BS EN 13205-1:2014

BSI Standards Publication

Workplace exposure — Assessment of sampler performance for measurement of airborne particle concentrations

Part 1: General requirements

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National foreword

This British Standard is the UK implementation of EN 13205-1:2014. Together with BS EN 13205-2:2014, PD CEN/TR 13205-3, BS EN 13205-4:2014, BS EN 13205-5:2014 and BS EN 13205-6:2014 it supersedes BS EN 13205:2002, which will be withdrawn upon publication of all parts of the series.

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

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

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ISBN 978 0 580 78058 5

ICS 13.040.30

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 June 2014.

Amendments issued since publication

Date	Text affected

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 13205-1

June 2014

ICS 13.040.30

Supersedes EN 13205:2001

English Version

Workplace exposure - Assessment of sampler performance for measurement of airborne particle concentrations - Part 1: General requirements

Exposition sur les lieux de travail - Évaluation des performances des dispositifs de prélèvement pour le mesurage des concentrations de particules en suspension dans l'air - Partie 1: Exigences générales

Exposition am Arbeitsplatz - Beurteilung der Leistungsfähigkeit von Sammlern für die Messung der Konzentration luftgetragener Partikel - Teil 1: Allgemeine Anforderungen

This European Standard was approved by CEN on 7 May 2014.

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Contents

Foreword

This document (EN 13205-1:2014) has been prepared by Technical Committee CEN/TC 137 “Assessment of workplace exposure to chemical and biological agents”, 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of an identical text or by endorsement, at the latest by December 2014 and conflicting national standards shall be withdrawn at the latest by December 2014.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 together with EN 13205-2, CEN/TR 13205-3, EN 13205-4, EN 13205-5 and EN 13205-6 will supersede EN 13205:2001.

EN 13205, *Workplace exposure — Assessment of sampler performance for measurement of airborne particle concentrations*, consists of the following parts:

- *Part 1: General requirements* (the present document);
- *Part 2: Laboratory performance test based on determination of sampling efficiency;*
- *Part 3: Analysis of sampling efficiency data* [Technical Report];
- *Part 4: Laboratory performance test based on comparison of concentrations*;
- *Part 5: Aerosol sampler performance test and sampler comparison carried out at workplaces;*
- *Part 6: Transport and handling tests.*

Significant technical changes from the previous edition, EN 13205:2001:

- This part of EN 13205 is based on Clauses 1 to 8 of the previous edition, EN 13205:2001.
- The scope has been limited to aerosol samplers, and the current version of the standard is not (directly) applicable to other types of aerosol instruments.
- The list of definitions has been expanded and many definitions are now given in EN 1540, *Workplace exposure — Terminology*. The method of calculating the uncertainty of a sampler or a measuring procedure has been revised in order to comply with ENV 13005. The concept of “overall uncertainty” is no longer used, instead the concept of “expanded uncertainty” is used.
- The list of Requirements (Table 1) has been reformulated/changed for some attributes. The current version of the standard envisages two different types of tests: A test of a candidate aerosol sampler and a test of a complete measuring method based on a candidate sampler, respectively. Two flow charts, one for each type of test, have been included to better demonstrate the relation between the different parts of EN 13205.
- Annex A has been added on how to calculate the expanded uncertainty for a measuring procedure based on aerosol sampling but also consisting of several other stages. This is a complete revision and expansion of Annex E in the previous version. A clause on symbols has been included.

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

EN 481 defines sampling conventions for the particle size fractions to be collected from workplace atmospheres in order to assess their impact on human health. Conventions are defined for the inhalable, thoracic and respirable aerosol fractions. These conventions represent target specifications for aerosol samplers, giving the ideal sampling efficiency as a function of particle aerodynamic diameter. In general, the sampling efficiency of real aerosol samplers will deviate from the target specification, and the aerosol mass collected will therefore differ from that which an ideal sampler would collect. In addition, the behaviour of real samplers is influenced by many factors such as external wind speed. In many cases there is an interaction between the influence factors and fraction of the airborne particle size distribution of the environment in which the sampler is used.

EN 482 contains general performance requirements for methods used for determining the concentrations of chemical agents in workplace atmospheres. These performance requirements include maximum values of expanded uncertainty (a combination of random and non-random measurement uncertainty) achievable under prescribed laboratory conditions for the methods to be used. The requirements of EN 482 apply to a complete measuring procedure, a combination of the stages consisting of sampling, sample transport/storage and sample preparation/analysis.

This part of EN 13205 gives performance requirements for samplers for the inhalable, thoracic or respirable aerosol fractions. Requirements for the aerosol sampler and transport of loaded collection samplers are stated. Furthermore, the method for calculating the expanded uncertainty for a measuring procedure based on aerosol sampling is described.

Different test procedures and types of evaluation are described in the other parts of EN 13205 in order to enable application of EN 13205 to a wide variety of instruments. In detail, three different performance tests for sampled concentration and a transport test of loaded collection substrates are described. The three tests differ in the amount of information obtained by the test and its corresponding cost. The first test method determines the sampling efficiency curve of a candidate sampler, the second compares concentrations sampled from three laboratory test atmospheres by a candidate sampler and a (previously) validated sampler, and the third method compares concentrations sampled from a specific workplace by a candidate sampler and a (previously) validated sampler. Additionally a method for determining equivalence between aerosol samplers at specific workplaces and an alternative handling test are presented.

EN 13205 (all parts) enables manufacturers and users of aerosol samplers to adopt a consistent approach to sampler validation, and provide a framework for the assessment of sampler performance with respect to EN 481 and EN 482.

It is the responsibility of the manufacturer of aerosol samplers to inform the user of the sampler performance under the laboratory conditions1) specified in other parts of this European Standard. It is the responsibility of the user to ensure that the actual conditions of intended use are within what the manufacturer specifies as acceptable conditions according to the performance test.

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1) The inhalable convention is undefined for particle sizes in excess of 100 µm or for wind speeds greater than 4 m/s. The tests required to assess performance are therefore limited to these conditions. Should such large particle sizes or wind speeds actually exist at the time of sampling, it is possible that different samplers meeting this part of EN 13205 give different results.

1 Scope

This European Standard specifies performance requirements that are specific to aerosol samplers, primarily inhalable, thoracic and respirable aerosol samplers. These performance requirements, which include conformity with the EN 481 sampling conventions, are applicable only to the process of sampling the airborne particles from the air, not to the process of analysing particles collected by the process of sampling. Although analysis of samples collected in the course of testing is usually necessary in order to evaluate the sampler performance, the specified test methods ensure that analytical errors are kept very low during testing and do not contribute significantly to the end result.

This part of EN 13205 specifies how the performance of aerosol measuring procedures is assessed with respect to the general requirements of EN 482, through the combination of errors arising in the sampling, sample transportation/storage and sample preparation/analysis stages.

This part of EN 13205 is applicable to all samplers used for the health-related sampling of particles in workplace air.

This part of EN 13205 is not applicable to the determination of analytical errors and factors related to them (for example the bias, precision and limit of detection of the analytical method). Where the aerosol sampler requires the use of an external (rather than integral) pump, the pump is not subject to the requirements of this part of EN 13205.

2 Normative references

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

EN 481, *Workplace atmospheres — Size fraction definitions for measurement of airborne particles*

EN 482:2012, *Workplace exposure — General requirements for the performance of procedures for the measurement of chemical agents*

EN 1540:2011, *Workplace exposure — Terminology*

EN 13205-2:2014, *Workplace exposure — Assessment of sampler performance for measurement of airborne particle concentrations — Part 2: Laboratory performance test based on determination of sampling efficiency*

CEN/TR 13205-3, *Workplace exposure — Assessment of sampler performance for measurement of airborne particle concentrations — Part 3: Analysis of sampling efficiency data*

EN 13205-4:2014, *Workplace exposure — Assessment of sampler performance for measurement of airborne particle concentrations — Part 4: Laboratory performance test based on comparison of concentrations*

EN 13205-5:2014, *Workplace exposure — Assessment of sampler performance for measurement of airborne particle concentrations — Part 5: Aerosol sampler performance test and sampler comparison carried out at workplaces*

EN 13205-6:2014, *Workplace exposure — Assessment of sampler performance for measurement of airborne particle concentrations — Part 6: Transport and handling tests*

EN 13890, *Workplace exposure — Procedures for measuring metals and metalloids in airborne particles — Requirements and test methods*

EN 14530, *Workplace atmospheres — Determination of diesel particulate matter — General requirements*

EN ISO 13137, *Workplace atmospheres — Pumps for personal sampling of chemical and biological agents — Requirements and test methods (ISO 13137)*

ISO 15767, *Workplace atmospheres — Controlling and characterizing uncertainty in weighing collected aerosols*

ISO 21438 (all parts), *Workplace atmospheres — Determination of inorganic acids by ion chromatography*

ISO 24095, *Workplace air — Guidance for the measurement of respirable crystalline silica*

3 Terms and definitions

For the purpose of this document, the terms and definitions given in EN 1540 and the following apply.

