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Air quality — Certification of automated measuring systems

Part 4: Performance criteria and test procedures for automated measuring systems for periodic measurements of emissions from stationary sources

bsi.

National foreword

This British Standard is the UK implementation of EN 15267-4:2017.

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This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Qualité de l'air - Certification des systèmes de mesurage automatisés - Partie 4 : Spécifications de performance et modes opératoires d'essai des systèmes de mesurage automatisés pour le mesurage périodique des émissions de sources fixes

Luftbeschaffenheit - Zertifizierung von automatischen Messeinrichtungen - Teil 4: Mindestanforderungen und Prüfprozeduren für automatische Messeinrichtungen für wiederkehrende Messungen von Emissionen aus stationären Quellen

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

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European foreword

This document (EN 15267-4:2017) has been prepared by Technical Committee CEN/TC 264 "Air quality", the secretariat of which is held by DIN.

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of an identical text or by endorsement, at the latest by July 2017, and conflicting national standards shall be withdrawn at the latest by July 2017.

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 is Part 4 of a series of European Standards:

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

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

— EN 15267-3, *Air quality — Certification of automated measuring systems — Part 3: Performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources*

— EN 15267-4, *Air quality — Certification of automated measuring systems — Part 4: Performance criteria and test procedures for automated measuring systems for periodic measurements of emissions from stationary sources*

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, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

0 Introduction

0.1 General

CEN has established standards for the certification of automated measuring systems (AMS) used for monitoring emissions from stationary sources and ambient air quality. This product certification is based on the following four sequential stages:

a) performance testing of the AMS;

b) initial assessment of the AMS manufacturer's quality management system;

c) certification of the AMS;

d) post certification surveillance.

This European Standard specifies the performance criteria and test procedures for performance testing of portable automated measuring systems (P-AMS) used for periodic measurements of stationary source emissions. Testing applies to complete measuring systems.

NOTE 1 Portable electrical apparatus designed to measure combustion flue gas parameters of heating appliances are specified in EN 50379–1 to EN 50379–3.

The application of P-AMS for periodic measurements of stationary source emissions is based on

— specification of the standard reference method (SRM) and validation of the SRM;

— specification of the alternative method (AM) if the P-AMS is based on an AM;

— certification of the P-AMS in accordance with EN 15267-1, EN 15267-2 and EN 15267-4 including demonstration of equivalence with the SRM in the field if the P-AMS is based on an AM;

— on-going quality management by the user of the P-AMS in line with EN ISO/IEC 17025.

NOTE 2 Examples for standard reference methods for different measured components are listed in Annex F.

The overall assessment for the purposes of certification is *conformity testing*, while the evaluation of performance against specified performance criteria is *performance testing*.

0.2 Legal drivers

This European Standard supports the requirements of the following EU Directives:

— Directive 2010/75/EU on industrial emissions (integrated pollution prevention and control)

— Directive 2003/87/EC on processes emitting greenhouse gases.

However, this European Standard can also be applied to the monitoring requirements specified in other EU Directives.

0.3 Periodic measurements

Certified P-AMS can be used as SRM or AM for periodic measurements of stationary source emissions.

0.4 Relationship to EN 14181

Certified P-AMS can be used as SRM or AM for the calibration and validation of stationary AMS for QAL2 and AST purposes.

0.5 Processes

Field testing of P-AMS is ordinarily carried out on industrial processes representative of the range of application of the SRM or AM. The premise is that if the P-AMS performs acceptably on these processes, then experience has shown that the P-AMS generally performs well on the majority of other processes. However, there are always exceptions and it is the responsibility of the user to ensure that the P-AMS performs adequately on a specific process.

The necessary field test of P-AMS is specified in this European Standard.

0.6 Performance characteristics

A combination of laboratory and field tests is detailed within this European Standard. Laboratory testing is designed to assess whether a P-AMS can meet, under controlled conditions, the relevant performance criteria. Field testing, is designed to assess whether a P-AMS can continue to work and meet the relevant performance criteria in real applications including transportation to the measurement site, set-up of the P-AMS and measurement.

The main P-AMS performance characteristics are:

— response time;

— repeatability standard deviation;

— lack of fit (linearity);

— short-term drift;

— influence of ambient temperature;

— influence of voltage variations;

— influence of vibration;

— influence of sample gas pressure;

— influence of sample gas flow for extractive P-AMS;

— cross-sensitivity to likely interferents contained in the stack gas other than the measured component;

— converter efficiency for NO_x P-AMS;

— response factors for P-AMS measuring TOC;

— reproducibility under field conditions;

— trueness and precision of the P-AMS against the SRM under field conditions if the P-AMS is based on an AM.

Additional performance characteristics specific to the SRM or AM are included in the performance test.

The quality assurance and quality control (QA/QC) procedures to be applied by the user of the P-AMS are also assessed in the performance test.

This European Standard is an application and elaboration of EN ISO 9169 with additional and alternative provisions for the performance test of P-AMS. Where this European Standard appears to differ from EN ISO 9169, it either elaborates upon the requirements of EN ISO 9169 or differs in minor ways owing to the necessity to conduct the performance test of P-AMS.

0.7 Relationship to EN 15267-3

This European Standard is based on EN 15267-3, which specifies the performance testing of stationary AMS for the continuous monitoring of emissions from stationary sources. Many requirements of this European Standard are identical to those of EN 15267-3. This European Standard deviates from EN 15267-3 only where the portable use and the use as SRM or AM require different or additional requirements. Therefore, this European Standard allows a combined testing where an AMS is designed for stationary and portable use. It also allows a reduced performance testing of P-AMS, which have been already certified according to EN 15267-3 for stationary use.

1 Scope

This European Standard specifies the general performance criteria and test procedures for portable automated measuring systems (P-AMS) used for periodic measurements of stationary source emissions. It applies to the performance testing of P-AMS based on measurement techniques specified by the standard reference method (SRM) or an alternative method (AM).

Performance testing is based on the general performance criteria and test procedures specified in this European Standard and on the specific requirements specified for the SRM or AM. This includes testing of the applicability and correct implementation of the QA/QC procedures specified for the SRM or AM.

This European Standard supports the requirements of particular EU Directives.

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 14793:2017, *Stationary source emissions — Demonstration of equivalence of an alternative method with a reference method*

EN 15259:2007, *Air quality - Measurement of stationary source emissions - Requirements for measurement sections and sites and for the measurement objective, plan and report*

EN 60068-2-6, *Environmental testing - Part 2-6: Tests - Test Fc: Vibration (sinusoidal) (IEC 60068-2-6)*

EN 60529, *Degrees of protection provided by enclosures (IP Code) (IEC 60529)*

EN ISO 14956, *Air quality - Evaluation of the suitability of a measurement procedure by comparison with a required measurement uncertainty (ISO 14956)*

3 Terms and definitions

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

3.1
automated measuring system
AMS
entirety of all measuring instruments and additional devices for obtaining a result of measurement

Note 1 to entry: Apart from the actual measuring device (the analyser), an AMS includes facilities for taking samples (e.g. probe, sample gas lines, flow meters and regulator, delivery pump) and for sample conditioning (e.g. dust filter, pre-separator for interferents, cooler, converter). This definition also includes testing and adjusting devices that are required for functional checks and, if applicable, for commissioning.

Note 2 to entry: The term “automated measuring system” (AMS) is typically used in Europe. The term “continuous emission monitoring system” (CEMS) is also typically used in the UK and USA.

3.2
portable automated measuring system
P-AMS
automated measuring system which is in a condition or application to be moved from one to another measurement site to obtain measurement results for a short measurement period

Note 1 to entry: The measurement period is typically 8 h for a day.

Note 2 to entry: The P-AMS can be configured at the measurement site for the special application but can be also set-up in a van or mobile container. The probe and the sample gas lines are installed often just before the measurement task is started.

3.3
reference method
RM
measurement method taken as a reference by convention, which gives, the accepted reference value of the measurand

Note 1 to entry: A reference method is fully described.

Note 2 to entry: A reference method can be a manual or an automated method.

Note 3 to entry: Alternative methods can be used if equivalence to the reference method has been demonstrated.

[SOURCE: EN 15259:2007]

3.4
standard reference method
SRM
reference method prescribed by European or national legislation

Note 1 to entry: Standard reference methods are used e.g. to calibrate and validate AMS and for periodic measurements to check compliance with limit values.

[SOURCE: EN 15259:2007]

3.5
alternative method
AM
measurement method which complies with the criteria given by EN 14793:2017 with respect to the reference method

Note 1 to entry: An alternative method can consist of a simplification of the reference method.

[SOURCE: Adapted from EN 14793:2017]

3.6
measurement method
method described in a written procedure containing all the means and procedures required to sample and analyse, namely: field of application, principle and/or reactions, definitions, equipment, procedures, presentation of results, other requirements and measurement report

[SOURCE: EN 14793:2017]

3.7
measurement
set of operations having the object of determining a value of a quantity

3.8
paired measurement
simultaneous recording of results of measurement at the same measurement point using two P-AMS of identical design

3.9
measurand
particular quantity subject to measurement

Note 1 to entry: The measurand is a quantifiable property of the stack gas under test, for example mass concentration of a measured component, temperature, velocity, mass flow, oxygen content and water vapour content.

[SOURCE: EN 15259:2007]

3.10
measured component
constituent of the waste gas for which a defined measurand is to be determined by measurement

Note 1 to entry: Measured component is also called determinand.

[SOURCE: EN 15259:2007]

3.11
interferent
substance present in the stack gas under investigation, other than the measured component, that affects the output

3.12
reference material
substance or mixture of substances, with a known concentration within specified limits, or a device of known characteristics

3.13
zero gas
gas mixture used to establish the zero point of a calibration curve when used with a given analytical procedure within a given calibration range

3.14
zero point
specified value of the output of the P-AMS which, in the absence of the measured component, represents the zero crossing of the P-AMS characteristic

Note 1 to entry: In case of oxygen and some flow monitoring AMS, the zero point is interpreted as the lowest measurable value.

3.15
span point
value of the output of the P-AMS for the purpose of calibrating, adjusting, etc. that represents a correct measured value generated by reference material between 70 % and 90 % of the range tested

3.16
measured signal
output of the P-AMS in analogue or digital form which is converted into the measured value with the aid of the analysis function of the analyzer

3.17
output
reading, or digital or analogue electrical signal, generated by the P-AMS in response to a measured object

3.18
independent reading
reading that is not influenced by a previous individual reading by separating two individual readings by at least four response times

3.19
individual reading
reading averaged over a time period equal to the response time of the P-AMS

3.20
averaging time
period of time over which an arithmetic or time-weighted average of concentrations is calculated

3.21
performance characteristic
quantity assigned to the P-AMS in order to define its performance

Note 1 to entry: The values of relevant performance characteristics are determined in the performance testing and compared to the applicable performance criteria.

3.22
response time
t_{90}
duration between the instant when an input quantity value of a measuring instrument or measuring system is subjected to an abrupt change between two specified constant quantity values and the instant when a corresponding indication settles within specified limits around its final steady value

Note 1 to entry: The response time is also referred to as the 90 % time.

Note 2 to entry: The response time is by convention the time taken for the output signal to pass from 0 % to 90 % of the final variation of indication.

