BRITISH STANDARD

BS EN 14907:2005

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

The European Standard EN 14907:2005 has the status of a British Standard

ICS 13.040.20

British Standards

National foreword

This British Standard is the official English language version of EN 14907:2005.

The UK participation in its preparation was entrusted by Technical Committee EH/2, Air quality, to Subcommittee EH/2/3, Ambient atmospheres, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

Additional information

This standard is essentially an improved version of EN 12341:1998, which applies to the PM_{10} mass fraction, but instead covers the $PM_{2,5}$ mass fraction. Owing to the urgent need for robust standard methods for suspended particulate matter, CEN considered it preferable to publish this standard now rather than delay, even though there are inconsistencies between the two versions of the test method, the equivalence test procedure in Annex A has not been widely evaluated and the nature of the filter conditioning parameters is imperfect. The United Kingdom consistently voted against its approval as a European Standard and against publication in this form.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the *BSI Catalogue* under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

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English Version

Ambient air quality - Standard gravimetric measurement method for the determination of the PM2,5 mass fraction of suspended particulate matter

Qualité de l'air ambiant - Méthode de mesurage gravimétrique de référence pour la détermination de la fraction massique PM 2,5 de matière particulaire en suspension

Luftbeschaffenheit - Gravimetrisches Standardmessverfahren für die Bestimmung der PM2,5-Massenfraktion des Schwebstaubs

This European Standard was approved by CEN on 22 July 2005.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

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Foreword

This European Standard (EN 14907:2005) 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 March 2006, and conflicting national standards shall be withdrawn at the latest by March 2006.

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

For relationship with EU Directive(s), see informative annex ZA, which is an integral part of this European Standard.

As part of a continuous quality improvement, it is anticipated that this standard and EN 12341 (PM_{10}) may be reviewed by the Technical Committee in the near future.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and 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 harmonised methodology for monitoring the 2,5 µm mass fraction of suspended particulate matter ($PM_{2,5}$) in ambient air, following Community Directive 96/62/EC on ambient air quality assessment and management [1], and Council Directive 1999/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air [2], which sets the parameters specific to the assessment of particulate matter.

The standard method set out in this European Standard is focused primarily on harmonisation and improvement of the data quality of measurement methods used in monitoring networks, but is not necessarily best suited for practical use in routine monitoring.

There are no traceable reference standards for $PM_{2,5}$ measurements. Therefore, the standard method set out in this European Standard defines the measured quantity by convention, specifically by the sample inlet design and associated operational parameters covering the whole measurement process. The standard contains:

- manual gravimetric standard measurement method for $PM_{2,5}$ using single filters;
- summary of performance characteristics of the method, including measurement uncertainty;
- procedure for determining whether non-standard measurement methods (like other manual gravimetric or automatic monitoring methods) are equivalent to this standard method (Annex A).

The precision and performance characteristics described in this European Standard were determined in 9 different comparative and validation trials. The trials were performed at 9 different sites in northern, middle and southern European countries in order to cover a wide range of relevant ambient air conditions. The trials were sponsored by the European Commission and the European Free Trade Association.

In addition to the measurement procedure of the 2,5 µm mass fraction of suspended particulate matter ($PM_{2,5}$) in ambient air being described in this European Standard, there is European Standard EN 12341 [3] dealing with the measurement of PM_{10}.

1 Scope

This European Standard describes a standard method for determining the $PM_{2,5}$ mass concentration of suspended particulate matter in ambient air by sampling the particulate matter on filters and weighing them by means of a balance.

Measurements are made over a sampling period of about 24 h, and in line with the Directive, are expressed as $\mu g/m^3$, where the volume of air is the volume at ambient conditions near the inlet at the time of sampling.

The range of application of the standard is from 1 $\mu g/m^3$ (i.e. the limit of detection of the standard measurement method expressed as its uncertainty) up to 120 $\mu g/m^3$ (i.e. the maximum concentration level observed during the field study undertaken by CEN/TC 264/WG 15 to validate the standard).

NOTE Although the standard is not validated for concentrations over 120 $\mu g/m^3$, its range of application could well be extended to commonly encountered ambient concentrations up to circa 200 $\mu g/m^3$ when using glass or quartz fibre filters. At these high concentrations and particulate mass loadings no filter clogging is to be expected. Also the flow rate can be easily maintained at the nominal setting.

The equivalence procedure in Annex A specifies two approaches, depending on whether the candidate method differs slightly or fundamentally from the standard method.

In the former case, involving only slight differences from the standard method (“variations on a theme”) Annex A provides a restricted procedure to compare only the pertinent differences, instead of a full field test. This part of the annex serves to give practical guidance for determining equivalence for measurement methods commonly used in monitoring networks, and includes examples of common variations to the standard method, such as different filter storing or conditioning procedures and the variation of the standard method for the application as automated filter changer.

In the latter case, involving a full set of field tests, the procedure serves to determine equivalence only within the range of conditions under which the field tests are carried out. The equivalence can be shown to hold for conditions prevailing within European countries by carrying out the field test in situations covering a suitable range of relevant ambient parameters (such as concentration and composition of the suspended particulate matter, temperature, and humidity).

Although this European Standard does not explicitly address automatic monitoring methods for the measurement of the $PM_{2,5}$ mass fraction in ambient air, the equivalence test procedure in Annex A applies both to non-automatic and automatic methods.

2 Normative references

The following referenced documents are indispensable for the application of this European Standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ENV 13005, *Guide to the expression of uncertainty in measurements*

CR 14377, *Air quality – Approach to uncertainty estimation for ambient air reference measurement methods*

3 Terms, definitions and abbreviations

For the purposes of this European Standard, the following terms, definitions and abbreviations apply.

