results are shown in Annex B.

This European Standard 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 European Standard.

2 Normative references

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

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

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

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

3.1.1
ambient air
outdoor air in the troposphere, excluding workplaces as defined by Directive 89/654/EEC [12] 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]

3.1.2
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]]

3.1.3
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]

3.1.4
coverage factor
numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

[SOURCE: JCGM 100]

3.1.5
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]

3.1.6
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

Note 1 to entry: A field blank is sometimes also called a procedure blank.

3.1.7
weighing room blank
filter that undergoes the same procedures of conditioning and weighing as a sample filter, but is stored in the weighing room

3.1.8
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]

3.1.9
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

3.1.10
parallel measurement
measurements from measuring systems, sampling from the same air over the same time period

3.1.11
performance characteristic
one of the parameters assigned to a sampler in order to define its performance

3.1.12
performance criterion
limiting quantitative numerical value assigned to a performance characteristic, to which conformance is tested

3.1.13
period of unattended operation
time period over which the sampler can be operated without requiring operator intervention

3.1.14
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 European Standard – 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.

3.1.15
reference method
RM
measurement method(ology) which, by convention, gives the accepted reference value of the measurand

3.1.16
sampled air
ambient air that has been sampled through the sampling inlet and sampling system

3.1.17
sampling inlet
entrance to the sampling system where ambient air is collected from the atmosphere

3.1.18
standard uncertainty
uncertainty of the result of a measurement expressed as a standard deviation

[SOURCE: JCGM 100]

3.1.19
suspended particulate matter
SPM
notion of all particles surrounded by air in a given, undisturbed volume of air

3.1.20
time coverage
percentage of the reference period of the relevant limit value for which valid data for aggregation have been collected

3.1.21
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]

3.2 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
—	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
—	φ_{L}	Leak flow rate (leak test)
—	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 European Standard, 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. adsorption of water and semi-volatile compounds, spurious addition or loss of material, buoyancy, or static electricity.

In order to minimize the effects of these factors, this European Standard 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 quality assurance/quality control (QA/QC) procedures within this European Standard 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 European Standard. 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.

5 Equipment and facilities

5.1 Sampling system components

5.1.1 General

This European Standard describes the designs for the sampling systems to be used within the standard method.

Sequential sampling systems for the standard measurement methods for PM_{10} and $PM_{2,5}$ typically consist of the following elements, illustrated schematically in Annex C:

- size-selective inlets, whose designs are prescribed in 5.1.2;
- connecting pipe-work between the inlet and the filter holder, described in 5.1.3;
- filter holder and filter, described in 5.1.4;
- flow control system, given by performance specifications in 5.1.5;
- sample changer;
- storage facility for filters in the sampler.

NOTE There are different filter storage facilities possible. Two options are given as an example: in option A there is only one combined blank and sampled filter magazine from which the unsampled filter is taken and where - after the 24 h loading period - the sampled filter is moved back to (see Annex C, option A). In option B the unsampled filter is taken from the left blank filter magazine and – after the 24 h loading period – the sampled filter is moved to the sampled filter magazine in the right (see Annex C, option B).

Requirements for the correct operation of the sampling system are specified in Table 1.

Table 1 — Requirements for sampling equipment

	Design/performance characteristic	**Requirement** [a]	**Subclause**
1	Sampler design	The sampler shall be designed in a way that it is possible to check and calibrate all sensors important to ensure the correct performance of the sampler. The manual of the sampler shall contain instructions on how to access the sensors.	
2	Inlet design	As prescribed	5.1.2
3	Temperature of filter during sampling	Within 5 °C of ambient temperature for ambient temperatures ≥ 20 °C	5.1.4
4	Nominal flow rate	2,3 m^3/h at ambient conditions	5.1.5
5	Constancy of sample volumetric flow	≤ 2,0 % sampling time (averaged flow) ≤ 5,0 % rated flow (instantaneous flow)	5.1.5
6	Leak tightness of the sampling system	$\varphi_L \leq 1{,}0$ % of sample flow rate	5.1.7
7	Single-filter sampling period	24 h ± 1 h	5.1.6
8	Uncertainty (95 % confidence) of sampling	≤ 5 min	5.1.6

	time measurement		
9	Uncertainty (95 % confidence) of sensor for ambient temperature measurement or, if applicable, the sensor for measurement of temperature in the flow measuring device	≤ 3 K	5.1.5
10	Uncertainty (95 % confidence) of sensor for ambient pressure measurement or, if applicable, the sensor for measurement of pressure in the flow measuring device	≤ 1 kPa	5.1.5
11	Uncertainty (95 % confidence) of sensors for internal temperatures (filter during sampling; filter during storage)	≤ 3 K	5.1.5
12	Temperature of storage of sampled filters in the instrument	Shall not induce additional losses of semi-volatile constituents of PM	5.1.8; 6.3.3
13	Recording of operational parameters	Measuring systems based on sequential samplers shall be able to transmit operational states by status signals of – at minimum – the following parameters: – flow rate (instantaneous and average) – pressure drop across the filter, if necessary – sampling time and sample volume – air temperature in filter section – temperature of filter storage.	
14	Effect of failure of mains voltage	Instrument parameters shall be secured against loss. On return of mains voltage the instrument shall automatically resume functioning.	
15	Effect of abortion of sampling due to high pressure drop over the filter	Instruments with filter changers shall have the ability to restart automatically with a new filter if the previous filter sample was aborted due to a high pressure drop across the filter.	

[a] The ranges given for the parameters need not to be reduced for the calibration uncertainties of the sensors used for their control.

5.1.2 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 or anodized aluminium or aluminium alloy.

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 m^3/h (see 5.1.5).

5.1.3 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 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 C, Figure C.1).

5.1.4 Filter holder and filter

The filter holder shall be made of an inert, non-corroding material such as stainless steel 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, polycarbonate, POM or PTFE grid material.

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 solar radiation and electrical apparatus (e.g. the sampling pump), and cooling elements such as air conditioning shall be minimized. During periods with average hourly ambient temperatures above 20 °C, the temperature of the sample filter shall differ by less than 5 °C from the temperature of the ambient air surrounding the sampler. This shall be checked by incorporating temperature measurements in the sampled air directly downstream of the filter, which shall be compared with ambient air temperature measurements.

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

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 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.

Annex D 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 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 may occur, reducing the sampling time to below 23 h.