3.1 Terms related to sampling and transportation

NOTE In addition to the terms and definitions given by entry numbers 3.1.1 to 3.1.21, in particular, the following general terms, terms related to the physical and chemical process of air sampling and terms related to the analytical method of EN 1540 are used in this document as well: respirable fraction, inhalable fraction, sampling efficiency, thoracic fraction, measuring procedure, analysis, analytical method, measurand and occupational exposure limit value.

3.1.1
airborne particles
fine matter, in solid or liquid form, dispersed in air

Note 1 to entry: Smoke, fume, mist and fog consist of airborne particles.

[SOURCE: EN 1540:2011, 2.2.3]

3.1.2
aerosol
airborne particles and the gas (and vapour) mixture in which they are suspended

Note 1 to entry: The airborne particles can be in or out of equilibrium with their own vapours.

Note 2 to entry: In occupational hygiene, the carrier gas is air, possibly contaminated by other gases and vapours.

[SOURCE: EN 1540:2011, 2.2.4, modified – Note 2 to entry has been added.]

3.1.3
aerosol sampler
(airborne) particle sampler
(airborne) particulate sampler
sampler that is used to transport airborne particles to a collection substrate

Note 1 to entry: The term aerosol sampler is commonly used although it is not in line with the definition of aerosol given in EN 1540:2011, 2.2.4.

Note 2 to entry: The transport can be either active or passive.

Note 3 to entry: For the purpose of this document, a sampler is not a pump or an air mover, but can include either of them in specific cases.

[SOURCE: EN 1540:2011, 3.2.1.5, modified – Note 3 to entry has been added.]

3.1.4
candidate sampler
any aerosol sampler that can be used to collect airborne particles in order to determine their concentration and whose performance is subjected to performance tests

Note 1 to entry: A candidate sampler that meets the performance criteria will be termed a validated sampler.

3.1.5
collected sample
product of the process of air sampling that consists of the collected chemical and/or biological agents only

Note 1 to entry: For the purpose of this document the collected sample comprises of airborne particles collected and retained on the sampling substrate for subsequent analysis.

[SOURCE: EN 1540:2011, 3.1.2, modified – Note 1 to entry has been added.]

3.1.6
collection substrate
sampling substrate
collection medium
sampling medium
medium on which airborne chemical and/or biological agents are collected for subsequent analysis

Note 1 to entry: Filters, polyurethane foams and sampling cassettes are examples of collection substrates for airborne particles.

Note 2 to entry: Activated carbon, silica gel and reagent impregnated filters are examples of collection substrates for gases and vapours.

Note 3 to entry: Agar media are examples of collection substrates for bioaerosols.

Note 4 to entry: The 25-mm or 37-mm plastic filter cassette often used for “total dust” sampling (with gravimetric analysis) in either its closed-face or open-face version is not part of the substrate in the definition above, since it is not weighed. On the other hand, some analytical methods for elements in samples collected with 25-mm or 37-mm plastic filter cassette require that particles deposited onto the internal surfaces of the filter cassette upstream of the filter to be included in the analysis, and in this case the internal surfaces of the filter cassette is part of the collection substrate.

[SOURCE: EN 1540:2011, 3.3.6, modified – Note 4 to entry has been added.]

3.1.7
collection efficiency
efficiency of collection and retention of sampled particles by the collection substrate

Note 1 to entry: The collection efficiency can, for example be influenced by the amount of particles deposited in the collection substrate.

Note 2 to entry: The collection efficiency (of a collection substrate) should not be confused with the sampling efficiency (of a sampler). For the definition of sampling efficiency see EN 1540:2011, 3.3.10.

3.1.8
inhalable fraction

mass fraction of total airborne particles which is inhaled through the nose and mouth

Note 1 to entry: The inhalable fraction is specified in EN 481.

Note 2 to entry: The inhalable fraction depends on the speed and direction of the air movement, on breathing rate and other factors.

[SOURCE: EN 1540:2011, 2.3.1.1, modified – Note 2 to entry has been added.]

3.1.9
inhalable sampler

aerosol sampler that is used to collect the inhalable fraction

Note 1 to entry: An inhalable sampler collects the inhalable fraction of airborne particles, as defined in EN 481, with a performance as stipulated in this document.

[SOURCE: EN 1540:2011, 3.2.1.5.1, modified – Note 1 to entry has been added.]

3.1.10
nominal flow rate

design flow rate recommended by the sampler manufacturer or measuring procedure

3.1.11
particle aerodynamic diameter

diameter of a sphere of 1 g cm^{-3} density with the same terminal settling velocity in calm air as the particle, under the prevailing conditions of temperature, pressure and relative humidity

Note 1 to entry: The particle aerodynamic diameter depends on the size, density and shape of the particle.

Note 2 to entry: For particles of aerodynamic diameter less than 0,5 µm, the particle thermodynamic diameter should be used instead of the particle aerodynamic diameter.

[SOURCE: EN 1540:2011, 2.3.2, modified – Note 2 to entry has been added.]

3.1.12
sampler inlet efficiency

for each particle aerodynamic diameter the ratio of aerosol concentration passing through the sampler inlet to the corresponding total airborne particle concentration

Note 1 to entry: The sampler inlet efficiency is the product of the aspiration efficiency, which characterises the aerodynamic behaviour of the sampler orifice, and the size-dependent effects of particle bounce and losses both inside and outside the inlet. The inlet losses can, for some samplers, also depend on external factors such as wind speed and aerosol size distribution.

3.1.13
penetration

internal penetration

for each particle aerodynamic diameter the ratio of the sampling efficiency to the sampler inlet efficiency

Note 1 to entry: The penetration describes the efficiency with which particles pass through the stage of internal aerodynamic separation, as for example in foams, cyclones, impactors or elutriators.

3.1.14
personal sampler

sampler, attached to a person, that collects gases, vapours or airborne particles in the breathing zone to determine exposure to chemical and/or biological agents

Note 1 to entry: For the purpose of this document “agent” means airborne particles.

[SOURCE: EN 1540:2011, 3.2.2, modified – Note 1 to entry has been added.]

3.1.15
respirable sampler

aerosol sampler that is used to collect the respirable fraction

Note 1 to entry: A respirable sampler collects the respirable fraction or airborne particles, as defined in EN 481, with a performance as stipulated in this document.

[SOURCE: EN 1540:2011, 3.2.1.5.3 modified – Note 1 to entry has been added.]

3.1.16
sampler specimen

sampler individual
single individual of a given type of aerosol sampler

3.1.17
sampling cassette

cassette mounted inside a sampler, designed in such a way that its collection substrate consists of all its interior surfaces (bounding the air-stream with sampled particles), and usually containing a filter or another suitable collection substrate

3.1.18
sampling method

part of the measuring procedure that describe the overall process of sampling, including sampler preparation and sample transport

3.1.19
sampling process

physical mechanisms by which particles are selectively aspirated into a sampler inlet, graded by means of inertial or other forces, transported to the collection substrate or to other internal surfaces, or lost from the collection substrate

Note 1 to entry: The losses from the collection substrate referred to here regard losses occurring during sampling and not during transport and/or storage.

3.1.20
thoracic sampler

aerosol sampler that is used to collect the thoracic fraction

Note 1 to entry: A thoracic sampler collects the thoracic fraction or airborne particles, as defined in EN 481, with a performance as stipulated in this document.

[SOURCE: EN 1540:2011, 3.2.1.5.2 modified – Note 1 to entry has been added.]

3.1.21
validated sampler

sampler that has been tested under specified conditions to comply with a required performance

Note 1 to entry: This European Standard distinguishes between three types of validated samplers. See below.

Note 2 to entry: A validated sampler which has previously been tested using the methods described in EN 13205–2 to comply with the requirements given in EN 13205–1 is designated as “validated sampler (type A)”. In a performance test according to EN 13205–2, the sampling efficiency curve of the candidate sampler will be determined as a function of particle size (and possibly other influencing factors).

Note 3 to entry: A validated sampler which has previously been tested using the methods described in EN 13205–4 to comply with the requirements given in EN 13205–1 is designated as “validated sampler (type B)”. In a performance test according EN 13205–4, the concentration sampled by the candidate sampler will be compared with the concentration sampled by a validated reference sampler, for at least three test aerosols.