3.1 Terms and definitions

3.1.1

ambient air

outdoor air in the lower troposphere excluding workplace air

3.1.2

$PM_{2,5}$ automatic monitoring method

method intended for the automatic on-line determination of the $PM_{2,5}$ mass concentration of suspended particulate matter in ambient air

3.1.3

high volume sampling method

HVS

method for sampling particulate matter with a flow rate of 30 m^3/h

3.1.4

low volume sampling method

LVS

method for sampling particulate matter with a flow rate of 2,3 m^3/h

3.1.5

$PM_{2,5}$

fraction of suspended particulate matter which passes through a size-selective inlet with a 50 % cut-off efficiency at 2,5 µm aerodynamic diameter

NOTE By convention, the size-selective standard inlet design prescribed in 5.1.2, used at the flow rate given in 5.1.5, possesses the required characteristics in order to sample the $PM_{2,5}$ fraction in ambient air.

3.1.6

suspended particulate matter

SPM

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

3.1.7

uncertainty (of measurement)

parameter, associated with the result of a measurement, that characterizes the dispersion of the values that would reasonably be attributed to the measurand (see also ENV 13005)

3.1.8

nominal flow rate

flow rate at the point set

3.2 Abbreviations

3.2.1

CM

candidate method (non-standard measurement method)

3.2.2

DQO

EU data quality objectives

3.2.3

PM

particulate matter

3.2.4
QA
quality assurance

3.2.5
QC
quality control

3.2.6
RH
relative humidity

3.2.7
SM
standard measurement method

3.2.8
SPM
suspended particulate matter

4 Principle

4.1 Description of the standard measuring principle

Ambient air is passed through a $PM_{2,5}$ size-selective inlet, at a known, constant flow rate. The $PM_{2,5}$ fraction is collected on a filter for a known period of about 24 h. The mass of the $PM_{2,5}$ material is determined by weighing the filter at 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:

- deposition losses of non-volatile $PM_{2,5}$ fraction within the pipework between the inlet and the filter;
- uncontrolled losses due to volatilisation of semi-volatile $PM_{2,5}$, both within the pipework between the inlet and the filter, and on the filter at any time between collection and weighing;
- possible changes in weight of the filters or $PM_{2,5}$ fraction due to adsorbed water, spurious addition or loss of material, buoyancy, or static electricity;
- flow rate.

4.2 Description of QA/QC procedures

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.

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.

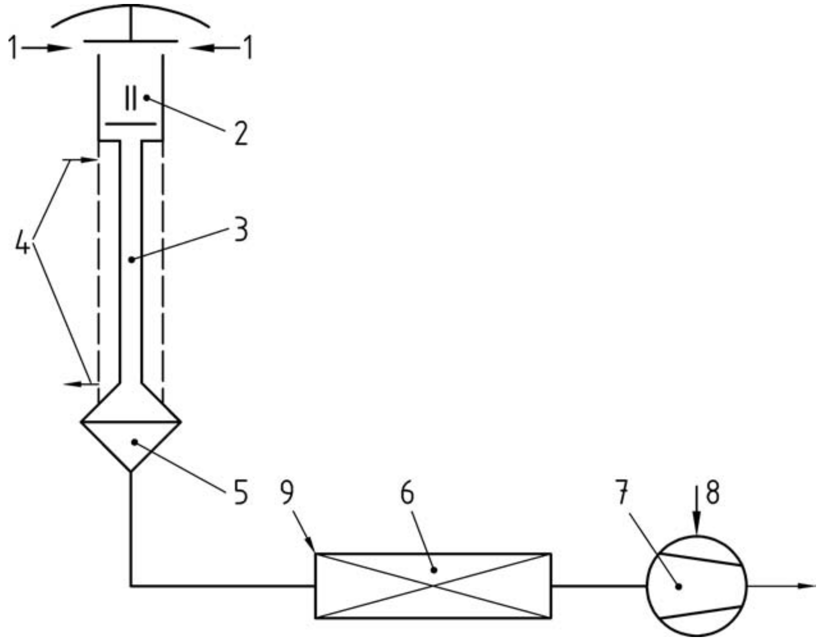
5 Equipment and facilities

5.1 Sampling system components

5.1.1 General

This European Standard contains two different designs for the sampling system to be used within the standard method. These designs operate at significantly different flow rates, and will be described throughout the text as the "low volume" or LVS and "high volume" or HVS designs.

The sampling system for the standard measurement method consists of the following elements, illustrated schematically in Figure 1.



Key

1 Air sample (T_a, p_a)
2 Impactor inlet
3 Connecting pipework
4 Sheath air (only LVS, see Note in 5.1.3)
5 Filter holder
6 Flow measuring device
7 Pump
8 Flow control system
9 Measurement of temperature T, pressure p and flow rate F
T_a Ambient temperature
p_a Ambient pressure
F_a Flow rate related to ambient conditions (T_a, p_a)

$$F_a = \frac{T_a \times p}{T \times p_a} \times F \quad (\mathrm{m^3/h})$$

Figure 1 – Scheme of PM$_{2,5}$ standard sampler

- size-selective inlet, whose design is prescribed in 5.1.2;
- connecting pipework 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.

The sampling system shall be made of an inert, non-corroding, electrically conducting material such as preferably stainless steel or anodised aluminium or aluminium alloy.

Correct operation of the sampling system also requires calibration devices regarding flow rate, and ambient temperature and pressure sensors, with specifications given in Clause 7.