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

5.1.6 Sampling period

The sampling period shall be (24 ± 1) h, and shall be recorded with an accuracy of ± 5 min. The sampler shall be able to provide information on start and stop times of sampling for each individual filter.

5.1.7 Leak tightness of the sampling system

5.1.7.1 General

The leak tightness (leak rate) of the complete flow path of the sampler (sample inlet, sampling line, filter) shall be tested. 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 standard gravimetric sampler can be used, provided that the stringency of such a test is equivalent to the one of the leak tests described in 5.1.7.

5.1.7.2 Low pressure method

In case of a determination of the leak rate by the low pressure method, the volume of the whole system shall be estimated. Then the system shall be closed at the inlet and the pressure be lowered by a built-in or separate pump by up to 75 % of the maximum pressure drop allowed by the manufacturer, with a minimum of about 40 kPa. 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 a time period of at least 5 min. The leak rate φ_L shall be determined three times. The leak rate φ_L is calculated according to Formula (1):

$$\varphi_{\mathrm{L}} = \frac{\Delta P \cdot V_{\mathrm{sys}}}{P_0 \cdot \Delta t} \qquad (1)$$

where

ΔP is pressure difference determined for the time interval Δt;

P_0 is pressure at time t_0;

V_{sys} is estimated total volume of the system (dead volume) ;

Δt is time interval needed for the pressure rise.

The maximum of the three leak rates determined shall be calculated. The complete sampling system shall be checked for tightness.

5.1.7.3 Volumetric method

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

5.1.8 Storage conditions

Users of this European Standard 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 6.3.3.).

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.

5.2 Weighing facilities

5.2.1 General

This European Standard describes the requirements for the weighing facilities to be used within the standard method. These requirements are specified in Table 2.

Table 2 — Requirements for weighing facilities

	Performance characteristic	Requirement	Subclause
1	Weighing room temperature	19 °C to 21 °C measured as hourly mean value [a]	5.2.2
2	Weighing room relative humidity	45 % RH to 50 % RH measured as hourly mean value [a]	5.2.2
3	Uncertainty (95 % confidence) of sensors for temperature measurement	≤ 0,2 K	5.2.2
4	Uncertainty (95 % confidence) of sensors for relative humidity measurement	≤ 2 % RH	5.2.2
5	Balance resolution	≤ 10 µg	5.2.3
6	Uncertainty (95 % confidence) of balance calibration	≤ 25 µg for a range of 0 mg to 200 mg	5.2.3
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.	5.2.2

[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.

5.2.2 Weighing room

A climate-controlled facility shall be used for conditioning and weighing the filters. This facility will be referred to within this European Standard 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 2.

The sensors used to measure the weighing room temperature and relative humidity shall fulfil the requirements given in Table 2.

The parameters listed in Table 2 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 E.

5.2.3 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 Filter conditioning, sampling and weighing procedures

6.1 General

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

NOTE When PTFE-coated tweezers are used, static charges can occur at fibre filters.

Storage periods shall be kept as short as possible. Table 3 gives guidance for maximum storage periods.

Table 3 — Recommended 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 development remains within specified limits (see 6.2)
Sampled filters and field blanks in the sampler	1 month
Sampled filters and field blanks in the weighing room before weighing	1 month

6.2 Filter conditioning and weighing prior to sampling

Prior to sampling, all filters shall be uniquely identified (the effect of the method for identifying filters shall be tested over a period of 1 m with repeated weighing to see if there is a significant effect upon mass) 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 after an additional conditioning for ≥ 12 h: result $m_{c,2.}$

The difference between the two results shall fulfil the requirement, see Formula (2):

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

NOTE The above difference in mass is equivalent to a difference in measured concentration of 0,7 µg/m^3 (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 (3):

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

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 D shows that the mass difference for a filter after preconditioning and subsequent regular conditioning is ≥ 40 µg, the above procedure may be preceded by a preconditioning at high relative humidity (air saturated with water vapour at 19 °C to 21 °C) for a period of ≥ 3 weeks.

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

6.3 Sampling procedure

6.3.1 Filter cassette loading

Filter holders shall be loaded with conditioned blank filters in a clean environment, e.g. the weighing room, ensuring the traceability of the filter and its position in the sequential sampler filter cassette.

6.3.2 Filter sampling

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

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

6.3.3 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 European Standard 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 should also ensure the prevention of condensation on the filters.

NOTE This may be achieved by transport in cool boxes. Effects of condensation within the cool box on the filters may be avoided by packing the cassettes in plastic bags or by sealing them, e.g. with parafilm.

Filters shall be introduced into the weighing room within 1 month after sampling of the first filter in the cassette.

6.4 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 $m_{s,2.}$

The difference between the two results shall fulfil the requirement, see Formula (4):

$$\left| m_{\mathrm{s},1} - m_{\mathrm{s},2} \right| \leq 60\ \mu\mathrm{g} \tag{4}$$

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 (5):

$$\left| m_{s,2} - m_{s,3} \right| \leq 60\ \mu g \tag{5}$$

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.

6.5 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 PTFE and PTFE-coated filters prior to weighing unless it can be demonstrated that there is no need for this (see Annex D).

NOTE 1 For other 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 may be evaluated by performing 40 consecutive weighings with and without static discharger (see also Annex D).

6.6 Filter blanks for ongoing quality control

6.6.1 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.

6.6.2 Weighing room blanks

The masses of the individual weighing room blank filters (see 6.2) 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 mass of each weighing room blank filter is recorded, and 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/m^3 (at nominal flow and 24 h of sampling).

6.6.3 Field blanks

For effective quality control, field blanks shall be obtained for all sampling sites (see 6.3.2). 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 6.4) 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 should be less than or equal to 60 µg. The detailed procedures for dealing with exceedances of this criterion are left to the local operator.

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

NOTE 2 A systematic exceedance of the field blank criterion may be an indicator for an insufficient suitability of the filter material.

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 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.

NOTE It is recommended that the designated body that is performing the ongoing quality control procedures is accredited according to EN ISO/IEC 17025 [15].