Note 4 to entry: A validated sampler which has previously been tested using the methods described in EN 13205–5 to comply with the requirements given in EN 13205–1 is designated as “validated sampler (type C)”. In a performance test according EN 13205–5, the concentration sampled by the candidate sampler at a workplace will be compared with the concentration sampled by a validated reference sampler.

3.2 Terms related to performance

NOTE In addition to the terms and definitions listed below, in particular, the following terms of EN 1540 related to (method) performance are used in this document as well: random uncertainty, non-random uncertainty, standard uncertainty, combined standard uncertainty, expanded uncertainty, uncertainty (of measurement), coverage factor, measuring range and precision.

3.2.1

bias

difference between the expectation of a test result or measurement result and a true value

Note 1 to entry: Bias is the total non-random error as contrasted to random error. There can be one or more non-random error components contributing to the bias. A larger systematic difference from the true value is reflected by a larger bias value.

Note 2 to entry: In practice, the accepted reference value is substituted for the true value. The accepted reference value (for definition see ISO 3534-2) can be, for example, the certified value of a reference material, the concentration of a standard test atmosphere or the target value of an interlaboratory comparison.

Note 3 to entry: In EN 13205–2, CEN/TR 13205–3, EN 13205–4 and EN 13205–5 the true value of the concentration of a chemical agent in air will be the concentration calculated to be sampled by an ideal sampler with a sampling efficiency identical to the sampling convention or sampled by a validated sampler.

Note 4 to entry: The definition has originally been taken from ISO 3534-2:2006, 3.3.2.

[SOURCE: EN 1540:2011, 5.3.1 modified – Notes 3 and 4 to entry have been added.]

3.2.2

other influence variable

variables/parameters (other than particle size, flow rate and sampler individual variability) which in the Critical review were considered to possibly have such an influence on the sampling efficiency that their effect need to be determined in the performance test

Note 1 to entry: The variables/parameters particle size, flow rate and sampler individual variability are explicitly incorporated into the performance test.

Note 2 to entry: The Critical review (see 6.2) which designate which variables/parameters will be considered to be other influence variables, will also determine at which values of each of the other influence variables the additional tests will be carried out.

3.2.3

sampler bias

bias of the sampling method

4 Symbols and abbreviations

4.1 Symbols

4.1.1 Latin

C_{OEL}	relevant occupational exposure limit, [mg/m^3]
$C_{0,1}$	concentration corresponding to 10 % of the relevant C_{OEL}, [mg/m^3]
$C_{0,5}$	concentration corresponding to 50 % of the relevant C_{OEL}, [mg/m^3]
C_2	concentration corresponding to 200 % of the relevant C_{OEL}, [mg/m^3]
m_{Analysed}	mass of the chemical compound analysed in the collected sample, [mg]
$m_{\text{Analysed-0,1}}$	mass of the chemical compound analysed in the collected sample from a sample collected from a concentration equal to $C_{0,1}$ during a sampling period t at the nominal flow rate of the sampler, [mg]
$m_{\text{Analysed-0,5}}$	mass of the chemical compound analysed in the collected sample from a sample collected from a concentration equal to $C_{0,5}$ during a sampling period t at the nominal flow rate of the sampler, [mg]
$m_{\text{Analysed-2}}$	mass of the chemical compound analysed in the collected sample from a sample collected from a concentration equal to C_2 during a sampling period t at the nominal flow rate of the sampler, [mg]
$m_{\text{Collected}}$	mass of the collected sample, [mg]
$m_{\text{Est-Collected}}$	estimated mass of the collected sample, [mg]
$m_{\text{Est-Collected-0,1}}$	estimated mass of the collected sample collected from a concentration equal to $C_{0,1}$ during a sampling period t at the nominal flow rate of the sampler, [mg]
$m_{\text{Est-Collected-0,5}}$	estimated mass of the collected sample collected from a concentration equal to $C_{0,5}$ during a sampling period t at the nominal flow rate of the sampler, [mg]
$m_{\text{Est-Collected-2}}$	estimated mass of the collected sample collected from a concentration equal to C_2 during a sampling period t at the nominal flow rate of the sampler, [mg]
Q^0	nominal flow rate of the sampler, [l/min]
s_{analysis}	(constant) standard deviation due to chemical analysis (incl. storage), [mg]
t	selected sampling time in the range from the minimum to the maximum sampling time according to the measuring procedure, [min]
U	expanded uncertainty, [-]
$u_{\text{a-nR}}$	non-random standard uncertainty due to analysis, [-]
$u_{\text{a-R}}$	random standard uncertainty due to analysis, [-]
u_{c}	combined standard uncertainty, [-]
$u_{\text{fr-nR}}$	non-random standard uncertainty due to measurement of flow rate, [-]

$u_{\text{fr-R}}$	random standard uncertainty due to measurement of flow rate, [-]
u_{nR}	combined standard uncertainty for non-random sources of error, [-]
u_{R}	combined standard uncertainty for random sources of error, [-]
$u_{\text{s-nR}}$	non-random standard uncertainty due to sampling, [-]
$u_{\text{s-R}}$	random standard uncertainty due to sampling, [-]
$u_{\text{st-nR}}$	non-random standard uncertainty due to measurement of sampling time, [-]
$u_{\text{t-nR}}$	non-random standard uncertainty due to transport losses, [-]
$u_{\text{t-R}}$	random standard uncertainty due to transport losses, [-]
$u_{\text{v-nR}}$	non-random standard uncertainty due to determination of sampled volume, [-]
$u_{\text{v-R}}$	random standard uncertainty due to determination of sampled volume, [-]

4.1.2 Greek

ξ_{Est}	estimated ratio of mass of collected sample to amount analysed in collected sample, [-]

5 Requirements

5.1 Summary of requirements

Table 1 — Summary of performance requirements for an aerosol sampler

Attribute	**Requirement**	**Test method**	**Notes**
Expanded uncertainty of an aerosol sampler	See 5.2	EN 13205–2:2014 EN 13205–4:2014 EN 13205–5:2014	
Expanded uncertainty of measuring procedure based on aerosol sampling	See 5.3	EN 13205–2:2014 EN 13205–4:2014 EN 13205–5:2014	
Specimen variability	Coefficient of variation in collected mass < 0,075, for a group of 6 identically exposed specimens	EN 13205–2:2014 EN 13205–4:2014 EN 13205–5:2014	[a]
Air flow stability (for samplers with integral pumps)	Relevant clauses of EN ISO 13137	Relevant clauses of EN ISO 13137 (modified if necessary)	[b]
Transport and handling	For sample loadings corresponding to concentrations in the range 0,5 times to 2 times a relevant occupational exposure limit value, all relative mass changes ≤ 0,05. For sample loadings corresponding to concentrations in the range 0,1 times to 0,5 times a relevant occupational exposure limit value, all relative mass changes ≤ 0,15.	EN 13205–6:2014, Clause 5	
Sample identification	Suitable area for sample identification provided	Visual check	
Instructions for use	Contents as in Clause 8	Visual check	
Design safety	Relevant clauses of EN ISO 13137	Relevant clauses of EN ISO 13137	
Electrical safety	Relevant clauses of EN ISO 13137	Relevant clauses of EN ISO 13137	

[a] Required for samplers of the respirable and thoracic aerosol fractions, but not for samplers of the inhalable aerosol fraction.

[b] If necessary, any more stringent requirements for air flow stability shall be specified in the manufacturer's information for use of the sampler. Only required if the sampler has an integral pump/air mover.

5.2 Expanded uncertainty for an aerosol sampler

The candidate sampler, *on itself*, is in conformity with the relevant EN 481 convention when the expanded uncertainty is less than or equal to 0,25:

a) for type A test (see EN 13205-2): for all the relevant particle size distributions (see EN 13205-2:2014, Table 2) and for all compulsory tests according to EN 13205-2:2014, Table 1 or resulting from the critical review – a candidate sampler fulfilling the requirements of a type A test will be termed a *validated sampler (type A)*.

   A type A test shall be complemented with a test according to EN 13205-5:2014, Annex A. The test aerosol shall have approximately 50 % of the airborne mass in the respirable/ thoracic fraction or approximately 70 % in the inhalable fraction, depending on the relevant fraction. The test aerosol shall be highly relevant for workplaces where the candidate sampler is intended to be used. The sampler with which the candidate sampler shall be compared shall be well-documented.