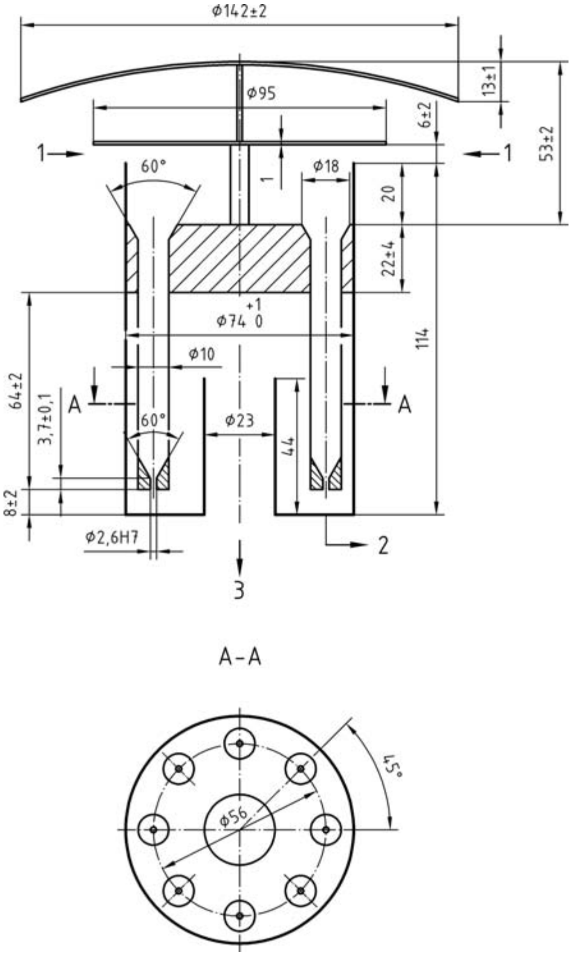
5.1.2 Standard inlet design

5.1.2.1 General

The critical dimensions of the inlet designs for LVS and HVS are given below in 5.1.2.2 and 5.1.2.3 respectively.

5.1.2.2 LVS standard inlet design

All measures in millimetres
Tolerance of all measures without tolerances: ± 0,2 mm respectively ± 0,5 °



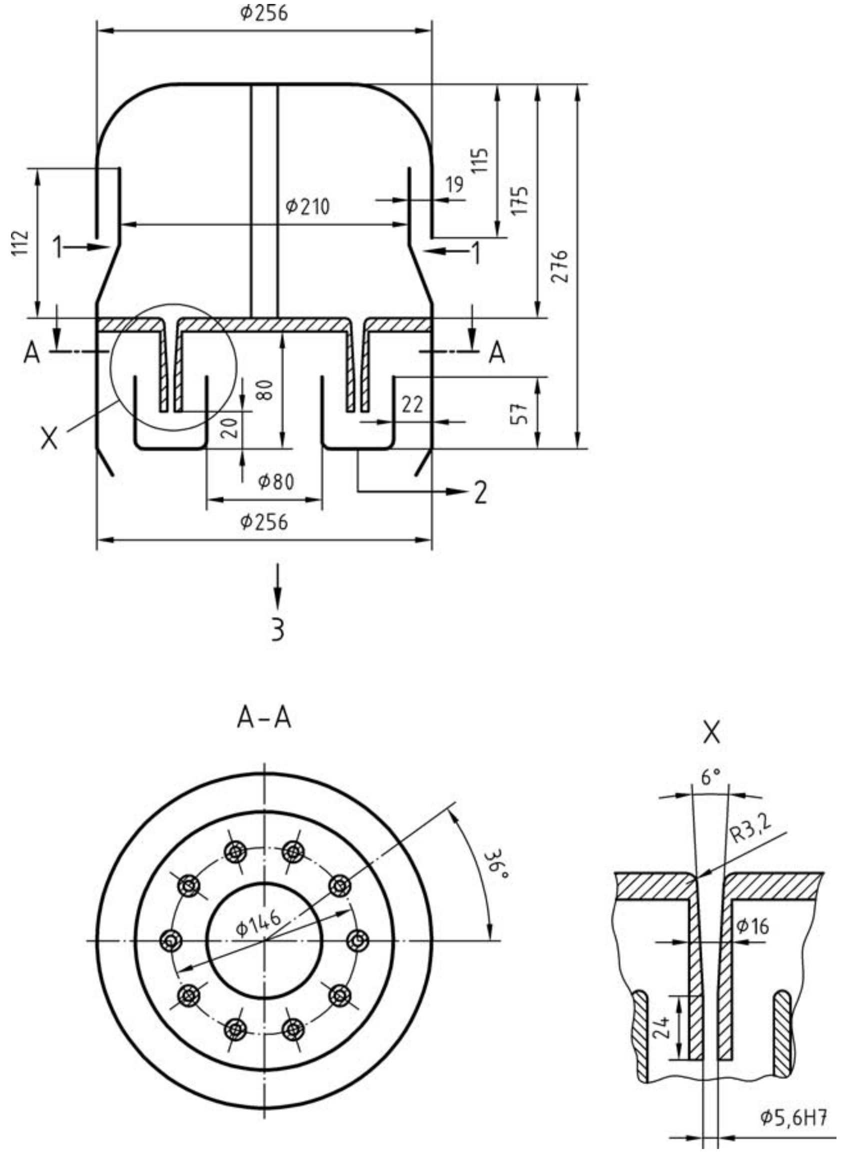
Key

1 Air sample
2 Drainage for impacted water
3 To filter
H7 Manufacturing tolerance

Figure 2 – Design of 2,3 m³/h $PM_{2,5}$ LVS inlet

5.1.2.3 HVS standard inlet design

All measures in millimetres
Tolerance of all measures without tolerances: ± 0,2 mm respectively ± 0,5 °



Key

1	Air sample
2	Drainage for impacted water
3	To filter
H7	Manufacturing tolerance

Figure 3 – Design of 30 m³/h $PM_{2,5}$ HVS inlet

5.1.3 Connecting pipework

The requirements for the connecting pipework between the inlet and the filter holder are to minimise deposition losses of particulate matter by kinetic processes, as well as losses due to thermal, chemical or electrostatic processes. Contact of the sampled air with cold surfaces which could cause condensation shall be avoided.