7.2 Frequency of calibrations, checks and maintenance

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

Table 4 — Required frequency of calibration, checks and maintenance

Calibration, checks and maintenance	Subclause	Frequency	Lab/ field	Action criteria [a]
Regular maintenance of components of the sampler	7.3	As required by manufacturer	L / F	
Checks of sensors for temperatures and pressure in the sampler	7.4	Every 3 months [b]	F	±3 K ±1 kPa
Calibration of sensors for temperatures and pressure in the sampler	7.5	Every year	L / F	±1,5 K ±0,5 kPa
Check of the sampler flow rate	7.6	Every 3 months [b]	F	5 %
Calibration of the sampler flow rate	7.7	Every year	L / F	1 %
Leak check of the sampling system	7.8	Every year	L / F	1 %
Checks of the weighing room sensors for temperature and relative humidity	7.9	Every 6 months	L	±1 K ±3 % RH
Calibration of the weighing room sensors for temperature and relative humidity	7.10	Every year	L	
Calibration of the balance	7.11	Every year	L	

[a] With reference to nominal values.

[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. Calibrations shall be performed every year.

7.3 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 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 regreasing 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.

7.4 Checks of sampler sensors

Where temperature and pressure (difference) sensors are essential for controlling the proper functioning of the instrument, these shall be checked using appropriate transfer standards with readings traceable to (inter)nationally accepted standards. These checks shall be performed before the flow rate check.

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

NOTE In case of temperature sensors, these may be sensors giving actual temperatures of e.g. ambient air and filter compartments.

7.5 Calibration of sampler sensors

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

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

NOTE In case of temperature sensors, these may be sensors giving actual temperatures of e.g. ambient air, sheath air and filter compartments.

7.6 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.

NOTE In practice, flow meters of proven applicability are graphite piston provers and mass-flow meters.

Users should 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 should be allowed sufficient time to condition to the actual temperatures at which measurements are performed.

If the inlet of the sampler consists of a straight tube without any joints or connections, the inlet may be removed before calibration in order to facilitate the procedure.

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.

7.7 Calibration of the sampler flow rate

Calibration shall be performed every year 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 ≤ 1,0 % at laboratory conditions. Flow calibrations shall include the sample line. All sensors shall be in operation during the flow calibration.

7.8 Leak check of the sampling system

The leak tightness of the sampling system shall be checked yearly as described in 5.1.7.

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

7.9 Checks of weighing room 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 4, the sensors shall be recalibrated and adjusted according to the manufacturer's instructions.

7.10 Calibration of weighing room sensors

The sensors shall be calibrated at least once per year 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 2,0 % (RH).

7.11 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.

8 Expression of results

Measurement results shall be expressed as µg/m^3, 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 (6)).

$$c = \frac{m_\mathrm{l} - m_\mathrm{u}}{\varphi_\mathrm{a} \cdot t} \tag{6}$$

where

c is the concentration, in micrograms per cubic metre (µg/m^3);

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 (m^3/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 uncertainty of measurements 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)* (see Clause 2), 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 (6)).

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 (7):

$$u_c^{\,2} = \sum \left(u_i\right)^2 \tag{7}$$

- calculation of the expanded uncertainty U, by multiplying u_c by the coverage factor k, see Formula (8):

$$U = k \cdot u_{\mathrm{c}} \tag{8}$$

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 can then be compared with the data quality objectives from Directive 2008/50/EC.

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 serves as a measure of these combined effects according to Formula (9):

$$u_{\mathrm{bs}}^2 = \frac{\sum (x_{\mathrm{i},1} - x_{\mathrm{i},2})^2}{2n} \tag{9}$$

where

$x_{\mathrm{i},1}$ and $x_{\mathrm{i},2}$ 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.

9.3 Individual uncertainty sources

9.3.1 General

From the model Formula (6) 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 inadequate greasing;
- 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. The PM cut-off diameter changes by about 1,5 % for a temperature change of 10 K. In principle this variation is an intrinsic part of the standard method, and therefore does not contribute to the uncertainty of the result.

It is considered that any random contribution to the measurement uncertainty will be incorporated within the between-sampler uncertainty u_{bs}.

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 made negligible by using vertical sampling lines, and 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 expected when this European Standard 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 European Standard 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 European Standard 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 European Standard 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 at separate weighing sessions (6.4).

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 uncertainty of the measurement is partly quantified by the constraint on mass change at the separate weighings of sampled filters given in 6.4. 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 F).

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 F). 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 and zero drift

Balances shall have an uncertainty, when calibrated, of less than 25 µg. This is clearly negligible in comparison with the mass changes covered in 9.3.2.5 and 9.3.2.6.

Uncorrected zero drift of a well calibrated balance can lead to errors of tens of µg. These errors are 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 PTFE filters. 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 hereof 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).

Consequently, the magnitude of the effects of adsorption of gases cannot be quantified. For the purpose of application of this European Standard the phenomenon is recognized but not considered in the uncertainty budget.

9.3.2.12 Flow rate (φ_a)

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 less than 2 % (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 3 %.

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 European Standard.

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 6.4, the maximum difference is required to be 5 min over the sampling period of 24 h, i.e. a variation of 0,35 %. Again, any effect on the uncertainty is considered to be negligible.

9.3.4 Uncertainty budget

The individual sources of uncertainty are summarized in Table 5.

Table 5 — Individual sources of uncertainty

Component	**Symbol**	**Contribution**
a) Mass ($m_l - m_u$)	u_m	63 µg
1) Inlet performance	u_{mip}	Negligible
2) Transport loss	u_{mtl}	Negligible
3) Filter efficiency	u_{mfe}	Negligible
4) Loss of semi-volatiles	u_{msv}	Zero by convention
5) Balance: calibration	u_{mba}	$\frac{25}{\sqrt{3}}$ µg
6) Mass of unsampled filter:	u_{mu}	
i) Effect of humidity on blank filter	u_{mlb}	$\frac{40}{\sqrt{3}}$ µg
ii) Buoyancy	u_{mb}	$\frac{3}{\sqrt{3}}$ µg
iii) Static	u_{ms}	Negligible
iv) Balance: zero drift	u_{mzd}	$\frac{10}{\sqrt{3}}$ µg
7) Mass of sampled filter:	u_{ml}	
i) Effect of exposure on blank filter (field blank)	u_{mfb}	$\frac{60}{\sqrt{3}}$ µg
ii) Effect of humidity on particulate matter	u_{mhp}	$\frac{60}{\sqrt{12}}$ µg
iii) Hysteresis effects due to sorption of water vapour	u_{mh}	46 µg
iv) Interaction with gases	u_{mg}	Not considered
v) Buoyancy	u_{mb}	$\frac{3}{\sqrt{3}}$ µg
vi) Static	u_{ms}	Negligible
vii) Contamination	u_{mc}	Negligible
viii) Balance: zero drift	u_{mzd}	$\frac{10}{\sqrt{3}}$ µg
b) Flow	u_f	1,7 %
1) Calibration	u_{fc}	$\frac{3}{\sqrt{3}}$ %
2) Drift	u_{fd}	Negligible
c) Time	u_t	Negligible
d) Between-sampler variation	u_{bs}	$\frac{2}{\sqrt{3}}$ µg/m^3