Note 3 to entry: Beside the different wording, this definition does not technically deviate from the definition of response time in EN 15267–3.

3.23
lack of fit
systematic deviation, within the measurement range, between the accepted value of a reference material applied to the measuring system and the corresponding result of measurement produced by the calibrated measuring system

Note 1 to entry: In common language lack of fit is often called “linearity” or “deviation from linearity”. Lack of fit test is often called “linearity test”.

3.24
converter efficiency
efficiency with which the converter unit of a NO_x analyser reduces NO_2 to NO

3.25
interference
negative or positive effect that a substance has upon the output of the P-AMS, when that substance is not the measured component

3.26
cross-sensitivity
response of the P-AMS to interferents

Note 1 to entry: See interference.

3.27
short-term zero drift
difference between two zero readings at the beginning and at the end of the measurement period

3.28
short-term span drift
difference between two span readings at the beginning and at the end of the measurement period

Note 1 to entry: The measurement period is typically 8 h for a day. Measurement periods of several days need a drift control on each day.

3.29
repeatability
ability of the P-AMS to provide closely similar indications for repeated applications of the same measurand under the same conditions of measurement

3.30
reproducibility
$\boldsymbol{R_f}$
measure of the agreement between two identical measuring systems applied in parallel in field tests at a level of confidence of 95 % using the standard deviation of the difference of the paired measurements

Note 1 to entry: Reproducibility is determined by means of two identical P-AMS operated side by side. It is an P-AMS performance characteristic for describing the production tolerance specific to that P-AMS. The reproducibility is calculated from the short-term averages of the output signals (raw values as analogue or digital outputs) obtained during the field test.

Note 2 to entry: The term “field repeatability” is sometimes used instead of reproducibility.

3.31
uncertainty
parameter associated with the result of a measurement, that characterises the dispersion of the values that could reasonably be attributed to the measurand

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

3.32
standard uncertainty
uncertainty of the result of measurement expressed as a standard deviation

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

3.33
expanded uncertainty
quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

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

Note 1 to entry: The interval about the result of measurement is established for a level of confidence of typically 95 %.

3.34
test laboratory
laboratory accredited to EN ISO/IEC 17025 for carrying out performance tests

Note 1 to entry: CEN/TS 15675 provides an elaboration of EN ISO/IEC 17025 for application to emission measurements, which should be followed when using standard reference methods.

3.35
field test
test at different industrial processes representative of the intended application of the P-AMS, where one can be a suitable test bench which covers all relevant influences present in the field, including the transportation from one site to another, setting-up the P-AMS at the measurement site and checking the function and drift

3.36
certification range
range over which the P-AMS is tested and certified for compliance with the relevant performance criteria

Note 1 to entry: Certification range is always related to the daily ELV.

3.37
emissions limit value
ELV
limit value given in regulations such as EU Directives, ordinances, administrative regulations, permits, licences, authorisations or consents

Note 1 to entry: ELV can be stated as concentration limits expressed as half-hourly, hourly and daily averaged values, or mass flow limits expressed as hourly, daily, weekly, monthly or annually aggregated values.

3.38
relevant body
competent authority or certification body, nominated by a competent authority or EU member state, that carries out the certification of automated measuring systems

[SOURCE: EN 15267-1:2009]

4 Symbols and abbreviations

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

4.1 Symbols

a	average value of the P-AMS readings in the linearity test
A	intercept of the regression function in the linearity test
b_f	sensitivity coefficient of sample gas flow
b_p	sensitivity coefficient of sample gas pressure
b_t	sensitivity coefficient of ambient temperature
b_v	sensitivity coefficient of supply voltage
B	slope of the regression function in the linearity test
c	concentration; value of the reference material
c_i	carbon mass concentration of substance i at 273 K and 1 013 hPa; individual reference material value
c_{ref}	carbon mass concentration of propane at 273 K and 1 013 hPa
$c_{NO,0}$	concentration of NO with ozone generator switched-off
$c_{NO,i}$	concentration of NO with ozone generator at setting i (i = 1 to n)
$c_{NOx,0}$	concentration of total NO_x with ozone generator switched-off
$c_{NOx,i}$	concentration of total NO_x with ozone generator at setting i (i = 1 to n)
$\overline{c}$	average of c values
d_c	residual
$d_{c,rel}$	relative residual
E_i	converter efficiency at setting i of the ozone generator (i = 1 to n)
f_i	carbon-related response factor for substance i
m_c	number of repetitions at reference material level c
n	number of measurements; number of parallel measurements
p_1	lower sample gas pressure
p_2	higher sample gas pressure
r_1	nominal flow rate
r_2	lowest flow rate specified by the manufacturer
R_f	reproducibility under field conditions
s_D	standard deviation from paired measurements
s_r	repeatability standard deviation of the measurement
$t_{n-1;\,0,95}$	two-sided Students t-factor at a confidence level of 95 % with a number of degrees of freedom n – 1
t_d	relative difference between the response times determined in rise and fall mode
t_r	response time determined in rise mode (average of four measurements)

t_f response time determined in fall mode (average of four measurements)

T_i *i*th temperature

u_c combined standard uncertainty

u_{ce} uncertainty contribution caused by converter efficiency for P-AMS measuring NO_x

$u_{d,s}$ uncertainty contribution caused by short-term span drift from field test

$u_{d,z}$ uncertainty contribution caused by short-term zero drift from field test

u_D uncertainty contribution caused by standard deviation from paired measurements under field conditions

u_f uncertainty contribution caused by influence of sample gas flow

u_i uncertainty contribution caused by cross-sensitivity (interference)

u_i uncertainty contribution to the total uncertainty of the measured values caused by a variation of influence quantity X_i

u_{lof} uncertainty contribution caused by lack of fit

u_{mb} uncertainty contribution caused by excursion of measurement beam

u_p uncertainty contribution caused by influence of sample gas pressure

u_r uncertainty contribution caused by repeatability standard deviation at span

u_{rm} uncertainty contribution caused by reference material provided by the manufacturer

u_t uncertainty contribution caused by influence of ambient temperature

u_v uncertainty contribution caused by influence of supply voltage

U_1 minimum voltage specified by the manufacturer

U_2 maximum voltage specified by the manufacturer

$U_{0,95}$ expanded uncertainty at a level of confidence of 95 %

x measured signal

x_i *i*th measured signal; average of the measured signals for substance *i*

$x_{i,min}$ minimum value of the average reading influenced by performance characteristic *i* during the performance test

$x_{i,max}$ maximum value of the average reading influenced by performance characteristic *i* during the performance test

$x_{i,adj}$ value of the average reading with the influence quantity at its nominal value during the performance test

$x_{1,i}$ *i*th measured signal of the first measuring system

$x_{2,i}$ *i*th measured signal of the second measuring system

$x_{c,i}$ individual P-AMS reading at reference material level *c*

x_{ref} average of the measured signals for propane

x_u upper limit of the certification range

$\overline{x}$ average of measured signals x_i

$\overline{x}_c$ average P-AMS reading at reference material level *c*

X_i ith influence quantity

4.2 Abbreviations

AM alternative method

AMS automated measuring system

AST annual surveillance test

ELV emission limit value

P-AMS portable automated measuring system

QA/QC quality assurance and quality control

QAL quality assurance level

QAL1 first quality assurance level

QAL2 second quality assurance level

QAL3 third quality assurance level

RM reference method

SRM *s*tandard reference method

TOC total organic carbon

5 General requirements

5.1 Application of performance criteria

The test laboratory shall test two identical portable automated measuring systems (P-AMS). The operating manual shall also be part of the P-AMS tested. All P-AMS tested shall meet the performance criteria specified in this European Standard as well as the performance criteria and the uncertainty requirement specified for the SRM or AM.

In the performance test two complete P-AMS as specified by the SRM or AM shall be tested (see Note 1 to 3.1). For the specific needs of the user the sampling and sample gas conditioning systems of the P-AMS can be adapted to allow the necessary flexibility for measurements with modified sampling probes, modified heated sampling lines or modified gas conditioning systems. The test laboratory shall specify in the test report the criteria to be considered by the user in case of such configurations.

5.2 Ranges to be tested

5.2.1 Certification range

The P-AMS shall be able to measure instantaneous values in a range that is at least two times the short-term average emission limit value in order to measure the short-term averages. If it is necessary to use more than one range setting of the P-AMS to achieve this requirement, these supplementary ranges will require additional testing (see 5.2.2).

The certification range over which the P-AMS is to be tested shall comprise minimum and maximum values. The coverage shall be fit for the intended application of the P-AMS. The certification range shall be specified as follows:

a) for waste incinerators as the range usually begins from zero, if the P-AMS is able to measure zero, and a value no greater than 1,5 times the daily average emissions limit value (ELV);

b) for large combustion plants as the range usually begins from zero, if the P-AMS is able to measure zero, and a value no greater than 2,5 times the daily average emissions limit value (ELV);

c) for other plants in relation to the corresponding emission limit value or any other requirement related to the intended application.

The certification range(s) and the performance criteria tested for each range shall be stated on the certificate.

The test laboratory should choose for the field test different industrial plants which cover a wide range of future applications. One of these industrial processes can be a test bench recognized by the competent authorities to be able to generate the appropriate gas matrices. In this case, the test bench shall meet the requirements in Annex A.

5.2.2 Supplementary ranges

Limited additional testing is required for all supplementary ranges. This additional testing shall at least include evaluations of the response time (see 10.6) and lack of fit (see 10.9). Cross-sensitivity (see 10.16) has to be tested for interferents that have shown relevance during testing in the certification range. The concentration of the relevant interferents shall be proportionally higher than the values specified in Table B.1, where the proportionality factor is given by the ratio of the considered supplementary range to the certification range. However, the concentrations for cross-sensitivity testing should be chosen with reference to the intended applications.

Supplementary ranges and the performance criteria tested for these ranges shall be stated on the certificate.

5.2.3 Lower limit of ranges

The lower limit of the certification range is usually zero.

NOTE For oxygen measuring P-AMS the lower limit of the certification range can differ from zero.

5.2.4 Expression of performance criteria with respect to ranges

The performance criteria presented in Clause 6 are expressed in terms of a percentage of the upper limit of the certification range for each measured component except for oxygen where the performance criteria are expressed as volume concentrations. A performance criterion with respect to ranges is a value that corresponds to the largest deviation allowed for each test, regardless of the sign of the deviation determined in the test.

5.2.5 Ranges of optical insitu P-AMS with variable optical length

The certification range for optical insitu P-AMS with variable optical length shall be defined in units of the measured component concentration multiplied by the length of the optical path.

The path length used for testing shall be stated on the certificate.

5.3 Performance testing of P-AMS based on certified AMS previously tested according to EN 15267-3

If the P-AMS is based on an AMS already certified according to EN 15267-3 for continuous emission monitoring, supplementary tests of performance characteristics specific to the P-AMS shall be performed. Already available data from the tests according to EN 15267-3 may be used.

5.4 Equivalence with the SRM

Equivalence with the SRM shall be demonstrated as part of the field test for both test items according to EN 14793:2017 if the P-AMS is based on an AM.

5.5 Manufacturing consistency and changes to P-AMS design

Certification is specific to the P-AMS version that has undergone performance testing. Subsequent design modifications that might affect the performance of the P-AMS can invalidate the certification.