Also, the pipework shall be designed to minimise the effect of solar heating so that the air sample is kept as close as possible to ambient temperature.

The temperature of the connecting pipework should be kept close to the ambient temperature as close as possible. The deviation of the temperature shall be less than ± 5 °C (preferably measured directly behind the filter).

NOTE This requirement can be met for the LVS by flowing a sheath of ambient air around the pipework between the inlet and the filter up to the close range of the filter. For the HVS, the high air velocity inside the connecting pipework is generally sufficient to meet the requirement.

The flow velocity in the pipework, determined by the tube diameter, that prevents significant losses due to diffusion or turbulent inertial impaction.

The pipework shall have no bends and be vertical.

The length of the connecting pipework between the inlet and the filter holder shall be no longer than 3 m.

The pipework shall be made of an inert, non-corroding, electrically conducting material preferably such as stainless steel or anodised aluminium.

5.1.4 Filter holder and filter

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

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 cooling elements such as electrical apparatus (e.g. the sampling pump), and air conditioning shall be minimised. During warm seasonal periods e.g. in spring, summer and autumn the temperature rise of the sample filter shall be limited to less than 5 °C measured above the temperature of the ambient air surrounding of the sampler, by incorporating temperature measurements preferably directly downstream the filter.

The filters shall be made of glass fibre, quartz fibre, PTFE or PTFE coated glass fibre.

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

NOTE It is recommended that filter manufacturers determine the filter separation efficiency according to standard methods such as EN 13274-7 [4] or EN 1822-1 [5].

For the LVS the filter holder shall be suitable for insertion of circular filters, such that the diameter of the free area through which the sampled air passes shall be between 34 mm and 41 mm.

For the HVS the filter holder shall be suitable for insertion of circular filters, such that the diameter of the free area through which the sampled air passes shall be between 135 mm and 143 mm.

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

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 $PM_{2,5}$ concentration. The flow control system shall be in accordance with basic physical principles.

As the sampled volume shall be expressed at ambient air conditions near the $PM_{2,5}$ 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.

Volumetric flow through the inlet shall be controllable to a nominal value of 2,3 m^3/h at ambient conditions for the LVS standard inlet, and 30 m^3/h for the HVS reference inlet. The instantaneous value of the flow rate shall be held constant within 5 % of the nominal value at ambient conditions.

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

This time duration can be determined using any timing device which provides the accuracy required in 6.4.

5.2 Weighing facilities

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", though it may be either a suitable room or cabinet. The temperature and the relative humidity shall be continuously monitored and controlled to 20 °C ± 1 K and (50 ± 5) % RH respectively.

WARNING The weighing room conditions in 5.2 should refer to the conditions given in EN 12341. The WG which drafted the standard strongly recommends that the relative humidity during conditioning shall be lowered. For reasons of legal continuity it was decided that this would be best accomplished by linking prEN 14907 to EN 12341 and reevaluating the parameters when EN 12341 is revised in the near future.

The balance used shall be installed and operated within the weighing room and have a resolution equal to or better than 10 µg for filters used with the LVS system, equal to or better than 100 µg for filters used with the HVS system.

6 Sampling and weighing procedure

6.1 General

This section covers the procedure to be followed for each measurement, including Quality Assurance and Quality Control measures to be applied.

6.2 Weighing room procedures

The following procedures shall be applied at every weighing session:

Weighing room conditions shall be monitored and documented.

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

NOTE 1 When PTFE-coated tweezers are used, static charges can occur at fibre filters.

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 20 µg for LVS or 200 µg for HVS from the reference mass, the situation shall be investigated and resolved before proceeding.

A static discharger shall be used on PTFE filters prior to weighing.

NOTE 2 A static discharger is not necessary with glass fibre or quartz filters.

Two blank reference filters of the same size and material as those used for the measurement shall be kept in the weighing room. Their weight shall be recorded at each weighing session, as a measure of climatic conditions affecting the weight of the LVS and HVS filters.

For the LVS design, if the masses of the blank reference filters have changed by less than 40 µg since the last weighing session, their average mass shall be recorded, and weighing of LVS filters can proceed. If the masses of the blank reference filters have changed by more than 40 µg, the situation shall be investigated and resolved before proceeding.

For the HVS design, if the masses of the blank reference filters have changed by less than 500 µg since the last weighing session, their average mass shall be recorded, and weighing of HVS filters can proceed. If the masses of the blank reference filters have changed by more than 500 µg, the situation shall be investigated and resolved before proceeding.

NOTE 3 The above changes in mass of 40 µg and 500 µg for LVS and HVS blank reference filters respectively are equivalent to a change in measured concentration of about 0,7 µg/m³ (at nominal flow and 24 h of sampling).

6.3 Unloaded filter weighing

Unloaded filters shall be conditioned in the weighing room for a minimum of 48 h before weighing (see 5.2).

Filters shall be weighed twice, with an interval of at least 12 h, to confirm that the filter weight has stabilised. If the masses differ by a mass more than 40 µg for LVS or 500 µg for HVS, the particular filter shall be discarded.

NOTE The above differences in mass of 40 µg for LVS and 500 µg for HVS are equivalent to a difference in measured concentration of 0,7 µg/m³ (at nominal flow and 24 h of sampling).

The unloaded filter mass shall be taken as the average of the two separate measurements.

Unloaded filters may be stored in the weighing room for up to 28 days before sampling.