   NOTE 1 CEN/TR 15230 lists samplers for the three fractions. For some of these substantial information exists on their internal penetration in various environments.

   The evaluation of the results from the test with the polydisperse test aerosol shall be carried out as in EN 13205-5:2014, Annex A.

   If two samplers which both have passed a type A test are compared, for example in a type B or type C test, the sampler for which there exist most concordant documentation shall be considered/used as the validated sampler over the other sampler.

   NOTE 2 Tests according to type A are usually carried out with spherical particles. Tests according to type B are usually carried out with aerosols that are more alike aerosols encountered at workplaces, concerning size distribution, material, shape, etc. It cannot be expected that two different types of candidate samplers which have almost identical sampling efficiencies according to type A, will also collect almost identical samples (corrected for sampled volume) when tested in a type B (or C) test.

b) for type B test (see EN 13205-4): for all the particle size distributions tested, and for all compulsory tests according to its Table 1 or resulting from the critical review – a candidate sampler fulfilling the requirements of a type B test will be termed a validated sampler (type B);

c) for type C test (see EN 13205-5): for the particle size distribution at the work environment of the test, and for all compulsory tests according to Table 1 (see EN 13205-4) or resulting from the critical review (see EN 13205-5) – a candidate sampler fulfilling the requirements of a type C test will be termed an *validated sampler (type C) for the work environment in question*.

All uncertainties (incl. the expanded uncertainty) and all relative entities are in this standard (in all its parts) given as their actual values, not as an percentage (i.e. a value 100 times larger). The reason for this is that it simplifies calculations in equations, where otherwise some percentages have to be reduced to their actual values if more than one percentage are to be multiplied.

This requirement shall be fulfilled for any wind speed in the intended range for practical use. The maximum tested wind speed in which the sampler meets the expanded uncertainty requirement determines the upper limit for practical use.

NOTE 3 If filter losses are expected, a type B test is preferably used.

5.3 Expanded uncertainty for a measuring procedure

The performance of a measuring procedure based on the candidate sampler shall be determined and evaluated according to EN 482. The required performance of the expanded uncertainty over the measuring range (specified in EN 482) is shown in Table 2. Annex A describes how the expanded uncertainty of a measuring procedure is determined from its sources of uncertainty.

Table 2 — Required expanded uncertainty for a measurement for comparison with limit values and periodic measurements

Reference period	**Measuring range**, C, mg/m^3	**Requirement on expanded uncertainty** [-]
Long-term	$0{,}1 \times C_{\text{OEL}} \leq C < 0{,}5 \times C_{\text{OEL}}$	0,50
Long-term	$0{,}5 \times C_{\text{OEL}} \leq C \leq 2 \times C_{\text{OEL}}$	0,30
Short-term (for example, 15 min)	$0{,}1 \times C_{\text{OEL}} \leq C < 2 \times C_{\text{OEL}}$	0,50

NOTE In this part of EN 13205, all expanded uncertainties will be expressed as fractions, not as percentage.

In cases where a measuring procedure based on a candidate sampler for the inhalable fraction does not fulfil the requirements on expanded uncertainty of EN 482 for a measuring procedure for the largest particle sizes, it can only be used when the size distribution of the aerosol has such small median aerodynamic diameters that the difference in collected mass between the candidate sampler and a validated sampler is < 10 %. The conditions where these size distributions might be encountered shall be presented in the instructions for use. It is up to the user to show that such sampler has no bias when used (in restricted conditions) by comparing it with a fully validated sampler.

6 Test methods

6.1 General

The performance test will consist of different parts depending on whether the performance test is for the candidate sampler on its own or for a measuring procedure based on the candidate aerosol sampler. The outline of the different parts for these two versions of a performance test are presented as flow charts in Figures 1 and 2.

NOTE The first version of test is intended mainly for sampler developers/manufacturers whereas the second version is intended mainly for users of measuring procedures (as for example occupational hygienists).

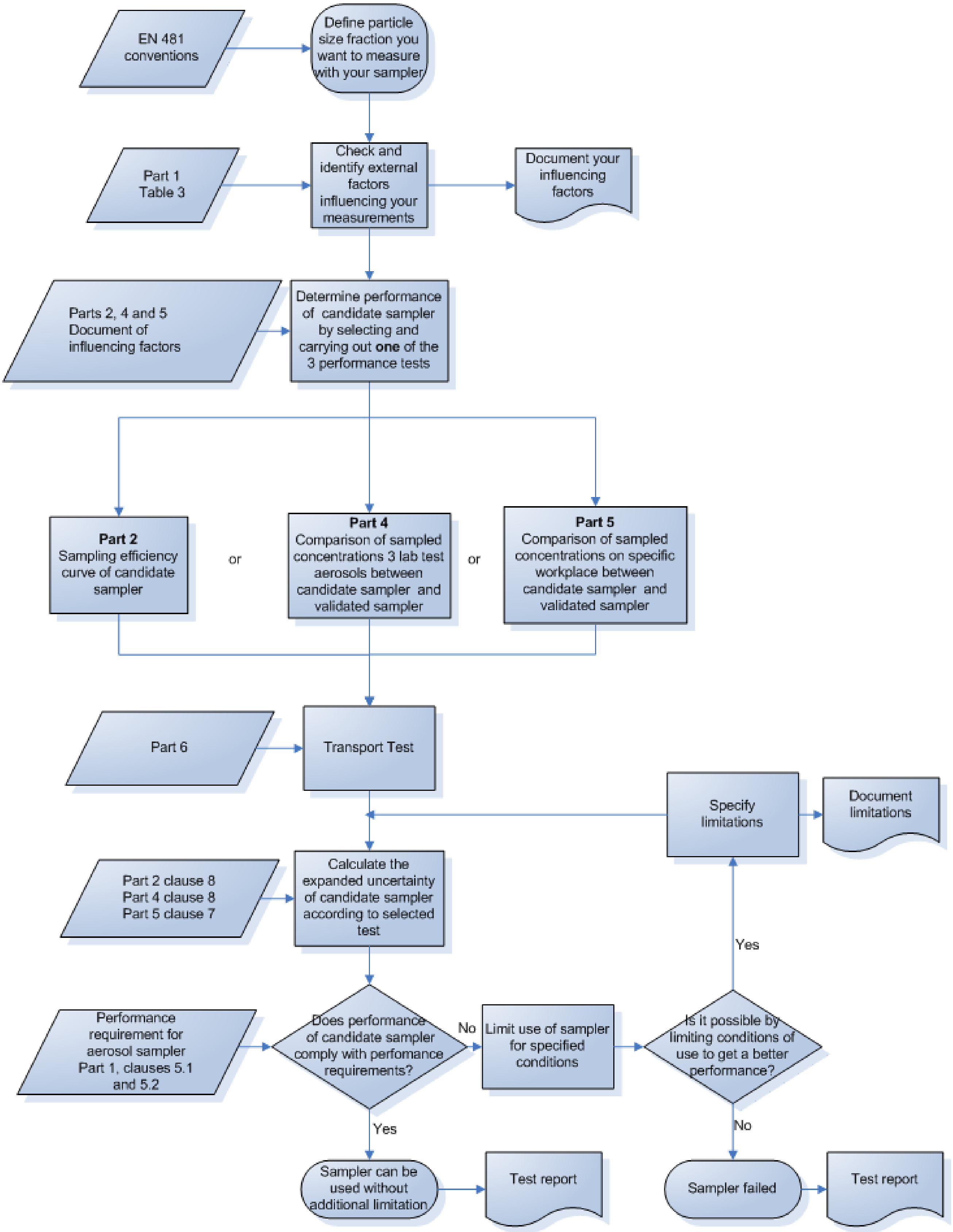

Figure 1 — Flow chart for determining the performance of a candidate sampler as on its own, see 7.1