NOTE Design modifications apply to both hardware and software.

Manufacturing consistency and changes to P-AMS design are described in EN 15267-2.

5.6 Qualifications of test laboratories

Test laboratories shall have the competence for performing emission measurements and carrying out the tests defined in this European Standard. Furthermore, test laboratories shall have knowledge on the uncertainties attributed to the individual test procedures applied during performance testing.

NOTE 1 The test laboratory can demonstrate the necessary competence e.g. by accreditation on the basis of EN ISO/IEC 17025.

CEN/TS 15675 provides an elaboration of EN ISO/IEC 17025 for application to emission measurements which should be followed when using standard reference methods.

NOTE 2 Annex F shows some examples for standard reference methods.

6 Performance criteria common to all P-AMS for laboratory testing

6.1 P-AMS for testing

All P-AMS submitted for testing shall be complete. The performance criteria apply to the complete P-AMS and not to the individual parts. The test report shall be issued for the specified P-AMS with all main components (e.g. analyser, cooler, pump) listed.

P-AMS using extractive sampling systems shall have appropriate provisions for filtering solids, avoiding chemical reactions within the sampling system, entrainment effects and effective control of water condensate.

Measuring systems with different options for the sampling system shall be tested with a sampling system agreed between the test laboratory and the manufacturer. The test laboratory shall describe in the test report the type of sampling system.

6.2 CE labelling

P-AMS shall comply with the requirements for CE labelling specified in applicable EU Directives. These include, for example:

— Electro-Magnetic Compatibility Directive 2004/108/EC, and

— Low-Voltage Directive 2014/35/EU covering electrical equipment designed for use within certain voltage limits.

NOTE The new Low-Voltage Directive 2014/35/EU is applicable from 20 April 2016.

P-AMS manufacturers or suppliers shall supply verifiable and traceable evidence of compliance with the requirements of the relevant EU Directives applicable to the equipment.

6.3 Output ranges and zero-point

P-AMS shall have a data output with a living zero point so that both negative and positive readings can be recorded.

NOTE The output from a P-AMS can be an analogue signal in the range from 4 mA to 20 mA or from 0 V to 10 V, or a digital signal transmitted e.g. by field bus or stored in a data file.

P-AMS shall have a display that shows the measurement response. The display may be external to the P-AMS.

6.4 Display of operational status signals

P-AMS shall have a means of displaying its operating status.

NOTE Status signals cover, for example, normal operation, stand-by, maintenance mode and malfunctions.

6.5 Degrees of protection provided by enclosures

Instruments that are designed to be used in areas where some kind of shelter against precipitation is in place, e.g. a porch roof, but where precipitation can reach the instrument due to wind etc., or in the open air with any weather protection shall at least meet the requirements of standard IP42 as specified in EN 60529.

6.6 Response time

P-AMS shall meet the performance criteria for response time specified in Clause 8 at ambient temperatures of 5 °C, 20 °C and 40 °C.

6.7 Repeatability standard deviation at zero point

P-AMS shall meet the performance criteria for repeatability standard deviation at the zero point specified in Clause 8.

NOTE 1 The detection limit is two times the repeatability standard deviation at zero.

NOTE 2 The quantification limit is four times the repeatability standard deviation at zero.

6.8 Repeatability standard deviation at span point

P-AMS shall meet the performance criteria for repeatability standard deviation at the span point specified in Clause 8.

6.9 Lack of fit

P-AMS shall have a linear output. The lack of fit test shall be performed at the beginning of the laboratory test. The test results shall meet the performance criteria for lack of fit specified in Clause 8.

6.10 Short-term zero and span drift

P-AMS shall allow for the testing for short-term zero and span drift.

P-AMS shall meet the performance criteria for short-term zero and span drift specified in Clause 8.

6.11 Set-up time after transport and influence of ambient temperature

The setting into operation and the influence of a slow change in ambient temperature shall be tested. The deviations of the P-AMS readings at the zero and span point shall not exceed the performance criterion specified in Clause 8, when the ambient temperature slowly changes from 5 °C to 25 °C and from 40 °C to 20 °C.

If the manufacturer submitting a P-AMS for testing specifies wider ambient temperature ranges to those above, the test shall be performed for these ranges.

NOTE Temperature ranges tested are indicated in the certificate.

6.12 Influence of voltage variations

The deviations of the P-AMS readings at the zero and span point shall not exceed the performance criterion specified in Clause 8 when the voltage supply to the P-AMS varies from –15 % from the nominal value below to +10 % from the nominal value above the nominal value of the supply voltage.

If the manufactures specifies different limits for battery operated P-AMS, these limits shall be applied.

P-AMS shall be capable of operating at a voltage that meets the requirements of EN 50160.

6.13 Influence of vibration

The deviations of the P-AMS readings at the zero and span point caused by vibrations typically expected at an industrial plant and typically expected for transportation shall not exceed the performance criteria specified in Clause 8.

6.14 Influence of sample gas flow for extractive P-AMS

The deviations of the P-AMS readings at the zero point and span point shall not exceed the performance criterion specified in Clause 8, when the sample gas flow is changed in accordance with the manufacturer's specification.

A status signal for the lower limit of the sample gas flow shall be provided.

6.15 Influence of sample gas pressure

The deviations of the P-AMS readings at the span point shall not exceed the performance criterion specified in Clause 8, when the sample gas pressure changes by 3 kPa above and below atmospheric pressure.

NOTE This typically applies to insitu P-AMS, but not to extractive P-AMS, since the sample gas is conditioned and typically not subject to significant variations of temperature and pressure once within the analyser.

6.16 Cross-sensitivity

The manufacturer shall describe any known sources of interference. Tests for non-gaseous interference sources, or gases other than those listed in Annex B, shall be agreed with the test laboratory.

P-AMS shall meet the performance criteria at the zero and span point for cross-sensitivity specified in Clause 8.

6.17 Converter efficiency for P-AMS measuring NO_x

Manufacturers shall specify, when seeking certification for P-AMS measuring NO_x, whether certification is required for the measurement of nitrogen monoxide (NO) and/or nitrogen dioxide (NO_2). If a converter is used, the converter shall meet the performance criteria for the converter efficiency specified in Clause 8.

NOTE 1 NO_x ordinarily means nitrogen monoxide (NO) plus nitrogen dioxide (NO_2).

NOTE 2 NO_x concentrations are generally expressed as NO_2.

6.18 Response factors for TOC measuring P-AMS

P-AMS for TOC shall meet the performance criteria specified in Clause 8.

6.19 Influences on P-AMS with in-stack sampling chamber

The manufacturer shall describe the P-AMS with in-stack sampling chamber and specify possible influences on the measured signals. Testing of these influences shall be agreed between the test laboratory, the manufacturer and the relevant body.

P-AMS with in-stack chamber normally consist of the following:

— a sampling chamber mounted within the stack;

— sample lines which enable zero and span gases to be injected into the sample chamber to check calibration;

— particle filters embedded in the sampling chamber to allow stack gas to diffuse into the sample chamber;

— a back purge system to prevent condensation of wet gas on the filters and probe optical components when the plant is off-line;

— an analytical instrument;

— sensors to monitor pressure and temperature in the stack gas for compensation purposes;

— a display unit to show measured response.

The gas within the stack diffuses into the sampling chamber according to the law of partial pressures. The results of the analysis are conveyed on a wet basis. If water vapour is present at high enough levels to interfere it shall be measured and the interference compensated for, or otherwise the interference shall be included in the uncertainty calculation.

The possible influences that can affect a P-AMS with in-stack chamber are as follows:

— moisture;

— cross-sensitivity from other gases;

— temperature of the stack gas which shall be above the dew point of that gas;

— vibration.

6.20 Influences related to storage and transportation

The manufacturer shall describe storage and transportation requirements and possible effects related to storage and transportation of the P-AMS. Testing of these influences shall be agreed between the test laboratory, the manufacturer and the relevant body.

The manufacturer shall specify the maximum range of storage temperature and humidity.

7 Performance criteria common to all P-AMS for field testing

7.1 Response time

P-AMS shall meet the performance criterion for the response time specified in Clause 8 and evaluated during the laboratory tests.

NOTE The test for the response time is repeated during the field test, as field conditions can influence the response time.

7.2 Short-term zero and span drift

The short-term zero and span drift shall not exceed the performance criteria specified in Clause 8.

The span materials (such as test gases) applied during testing shall produce a P-AMS reading between 70 % and 90 % of the upper limit of the certification range.

NOTE As field conditions can influence drift behaviour, tests for this characteristic are repeated during the field test.

7.3 Reproducibility

P-AMS shall meet the performance criterion for reproducibility under field conditions specified in Clause 8.

8 Performance criteria specific to measured components

8.1 General

Clause 8 defines the performance criteria for P-AMS specific to measured components. The P-AMS to be tested shall meet at least the performance criteria specified in this European Standard. If the SRM or AM standard sets additional or more stringent requirements, these shall be met.

The values for individual parameters given in these sections are expressed as a percentage of the upper limit of the certification range of the P-AMS under test.

Where regulations specify uncertainty requirements, the P-AMS shall meet both the individual performance criteria specified in this European Standard and the uncertainty requirements specified by the applicable regulations. The uncertainty budget shall be determined using the procedure described in Annex D.

8.2 Gas monitoring P-AMS

8.2.1 Performance criteria

P-AMS for measuring gaseous measured components shall meet the performance criteria specified in Table 1 and Table 2, unless more stringent requirements are specified in the method specific standard. The maximum allowable deviations (as absolute values) of the measured signals are given as volume concentration (volume fraction) for oxygen measuring P-AMS and as percentages of the upper limit of the certification range for other gases.

For P-AMS which measure moisture as a means of providing data corrected to dry conditions, moisture shall be included as a measured component and the P-AMS shall meet the performance criteria in Table 1 and Table 2.

Table 1 shows the performance criteria, which are tested in the laboratory. Table 2 shows the performance criteria, which are tested during the field test.

Table 1 — Performance criteria for gas monitoring P-AMS in laboratory tests

Performance characteristic	Performance criteria		Test in sub-clause
	Gases except O_2	O_2	
Response time	≤ 200 s ≤ 400 s for NH_3, HCl and HF	≤ 200 s	10.6
Repeatability standard deviation at zero point	≤ 2,0 % [a]	≤ 0,20 % [b]	10.7
Repeatability standard deviation at span point	≤ 2,0 % [a]	≤ 0,20 % [b]	10.8
Lack of fit	≤ 2,0 % [a]	≤ 0,30 % [b]	10.9
Short-term zero drift	≤ 2,0 % [a]	≤ 0,20 % [b]	10.10
Short-term span drift	≤ 2,0 % [a]	≤ 0,20 % [b]	10.10
Influence of ambient temperature change from 5 °C to 25 °C and from 40 °C to 20 °C at zero point	≤ 5,0 % [a]	≤ 0,50 % [b]	10.11
Influence of ambient temperature change from 5 °C to 25 °C and from 40 °C to 20 °C at span point	≤ 5,0 % [a]	≤ 0,50 % [b]	10.11
Influence of voltage, at –15 % below and at +10 % above nominal supply voltage [c]	≤ 2,0 % [a]	≤ 0,20 % [b]	10.12
Influence of vibration	≤ 2,0 % [a]	≤ 0,20 % [b]	10.13
Influence of sample gas pressure at span point, for a pressure change Δp of 3 kPa	≤ 2,0 % [a]	≤ 0,20 % [b]	10.14
Influence of sample gas flow on extractive P-AMS for a given specification by the manufacturer	≤ 2,0 % [a]	≤ 0,20 % [b]	10.15
Cross-sensitivity	≤ 4,0 % [a]	≤ 0,40 % [b]	10.16
Converter efficiency for P-AMS measuring NO_x	≥ 95,0 %	–	10.17

[a] Percentage value as percentage of the upper limit of the certification range.