6.4 Sampling period

The sampling period shall be (24 ± 1) h, and shall be recorded with an accuracy of ± 5 min.

6.5 Sample storage and transport procedures

All filters shall be left unfolded and protected during storage and transport, for example in the filter holder, in clean glass petri dishes, or similar containers.

If the minimum hourly mean ambient temperature (T_a) over the sampling period is above 23 °C, the filter shall be kept at or below the temperature T_a for a maximum time of 15 days before introduction to the weighing room. If T_a is equal to or below 23 °C, the filter may be kept at or below a temperature of 23 °C for the maximum time of 15 days before introduction to the weighing room.

Transport of loaded filters shall be in covered containers, and in line with the temperature conditions given above.

NOTE The rationale for defining storage and transport conditions is to minimize changes to particle mass, for example by loss of semi-volatile material, and to minimize undesirable factors such as condensation.

The temperature of 23 °C was chosen to be the weighing room temperature (20 °C) with 3 °C tolerance, to take into account practical considerations.

6.6 Loaded filter weighing

Loaded filters shall be placed in the weighing room for a minimum of 48 h before weighing, and then again after a further 24 h to 72 h. If the masses differ by more than 60 µg for LVS or 800 µg for HVS the result shall not be taken into account.

NOTE The above differences in mass of 60 µg for LVS and 800 µg for HVS are equivalent to a difference in measured concentration of 1 µg/m³ (at nominal flow and 24 h of sampling).

The loaded filter mass shall be taken as the average of the two separate measurements.

7 Additional quality assurance and quality control

7.1 General

This section covers quality assurance and quality control activities additional to those in Clause 6, to be used on a less frequent basis.

7.2 Maintenance of the sampling system

Maintenance of mechanical parts of the sampling system (inlet and connecting pipework) shall be carried out according to the manufacturer’s instructions.

Sample inlets shall be cleaned and greased according to the manufacturer's requirements, taking into account local particulate concentrations. If no instructions on cleaning intervals are given by the manufacturers the inlets shall be greased at least every 15th sample.

7.3 Calibration

7.3.1 Flow rate

The flow rate for the reference LVS and HVS instruments shall be checked against an appropriate transfer standard flow meter traceable to a national or international standard, at least every three months. The expanded uncertainty (at 95 % confidence) of the transfer standard flow meter measurements shall be better than 2 % at laboratory conditions.

If the flow rate determined using the transfer standard deviates more than 2 % from the value required for correct operation of the inlet, the flow controller shall be adjusted according to the manufacturer's instructions.

7.3.2 Ambient temperature and pressure sensors

Where temperature and pressure measurements separate from the flow control unit are needed to produce the correct $PM_{2,5}$ concentration (i.e. with ambient volume units), ambient temperature and pressure shall be determined using adequately calibrated instruments.

7.3.3 Balance

The balance shall be calibrated against appropriate masses traceable to national or international standards at least once a year.

7.3.4 Weighing room temperature and relative humidity sensors

The uncertainty (95 %) of the temperature measurement shall be better than ± 0,5 K, and of the relative humidity measurements better than ± 2,0 % RH.

The sensors shall be checked against appropriate transfer standards every 3 months, and calibrated against appropriate national or international standards at least once a year.

7.4 Field blanks

Blank filters which are conditioned alongside filters used for sampling shall be weighed before and after transportation to the monitoring site together with the filters used for sampling. The detailed procedure for use of these field blanks to assess local factors affecting filter weighing is left to the local operator. If the blank masses differ by a mass more than 40 µg for LVS or 500 µg for HVS the reason shall be investigated.

NOTE The above differences in mass of 40 µg for LVS and 500 µg for HVS are equivalent to a difference in measured concentration of 0,7 µg/m³ (at nominal flow and 24 h of sampling).

8 Expression of results

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

The result is calculated as the difference in mass between the loaded and unloaded filter, divided by the sample volume, determined as the flow rate multiplied by the sampling time.

$$C = \frac{m(l) - m(u)}{F \times t} \tag{1}$$

where C is the concentration, in µg/m³;

$m(l)$ is the loaded filter mass, in µg;

$m(u)$ is the unloaded filter mass, in µg;

F is the volume flow rate at ambient air conditions, in m^3/h;

t is the sampling time, in h.

9 Performance characteristics of the method

9.1 General

The performance characteristics of the standard measurement method are covered in the following four sections:

- 9.2 outlines the GUM approach for determining the uncertainty of measurements made using the standard method;
- 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;

- 9.4 compares the uncertainty with the data quality objectives from Annex B.

9.2 GUM concept

Following CR 14377, the assessment of measurement uncertainty of the standard measurement method shall be based on the approach described in the ISO Guide to the expression of uncertainty in measurement (GUM) (see Clause 2), also published as ENV 13005. The approach requires:

— Establishment of a model equation which represents the procedure for obtaining the desired output quantity from the input quantities (see Clause 8).

$$C = \frac{m(l) - m(u)}{F \times t} \tag{1}$$

where

C is the concentration, in µg/m³;

$m(l)$ is the loaded filter mass, in µg;

$m(u)$ is the unloaded filter mass, in µg;

F is the volume flow rate at ambient air conditions, in m^3/h;

t is the sampling time, in h.

The output quantity C is the $PM_{2,5}$ mass concentration; the input quantities are the masses $m(l)$ and $m(u)$ of the loaded and unloaded filter respectively, the flow rate F, 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:

$$u_c^2 = \sum (u_i)^2 \tag{2}$$

— Calculation of the expanded uncertainty U, by multiplying u_c by the coverage factor k:

$$U = k \times u_c \tag{3}$$

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 Annex B.