- for a nominal sample volume of 55,2 m^3 (2,3 m^3/h x 24 h)
- at the levels of the limit values for PM_{10} and $PM_{2,5}$.

$$u_{\mathrm{c}}^2 = \frac{u^2(m_{\mathrm{l}} - m_{\mathrm{u}})}{(m_{\mathrm{l}} - m_{\mathrm{u}})^2} + u^2(\varphi) + \frac{u^2(t)}{t^2} + \frac{u_{\mathrm{bs}}^2}{L^2} \tag{10}$$

where

$(m_{\mathrm{l}} - m_{\mathrm{u}})$ is calculated at the level of the limit value;

L is the daily limit value.

NOTE Following Directive 2008/50/EC the uncertainty is calculated for individual measurements, in this case being measurements over a period of 24 h. For $PM_{2,5}$ a limit value is only defined with a reference period of 1 year. Therefore a "pseudo-daily" limit value for $PM_{2,5}$ of 30 µg/m^3 is used in Reference [11].

The combined relative uncertainties are then

- PM_{10}: 3,8 %
- $PM_{2,5}$: 5,8 % for a level of 30 µg/m^3.

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, 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 (11):

$$U = 2u_c \tag{11}$$

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 European Standard 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 (12):

$$u_{\mathrm{c}}^2 = \frac{u^2(m_{\mathrm{l}} - m_{\mathrm{u}})}{(m_{\mathrm{l}} - m_{\mathrm{u}})^2} + u^2(\varphi) + \frac{u^2(t)}{t^2} + \frac{u_{\mathrm{bs}}^2}{L^2 \times 0{,}9 \times 365} \tag{12}$$

Table 6 summarizes the expanded uncertainty of the standard measurement method at the daily and annual limit values, together with the EU uncertainty requirements.

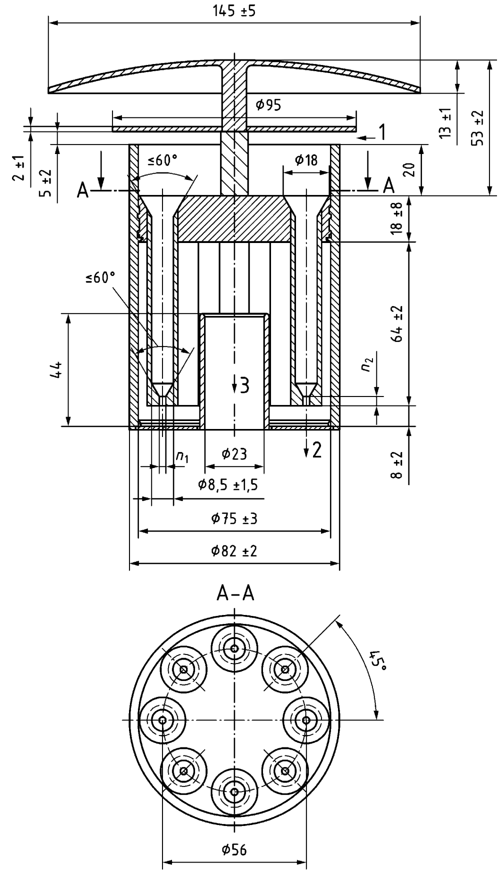
Table 6 — Expanded uncertainties of the standard method

Limit value	EU uncertainty requirement %	Expanded relative uncertainty %
PM_{10}		
– daily: 50 µg/m^3	25	7,7
– annual: 40 µg/m^3	-	7,1
$PM_{2,5}$		
– daily: 30 µg/m^3 [a]	25	11,6
– annual: 25 µg/m^3	25	10,1
[a] See NOTE in 9.3.		

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 without tolerances: ± 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 ± manufacturing tolerance

for PM_{10}: 6,5 ± manufacturing tolerance

n2 nozzle length

for $PM_{2,5}$: 3,7 ± 0,1

for PM_{10}: 7,0 ± 0,1

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
(normative)

Other samplers

B.1 General

The present European Standard represents an evolution of earlier European Standards (EN 12341:1998 and EN 14907:2005) through the development of the 2,3 m^3/h sampler to include constraints on the filter temperature during and after sampling, the ability to cool filters after sampling, and the ability to monitor temperatures at critical points in sheath air cooling the sampling system. It is recommended that when equipment is procured, it complies fully with the present European Standard. However, older versions of these 2,3 m^3/h samplers that do not employ sheath air cooling, the ability to cool filters after sampling, or the ability to monitor temperatures at critical points in the sampling system have a special status in terms of their use as reference samplers. Historical results obtained using these samplers will remain valid. These samplers can still be used for monitoring purposes and for equivalence trials, provided that a well justified additional allowance is made to their uncertainties.

In addition, three specific sampling systems – the “long nozzle” 2,3 m^3/h sampler and the 68 m^3/h sampler for PM_{10} in EN 12341:1998, and the 30 m^3/h $PM_{2,5}$ inlet in EN 14907:2005 – also have a special status in terms of their use as reference samplers. Historical results obtained using these samplers will remain valid. These samplers can still be used for monitoring purposes and for equivalence trials, provided that a well-justified additional allowance is made to their uncertainties.

Other sampling systems can be used provided that a well justified additional allowance is made to their uncertainties as derived from equivalence tests. The application of all samplers mentioned shall be subject to the monitoring of necessary parameters as described in this European Standard and the application of a regime of quality assurance/quality control that is of the level described in this European Standard.

When using sampling systems that operate at flow rates different from 2,3 m^3/h, requirements for filter conditioning and weighing can be obtained from Clause 6 by applying a scaling factor equal to the ratios of the flow rates of the non-reference and reference samplers.