[b] Percentage value as oxygen volume concentration (volume fraction).

[c] If the manufactures specifies different limits for battery operated P-AMS, these limits shall be applied.

Table 2 — Performance criteria for gas monitoring P-AMS in field tests

Performance characteristic	Performance criteria		Test in sub-clause
	Gases except O_2	O_2	
Response time	≤ 200 s ≤ 400 s for NH_3, HCl and HF	≤ 200 s	12.1
Short-term zero drift	≤ 5,0 % [a]	≤ 0,20 % [b]	12.2
Short-term span drift	≤ 5,0 % [a]	≤ 0,20 % [b]	12.2
Reproducibility, R_f	≤ 3,3 % [a]	≤ 0,20 % [b]	12.3
[a] Percentage value as percentage of the upper limit of the certification range. [b] Percentage value as oxygen volume concentration (volume fraction).			

8.2.2 P-AMS for total organic carbon

P-AMS for measuring total organic carbon (TOC) shall meet the performance criteria specified in Table 1 and Table 2.

Furthermore, the performance criteria for the effect of oxygen and the response factors specified in Table 3 shall be applied in 10.18.

Table 3 — Performance criteria for P-AMS measuring Total Organic Carbon (TOC) in laboratory tests

Performance characteristic	Performance criteria
Effect of oxygen	≤ 2,0 % [a]
Range of response factors:	
Methane	0,90 to 1,20
aliphatic hydrocarbons	0,90 to 1,10
aromatic hydrocarbons	0,80 to 1,10
Dichloromethane	0,75 to 1,15
aliphatic alcohols	0,7 to 1,0
esters and ketones	0,7 to 1,0
organic acids	0,5 to 1,0
[a] Percentage value as percentage of the upper limit of the certification range.	

NOTE EN 12619 specifies performance criteria including response factors for TOC analysers which use flame ionization detection (FID), particularly when the FID is used as SRM. However, the performance criteria in this European Standard apply to any techniques that can be used to measure TOC or a surrogate for TOC. For example, other techniques, such as Fourier Transform Infrared (FTIR) can be used to measure TOC if P-AMS using other techniques meet the required performance criteria.

8.3 Particulate matter monitoring P-AMS

P-AMS for measuring particulate matter shall meet the performance criteria detailed in Table 4 and Table 5. The maximum allowable deviations (as absolute values) of the measured signals are given as percentages of the upper limit of the certification range.

Table 4 details the performance criteria, which are tested in the laboratory. Table 5 details the performance criteria, which are tested during the field test.

Table 4 — Performance criteria for particulate matter monitoring P-AMS in laboratory tests

Performance characteristic	Performance criteria	Test in sub-clause
Response time	≤ 200 s	10.6
Repeatability standard deviation at zero	≤ 2,0 % [a]	10.7
Repeatability standard deviation at span	≤ 5,0 % [b]	10.8
Lack of fit	≤ 3,0 % [a]	10.9
Short-term zero drift	≤ 3,0 % [a]	10.10
Short-term span drift	≤ 3,0 % [b]	10.10
Influence of ambient temperature change from 5 °C to 25 °C and from 40 °C to 20 °C at zero point	≤ 5,0 % [a]	10.11
Influence of ambient temperature change from 5 °C to 25 °C and from 40 °C to 20 °C at span point	≤ 5,0 % [a]	10.11
Influence of voltage at −15 % and at +10 % from nominal supply voltage [c]	≤ 2,0 % [a]	10.12
Influence of vibration	≤ 2,0 % [a]	10.13

[a] Percentage value as percentage of the upper limit of the certification range.

[b] Percentage value as percentage of the emission limit value.

[c] If the manufactures specifies different limits for battery operated P-AMS, these limits shall be applied.

NOTE The response time does not apply to batch-measurement techniques such as beta-ray-attenuation.

Table 5 — Performance criteria for particulate matter monitoring P-AMS in field tests

Performance characteristic	Performance criteria	Test in sub-clause
Response time	≤ 200 s	12.1
Short-term zero drift	≤ 3,0 % [a]	12.2
Short-term span drift	≤ 3,0 % [b]	12.2
Reproducibility, R_f — for concentrations > 20 mg/m³ — for concentrations ≤ 20 mg/m³	 ≤ 2,0 % [a] ≤ 3,3 % [a]	12.3
[a] Percentage value as percentage of the upper limit of the certification range. [b] Percentage value as percentage of the emission limit value.		

Reference materials shall be assessed as appropriate to perform the drift and linearity test.

9 General test requirements

The test laboratory shall perform all relevant tests on two identical P-AMS. These two P-AMS have to be tested in the laboratory and field. Multiple-component P-AMS shall meet the performance criteria on each individual measured component with all measurement channels operating simultaneously.

NOTE 1 EN 15267–1 allows the parallel testing of two identical AMS in the laboratory and two other identical AMS in the field to reduce the time for testing which is not relevant for P-AMS.

NOTE 2 The test is performed in such a way that the material under analysis (measured component) is admitted to all measurement channels in the laboratory test and in the field test.

Test results which have been obtained for an AMS certified for continuous emission monitoring according to EN 15267-3 may be used to characterize the P-AMS to be tested. Supplementary tests for the influence of frequent moving and different measurement sites shall be performed (see 5.3).

Changes in the environmental and test conditions shall not have a significant influence on the performance characteristic tested. Therefore, all environmental and test conditions which have an influence on the P-AMS, shall be kept stable as far as practicable. The environmental and test conditions shall be recorded during the test. All test results shall be reported at standard conditions (0 °C, 1 013 hPa, dry gas).

The test laboratory shall evaluate the performance of the P-AMS at the lowest certification range of the intended applications. The test laboratory shall also perform selected additional tests to demonstrate satisfactory performance over the supplementary ranges. These additional tests shall at least include evaluations of the response time, lack of fit and cross sensitivity.

NOTE 3 Certification range is selected by the manufacturer in consultation with the test laboratory.

The test requirements specified in Clause 10 to Clause 12 are the minimum requirements. The tests are divided into two sections, covering general test requirements for all P-AMS, followed by measured component specific test requirements. They include

— description of the test method,

— evaluation procedure,

— assessment of performance against the relevant performance criterion and

— where appropriate, information on any specialized test equipment.

If a test requires two or more test cycles and the P-AMS meets the performance criterion by a factor of two or more for the first test then any subsequent testing for this performance characteristic may be omitted.

If a test requires several readings, the average of these readings shall be determined. If a test has to be repeated (several test cycles), the averages of the individual test cycles shall be determined and meet the applicable performance criteria.

The expanded uncertainty of the concentration of test gases at a confidence level of 95 % shall not exceed 3 %. For the lack of fit test, the bench shall provide gases, the concentration of which shall not have an expanded uncertainty greater than 33 % of the lack of fit criterion.

Tests do not have to be performed in the numerical order in this document, as the selection of tests and their order depend on the characteristics and type of individual P-AMS. However, the first two laboratory tests using test gases are the response time test followed by the lack of fit test.

NOTE 4 The field test is usually carried out after all laboratory tests are passed.

The test laboratory shall document whether the P-AMS meets all of the relevant performance criteria, and shall record all environmental conditions pertaining during testing.

10 Test procedures for laboratory tests

10.1 P-AMS for testing

The test laboratory shall check whether the P-AMS are complete and identical, by examining the appropriate parts specified in the manufacturer's documentation. A P-AMS generally includes the analyser, the sampling system and the sample gas conditioning system, any special test components and the operating instructions.

The test laboratory shall check that extractive P-AMS have appropriate provisions for filtration of solids, avoidance of chemical reactions within the sampling system, entrainment effects and effective control of water condensate.

The test laboratory shall include diagrams and photographs of both P-AMS, in the test report, and copies of the operating manual(s) for the P-AMS.

The hardware used shall be photographed and the software version established. Changes in the P-AMS configuration are not permitted during testing.

Minor repairs needed to perform the test but without influence on the instrument performance may be carried out, and the test continued. Repairs of the P-AMS shall be documented in the test report.

10.2 CE labelling

If the P-AMS needs to comply with the requirements for CE labelling as specified in applicable EU Directives, then the test laboratory shall verify whether there is traceable evidence of compliance.

10.3 Output ranges and zero point

The test laboratory shall check whether the output ranges on the P-AMS can be adjusted and whether such ranges are appropriate for the intended applications.

The emission limit values to be monitored with this P-AMS should be documented, together with an indication of the suitability of the P-AMS ranges for (i) applicable EU Directives and (ii) other intended applications.

The test laboratory shall check that the reference materials and the associated procedures are fit for purpose.

The test laboratory shall check that the indicated zero point on the measurement display and output of the P-AMS is a true living zero, and that the P-AMS can display both positive and negative readings.

The test laboratory shall use reference materials to verify that the output range is at least the upper limit of the supplementary ranges of the intended applications.

10.4 Display of operational status signals

The test laboratory shall assess whether the P-AMS has a means of displaying and provide data for recording the relevant operational status (e.g. standby, service, malfunction).

10.5 Degrees of protection provided by enclosures

The effect of liquid water on the P-AMS shall be assessed by inspection in relation to EN 60529.

The P-AMS manufacturer shall provide to the test laboratory the report of testing of the enclosure according to EN 60529. The test laboratory shall assess this test report to ensure compliance with the requirements of 6.5.

10.6 Response time

The test laboratory shall determine the P-AMS response time using zero and span reference materials (see Figure 1). The zero and span reference materials shall be stable test gases when determining the response time of gas-measuring P-AMS. The test shall be performed with wet test gases with a water vapour volume content of at least 15 %.

NOTE 1 The zero and span reference material can include surrogates such as filters for *in situ* dust analysers.

NOTE 2 This test provides the initial stabilization period, which is then used in other tests described in this European Standard.

NOTE 3 This test can also be combined with the lack of fit test or the test for the temperature influence, using e.g. the highest concentration in that test to determine the response time.

NOTE 4 The response time test is also repeated in the field as real waste gas conditions can influence response times.

The change from zero gas to span gas shall be made almost instantly with use of a suitable valve. The valve outlet shall be mounted directly to the inlet of the sampling system, and both zero gas and span gas shall have the same "oversupply" which is vented with use of a tee. The gas flows of both zero gas and span gas shall be chosen in such a way that the dead time in the valve and tee can be neglected compared with the lag time of the analyser.

The step change shall be made by switching the valve from zero gas to span gas. This event shall be timed and is the start ($t = 0$) of the (rise) response time according to Figure 1. When the reading has stabilized, zero gas shall be applied again, and this event is the start ($t = 0$) of the (fall) response time according to Figure 1. When the reading has stabilized at zero, the whole cycle as shown in Figure 1 is complete.