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_{field} of differences between identical samplers serves as a measure of these combined effects according to Equation 4.

$$u_{field}^2 = \frac{\sum (X_{i,1} - X_{i,2})^2}{2n} \tag{4}$$

where

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

n is the number of paired values.

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

9.3 Individual uncertainty sources

9.3.1 General

From the model equation (1), 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: *m(l)* - *m(u)*

9.3.2.1 Change of mass because inlet particulate size selection performance deviates from the designated characteristic

The designated particulate size selection characteristic for the $PM_{2,5}$ fraction of suspended particulate matter is defined by the designs in 5.1.2, 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 designated flow rate.

These deviations are limited by the design tolerances in 5.1.2 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 $PM_{2,5}$ cut-off diameter changes by about 1,5 % for a temperature change of 10 K. Since very little of the mass in the $PM_{2,5}$ fraction is found in particles close in size to the cut-off diameter, the effect on the sampled mass is considered to be negligible.

It is considered that any random contribution to the measurement uncertainty will be incorporated within the field test parameter u_{field}.

9.3.2.2 Deposition losses in the connecting pipework

There are several different mechanisms which can potentially lead to losses of particulate matter in the pipework between the inlet and the filter [6]. Turbulent inertial deposition is the most critical mechanism, but for $PM_{2,5}$ the loss within tubing up to 3 m length is expected to be less than 0,1 %.

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 pipework.

Other factors influencing the transport losses in the connecting pipework are thermophoretic and diffusiophoretic deposition, which are kept negligible by avoiding a large temperature drop between the connecting pipework and the sampled air.

These factors are all limited by the requirements in Clause 5.

Finally, particle diffusion is only significant for very small particles, which have a negligible contribution to the observed $PM_{2,5}$ mass.

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

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 $PM_{2,5}$ mass can be composed of semi-volatile components, such as ammonium nitrate, which can volatilise at any time between entry to the sample inlet and weighing of the loaded filter, at a rate predominantly determined by the temperature of the sampling system and the filter. Hence, some loss of semi-volatile material is expected when this European Standard is followed and the loss may differ between the different location, day and SM values.

This volatilisation 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.

However, the definition of $PM_{2,5}$ for the purpose of this European Standard incorporates these losses of semi-volatile material. Therefore, the average effect of volatilisation losses on the measurement of $PM_{2,5}$ is considered to be zero by convention, when the constraints set out in this European Standard are followed.

The effect on uncertainty of variation in losses of material from similar samples experiencing similar storage, transport and conditioning will be included in the variation within the field test, u_{field}.

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 field tests, and are assessed separately.

9.3.2.5 Change in filter mass between the unloaded and loaded weighings (excluding the particulate 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 of nominally the same material.

For the purpose of this European Standard only changes in the effect of humidity between the unloaded and loaded weighings are relevant. This effect is controlled by the conditioning requirements for unloaded and loaded 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 test, u_{field}. However, a change in average relative humidity from say 45 % to 55 % between the unloaded and loaded filter weighing sessions would be permissible according to the standard but will not have been accounted for in the u_{field} parameter, as the individual filters will have experienced the same conditions. The maximum effect is quantified by the constraints on mass change on unloaded filters at separate weighing sessions given in 6.2 and 6.3.

9.3.2.6 Variation in mass of particulate matter due to water content

A second function of the conditioning constraints is to bring the collected particulate matter to a standard level of water content by prescribing the temperature and relative humidity before and during weighing.

The effect of this on the uncertainty of the measurement is quantified by the constraint on mass change at the separate weighings of loaded filters given in 6.6.

9.3.2.7 Changes in buoyancy effects between the unloaded and loaded 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 for LVS filters, and less than 30 µg for HVS filters.

9.3.2.8 Balance accuracy and zero drift

Typical balances have a repeatability and accuracy, when calibrated, of less than 10 µg for LVS filters and 100 µg for HVS filters (see Clause 7). 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 for LVS filters and hundreds of µg for HVS filters. These errors are controlled by the procedures for use of reference masses 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_{field}.

9.3.2.10 Contamination or loss of filter material between unloaded and loaded 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 test, u_{field}.

9.3.3 Flow rate (F)

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 %. 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 tests, 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 pipework 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 test, $u_{\text{field.}}$

9.3.4 Time (t)

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

Firstly, the measurement unaccuracy 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.

9.3.5 Field test uncertainty

The uncertainties u_{field} used in this standard were obtained from the field study undertaken by CEN/TC 264/WG 15 on $PM_{2,5}$, carried out over almost 3 years at 9 sites such that a broad range of relevant ambient parameters prevailing within European countries was covered.

The results from this study are given in a separate report [7].

The uncertainties u_{field} were derived from the results from all the sites using the equation given in 9.2.

9.3.6 Uncertainty budget

The individual sources of uncertainty are summarised in Table 1.

Table 1 – Individual sources of uncertainty

Contribution	**Symbol of**	**Component additional to field test – low volume**	**Component additional to field test – high volume**
Mass m(l) – m(u)	u_m		
Inlet performance	u_{mip}	Negligible	Negligible
Transport loss	u_{mtl}	Negligible	Negligible
Filter efficiency	u_{mfe}	Negligible	Negligible
Loss of semi-volatiles	U_{msv}	Zero by convention	Zero by convention
Effect of humidity on filter	u_{mhf}	$\frac{40}{\sqrt{3\mu g}}$	$\frac{500}{\sqrt{3\mu g}}$
Effect of humidity on particulate	u_{mhp}	$\frac{60}{\sqrt{3\mu g}}$	$\frac{800}{\sqrt{3\mu g}}$
Buoyancy	u_{mb}	$\frac{3}{\sqrt{3\mu g}}$	$\frac{30}{\sqrt{3\mu g}}$
Static	u_{ms}	Negligible	Negligible
Contamination	u_{mc}	Negligible	Negligible
Balance : calibration	u_{mba}	$\frac{10}{\sqrt{3\mu g}}$	$\frac{100}{\sqrt{3\mu g}}$
Balance : zero drift	u_{mzd}	$\frac{10}{\sqrt{3\mu g}}$	$\frac{100}{\sqrt{3\mu g}}$