EXAMPLE For a sampler operated at 30 m^3/h, the scaling factor for filters blanks equals 30 / 2,3.

The results of the equivalence tests presented below are based on historical data. Consequently, these have been obtained with samplers that may not fulfil all (additional) requirements for quality control and quality assurance of the current European Standard. However, it is assumed that fulfilment of all requirements will only lead to improved sampler performance, and, hence, to an improvement in comparability of the results produced. The differences observed and the resulting uncertainties should therefore be considered as “worst cases”.

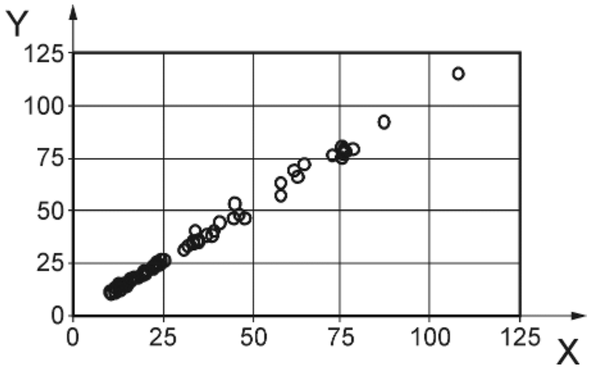
B.2 PM_{10}

B.2.1 Reference samplers ex. EN 12341:1998

B.2.1.1 Sampler operating at 2,3 m^3/h with different nozzle design

EN 12341:1998 describes a sampler operating at a nominal flow rate of 2,3 m^3/h with an inlet design differing from the one in this European Standard. It has been shown that the design specified in this European Standard (Figure A.1) leads to a steeper cut-off curve for PM_{10}, resulting in a reduction of “over-sampling” of coarse particles with diameters > 10 µm [18]. Investigations into the practical effects of the use of both types of nozzles [18] to [20] have shown that only under exceptional practical conditions (e.g. occurrence of large fractions of particles with diameter > 10 µm) differences in measured mass concentrations may be found.

WG 15 therefore considers the results for both types of inlets to be equivalent. Data from comparison measurements are graphically displayed in Figure B.1 and Figure B.2.



Key

X	*C* (µg/m3), short nozzles
Y	*C* (µg/m3), long nozzles

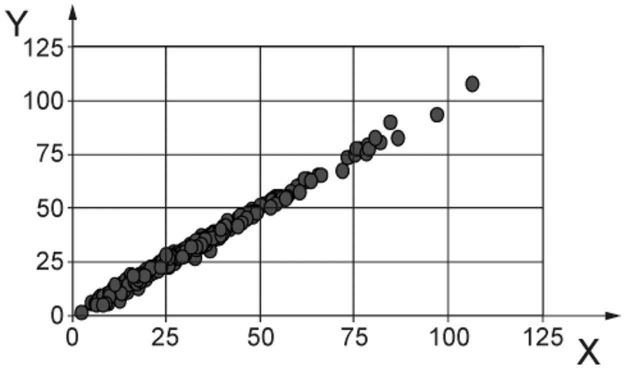
REGRESSION OUTPUT:

slope b	1,056	
uncertainty of b	0,008	significant
intercept a	-0,78	
uncertainty of a	0,34	significant
number of data pairs	74	

EQUIVALENCE TEST RESULTS:

random term	1,5	µg/m³
bias at LV	2,0	µg/m³
combined uncertainty	2,5	µg/m³
relative uncertainty	5,0 %	pass
ref uncertainty	0,7	µg/m³
limit value	50	µg/m³

Figure B.1 — Equivalence of samplers with short and long nozzles at a site with a large coarse fraction for PM$_{10}$



Key

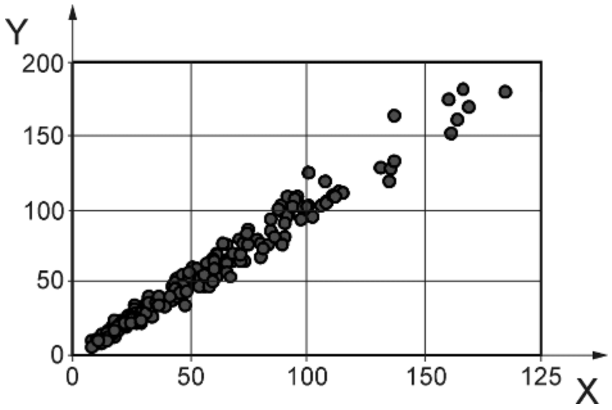
X	*C* (µg/m^3), short nozzles	
Y	*C* (µg/m^3) long nozzles	
REGRESSION OUTPUT:		
slope b	0,999	
uncertainty of b	0,004	
intercept a	-0,21	
uncertainty of a	0,13	
number of data pairs	393	
EQUIVALENCE TEST RESULTS:		
random term	1,2	µg/m³
bias at LV	-0,3	µg/m³
combined uncertainty	1,2	µg/m³
relative uncertainty	2,4 %	pass
ref uncertainty	0,7	µg/m³
limit value	50	µg/m³

Figure B.2 — Equivalence of samplers with short and long nozzles at other sites for PM$_{10}$

Whenever this sampler is used no additional contribution needs to be made to the uncertainty of the measurement results.

B.2.1.2 Sampler operated at 68 m^3/h flow rate

EN 12341:1998 describes a “high-volume sampler” (HVS) operating at a nominal flow rate of 68 m^3/h. This sampler has been compared with the reference sampler in a series of campaigns preceding the publication of EN 12341:1998. The results of these comparisons are given in Figure B.3.



Key

X	*C* (µg/m^3), Reference
Y	*C* (µg/m^3), 68 m^3/h sampler

REGRESSION OUTPUT:

slope b	1,031	
uncertainty of b	0,011	significant
intercept a	-2,33	
uncertainty of a	0,72	significant
number of data pairs	218	

EQUIVALENCE TEST RESULTS:

random term	5,9	µg/m³
bias at LV	-0,8	µg/m³
combined uncertainty	6,0	µg/m³
relative uncertainty	11,9 %	pass
ref uncertainty	1,1	µg/m³
limit value	50	µg/m³

Figure B.3 — Equivalence of reference sampler with sampler operating at 68 m^3/h for PM$_{10}$

The bias found reflects the comparability of both samplers. The relatively large scatter may be due to the application of regimes of QA/QC that are far less stringent than that described in this European Standard. These regimes reflected the state-of-the-art at the time of the performance of the comparisons.