The elapsed time (response time) between the start of the step change and reaching of 90 % of the difference between the P-AMS final stable reading of the applied concentration and the P-AMS reading at the start of the step change shall be determined for both the rise and fall modes.

The test shall be performed at an ambient temperature of 20 °C and the whole cycle be repeated four times with a time elapse between two experiments of four times the response time but for at least

10 min. If the P-AMS meets the performance criterion by a factor of two or more for the first test then any subsequent testing may be omitted.

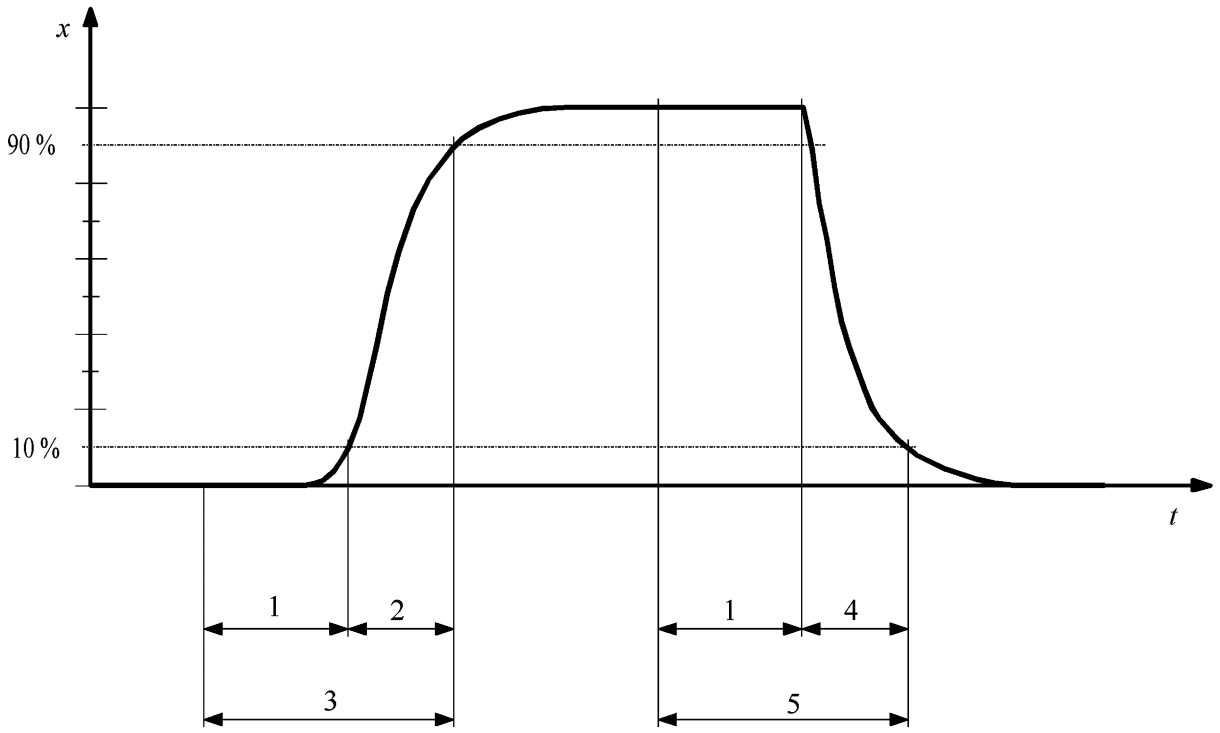
The average of the response times (rise) and the average the response times (fall) shall be calculated.

The larger average value of the response time (rise) and the response time (fall) shall be used as the response time of the P-AMS and be compared with the applicable performance criteria specified in Clause 8.

The test shall be repeated at ambient temperatures of 5 °C and at 40 °C. If the response time (rise) and the response time (fall) obtained at these temperatures deviate less than 20 % from the values obtained at 20 °C for the first test then any subsequent testing may be omitted.

The average of the response times (rise) and the average the response times (fall) shall be calculated for the ambient temperatures of 5 °C and 40 °C.

The larger average value of the response time (rise) and the response time (fall) shall be used for each temperature as the response time of the P-AMS and be compared with the applicable performance criteria.



Key

1	lag time	x	measured signal
2	rise time	t	time
3	response time (rise), t_r		
4	fall time		
5	response time (fall), t_f		

Figure 1 — Diagram illustrating the response time

The relative difference in response times shall be calculated according to Formula (1):

$$t_d = \left| \frac{t_r - t_f}{t_r} \right| \quad (1)$$

where

t_d is the relative difference between the response times determined in rise and fall mode;

t_r is the response time (rise);

t_f is the response time (fall).

The values of t_d, t_r and t_f shall be reported individually in the test report.

10.7 Repeatability standard deviation at zero point

The repeatability standard deviation at zero point shall be determined by application of a reference material at the zero point.

If the repeatability standard deviation at zero point is determined during the lack of fit test, the reference material at zero concentration applied during the test shall be used.

The measured signals of the P-AMS at zero point shall be determined after application of the reference material by waiting the time equivalent to one independent reading and then recording 20 consecutive individual readings.

In the case of oxygen sensors, a zero gas shall have a volume concentration of less than 0,2 % oxygen. Some oxygen analysers, such as those based on Zirconia sensors, are not suited to responding to pure zero gases. Therefore a lower volume concentration of 2,0 % is to be used.

The measured signals obtained shall be used to determine the repeatability standard deviation at zero point using Formula (2):

$$s_r = \sqrt{\frac{\sum \left(x_i - \bar{x} \right)^2}{n-1}} \quad (2)$$

where

s_r is the repeatability standard deviation;

x_i is the ith measured signal;

$\bar{x}$ is the average of the measured signals x_i;

n is the number of measurements, n = 20.

The repeatability standard deviation at zero point shall meet the performance criterion specified in Clause 8.

The individual readings and the repeatability standard deviation at zero point shall be reported.

10.8 Repeatability standard deviation at span point

The repeatability standard deviation at span point shall be determined by application of a reference material at the span point.

If the repeatability standard deviation at span point is determined during the lack of fit test, the highest value of reference material applied during the test shall be used.

The measured signals of the P-AMS at span point shall be determined after application of the reference material by waiting the time equivalent to one independent reading and then recording 20 consecutive

individual readings. The measured signals obtained shall be used to determine the repeatability standard deviation at span using Formula (2).

The repeatability standard deviation at span shall meet the performance criteria specified in Clause 8.

The individual readings and the repeatability standard deviation at span shall be reported.

10.9 Lack of fit

The test laboratory shall perform the lack of fit test according to Annex C at the beginning of the laboratory test. The linearity of the response of the P-AMS shall be checked using at least seven different reference materials, including a zero concentration.

This test requires the following equipment:

— gas mixing system compliant with national standards and able to provide gas concentrations with a maximum expanded uncertainty of 33 % of the lack of fit criterion;

— test standards (e.g. zero gas, test gas of suitable concentration, reference materials);

— data recording system.

The reference material with zero concentration, as well as the reference materials shall have a verifiable quantity and quality.

In case of gaseous reference materials, these reference materials can be obtained from different gas cylinders or can be prepared by means of a calibrated dilution system from one single gas concentration. The test gas concentrations shall be selected so that the measured values are equally spaced over the certification range. It is necessary to know the values of the ratios of their concentrations precisely enough so that an incorrect failure of the lack of fit test does not occur. The dry or wet test gases shall be applied to the inlet of the P-AMS.

The reference materials shall be applied in an order, which avoids hysteresis effects.

NOTE 1 For the application of seven reference materials, avoidance of hysteresis effects can be achieved e.g. by the following sequence:

— reference material with zero concentration;

— reference material concentration approximately 70 % of the upper limit of the certification range;

— reference material concentration approximately 40 % of the upper limit of the certification range;

— reference material with zero concentration;

— reference material concentration approximately 60 % of the upper limit of the certification range;

— reference material concentration approximately 10 % of the upper limit of the certification range;

— reference material concentration approximately 30 % of the upper limit of the certification range;

— reference material concentration approximately 90 % of the upper limit of the certification range;

— reference material with zero concentration.

After each change in concentration, the measured signals of the P-AMS shall be determined by waiting the time equivalent to one independent reading and then recording three consecutive individual readings. The three individual readings shall be averaged.

The test shall be repeated three times. If the P-AMS meets the performance criterion by a factor of two or more for the first test then any subsequent testing may be omitted.

The lack of fit test shall be repeated after the vibration test with one test cycle (no repetition).

NOTE 2 This procedure means that the quality of the reference material can influence the result of the tests. It should be noted, however, that it is the result that leads to a pass or failure in the test. In some cases, a reference material with a higher quality can change the result from fail to pass.

NOTE 3 Where no other method is practicable, the linearity test can also be performed with the aid of reference materials such as grating filters or gas filters.

NOTE 4 The reference material at zero concentration applied during the lack of fit test can also be used to determine the repeatability standard deviation at zero point (see 10.7).

NOTE 5 The highest value of reference material applied during the lack of fit test can also be used to determine the repeatability standard deviation at span point (see 10.8).

NOTE 6 This test is performed in the same way for supplementary ranges (see 5.2.2).

The lack of fit shall be evaluated according to Annex C. In this test procedure, a regression line is established between the instrument readings of the P-AMS (x values) and the reference material values (c values). In the next step, the average of P-AMS readings at each level is calculated. Then the deviation (residual) of this average to the regression line is calculated.

The relative residuals $d_{c,\mathrm{rel}}$ shall meet the applicable performance criteria specified in Clause 8 for all reference materials applied.

Test records, raw data and results of P-AMS characteristics shall be documented. The individual values shall be presented together with a statement of the test period for each P-AMS. The test set-up and ambient conditions shall also be documented.

10.10 Short-term zero and span drift

The test of the short-term zero and span drift shall be performed at room temperature. The temperature shall be kept constant within ± 2 °C. Zero and span material shall be applied alternately for at least three times the response time at the beginning and at the end of the daily measurement period.

NOTE A test of the short-term drift performed after the response time test can show that drift is not influencing the results of the other tests.

10.11 Set-up time after transportation and influence of ambient temperature

The test of setting the P-AMS into operation and the test of the influence of a slow change in ambient temperature shall be carried out with the P-AMS placed in a climatic chamber. Only one test cycle is necessary.

The switched-off P-AMS shall be stored in the climatic chamber for at least 12 h at a temperature of 5 °C. After this time period the P-AMS shall be switched-on. The time until the readiness for operation is indicated by the P-AMS shall be recorded. If there is no readiness feature, the time specified by the manufacturer shall be waited.

After having reached the readiness for operation the temperature in the climatic chamber shall be smoothly increased over 6 h from 5 °C to 25 °C. The P-AMS reading at the zero and span point shall be recorded at the beginning of this time period and then after each hour.

The switched-off P-AMS shall then be stored in the climatic chamber for at least 12 h at a temperature of 40 °C. After this time period the P-AMS shall be switched-on. The time until the readiness for

operation is indicated by the P-AMS shall be recorded. If there is no readiness feature, the time specified by the manufacturer shall be waited.