Table 1 *(continued)*

Contribution	**Symbol of**	**Component additional to field test – low volume**	**Component additional to field test – high volume**
Mass m(l) – m(u)	u_m		
Flow	u_f		
Calibration	u_{fc}	$\frac{3}{\sqrt{3\%}}$	$\frac{3}{\sqrt{3\%}}$
Drift	u_{fd}	Negligible	Negligible
Time	u_t	Negligible	Negligible
Field test	u_{field}	$\frac{1\mu g}{m^3}$	$\frac{1\mu g}{m^3}$
Combined uncertainty	u_c	$\frac{1.4\mu g}{m^3}$	$\frac{1.4\mu g}{m^3}$

The combined uncertainty is calculated as follows.

Firstly, the "additional" uncertainties for u_m and u_f are calculated:

$$u_m = \surd\,(\Sigma\, u_{mi}^2)\ \mu g \tag{5}$$

$$u_f = u_{fc}\ \%$$

where

u_{mi} is the single contributions u to the uncertainty u_m (6)

Then, the combined uncertainty for a given concentration C (in µg/m^3) is calculated using Equation 7.

$$u_c = \surd\,(u_{field}^2 + u_m^2/V^2 + C^2 \cdot u_f^2 /100^2)\ \mu g/m^3 \tag{7}$$

where

$V = F \times t$ is the nominal sampled volume in cubic metres;

C is the mass concentration of $PM_{2,5}$, specified as daily and annual mean in Table 2, in 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 from Annex B, notably the daily and annual limit values respectively.

For the daily limit value, the expanded uncertainty at a 95 % level of confidence is given by:

$$U = 2 \times u_c \ \mu g/m^3 \qquad (8)$$

The annual value is obtained by averaging 365 daily values, taking into account that components of uncertainty which contribute randomly will have a reduced impact. For the purpose of this standard it is assumed that the u_{field} parameter represents random contributions, while other contributions remain as they were for the daily values.

The annual expanded uncertainty is given by:

$$U_{ann} = 2 \times \sqrt{} \, (u_{field}^2/365 + u_m^2/V^2 + C^2 \times u_f^2 /100^2) \ \mu g/m^3 \qquad (9)$$

Table 2 summarizes the expanded uncertainty of the standard measurement method (SM) at the daily and annual limit values, together with the EU Data Quality Objectives (DQO).

NOTE At present no official EU limit values have been established. Therefore, default values have been used, following the provisional suggestions from the CAFÉ committee. The values given in the table should be considered as indicative, in order to compare with the pertinent DQO's for $PM_{2,5}$, given as percentages.

Table 2 – Expanded uncertainty of the standard measurement method

Default limit value	EU DQO	LVS SM expanded uncertainty		HVS SM expanded uncertainty	
		$\mu g/m^3$	**%**	$\mu g/m^3$	**%**
Daily mean					
35 $\mu g/m^3$	25 %	2,8	8	2,8	8
Annual mean					
20 $\mu g/m^3$	25 %	1,7	8,5	1,7	8,5

Annex A
(informative)

Equivalence test procedure for non-standard measurement methods

A.1 General

This annex describes a procedure for determining whether non-standard measurement methods (candidate methods (CM)) are to be considered equivalent to the standard measurement method (SM) for monitoring the $PM_{2,5}$ fraction of total suspended particulates in ambient air.

For example, the methodology may be used to evaluate other sample inlets, or automated methods such as those based on the use of oscillating microbalances, ß-ray attenuation, or optical techniques.

To judge whether a candidate method is equivalent to the standard measurement method, the CM shall meet the Data Quality Objectives (DQO) from Annex B, regarding data capture, time coverage and expanded uncertainty.

Equivalence does not necessarily have to cover the wide range of prevailing conditions within European countries. It can also be awarded for specific ambient situations within EU member states.

The equivalence procedure was drafted by an ad-hoc EC working group on "Guidance for the Demonstration of Equivalence", by describing the principles and methodologies to be used for the demonstration of the equivalence of alternative methods to the EN standard methods. It is intended for use by the laboratories nominated by National Competent Authorities [1] to perform the tests relevant to the demonstration of equivalence of ambient air measurement methods.

Although not normative, application of the "Guidance for the Demonstration of Equivalence" is provisionally recommended by the so-called CAFE committee.

The formal procedures for equivalence testing are given in A.2.

In A.3 an overview is given of the test procedure to be employed: a limited laboratory test to investigate candidate methods which differ only slightly from the standard measurement method, or a full field test where the candidate method is more fundamentally different from the standard method.

All details to perform the equivalence tests are described in [8].

A.2 Formal procedures

Each member state may propose methods deviating from the standard method defined in the Daughter Directives and elaborated in CEN standard measuring methods. The initiatives for such proposals will - most likely – come from national or regional laboratories performing air quality measurements related to the implementation of the Daughter Directives. It is therefore possible for equivalence to be granted for ‘regional’ conditions (composition of ambient air, meteorological conditions). In order to promote economy of scale, regional or national laboratories are encouraged to consult prior to equivalence testing, and to cooperate in order to broaden the scope of equivalence. However, where the scope of equivalence is restricted in any way, the equivalent method must be used within the range of conditions that were tested, for the measurements to comply with the relevant Daughter Directive. The laboratory proposing the use of a method shall notify its competent authority, and check in advance that the candidate method fulfils the requirements of data capture and time coverage set for the continuous/fixed measurements and has the potential of meeting the uncertainty requirement for the standard measuring method at the limit value concentration.