Whenever this sampler is used the uncertainty of the measurement results produces should include a contribution due to the bias with the current reference sampler. When results for this sampler are used as such, the bias term (in quadrature) is of the form of Formula (B.1):

$$u^2 = \left(-0{,}03y + 2{,}26\right)^2 \quad \text{(B.1)}$$

where

u is the bias due to deviation of results of the sampler from those of reference method, in micrograms per cubic metre (µg/m^3);

y is the measurement result of the sampler, in micrograms per cubic metre (µg/m^3).

B.2.2 Other samplers

B.2.2.1 Sampler operated at 30 m^3/h flow rate

The sampler evaluated is not a reference sampler for the measurement of PM_{10} as described in EN 12341:1998. However, this sampler has been widely used and is used, e.g. for the demonstration of equivalence of automated measurement systems for PM_{10}.

Below the compiled results of a series of parallel measurements of PM_{10} featuring the reference sampler and the sampler operated at 30 m^3/h are presented after evaluation of equivalence in accordance with the data described in Reference [11] in Figure B.4. The results were compiled from the following sources:

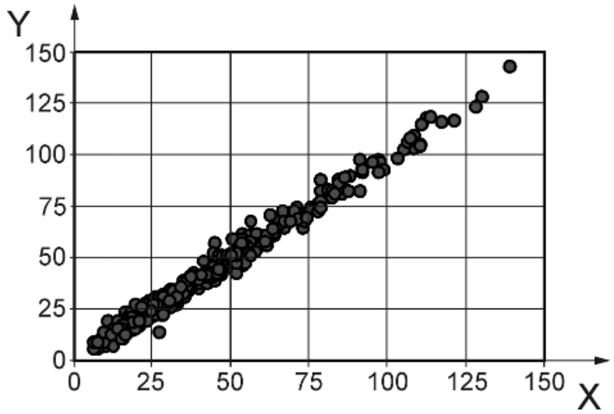
— the Länder Arbeitsgemeinschaft für Immissionsschütz (LAI), Germany,

— the STIMES-Arbeitsgruppe PM_{10}, Germany,

— the Umweltbundesamt (Austria),

— the Joint Research Centre Institute for Environment and Sustainability of the European Commission.

The parallel measurements have been performed at various locations, including traffic-oriented, urban background and rural locations, during different meteorological seasons.



Key

X	*C* (µg/m^3), Reference
Y	*C* (µg/m^3), 30 m^3/h sampler

REGRESSION OUTPUT:		
slope b	0,986	
uncertainty of b	0,004	significant
intercept a	-0,06	
uncertainty of a	0,16	
number of data pairs	790	
EQUIVALENCE TEST RESULTS:		
random term	2,4	µg/m³
bias at LV	-0,8	µg/m³
combined uncertainty	2,5	µg/m³
relative uncertainty	5,0 %	pass
ref uncertainty	0,67	µg/m³
limit value	50	µg/m³

Figure B.4 — Equivalence of reference sampler with sampler operating at 30 m^3/h for PM$_{10}$

The bias found reflects the comparability of both samplers. The relatively large scatter may be due to the application of regimes of QA/QC that are far less stringent than that described in this European Standard. These regimes reflected the state-of-the-art at the time of the performance of the comparisons.

Whenever this sampler is used the uncertainty of the measurement results produces should include a contribution due to the bias with the current reference sampler. When results for this sampler are used as such, the bias term (in quadrature) is of the form of Formula (B.2):

$$u^2 = (0,014y)^2 \qquad \text{(B.2)}$$

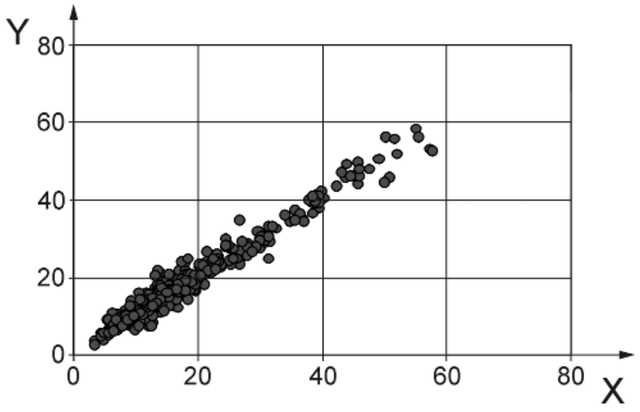
where

u is the bias due to deviation of results of the sampler from those of reference method, in micrograms per cubic metre (µg/m^3);

y is the measurement result of the sampler, in microgram per cubic metre (µg/m^3).

B.2.2.2 Sampler operated at 1,0 m^3/h flow rate

This specific sampler operating at a nominal flow rate of 1,0 m^3/h is not a reference sampler for the measurement of PM$_{10}$ as described in EN 12341:1998. This sampler has been tested in a number of comparative studies. The results of these studies [21; 22] show that these samplers provide results that are equivalent with those of the reference sampler described in this European Standard are presented in Figure B.5. However, potential users of this sampler type should take due care to ensure that the conditions under which this sampler was tested are representative for their own practical operating conditions.



Key

X	*C* (µg/m^3), Reference	
Y	*C* (µg/m^3), 1,0 m^3/h sampler	
REGRESSION OUTPUT:		
slope b	0,998	
uncertainty of b	0,010 1	
intercept a	0,70	
uncertainty of a	0,216	significant
number of data pairs	384	
EQUIVALENCE TEST RESULTS:		
random term	2,1	µg/m³
bias at LV	0,6	µg/m³
combined uncertainty	2,1	µg/m³
relative uncertainty	4,3 %	pass
ref uncertainty	0,67	µg/m³
limit value	50	µg/m³

Figure B.5 — Equivalence of reference sampler with sampler operating at 1,0 m^3/h for PM$_{10}$

The bias found reflects the comparability of both samplers. The relatively large scatter may be due to the application of regimes of QA/QC that are far less stringent than that described in this European Standard. These regimes reflected the state-of-the-art at the time of the performance of the comparisons.