After having reached the readiness for operation the temperature in the climatic chamber shall be smoothly decreased over 6 h from 40 °C to 20 °C. The P-AMS reading at the zero and span point shall be recorded at the beginning of this time period and then after each hour.

If it is not possible for reactive gases to perform all temperature steps in 1 h, the test may be performed at the beginning and at the end of the stabilization phase.

The deviations between the P-AMS reading obtained at the beginning of the time period and the readings successively obtained during the temperature change shall be determined for each temperature cycle. The deviations shall meet the applicable performance criteria specified in Clause 8.

The times until the readiness for operation is indicated by the P-AMS as well as the individual readings and deviations at zero point and span point obtained for both temperature cycles shall be reported.

If the P-AMS is applicable to a wider temperature range, the test shall be performed additionally at the highest temperature range specified by the manufacturer.

The individual readings, averages and deviations at each temperature as well as the maximum deviation at zero point and at span point shall be reported.

In addition, the test laboratory shall determine and report the maximum sensitivity coefficient for the temperature dependence. The sensitivity coefficients at each temperature shall be calculated by Formula (3):

$$b_{\mathrm{t}} = \frac{\left(x_i - x_{i-1}\right)}{\left(T_i - T_{i-1}\right)} \tag{3}$$

where

b_{t} is the sensitivity coefficient of ambient temperature;

x_i is the average reading at temperature T_i;

x_{i-1} is the average reading at temperature T_{i-1};

T_i is the current temperature in the test cycle;

T_{i-1} is the previous temperature in the test cycle.

NOTE A graph showing the results of the examination can be provided in the report.

10.12 Influence of voltage variations

The supply voltage to the P-AMS shall be varied, using an isolating transformer, in steps of 5 % from the nominal supply voltage to at least the upper and the lower limits specified in Clause 8.

The measured signals of the P-AMS at zero point and at span point shall be determined at each voltage by waiting the time equivalent to one independent reading and then recording three consecutive individual readings. The three individual readings shall be averaged.

NOTE After changes in voltage the P-AMS can need time to stabilize.

The deviations between the average readings at each voltage and the average reading at the nominal supply voltage shall be determined. The deviations shall meet the applicable performance criteria specified in Clause 8 for all voltages.

This test shall be repeated three times at the zero point and three times at the span point. If the P-AMS meets the performance criterion by a factor of two or more for the first test then any subsequent testing may be omitted.

The individual readings, averages and deviations at each voltage as well as the maximum deviation at zero point and at span point shall be reported.

In addition, the test laboratory shall determine and report the sensitivity coefficient for the voltage dependence. The sensitivity coefficient shall be calculated by Formula (4):

$$b_v = \frac{(x_2 - x_1)}{(U_2 - U_1)} \quad (4)$$

where

b_v is the sensitivity coefficient of supply voltage;

x_1 is the average reading at voltage U_1;

x_2 is the average reading at voltage U_2;

U_1 is the minimum voltage specified by the manufacturer;

U_2 is the maximum voltage specified by the manufacturer.

For reporting the voltage dependence, the highest value of the results at zero and span point shall be taken.

10.13 Influence of vibration

The P-AMS shall be examined in the laboratory and in the field in respect to whether normal vibrations and transportation affect the performance of the P-AMS.

The measured signals of the P-AMS at zero point and at span point shall be determined before and after the vibration test by waiting the time equivalent to one independent reading and then recording three consecutive individual readings. The three individual readings shall be averaged.

The vibration test shall be performed in accordance with the relevant section of EN 60068-2-6 with the following parameters:

a) continuous increase of frequency from 10 Hz to 150 Hz

   — in the frequency range from 10 Hz to 60 Hz: 0,35 mm maximum amplitude

   — in the frequency range from 60 Hz to 150 Hz: constant acceleration with $0{,}5 \cdot g$ ($g = 9{,}81\ m/s^2$)

b) duration of endurance: 10 sweep cycles per axis

The measuring system shall be mounted in its normal operating orientation during the vibration test. The vibration shall be applied subsequently along each of three mutually perpendicular major axes.

If any resonant frequencies are observed, a vibration test shall be carried out at each observed frequency for a period of 2 min.

This shall be followed by a functional test. If no resonant frequencies are observed, a vibration test shall be made at a frequency of 25 Hz for a period of 2 min. This shall be followed by a functional test. Any influence on the P-AMS from vibrations at the site of installation shall be assessed. Remedial measures having proved necessary in field testing shall be described.

The deviations between the average readings before and after the vibration tests shall be determined. All deviations shall meet the applicable performance criteria specified in Clause 8.

The individual readings, averages and deviations at each vibration test as well as the maximum deviation shall be reported.

10.14 Influence of sample gas pressure

The test laboratory shall determine the influence of variations in sample gas pressure on the response of the P-AMS. The sample shall be nitrogen containing the measured component at a concentration of between 70 % and 90 % of the upper limit of the certification range.

NOTE The effect of sample gas pressure typically applies to insitu P-AMS, but not to extractive P-AMS, since the sample gas is conditioned and typically not subject to significant variations of temperature and pressure once within the analyser.

The test laboratory shall measure the output signal of the P-AMS when the sample gas pressure is at the following levels:

a) ambient atmospheric pressure;

b) approximately 3 kPa above ambient atmospheric pressure, within limits of ± 0,2 kPa;

c) approximately 3 kPa below ambient atmospheric pressure, within limits of ± 0,2 kPa.

During the measurement period the temperature shall be held stable to within ± 1,0 K.

The measured signals of the P-AMS shall be determined at each pressure by waiting the time equivalent to one independent reading and then recording three consecutive individual readings. The three individual readings shall be averaged.

The deviations between the average reading at each pressure and the average reading at the ambient atmospheric pressure shall be determined. The deviations shall meet the applicable performance criteria specified in Clause 8.

The individual readings, averages and deviations at each pressure as well as the maximum deviation shall be reported.

In addition, the test laboratory shall determine and report the sensitivity coefficient for the pressure dependence. The sensitivity coefficient shall be calculated by Formula (5):

$$b_{\mathrm{p}} = \frac{\left(x_2 - x_1\right)}{\left(p_2 - p_1\right)} \tag{5}$$

where

b_{p} is the sensitivity coefficient of sample gas pressure;

x_1 is the average reading at sample gas pressure p_1;

x_2 is the average reading at sample gas pressure p_2;

p_1 is the lower sample gas pressure;

p_2 is the higher sample gas pressure.

10.15 Influence of the sample gas flow for extractive P-AMS

The P-AMS shall initially be operated with the flow rate prescribed by the manufacturer. This flow rate shall then be changed to the lowest flow rate specified by the manufacturer.

NOTE Influence of the sample gas flow typically applies to extractive P-AMS, since *in situ* P-AMS mostly are not influenced by flow rate.

If the manufacturer's documentation permits only minor tolerances these are binding and shall not be extended.

The measured signals of the P-AMS at the zero point and span point shall be determined at both flow rates by waiting the time equivalent to one independent reading and then recording three consecutive individual readings. The three individual readings shall be averaged.

The deviation between the average readings at both flow rates shall be determined. The deviation shall meet the applicable performance criteria specified in Clause 8.

This test shall be repeated three times at the zero point and three times at the span point. If the P-AMS meets the performance criterion by a factor of two or more for the first test then any subsequent testing may be omitted.

The individual readings, averages and the deviations as well as the maximum deviation shall be reported.

The functionality of the status signal shall be tested at the same time.

In addition, the test laboratory shall determine and report the sensitivity coefficient for the flow rate dependence. The sensitivity coefficient shall be calculated by Formula (6):

$$b_{\mathrm{f}} = \frac{\left(x_2 - x_1\right)}{\left(r_2 - r_1\right)} \tag{6}$$

where

b_{f} is the sensitivity coefficient of flow rate;

x_1 is the average reading at flow rate r_1;

x_2 is the average reading at flow rate r_2;

r_1 is the nominal flow rate;

r_2 is the lowest specified flow rate.

10.16 Cross-sensitivity

The influence of potentially interfering substances also present in the stack gas shall be determined by admitting test gas mixtures to the input of the complete P-AMS (upstream of the test gas cooler, where present). The gas mixtures shall be produced with a mixing system in which an interferent is added to the gases for zero point and span point. The mixing system shall be compliant with national standards and shall have a maximum expanded uncertainty of 1 %. Reference materials (e.g. gases) shall be certified (traceable to national standards) and shall have an expanded uncertainty no greater than 2 %.

Interferents and their concentrations are defined in relation to the measuring principle and the intended measurement objective. The interferents listed in Annex B shall be examined. The interferents shall be admitted individually.

For P-AMS measuring in hot and wet waste gases the water-vapour interference test has to be performed at water-vapour volume concentration of about 20 % and 30 %.

Test gas without interferent and then with the interferent shall be applied. The measured signals of the P-AMS shall be determined for each test gas by waiting the time equivalent to one independent reading and then recording three consecutive individual readings. The three individual readings shall be averaged.

The deviations between the average readings with and the average reading without the interferent present at the zero point and span point shall be determined for each interferent.

All positive deviations above 0,5 % of the span gas concentration shall be summed and all negative deviations below –0,5 % of the span gas concentration shall be summed at both the zero point and span point. The maximum of the absolute values of the four summations shall meet the performance criteria specified in Clause 8.

For total organic carbon P-AMS, the influence of oxygen shall be additionally examined at zero point and span point for an oxygen volume concentration of 3 %, 10 % and 21 %. Propane should be used as a span gas. The deviation between the average readings at the zero point obtained with an oxygen volume concentration of 3 %, 10 % and 21 %, and the deviation between the average readings at the span point obtained with an oxygen volume concentration of 3 %, 10 % and 21 % shall be determined. Both deviations shall meet the performance criteria specified in Clause 8.

The individual readings, averages and deviations at zero point and span point and for all interferents as well as the maximum deviation shall be reported.

10.17 Converter efficiency for P-AMS measuring NO_x

The test laboratory shall determine the efficiency of the NO_x converter by carrying out the following procedure.

The following equipment is required:

— source of nitrogen monoxide such as a compressed gas cylinder containing nitrogen monoxide in nitrogen at a concentration of the order of 80 % of the upper limit of the certification range; the actual concentration need not be known provided that it remains constant throughout the test;

— source of oxygen, such as a compressed gas cylinder containing air or oxygen;

— an ozone generator, capable of providing varying amounts of ozone from oxygen.

The test laboratory shall ensure that the total flow rate of nitrogen monoxide and air (or oxygen) is greater than the flow rate of gas through the analyser. In all of the following steps, determine the responses of the analyser to both the nitrogen monoxide and total NO_x.

This procedure evaluates the concentration of nitrogen dioxide being produced, which should be in the range 10 % to 90 % of the NO_x.

Turn off the ozone generator. Then the concentration $c_{NOx,0}$ of total NO_x and the concentration $c_{NO,0}$ of NO shall be determined by waiting the time equivalent to one independent reading, then recording three consecutive individual readings and averaging the three individual readings for each concentration.

Afterwards, turn on the ozone generator and vary the output of the ozone generator stepwise to obtain at least five different ozone concentrations. At each level the displayed concentrations of total NO_x ($c_{NOx,1}$, $c_{NOx,2}$, …, $c_{NOx,n}$) and nitrogen monoxide ($c_{NO,1}$, $c_{NO,2}$, …, $c_{NO,n}$) shall be determined by waiting the time equivalent to one independent reading, then recording three consecutive individual readings and averaging the three individual readings for each concentration.