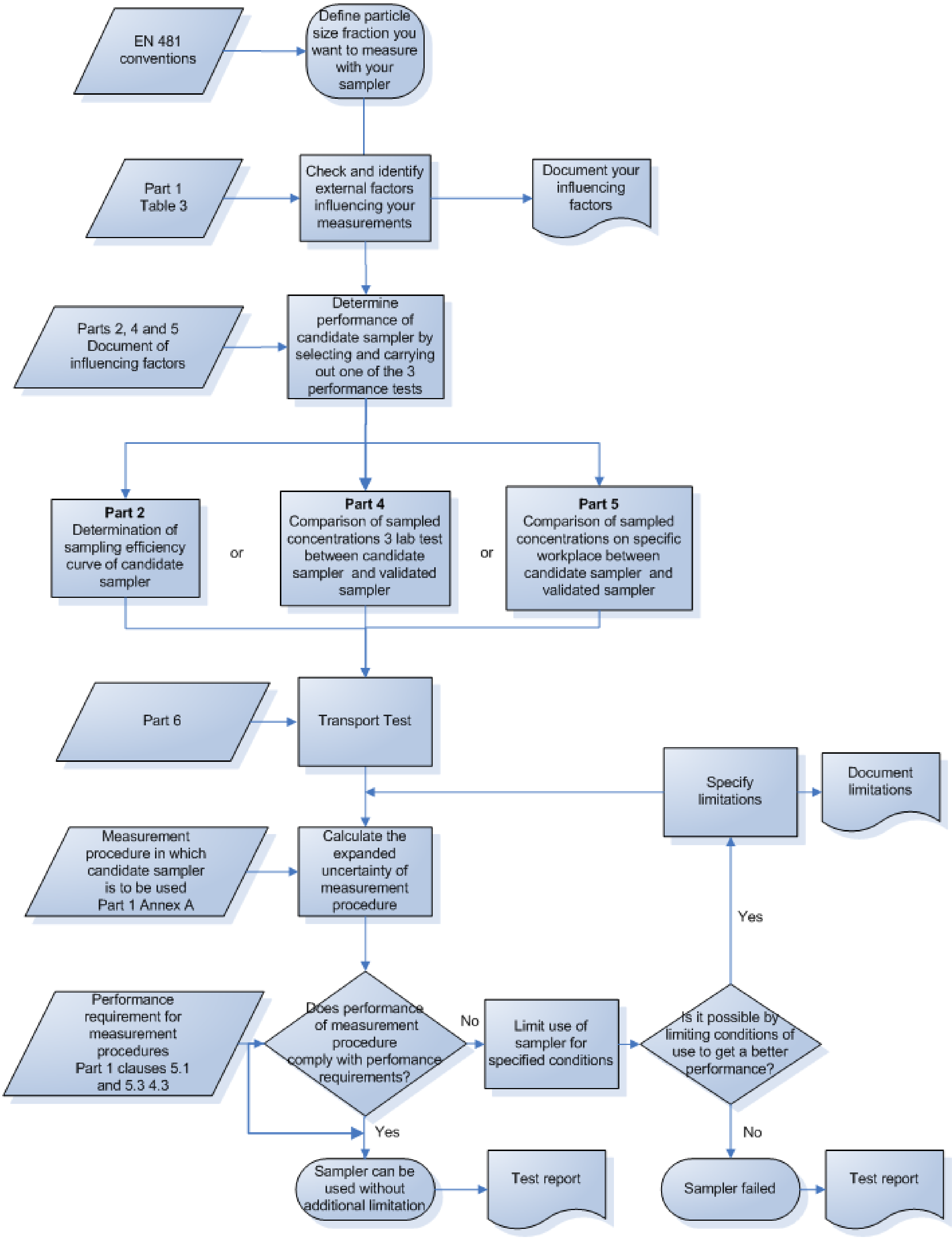

Figure 2 — Flow chart for determining the performance of a candidate as part of a measuring procedure, see 7.2

6.2 Critical review in order to delimit the performance test

The critical review forms the first stage of the sampler performance evaluation and determines the design of the laboratory tests (see EN 13205-2:2014and EN 13205-4:2014 respectively) and the workplace test (see EN 13205-5:2014, 6.5.1). Its purpose is to identify which environmental and other variables are likely to affect the sampling efficiency. These are the “other influence variables”. The critical review shall explain the evidence for the inclusion or exclusion of variables from the tests, making reference where possible to published results. The review shall consider the environments in which the sampler will be used and decide the values for the other influence variables, such as wind conditions, aerosols and other parameters (perhaps not listed in Table 3) to be used in the tests. The critical review shall be documented in the test report, drawing attention to any limitations in the scope of the performance evaluation arising from the decisions made.

Table 3 — Principal factors influencing the performance of aerosol samplers

Factor	Nature of effect	Sampler types affected
Particle size	Size-dependent selection of particles	All sampler types
Wind speed	Wind speed at inlet affects aspiration, especially for high winds, large particles	Any sampler not having an isokinetic inlet
Wind direction	Wind orientation at inlet affects aspiration	Any sampler not having an omnidirectional inlet
Aerosol composition	Particle bounce and re-entrainment; breakdown of agglomerates	For example, cyclones, impactors
Sampled aerosol mass	Collection efficiency and/or penetration changes as surfaces become heavily loaded	For example, impactors, cyclones, porous foams
Aerosol charge	Attraction to and repulsion from surfaces	All samplers, particularly non-conducting samplers
Sampler specimen variability	Small dimensional differences cause large aerodynamic effects	Samplers with internal penetration (for example, cyclones and impactors)
Flow rate variations	Particle separation mechanism strongly flow-dependent	Samplers with internal penetration (for example, cyclones, elutriators, impactors)
Surface treatments	Collection efficiency depends on for example, greases used to coat collection surfaces	For example, impactors

Table 3 gives an informative checklist of the principal variables known to influence aerosol samplers, and examples of the samplers for which they can cause measurable effects. The critical review shall consider these variables, and also the potential effects of temperature, pressure, humidity, vibration, movement, orientation, sample transportation and electromagnetic susceptibility. The following common problems with samplers shall also be addressed:

- whether the sampling process can lead to the breakdown of agglomerates, i.e. alter the size distribution of the aspirated aerosol;
- whether the sampler inlet can collect particles flying towards it or sedimenting into it, as well as those entering under the influence of air suction alone;
- whether there can be interaction between sampler flow rate and external wind speed, if the pressure drop across the sampler is small;

- whether the samplers may behave differently with liquid or solid particles, or particles having different bounce characteristics.

6.3 Overview of test methods

Annex A describes how the expanded uncertainty of a measuring procedure based on aerosol sampling is calculated for assessment according to the requirements of EN 482, by the combination of components of the uncertainty due to sampling, transport and analysis.

EN 13205-2 specifies a laboratory test method for determining how closely an aerosol sampler matches the target sampling convention. EN 13205-2 describes how the data obtained from the test shall be treated in order to calculate the performance characteristics of the sampler. This test method is suited to samplers intended to follow the conventions laid down in EN 481, and which physically separate particles from their carrier gas by aerodynamic processes.

CEN/TR 13205-3 describes calculation formulae, etc. for use in conjunction with EN 13205-2.

EN 13205-4 describes procedures for determining the performance of a candidate sampler in a comparative test with a validated sampler, in a laboratory test. These comparison tests are suited to samplers that physically separate particles from their carrier gas by aerodynamic processes, or additionally to any other aerosol sampler intended for measuring the concentration of aerosol particles in a gas. In the laboratory comparison test, the sampling characteristics of the candidate sampler are indirectly compared with the EN 481 sampling conventions.

EN 13205-5 describes procedures for determining the performance of a candidate sampler in a comparative test with a validated sampler, at a specific workplace. These comparison tests are suited to samplers that physically separate particles from their carrier gas by aerodynamic processes, or additionally to any other aerosol sampler intended for measuring the concentration of aerosol particles in a gas. In the workplace comparison test, the sampling characteristics of the candidate sampler are indirectly compared with the EN 481 sampling conventions. The outcome of any workplace comparison is dependent both on the circumstances existing in the workplace, and on the performances of the samplers included.

EN 13205-5:2014, Annex A suggests a procedure for determining correction factors between two aerosol samplers by means of a field comparison at a specific workplace. The outcome of any workplace comparison is dependent both on the circumstances existing in the workplace, and on the performances of the samplers included. The purpose of the procedure is to allow the use of non-standard aerosol samplers where equivalence with validated samplers has been established by means of a standardised test.

EN 13205-6:2014, Clause 5 describes a test procedure to determine potential errors introduced during transport of samples.

EN 13205-6:2014, Clause 6 describes a test procedure to assess the usability of aerosol samplers and potential errors introduced during handling and/or transport of samples.

NOTE 1 EN 13205–5:2014 and its Annex A both describe tests carried out at a specific workplace. Whereas EN 13205–5:2014, Annex A only describes experiments to determine a correction factor to recalculate the concentration measured with one sampler into that of the other, the main part of EN 13205–5 describes a performance test carried out at a specific workplace.

NOTE 2 EN 13205–6:2014, Clause 5 describes a test procedure to determine transport losses when samples are sent by mail, whereas EN 13205–6:2014, Clause 6 describes a laboratory test to simulate vibration of the samplers/samples.