Whenever this sampler is used the uncertainty of the measurement results produces should include a contribution due to the bias with the current reference sampler. When results for this sampler are used as such, the bias term (in quadrature) is of the form of Formula (B.3):

$$u^2 = (0,7)^2 \tag{B.3}$$

where

u is the bias due to deviation of results of the sampler from those of reference method, in microgram per cubic metre (μg/m^3).

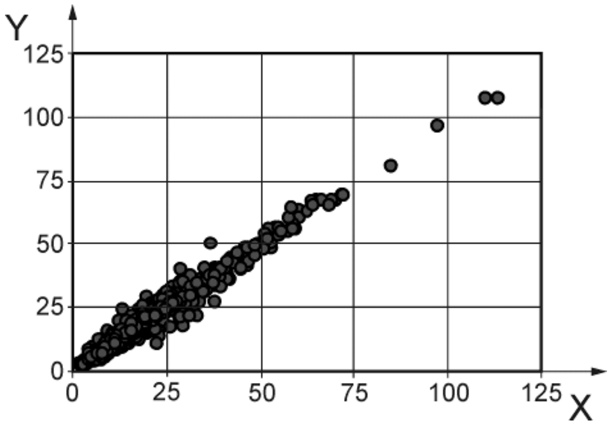
B.3 PM$_{2,5}$ — Sampler operated at 30 m^3/h flow rate

EN 14907:2005 describes a sampler operating at a nominal flow rate of 30 m^3/h. Below the compiled results of a series of parallel measurements of PM$_{2,5}$ featuring the reference sampler operated at 2,3 m^3/h and the sampler operated at 30 m^3/h are presented after evaluation of equivalence in accordance with the data of Reference [11]. The results were compiled from the following sources:

— CEN/TC 264/WG 15,

— the STIMES-Arbeitsgruppe PM$_{2,5}$, Germany.

The parallel measurements have been performed at various locations, including traffic-oriented, urban background and rural locations, during different meteorological seasons. The results are presented in Figure B.6.



Key

X	*C* (µg/m^3), Reference	
Y	*C* (µg/m^3), 30 m^3/h sampler	
REGRESSION OUTPUT:		
slope b	1,005	
uncertainty of b	0,007	
intercept a	-0,16	
uncertainty of a	0,20	
number of data pairs	615	
EQUIVALENCE TEST RESULTS:		
random term	2,8	µg/m³
bias at LV	0,0	µg/m³
combined uncertainty	2,8	µg/m³
relative uncertainty	9,3 %	pass
ref uncertainty	0,8	µg/m³
limit value	30	µg/m³

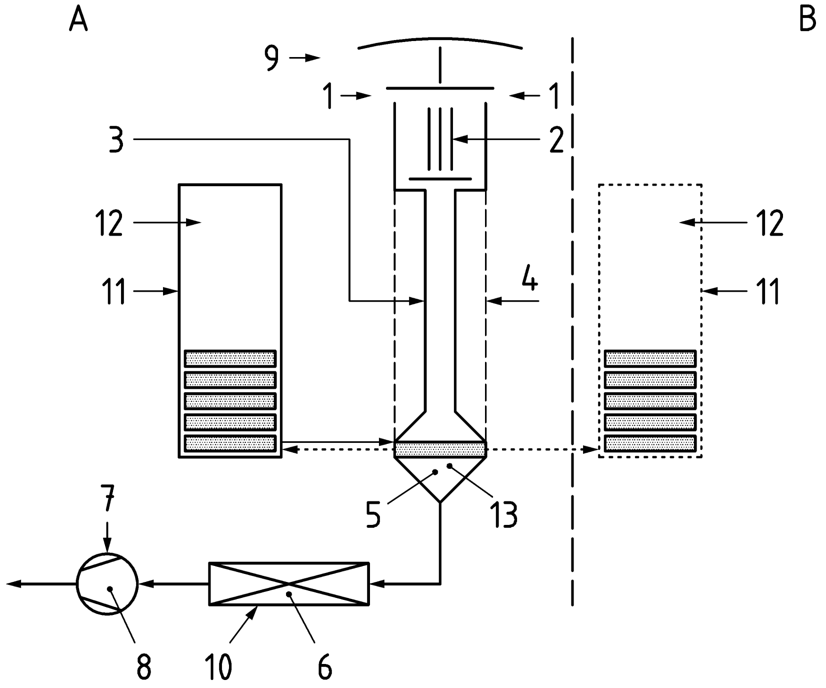
Figure B.6 — Equivalence of reference sampler with sampler operating at 30 m^3/h for PM$_{2,5}$

The bias found reflects the comparability of both samplers. The relatively large scatter may be due to the application of regimes of QA/QC that are far less stringent than that described in this European Standard. These regimes reflected the state-of-the-art at the time of the performance of part of the comparisons.

Whenever this sampler is used no additional contribution needs to be made to the uncertainty of the measurement results.

Annex C
(informative)

Scheme of PM standard sampler



Key

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

Figure C.1 — Scheme of PM standard sampler

Annex D
(informative)

Suitability tests for filters

D.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 should be able to retain particles of a nominal aerodynamic size of 0,3 µm with an efficiency ≥ 99,5 %.

D.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 6.2 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.

D.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, should be below 20 %.

D.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 6.2 and weigh without static discharging;
- reweigh the filters after static discharging;
- the maximum acceptable difference for individual results is 40 ug.

D.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 6.2,

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

c) a subsequent conditioning as described in (6.2), 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 6.2;
- 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 6.2, 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:

- $m_{i,2} – m_{i,3} \leq 40$ µg,
- $m_{i,3} – m_{i,7} \leq 40$ µg.

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.

Annex E
(normative)

Initial suitability testing of weighing facilities

E.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 5.2.2.

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 5.2 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.

E.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.

E.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 6.5). 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 F
(informative)

Results of experimental work

Within the frame of the drafting of this (revised) European Standard a limited number of experiments has been performed to address some of the major sources of uncertainty associated with the application of the procedure:

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

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

c) 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 have been 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 have been involved in the tests.

The results of the tests may be 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 preconditioned field blanks 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;

3) that a reduction of the range of relative humidities permitted for conditioning and weighing from (45 to 55) % RH to (45 to 50) % RH would reduce the average uncertainty due to possible variations in relative humidity from 2,8 µg/m^3 to 1,1 µg/m^3 for the filters investigated.

The results of these experiments have led to the new requirements and recommendations given in 6.2, 6.4 and Annex B.