NOTE 1 Ozone is formed which reacts with the nitrogen monoxide to produce nitrogen dioxide before the gases enter the analyser.

The highest O_3 concentration shall be selected such that after the reaction a low level of NO remains to avoid reactions of ozone in the analyser.

Calculate the ratios $c_{NOx,1}/c_{NOx,0}$, $c_{NOx,2}/c_{NOx,0}$, …, $c_{NOx,n}/c_{NOx,0}$. The concentration of total NO_x should be constant in each case and independent of the ratio of the concentrations of nitrogen dioxide to nitrogen monoxide.

Calculate the converter efficiency E_i for each ozone concentration, expressed as a percentage, using Formula (7):

$$E_i = \frac{\left(c_{\mathrm{NOx},i} - c_{\mathrm{NO},i}\right) - \left(c_{\mathrm{NOx},0} - c_{\mathrm{NO},0}\right)}{c_{\mathrm{NO},0} - c_{\mathrm{NO},i}} \times 100\,\% \quad (7)$$

where

E_i is the converter efficiency at setting i of the ozone generator;

$c_{\mathrm{NOx},0}$ is the concentration of total NO_x with ozone generator switched-off;

$c_{\mathrm{NO},0}$ is the concentration of NO with ozone generator switched-off;

$c_{\mathrm{NOx},i}$ is the concentration of total NO_x with ozone generator at setting i (i = 1 to n);

$c_{\mathrm{NO},i}$ is the concentration of NO with ozone generator at setting i (i = 1 to n).

The converter efficiency shall be determined in the laboratory before and after the field test.

NOTE 2 This test allows the determination of the amount of effort and the functioning of the converter under real use.

The converter efficiency shall meet the performance criterion specified in Clause 8.

The results shall be presented in tabular form.

10.18 Response factors

The response factors (weighting factors) for total organic carbon measuring P-AMS shall be evaluated using defined test gas concentrations admitted to the P-AMS from test gas containers or by evaporating produced mixtures.

This test requires certified reference materials and a gas-mixing system compliant with national standards and with an expanded uncertainty no greater than 2 % of the combined concentration.

The evaluation shall cover at least the following organic compounds:

— methane;

— ethane;

— benzene;

— toluene;

— dichloromethane;

For total organic carbon measuring P-AMS for use in measuring emissions from waste incinerators, the response factors of the following organic compounds shall also be evaluated:

— propane;

— ethyne;

— ethyl benzene;

— p-xylene;

— chlorobenzene;

— tetrachloroethylene;

— n-butane;

— n-hexane;

— n-octane;

— isooctane;

— propene;

— methanol;

— butanol;

— acetic acid;

— acetic acid methyl ester;

— trichloromethane;

— trichloroethylene.

The measured signals of the P-AMS shall be determined for propane and for each organic compound by waiting the time equivalent to one independent reading and then recording three consecutive individual readings. The three individual readings shall be averaged for propane and for each organic compound.

The response factors shall be calculated for each organic compound by the Formula (8):

$$f_i = \frac{\left(\frac{x_i}{c_i}\right)}{\left(\frac{x_{\text{ref}}}{c_{\text{ref}}}\right)} \tag{8}$$

where

f_i is the carbon-related response factor for substance *i*;

x_i is the average of the measured signals for substance *i*;

x_{ref} is the average of the measured signals for propane;

c_i is the carbon mass concentration of substance *i* at 273 K and 1 013 hPa;

c_{ref} is the carbon mass concentration of propane at 273 K and 1 013 hPa.

The response factors determined shall meet the applicable performance criteria specified in Table 3.

The individual readings, averages and response factors for each organic compound shall be reported.

10.19 Influences on P-AMS with in-stack sampling chamber

Tests shall be performed as agreed between the test laboratory, the manufacturer and the relevant body.

10.20 Influences related to storage and transportation

Tests shall be performed as agreed between the test laboratory, the manufacturer and the relevant body.

11 Requirements for the field test

The field test shall be performed with two identical P-AMS.

The field test shall be carried out at least at five different industrial processes representative of the intended application of the P-AMS where one process can be a suitable test bench which covers all relevant influences present in the field, with at least six measurements over the required averaging period (e.g. 10 min, 30 min or 1 h) for each process.

When selecting the industrial facility, the test laboratory shall ensure that the mass concentrations of the measured component are available in a range sufficient to assess the measurement results. The range of concentrations should cover the ranges of the intended application.

Part of the field test may be performed at an appropriate test bench which provides the conditions of the intended application in the field especially with respect to the gas matrix and the intended measurement range.

Each measurement campaign shall cover separate transportation of the P-AMS to the plant, setting-up the P-AMS, performance of the measurements, disassembly of the P-AMS and transportation back to the laboratory or to the next test site. The measurement period of each measurement campaign shall cover one full measuring day of at least 8 h.

The field test shall be performed with two complete and identical P-AMS operated in parallel on the same stack at the same time. Any additional equipment required is specified in the various test procedures.

At least six parallel measurements shall be performed with the P-AMS at each measuring day, including comparison with two SRM operated in parallel.

The measurement site at the specific plant shall be selected in accordance with EN 15259.

In the case of *in situ* measurement methods, the two P-AMS shall be arranged in such a way that a representative measurement is ensured for both P-AMS in the same measurement cross section.

In exceptional cases, which shall be justified, a common sampling system may be used for both P-AMS under test.

NOTE For example, in the field test on a plant exhibiting only slight variation from the pollutant concentration being measured and therefore requiring the addition, i.e. input of high concentrations, of the measured component into the sample gas flow.

The measured signals from both P-AMS throughout the field test shall be recorded as 1 min values. Depending on the task, internal test cycles shall be separately recorded and assessed.

The test laboratory shall document and maintain records of all data from the field test.

12 Test procedures common to all P-AMS for field tests

12.1 Response time

The response time shall be evaluated by admitting reference material at the zero and span points to the input of the complete P-AMS. The test shall be performed at the beginning of each measuring day, using the procedures described in 10.6 but at the ambient temperature on site and without repetition.

12.2 Short-term zero and span drift

At the beginning of the measuring day, zero and span materials are supplied to the probe of the analyser. Adjustments are made until the correct zero and span values are given by the data sampling system.

At the end of the measuring day, zero and span checks shall be performed by supplying test materials at the probe of the analyser.

All manually determined zero point and span point values are used for the purpose of evaluation and presented in tabular form together with the associated times.

Drift of zero point and span point during the measuring day shall be recorded for calculation of the influence on measurement uncertainty.

12.3 Reproducibility

Reproducibility shall be determined during field tests from simultaneous measurements by means of two identical P-AMS at the same measurement point (paired measurements).

For statistical reasons at least 30 paired measurements in total are necessary.

The measured signals of both P-AMS (raw values as analogue or digital output signals without any conversion) shall be recorded as individual values (e.g. minute mean values) on an electronic data register. The relevant status signals, such as measurement, malfunction and maintenance, shall also be recorded. Taking into account status signals, the individual values shall be condensed into 30 min mean values, provided that for each 30 min at a minimum 20 min are covered by individual values. Measured signals from malfunction, maintenance or test cycles taking place in the P-AMS shall not be taken into consideration for evaluation.

In specific cases, shorter averaging time of measured value pairs, e.g. 10 min, may be used, if the measured component has to be evaluated on this averaging time (e.g. for CO), or if higher concentrations of the measured component are not available over prolonged intervals as a result of the dynamics of the emission profile.

At the end of the field tests, the reproducibility shall be calculated on the basis of all valid paired values, i.e. the condensed measured signals from the P-AMS, accrued throughout the entire period of the field tests with both P-AMS in accordance with Formula (9) using the standard deviation of the difference of the paired measurements as given by Formula (10) and with a statistical confidence of 95 % for the *t*-distribution (two-sided):

$$R_{\mathrm{f}} = t_{n-1;0,95} \times s_{\mathrm{D}} \tag{9}$$

$$s_{\mathrm{D}} = \sqrt{\frac{\sum_{i=1}^{n}\left(x_{1,i} - x_{2,i}\right)^2}{2n}} \tag{10}$$

where

R_{f} is the reproducibility under field conditions;

$t_{n-1;0,95}$ is the two-sided Students *t*-factor at a confidence level of 95 % with a number of degrees of freedom $n-1$;

s_{D} is the standard deviation from paired measurements;

$x_{1,i}$ is the *i*th measured signal of the first measuring system;

$x_{2,i}$ is the *i*th measured signal of the second measuring system;

n is the number of paired measurements.

NOTE The determination of the reproducibility under field conditions is in accordance with ISO 5725-2.

In the test report, the paired values shall be plotted on a graph.

For calculating the uncertainty, the standard deviation from the paired measurement values shall be documented.

13 Equivalence with the SRM

The equivalence of a P-AMS based on an AM with the SRM shall be demonstrated by application of EN 14793:2017 and use of the results obtained from the parallel measurements with the SRM in the field test. The results shall be assessed on the basis of the performance criteria specified for the SRM such as the maximum allowable standard deviation of repeatability and the standard deviation of reproducibility or the maximum permissible measurement uncertainty.

14 Measurement uncertainty

The values of the uncertainties determined during the field and laboratory test shall be used to determine the combined uncertainty of the P-AMS measured values according to Annex D.

When calculating the combined uncertainty, the repeatability in the laboratory or the reproducibility in the field shall be used, whichever is greater.

NOTE In addition to the uncertainty contribution from the tested P-AMS, EN ISO 14956 also allows to take into account the uncertainty of external input quantities (e.g. measured values from the peripheral instruments on the site used for conversion to standard conditions) when the combined standard uncertainty is calculated according to Formula (4) of EN ISO 14956.

The expanded uncertainty of the P-AMS determined from the tests according this standard shall meet the maximum permissible uncertainty specified in applicable SRM (see examples in Annex F).

The test laboratory shall report the expanded uncertainty in relation to the maximum permissible uncertainty.

15 Test report

The test report shall provide a comprehensive and detailed account of the testing and the P-AMS performance.

The test report shall specify the criteria to be considered by the user in case of real measurements with e.g. modified sampling probes, modified heated sampling lines or modified gas conditioning systems.

Annex E specifies requirements for a test report.

NOTE The test report is part of the documentation of the certified P-AMS.

Annex A
(normative)

Minimum requirements for a test bench

The generation mode of the testing bench should be able to provide matrices of gases and the relevant concentration levels with regard to the actual conditions encountered on industrial site and ELV. The gas shall be issued in the testing bench at levels of temperature and humidity corresponding to actual conditions. Indeed it should be recalled that the major source of uncertainty in an emission measurement method is the sampling part and that it shall be implemented in the conditions as close as possible to the conditions of site.

It is also necessary to ensure that the generation period is in line with the minimum sampling duration provided in the standards describing measurement methods;

Comparison of measuring devices shall be carried out at measurements points where the equivalence of the concentrations of the parameters to be measured has been demonstrated.

The body organizing the inter-comparisons of methods on its test bench shall have the necessary competence.