7 Types of evaluation

7.1 Sampler evaluation

There are three different types of sampler evaluation. These types are defined as follows:

- type A: EN 13205-1:2014, Clause 6 + EN 13205-2 + CEN/TR 13205-3 + one test aerosol according to EN 13205-4:2014 or EN 13205-5:2014, 5.2a + EN 13205-6:2014, Clause 5;
- type B: EN 13205-1:2014, Clause 6 + EN 13205-4 + EN 13205-6:2014, Clause 5;
- type C: EN 13205-1:2014, Clause 6 + EN 13205-5 + EN 13205-6:2014, Clause 5.

These types are ranked in order of the quality of information available to the user of the sampler following testing. The type A test gives the user more information from which to assess the likely performance of the sampler in particular conditions of use. All three tests also allow the user to estimate the expanded uncertainty of a specified measuring procedure (see 7.2 and Annex A). The type A test determines the performance for the largest range of size distributions. The type B test is only based on three test aerosols (size distributions), whereas the type C test is only valid for the aerosol encountered at the work environment of the test. EN 13205-6 describes a test procedure to determine transport losses when samples are sent by mail.

7.2 Evaluation of a measuring procedure

The evaluation of a measuring procedure requires that all stages of the procedure is evaluated, not only the sampling stage or the analytical stage. The evaluation of the analytical stage shall be performed according to a relevant standard, for example, ISO 15767 for aerosol mass by weighing, ISO 24095 for respirable crystalline silica, EN 13890 for metals and metalloids, EN 14530 for diesel exhaust fume, and ISO 21438 (all parts) for inorganic acids.

The sampler evaluation could be any of a type A, B or C test, but the evaluation of a measuring procedure will be ranked in the same order as that for the evaluation of the sampler, see 7.1. Annex A describes how the performance of all the stages of a measuring procedure are combined.

8 Instructions for use

The instructions for use shall be unambiguous, comprehensive and may include useful illustrations. The information for use shall contain at least the following information:

a) what EN 481 sampling convention (if any) the sampler is intended to follow;

b) limitations on the use of the sampler (for example, 5.3);

c) the aerosol size distributions, wind speeds and other operating conditions for which the sampler meets the performance requirements in 5.2;

d) the nominal flow rate;

e) how to set up the sampler and adjust its operating parameters (for example, volumetric flow rate);

f) requirements for an external pump where used; volumetric flow rate, pressure drop, pulsation. Examples of recommended pumps shall be given;

g) recommended batteries and battery charger where used;

h) duration of operating time for fully charged batteries (where used), under typical operating conditions;

i) temperature range for storage and operation of the sampler;

j) details of particle collection substrates to be used (for example, filter diameter, material, pore size);

k) definition of which collection substrate(s) constitutes the sample(s);

l) general guide to typical applications and methods of sample analysis;

m) minimum service requirements;

n) maintenance, cleaning and calibration of the sampler, for example, checking that O-rings and gaskets are not worn out and that the sampler is airtight;

o) warnings of known problems that can be encountered during use, for example concerning orientation, mechanical shocks;

p) prohibitions on use in certain conditions, for example, explosive atmospheres, if applicable.

9 Marking, quality control

9.1 Marking

Samplers for the measurement of airborne particles shall be permanently marked. The marking shall enable the identification of the following:

— manufacturer;

— identification of the sampler.

For samplers evaluated using type A or type B tests and meeting the requirements of this part of EN 13205, the number of this part of EN 13205 (“EN 13205-1”) and the type of evaluation shall be stated.

9.2 Quality control

Manufacturers shall follow a stated and recognised quality programme.

Annex A
(normative)

Calculation of expanded uncertainty for a measuring procedure

A.1 General

For comparison of the performance characteristics of a sampling method with the general performance requirements of EN 482, the entire measuring procedure of which aerosol sampling forms a part shall be considered. The measuring procedure is divided into four steps. Then the following four main components can be considered for the determination of the uncertainty of the measuring procedure:

a) uncertainty associated with the sampling efficiency (incl. calibration of experimental set-up) (see A.2.2);

b) uncertainty associated with the measurement of sampled volume (see A.2.3);

c) uncertainty associated with transport losses (see A.2.4); and

d) uncertainty associated with (chemical) analysis, incl. sample storage and preparation (see A.2.5).

This requires that the random and non-random uncertainty components for all the four stages are determined (or estimated) and combined. The determination of the uncertainty component of the analytical stage is outside the scope of this standard, but this annex gives the method by which these uncertainty components can be combined to calculate the expanded uncertainty of the measuring procedure.

For more detailed information on the topic of performance evaluation generally see Bibliography, references [1] to [9].

A.2 Expanded uncertainty for a measuring procedure

A.2.1 General

The expanded uncertainty of a measuring procedure is calculated from Formulae (A.1) and (A.2). First the combined standard uncertainty is calculated:

$$\begin{cases} u_{\mathrm{R}}{}^{2} = u_{\mathrm{s\text{-}R}}{}^{2} + u_{\mathrm{v\text{-}R}}{}^{2} + u_{\mathrm{t\text{-}R}}{}^{2} + u_{\mathrm{a\text{-}R}}{}^{2} \\ u_{\mathrm{nR}}{}^{2} = u_{\mathrm{s\text{-}nR}}{}^{2} + u_{\mathrm{v\text{-}nR}}{}^{2} + u_{\mathrm{a\text{-}nR}}{}^{2} \\ u_{\mathrm{c}}{}^{2} = u_{\mathrm{R}}{}^{2} + u_{\mathrm{nR}}{}^{2} \end{cases} \tag{A.1}$$

where

u_{c}	is the combined standard uncertainty;
u_{R} and u_{nR}	are the combined standard uncertainties for the random and non-random components of error;
$u_{\mathrm{s\text{-}R}}$, $u_{\mathrm{v\text{-}R}}$, $u_{\mathrm{t\text{-}R}}$ and u_{a-R}	are the random components of standard uncertainty due to sampling, determination of sampled volume, transport losses and analysis (incl. storage);

$u_{\text{s-nR}}$, $u_{\text{v-nR}}$ and $u_{\text{a-nR}}$ are the non-random components of standard uncertainty due to sampling, determination sampled volume and analysis (incl. storage).

NOTE It is only random errors that can be decreased by averaging over a set of several individual samples from the same population. In most cases the non-random errors will be (almost) identical for all individual samples from a given population, and are thus *not* reduced by averaging.

If the combined non-random standard uncertainty turns out to be larger than, or of similar magnitude as, the random standard uncertainty, the measuring procedure is dominated by systematic errors. The methods described in EN 482, this document and other daughter standards of EN 482 cannot give good estimates of the expanded measurement uncertainty in such cases. Such a measuring procedure should not be used without explicit determination of the bias.

In many cases one or more of the standard uncertainties referred to in Formula (A.1) can depend on the sampled concentration or the amount collected. In order to perform the calculations, values have to be assigned to these quantities. This is described in this Annex.

The expanded uncertainty is calculated from the combined standard uncertainty using a coverage factor of 2.

$$U = 2u_{\text{c}} \tag{A.2}$$

where

U is the expanded uncertainty; and

u_{c} is the combined standard uncertainty

The general way of calculating the expanded uncertainty is the same for sampler evaluations according to either Type A (EN 13205-2), Type B (EN 13205-4) or Type C (EN 13205-5).

A.2.2 Combined standard uncertainty of the sampling efficiency

For a sampler evaluated according to Type A (EN 13205-2) the random and non-random standard uncertainties, $u_{\text{s-R}}$ and $u_{\text{s-nR}}$, are obtained from EN 13205-2:2014, 8.4.5 or 8.4.6, depending on whether it is feasible to distinguish between different values of the influence variables.

For a sampler evaluated according to Type B (EN 13205-4) the random and non-random standard uncertainties, $u_{\text{s-nR}}$ and $u_{\text{s-nR}}$, are obtained from EN 13205-4:2014, 8.4.5 or 8.4.6, depending on whether it is feasible to distinguish between different values of the influence variables.

For a sampler evaluated at a specific workplace according to Type C (EN 13205-5) the random and non-random standard uncertainties, $u_{\text{s-nR}}$ and $u_{\text{s-nR}}$, are obtained from either EN 13205-5:2014, Formula (17) or EN 13205-5:2014, Formula (18), depending on whether there is any coupling between the flow rate and internal penetration.