The competent authority shall then appoint one or more laboratories or test houses responsible for the performance of the experimental work associated with the equivalence evaluation described below, including the application of the standard measuring method. This can be the laboratory/laboratories already using the candidate and/or standard measuring method.

If at any stage of the test programme the uncertainty of the candidate method fails to meet the uncertainty criterion, the equivalence evaluation may be terminated, and a report of the results obtained prepared for the competent authority. This may be used as a basis to reduce relevant uncertainty sources, after which tests appropriate to these uncertainty sources may be repeated and the resulting uncertainty again compared with the uncertainty criterion.

After completion of the relevant test and evaluation programme the results of the tests and evaluations shall be reported to the competent authority. The competent authority will then decide on acceptance/rejection of the candidate method as an equivalent method. In the case of acceptance, an evaluation report with conclusions should be submitted to the European Commission for review. The European Commission may review this report and may, if required, consult a committee of experts about the claim to equivalence. The European Commission shall report its findings and conclusions to the competent authority. If the Commission produces a negative conclusion on the claim to equivalence, then the competent authority should reconsider its original decision. It is essential that the technical competence of the testing laboratories be according to the criteria specified in EN ISO/IEC 17025 [9].

A.3 Overview of test procedure

Testing for equivalence can take one of two forms: laboratory tests where the contributions of the different uncertainty sources to the measurement uncertainty will be assessed, or a full field test procedure where the candidate method will be tested side-by-side with the $PM_{2,5}$ standard measurement method.

If the CM involves only slight differences from the standard measurement method described in this standard (a “variation on a theme”) a restricted laboratory procedure is required to quantify the associated individual source(s) of uncertainty of the CM, and the field test is not required. For example:

- application of the standard sampler as automated filter changer (uncertainty parameter: u_{msv});
- different weighing conditions, e.g. higher relative humidity in the weighing room (uncertainty parameters u_{mhf}, u_{mhp});
- different flow control (uncertainty parameter: u_{fc});
- use of other filter media, e.g. cellulose nitrate filters (uncertainty parameters: u_{mfe}, u_{mhf}, u_{ms});
- transportation of loaded filters to the weighing room at temperatures above 23 °C (uncertainty parameter: u_{msv});
- storage of the filters in the cooled transport/storage facility not immediately after finishing the sampling period (uncertainty parameter: u_{msv}).

When the CM is more fundamentally different from the standard measurement method SM, a full field test procedure shall be carried out to determine the equivalence of the CM. The full field test procedure shall consist of a series of field tests where CM is tested side-by-side with the SM.

When testing a CM which differs from the $PM_{2,5}$ standard measurement method only in having a different design of sample inlet, the analysis of SM and CM filters for the soluble fraction of tracer ions that have characteristic size distributions in the region of 2,5 µm, such as sulfate, ammonium or nitrate shall be considered.

The CM shall be tested in a way that is representative for its practical use. Frequencies of tests and re-calibrations used in practice shall be applied in the test procedure.

Results of existing studies, when demonstrably obtained according to the requirements of this test procedure, may be used to determine uncertainty components.

All details to perform the equivalence test are described in [8].

Annex B
(normative)
Data-quality objectives (source: Annex VIII of [2])

The following data-quality objectives for the required accuracy of assessment methods, of minimum time coverage and of data capture of measurement are laid down to guide quality-assurance programmes.

Table B.1 – Data-quality objectives

	Particulate matter
Continuous measurement	
Accuracy	25 %
Minimum data capture	90 %
Indicative measurement	
Accuracy	50 %
Minimum data capture	90 %
Minimum time coverage	14 % (one measurement a week at random, evenly distributed over the year, or at eight weeks evenly distributed over the year.)

The accuracy of the measurement is defined as laid down in ENV 13005 or in ISO 5725-1 [10]. The percentages in Table B.1 are given for individual measurements averaged, over the period considered, by the limit value, for a 95 % confidence interval (bias * two times the standard deviation). The accuracy for continuous measurements should be interpreted as being applicable in the region of the appropriate limit value.

Annex ZA
(informative)

Relationship with EU Directives

This European Standard 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 EU Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air.

WARNING — Other requirements and EU Directives may be applicable falling within the scope of use of this European Standard.

Bibliography

[1] Council Directive 96/62/EC on ambient air quality assessment and management. Official Journal L 296, 21.11.1996.

[2] Council Directive 1999/30/EC relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air. Official Journal L 163/41, 29.6.1999.

[3] EN 12341, *Air quality - Determination of the PM10 fraction of suspended particulate matter - Reference method and field test procedure to demonstrate reference equivalence of measurement methods*

[4] EN 13274-7, *Respiratory protective devices - Methods of test – Part 7: Determination of particle filter penetration*

[5] EN 1822-1, *High efficiency air filters (HEPA and ULPA) - Part 1: Classification, performance testing, marking*

[6] Willeke, K., Baron, P. A., *Aerosol Measurement – Principles, Techniques and Applications*. Van Nostrand Reinhold, New York, 1993

[7] CEN/TC 264/WG 15 Field test report (in preparation, will be specified after Formal Vote)

[8] *Demonstration of Equivalence of Ambient Air Monitoring Methods*. EC Working Group on Guidance for the Demonstration of Equivalence (in preparation, will be specified after Formal Vote)

[9] EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025:1999)*

[10] ISO 5725-1, *Accuracy (trueness and precision) of measurement methods and results - Part 1: General principles and definitions*

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