Annex G
(informative)

Impactor efficiency

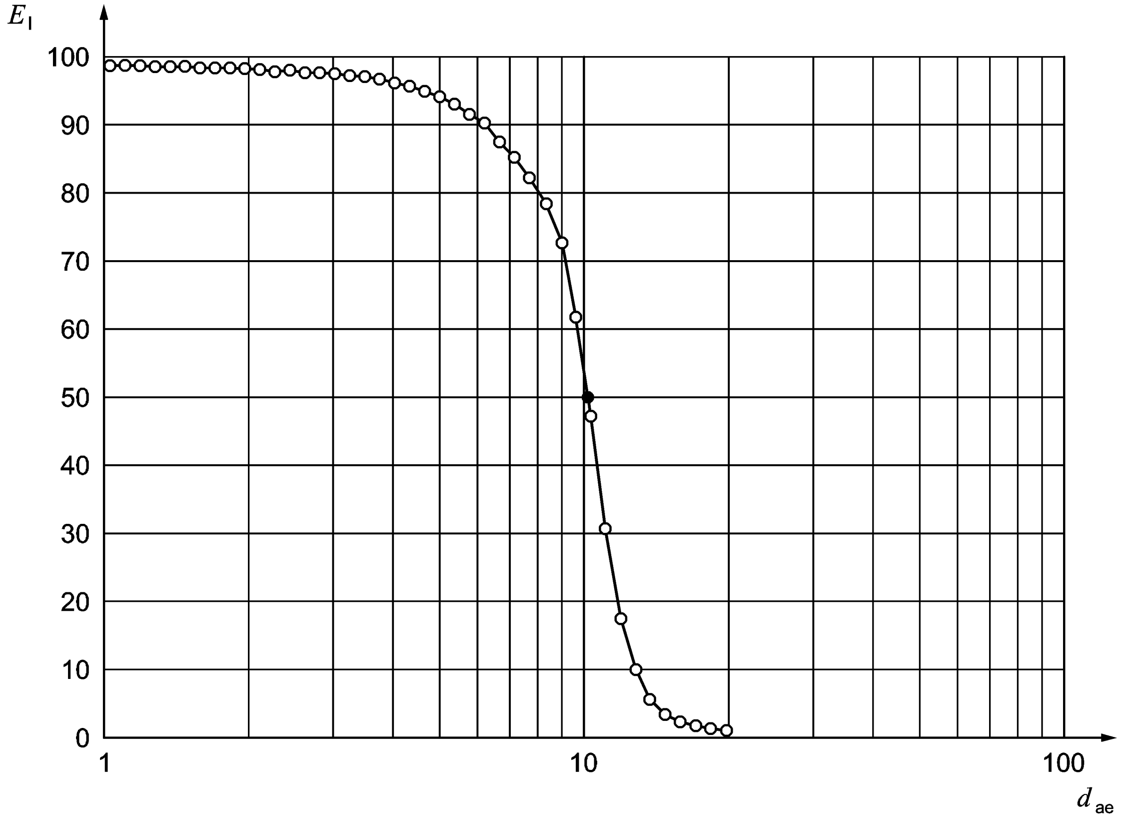


Figure G.1 — Impactor efficiency E_I in relation to the particle aerodynamic diameter d_{ae} of the standard inlet for the sampling of PM_{10} [25]

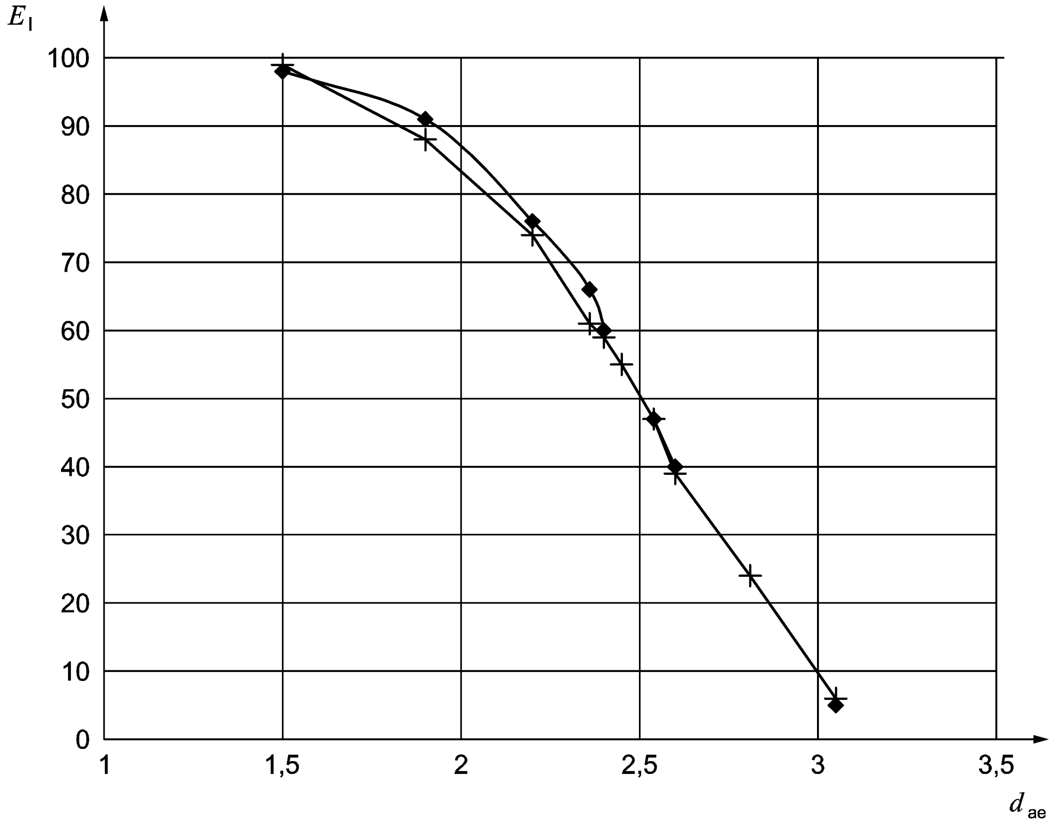


Figure G.2 — Impactor efficiency E_I in relation to the particle aerodynamic diameter d_{ae} of the standard inlet for the sampling of $PM_{2,5}$ (two test runs)

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