A.2.3 Combined standard uncertainty of the measurement of sampled volume

A.2.3.1 Standard uncertainty of the measurement of sampling flow rate

Flow rate measurements can be carried out using a range of different devices, for example, rotameters, mass flow meters, bubble flow meters or dry piston flow meters. Flow rate measurement error arises from two sources: the calibration of the flow meter (non-random) the reading of the flow meter (random) and, where appropriate, correction of the flow rate reading to ambient pressure and temperature. The uncertainty of the flow rate calibration shall be calculated from the data given on the flow meter test certificate. The uncertainty of the flow rate reading shall be calculated from measurements carried out under repeatability conditions.

EN 482:2012, Table B.1 gives, for different methods of measuring the flow rate, indicative values (expressed in %) for the random and non-random standard uncertainties for the measurement of flow rate, $u_{\text{fr-R}}$ [-] and $u_{\text{fr-nR}}$ [-], respectively. These values are expressed as percentage in EN 482. Recalculate them into fractions by dividing by 100 before using the values in Formula (A.3) of this document.

If a generally applicable estimate of uncertainty is to be made for a method that does not specify the use of a particular type of flow meter, the uncertainty components for a mass flow meter given in EN 482:2012, Table B.1, shall be used, as this constitutes a worst-case scenario (if the use of an inappropriate “rotameter” is disregarded).

A.2.3.2 Standard uncertainty of the measurement of sampling time

Sampling time can be measured very exactly with a radio-controlled clock, a quartz clock or stopwatch. The major source of uncertainty in measurement of sampling time is the accuracy with which the reading is taken, i.e. to the nearest minute or second. This non-random uncertainty component is very small in the case of long-term measurements (for example, > 2 h) and may be disregarded, but for short-term measurements it needs to be taken into account. For example, if the time is recorded to the nearest minute both at start and stop, the relative standard deviation of the non-random measurement error, $u_{\text{st-nR}}$ [-], is 0,027 for a sampling time of 15 min (assuming subtraction of one rectangular probability distributions from another rectangular probability distribution, i.e. a triangular distribution).

A.2.3.3 Calculation of combined standard uncertainty of the measurement of the sampled volume

The random and non-random standard uncertainty of the measurement of the sampled volume is calculated from Formula (A.3):

$$\begin{cases} u_{\text{v-R}} = u_{\text{fr-R}} \\ u_{\text{v-nR}}^{2} = u_{\text{fr-nR}}^{2} + u_{\text{st-nR}}^{2} \end{cases} \tag{A.3}$$

where

$u_{\text{v-R}}$	is the random standard uncertainty due to determination of the sampled volume;
$u_{\text{fr-R}}$	is the random standard uncertainty due to measurement of the flow rate;
$u_{\text{v-nR}}$	is the non-random standard uncertainty due to determination of the sampled volume;
$u_{\text{fr-nR}}$	is the non-random standard uncertainty due to measurement of the flow rate;
$u_{\text{st-nR}}$	is the relative standard deviation of the non-random measurement error of the sampling time.

A.2.4 Combined standard uncertainty of sample losses during transport

The random and non-random standard uncertainty of the measurement of sample losses during transport are determined according to Formula (4) in EN 13205-6:2014, 5.3.

A.2.5 Combined standard uncertainty of the analysis

For the evaluation of the measuring procedure, the candidate sampler shall be treated as being used according to the measuring procedure for the corresponding dust fraction, either of the country of the orderer/customer of the performance test or of the country of the test laboratory. Whichever shall be specified in the test report.

For the evaluation of the measuring procedure, the evaluation of the chemical analysis shall be treated as being based on samples analysed according to the corresponding analytical method. International standards are available for aerosol mass by weighing (ISO 15767), respirable crystalline silica (ISO 24095), metals and metalloids (EN 13890), diesel exhaust fume (EN 14530), and inorganic acids (ISO 21438 (all parts)). If no specific analytical method is intended, the method for gravimetric analysis, either of the country of the orderer/customer of the performance test or of the country of the test laboratory shall be used. Whichever was selected shall be specified in the test report.

See the proper standard for the analytical method in question for how the standard uncertainties for the chemical analysis, $u_{\text{a-R}}$ and $u_{\text{a-nR}}$, are determined, for example, ISO 15767 for aerosol mass by weighing, ISO 24095 for respirable crystalline silica, EN 13890 for metals and metalloids, EN 14530 for diesel exhaust fume, and ISO 21438 (all parts) for inorganic acids.

NOTE 1 Some of these (and other) analytical standards cannot contain a performance test for storage losses. When a storage test is needed, a modified version of the test in EN 13890 can be used.

The uncertainty of the analysis shall be determined experimentally and can depend on a number of factors, including sampled amount, sample matrix and sample particle size distribution.

NOTE 2 Values taken from other documents can be expressed in per cent (%). In order to use such values in the formulae of this document, they are first recalculated into fractions by dividing them by 100.

A.2.6 Calculation of the combined standard uncertainty

A.2.6.1 Selection of occupational limit value

If no occupational limit value (C_{OEL}) is specified for the evaluation of the measuring procedure, the evaluation shall be based on the long-term occupational limit value corresponding to the measuring procedure selected in A.2.5. Whichever selected shall be specified in the test report.

A.2.6.2 Components of standard uncertainty as constants

If *all* components of standard uncertainty referred to in Formula (A.1) can be expressed as constant relative numbers (*for example,* as a percentage), *i.e.* the standard uncertainties are independent of any possibly influence factor such as sampling time, sampled concentration, sampled amount, etc, *then* the combined standard uncertainty will be constant (for all sampled concentrations etc.) and can be calculated directly from Formula (A.1).

A.2.6.3 Components of standard uncertainty as functions of variables

A.2.6.3.1 General

In cases where some components of the standard uncertainty are functions of some variables, the combined standard uncertainty will not be constant but instead a function of several variables and in these cases Formula (A.1) needs to be modified. Examples of such variables are the concentration at which samples were collected, the amount of analyte collected, the amount of aerosol deposited/collected, etc.

The dependence on the actual concentration is incorporated into the calculations by determining the specified measuring range, defined by three sampled concentrations, $C_{0,1}$, $C_{0,5}$ and C_2, all [mg/m^3], corresponding to 10, 50 and 200 % of the selected occupational limit value, C_{OEL} [mg/m^3], respectively, see Formula (A.4):

$$\begin{cases} C_{0,1} = 0{,}1 \times C_{\text{OEL}} \\ C_{0,5} = 0{,}5 \times C_{\text{OEL}} \\ C_2 = 2 \times C_{\text{OEL}} \end{cases} \tag{A.4}$$

Select a sampling time or a set of sampling times of interest for the calculations, t, according to the selected measuring procedure. It shall only be assumed that a long-term sample will last for 8 h if the measuring procedure explicitly requires this sampling time.

NOTE In some cases it can be of interest to calculate the expanded uncertainty for several sampling times, ranging from short-term sampling (usually 15 min) over 2, 4 and 6 h.

Calculate the amounts analysed, $m_{\text{Analysed-0,1}}$, $m_{\text{Analysed-0,5}}$ and $m_{\text{Analysed-2}}$, respectively, all [mg], for the concentrations according to Formula (A.4), $C_{0,1}$, $C_{0,5}$ and C_2, respectively, and selected sampling time(s) of interest, t, using the nominal flow rate of the sampler, Q^0 [l/min], according to Formula (A.5):

$$\begin{cases} m_{\text{Analysed-0,1}} = 0{,}001 \times C_{0,1}\, Q^0 t \\ m_{\text{Analysed-0,5}} = 0{,}001 \times C_{0,5}\, Q^0 t \\ m_{\text{Analysed-2}} = 0{,}001 \times C_2\, Q^0 t \end{cases} \tag{A.5}$$

A.2.6.3.2 Random standard uncertainty of the analytical stage

The standard uncertainty of the analytical stage can for some collection substrates and analytical methods depend on the amount determined by analysis. In this case the variance of the analytical stage usually is constant (as for example for gravimetric analysis) and the random standard uncertainty of the analytical stage, $u_{\text{a-R}}$, is expressed as a ratio of the standard deviation of the mass of amount analysed to the mass of amount analysed according to Formula (A.6):

$$u_{\text{a-R}} = \frac{s_{\text{analysis}}}{m_{\text{Analysed}}} \tag{A.6}$$

where

m_{Analysed} is the measured or otherwise known amount analysed [mg];

s_{analysis} is the (constant) standard deviation due to chemical analysis (incl. storage) [mg]; and

$u_{\text{a-R}}$ is the non-random component of standard uncertainty due to analysis (incl. storage).

NOTE The standard deviation of gravimetric analysis is constant because the weight of the substrate far overrides the weight of the collected sample. Effectively, the standard deviation of gravimetric analysis is the standard deviation of weighing the substrate twice (rather than of weighing the collected sample) and correcting for the weight change of the blanks. See ISO 15767.

A.2.6.3.3 Non-random standard uncertainty of the analytical stage

The non-random standard uncertainty of the sampling efficiency can for some types of samplers and/or collection substrates depend on the amount collected or even deposited onto the internal surfaces of the sampler upstream of the collection substrate. In this case the non-random standard uncertainty of the sampling efficiency is expressed as a function of the mass collected, $m_{\text{Collected}}$ [mg], *i.e.* $u_{\text{s-nR}} = u_{\text{s-nR}}\left(m_{\text{Collected}}\right)$. The shape and parameterization of the function $u_{\text{s-nR}}\left(m_{\text{Collected}}\right)$ needs to be determined by separate experiments, if these are deemed necessary by the critical review (see 6.2).

NOTE It is generally assumed that the performance of the sampling stage is independent of the sampled concentration. In many cases the sampler performance is also independent of the amount of particles separated out of the air stream at the stage of internal aerodynamic separation and the amount of sample collected. However, there exist samplers that are sensitive to this. One example is that the penetration of some type of cyclones depends slightly on the amount of particles separated onto the cyclone walls. Another example is that the ability of the collection substrate of some type of impactors to retain depositing particles decreases with increasing amount of collected sample. (*I.e.* for both types of samplers the sampling efficiency can depend on the *non*-sampled fraction of the total airborne concentration. This case will not be explicitly shown, but its effect can easily be deduced along similar lines as used for the amount of collected mass.)

A.2.6.3.4 Analysed amount as minor fraction of amount collected

This clause is only relevant if both, A.2.6.3.2 and A.2.6.3.3 are applicable.

If only a subfraction of the mass collected is analytically determined, for example, an element, it is not the mass analysed, m_{Analysed}, but instead (possibly) the total mass collected, $m_{\text{Collected}}$, that was used to describe the influential variable in an experiment to determine the efficiency of the sampler. In this case the ratio of the analyte to the collected mass needs to be estimated.

The total mass collected, $m_{\text{Est-Collected}}$, is estimated as the average of measured or otherwise known ratios of total mass collected to amount analysed, ξ_{Est}, for the a particle size distribution relevant for the substance selected for the evaluation of the measuring procedure. Estimate the ratio of total mass collected to amount analysed is determined according to Formula (A.7) as

$$\xi_{\text{Est}} = \left\langle \frac{m_{\text{Collected}}}{m_{\text{Analysed}}} \right\rangle \tag{A.7}$$

where

m_{Analysed} is measured or otherwise known amount analysed, [mg];

$m_{\text{Collected}}$ is measured or otherwise known total mass collected, [mg]; and

ξ_{Est} is the estimated ratio of mass of collected sample to amount analysed in collected sample.

Estimate the collected mass for each concentration based on this estimated ratio, see Formula (A.8):

$$\begin{cases} m_{\text{Est-Collected-0.1}} = \xi_{\text{Est}}\, m_{\text{Analysed-0,1}} \\ m_{\text{Est-Collected-0.5}} = \xi_{\text{Est}}\, m_{\text{Analysed-0,5}} \\ m_{\text{Est-Collected-2}} = \xi_{\text{Est}}\, m_{\text{Analysed-2}} \end{cases} \tag{A.8}$$

where

$m_{\text{Analysed-0,1}}, m_{\text{Analysed-0,5}}$ and $m_{\text{Analysed-2}}$ are the amounts analysed in the collected samples from the three concentrations $C_{0,1}$, $C_{0,5}$ and C_2, respectively, [mg];

$m_{\text{Est-Collected-0,1}}, m_{\text{Est-Collected-0,5}}$ and $m_{\text{Est-Collected-2}}$ are the estimated masses of the collected samples from the three concentrations $C_{0,1}$, $C_{0,5}$ and C_2, respectively, [mg]; and

ξ_{Est} is the estimated ratio of total mass collected to amount analysed.

NOTE The estimated ratio ξ is only needed if the *collected* mass influences any standard uncertainty *and* the *analysed* mass influences any other standard uncertainty. Otherwise, $\xi_{\text{Est}} \equiv 1$.

A.2.6.3.5 Calculation of combined standard uncertainty

For the three sampled concentrations $C_{0,1}$, $C_{0,5}$ and C_2, respectively, the combined standard uncertainty is calculated using the corresponding calculated values for the mass collected and/or the amount analysed from Formula (A.9):

$$\begin{cases} u_{\mathrm{R}}^{2} = u_{\mathrm{s\text{-}R}}^{2} + u_{\mathrm{v\text{-}R}}^{2} + u_{\mathrm{t\text{-}R}}^{2} + \left(\dfrac{s_{\mathrm{a\text{-}R}}\left(m_{\mathrm{Analysed}}\right)}{m_{\mathrm{Analysed}}} \right)^{2} \\ u_{\mathrm{nR}}^{2} = u_{\mathrm{s\text{-}nR}}\left(m_{\mathrm{Collected}}\right)^{2} + u_{\mathrm{v\text{-}nR}}^{2} + u_{\mathrm{a\text{-}nR}}^{2} \\ u_{\mathrm{c}}^{2} = u_{\mathrm{R}}^{2} + u_{\mathrm{nR}}^{2} \end{cases} \tag{A.9}$$

where

m_{Analysed}	is the amount analysed, [mg];
$m_{\mathrm{Collected}}$	is the total mass collected, [mg];
s_{analysis}	is the (constant) standard deviation due to the chemical analysis (incl. storage) [mg];
u_{c}	is the combined standard uncertainty;
u_{nR}	is the combined standard uncertainty for the non-random sources of error;
u_{R}	is the combined standard uncertainty for the random sources of error;
$u_{\mathrm{s\text{-}R}}$, $u_{\mathrm{v\text{-}R}}$ and $u_{\mathrm{t\text{-}R}}$	are the random sources of standard uncertainty due to sampling, determination of sampled volume and transport losses; and
$u_{\mathrm{s\text{-}nR}}$, $u_{\mathrm{v\text{-}nR}}$ and $u_{\mathrm{a\text{-}nR}}$	are the non-random sources of standard uncertainty due to sampling, determination of sampled volume and analysis (incl. storage).

A.2.7 Calculation of the expanded uncertainty

Calculate the expanded uncertainty from the combined standard uncertainty using Formula (A.2).

EN 482 has different requirements for measuring procedures depending on the reference period, and for long-term reference periods also depending on the concentration sampled. Compare the calculated expanded uncertainty values with the requirements of EN 482:2012, Table 1 (see also Table 2 above).

A.3 Test report for an evaluation of a measuring procedure

A.3.1 General

The test report shall be divided into sections as described.

A.3.2 Testing laboratory details and sponsoring organisation

- — name and address of testing laboratory, personnel carrying out the evaluation of the measuring procedure and date of work;

- name of organisation sponsoring the test.

A.3.3 Description of evaluated measuring procedure

- title and reference of measuring procedure;
- Occupational Exposure Limit value (OEL) for which the measuring procedure is evaluated;
- list of samplers, collection substrates, transportation methods and analytical methods for which the measuring procedure is evaluated;
- sampling convention(s) against which the evaluation is made;
- scope of the evaluation, and any limitations to the use of the measuring procedure that arise from the limited nature of the evaluation;
- sources for all data on combined standard uncertainties upon which the evaluation rests.

If several, conflicting, sources of data exist, a discussion explaining why some of the data was not used in the evaluation.

A.3.4 Tabulation of source data on standard uncertainties

List the data on combined standard uncertainties needed for the evaluation of the measuring procedure.

A.3.5 Presentation of calculated combined standard uncertainties and expanded uncertainties

List the individual combined standard uncertainties for the four sources of uncertainty (sampling, volume determination, transport and analysis), as well as all four combined, for the three concentrations ($C_{0,1}$, $C_{0,5}$ and C_2) and any other evaluated influence variable value, such as sampling time, collected mass and sample matrix.

A.3.6 Performance of measuring procedure

List the expanded uncertainties for the three concentrations ($C_{0,1}$, $C_{0,5}$ and C_2) and any other evaluated influence variable values, such as sampling time, collected mass and sample matrix.

List specifically the combinations of concentration and influence variable values for which the measuring procedure does not fulfil the requirements of the EN 482.

If the combined standard uncertainty for non-random sources of error is of similar magnitude or exceeds the combined standard uncertainty for random sources of error, state that the calculated expanded uncertainty is not a good estimate of the actual expanded uncertainty. In order to be used, this measurement procedure needs explicit determination of the bias in each situation.

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