NOTE The test bench provider can demonstrate the necessary competence e.g. by accreditation on the basis of EN ISO/IEC 17043.

Annex B
(normative)

Interferents

Table B.1 — Concentrations of interferents used during cross sensitivity tests

Interferent	Mass or volume concentration	
	Value	Unit
O_2	3 [a] and 21	%
H_2O	20 and 30	%
CO	300	mg/m^3
CO_2	15	%
CH_4	50	mg/m^3
N_2O	20	mg/m^3
N_2O (fluidised-bed firing)	100	mg/m^3
NO	300	mg/m^3
NO_2	30	mg/m^3
NH_3	20	mg/m^3
SO_2	200	mg/m^3
SO_2 (coal-fired power stations without desulphurisation)	1 000	mg/m^3
HCI	50	mg/m^3
HCI (coal-fired power stations)	200	mg/m^3

[a] A test with 3 % oxygen volume concentration is used instead of a test without interferent.

Annex C
(normative)

Test of linearity

C.1 Description of the test procedure

In this test procedure, a regression line is established between the instrument readings of the P-AMS (*x* values) and the reference material values (*c* values). In the next step, the average of P-AMS readings at each reference material level is calculated. Then the deviation (residual) of this average to the regression line is calculated.

C.2 Establishment of the regression line

A linear regression for the function in Formula (C.1) is established:

$$x_i = a + B\left(c_i - \overline{c}\right) \tag{C.1}$$

For the calculation, all measurement points are taken into account. The total number of measurement points (n) is equal to the number of reference material levels (including zero) times the number of repetitions (these are the results of the at least three readings) at a particular reference material level.

The coefficient a is obtained by Formula (C.2):

$$a = \frac{1}{n}\sum_{i=1}^{n} x_i \tag{C.2}$$

where

$a$is the average value of the x values, i.e. the average of the P-AMS readings;

x_i is the individual P-AMS reading;

n is the number of measured signals.

The coefficient B is obtained by Formula (C.3):

$$B = \frac{\sum_{i=1}^{n} x_i \left(c_i - \overline{c}\right)}{\sum_{i=1}^{n} \left(c_i - \overline{c}\right)^2} \tag{C.3}$$

where

$\overline{c}$ is the average of the c values, i.e. the average of the reference material values;

c_i is the individual reference material value.

Secondly the function $x_i = a + B\left(c_i - \overline{c}\right)$ is converted to $x_i = A + B\,c_i$ through the calculation of A according to Formula (C.4):

$$A = a - B\,\overline{c} \tag{C.4}$$

C.3 Calculation of the residuals of the average concentrations

The residuals of the average concentration at each concentration level to the regression line are calculated as follows.

Calculate at each concentration level the average of the P-AMS readings at one and the same reference material level *c* according to Formula (C.5):

$$\overline{x}_c = \frac{1}{m_c}\sum_{i=1}^{m_c} x_{c,i} \tag{C.5}$$

where

$\overline{x}_c$ is the average P-AMS reading at reference material level *c*;

$x_{c,i}$ is the individual P-AMS reading at reference material level *c*;

m_c is the number of repetitions at one and the same reference material level *c*.

Calculate the residual d_c of each average according to Formula (C.6):

$$d_c = \overline{x}_c - \left(A + Bc\right) \tag{C.6}$$

Convert d_c into a relative residual $d_{c,\mathrm{rel}}$ according to Formula (C.7) by dividing d_c by the upper limit of the certification range x_u:

$$d_{c,\mathrm{rel}} = \frac{d_c}{x_\mathrm{u}} \times 100\,\% \tag{C.7}$$

Annex D
(normative)

Determination of the total uncertainty

D.1 Determination of uncertainty contributions

The individual standard uncertainties, the combined standard uncertainty and the expanded uncertainty shall be determined according to the requirements of EN ISO 14956 or ISO/IEC Guide 98-3 (GUM).

The individual standard uncertainties caused by the relevant performance characteristics shall be calculated by use of the maximum deviations or maximum standard deviations determined for the two P-AMS tested. This provides a worst-case estimate of the total uncertainty in the performance test.

D.2 Elements required for the uncertainty determinations

Table D.1 shows the uncertainty contributions which are to be combined when determining the combined standard uncertainty u_c. Specific contributions depend on the type of P-AMS, although some are common to all types of P-AMS.

Table D.1 — Uncertainty contributions

Number i	**Performance characteristic**	**Uncertainty** u_i
1	Lack of fit	u_{lof}
2	Short-term zero drift from field test	$u_{d,z}$
3	Short-term span drift from field test	$u_{d,s}$
4	Influence of ambient temperature	u_t
5	Influence of supply voltage	u_v
6	Cross-sensitivity (interference)	u_i
7	Repeatability standard deviation at span [a]	$u_r = s_r$
8	Standard deviation from paired measurements under field conditions [a]	$u_D = s_D$
9	Uncertainty of the reference material provided by the manufacturer [b]	u_{rm}
10	Excursion of measurement beam [b]	u_{mb}
11	Converter efficiency for P-AMS measuring NO_x [b]	u_{ce}

[a] Either the repeatability standard deviation at span or the standard deviation from paired measurements under field conditions is used, whichever is the larger.

[b] This uncertainty contribution is relevant for specific P-AMS only.

If the P-AMS depends on the regular use of reference materials for its continued accurate and precise operation – for example, during weekly span checks – then the uncertainty of the reference materials shall be included within the calculation of the total uncertainty.

The combined uncertainty u_c shall be determined by use of Formula (D.1) and summation of the uncertainty contributions u_i of the relevant performance characteristics specified in Table D.1:

$$u_c = \sqrt{\sum_{i=1}^{N} u_i^2} \tag{D.1}$$

The expanded uncertainty U shall be determined using Formula (D.2):

$$U = 1{,}96\ u_c \tag{D.2}$$

In the above calculation, most the values of u_i for a parameter i are determined from test data, where the probability distribution of values is rectangular for most parameters and a normal distribution for a few parameters. Factor 1,96 may be used since the number of measurements to determine the uncertainty contribution and the associated number of degrees of freedom is sufficiently high or a rectangular distribution is assumed.

In the case of rectangular distributions the standard uncertainties for each performance characteristic are calculated according to EN ISO 14956 by Formula (D.3):

$$u_i = \sqrt{\frac{\left(x_{i,\max} - x_{i,\mathrm{adj}}\right)^2 + \left(x_{i,\min} - x_{i,\mathrm{adj}}\right) \times \left(x_{i,\max} - x_{i,\mathrm{adj}}\right) + \left(x_{i,\min} - x_{i,\mathrm{adj}}\right)^2}{3}} \tag{D.3}$$

where

$x_{i,\min}$ is the minimum value of the average reading influenced by performance characteristic i;

$x_{i,\max}$ is the maximum value of the average reading influenced by performance characteristic i;

$x_{i,\mathrm{adj}}$ is the value of the average reading with the influence quantity at its nominal value during adjustment.

Formula (D.3) can be simplified in the following cases:

— if the value $x_{i,\mathrm{adj}}$ is at the centre of the interval bounded by the maximum value $x_{i,\max}$ and the minimum value $x_{i,\min}$ of all values x_i, then the standard uncertainty u_i is given by Formula (D.4):

$$u_i = \frac{\left(x_{i,\max} - x_{i,\min}\right)}{\sqrt{12}} \tag{D.4}$$

If the absolute values of the deviation above and below the central value is expressed by Δx_i (see Formula (D.5)), then the standard uncertainty u_i is given by Formula (D.6):

$$\left|x_{i,\max} - x_{i,\mathrm{adj}}\right| = \left|x_{i,\min} - x_{i,\mathrm{adj}}\right| = \Delta x_i \tag{D.5}$$

$$u_i = \frac{\Delta x_i}{\sqrt{3}} \tag{D.6}$$

— if the value of $x_{i,\mathrm{adj}}$ is the same as either $x_{i,\min}$ or $x_{i,\max}$, then the standard uncertainty u_i is given by Formula (D.7):

$$u_i = \frac{\left(x_{i,\max} - x_{i,\min}\right)}{\sqrt{3}} \tag{D.7}$$

D.3 Example of an uncertainty calculation for a CO measuring P-AMS

A CO measuring P-AMS has been tested for a certification range of 0 mg/m³ to 100 mg/m³ and an ELV of 50 mg/m³ expressed as a daily average. Table D.2 shows the performance characteristics of the P-AMS.

Table D.2 — Performance characteristics for the uncertainty calculation

Performance characteristic	Test data
Certification range of the P-AMS	0 mg/m³ to 100 mg/m³
Emission limit value of CO expressed in standard conditions of temperature and pressure and at oxygen reference volume concentration	50 mg/m3
Test gas concentration (concentration of CO in N_2)	80 mg/m³ (1 ± 2,0 %)
Response time	120 s
Repeatability standard deviation at zero point	0,30 % [a]
Repeatability standard deviation at span point	0,45 % [a]
Lack of fit	0,6 % [a]
Short-term zero drift	0,01 % [a]
Short-term span drift	0,5 % [a]
Influence of ambient temperature at zero point	0,5 % [a]
Influence of ambient temperature at span point	1,0 % [a]
Influence of sample gas pressure	0,4 % [b]
Influence of sample gas flow	0,2 % [a]
Influence of voltage	0,12 % [a]
Cross-sensitivity	
CO_2 (15 %)	–0,8 mg/m³
N_2O (20 mg/m³)	0,5 mg/m³
CH_4 (50 mg/m³)	1,2 mg/m³
Standard deviation from paired measurements under field conditions	0,38 % [a]

[a] expressed in percent of the range

[b] expressed in percent of the measured value

The deviations of the measured signals obtained in the performance testing of the individual performance characteristics are converted to standard uncertainties on the basis of rectangular distributions. The worst-case values from the two P-AMS tested are used for the calculations, as they correspond to the maximum variation of the corresponding influence quantities.

The P-AMS depends on the test gas for continued quality assurance and control. Therefore, the uncertainty of the test gas is included in the uncertainty calculations.

The repeatability standard deviation at span is used in the calculations, since it is greater than the standard deviation from paired measurements under field conditions.

Table D.3 shows the uncertainty calculations for each applicable performance characteristic.

Table D.3 — Uncertainty calculations

Performance characteristic	**Standard uncertainty**	**Value of the standard uncertainty** mg/m³	**Square of the standard uncertainty** (mg/m³)²
Repeatability standard deviation at span	u_r	$\lvert 0,45\% \rvert \times 100 = 0,45$	0,202 5
Lack of fit	u_{lof}	$\frac{\lvert 0,6\% \rvert \times 100}{\sqrt{3}} = 0,35$	0,122 5
Short-term zero drift	$u_{d,z}$	$\frac{\lvert 0,01\% \rvert \times 100}{\sqrt{3}} = 0,006$	0,000 04
Short-term span drift	$u_{d,s}$	$\frac{\lvert 0,5\% \rvert \times 100}{\sqrt{3}} = 0,29$	0,084 1
Influence of ambient temperature	u_t	$\frac{1,0\% \times 100}{\sqrt{3}} = 0,58$	0,336 4
Influence of sample gas pressure	u_p	$\frac{0,4\% \times 50}{\sqrt{3}} = 0,12$	0,014 4
Influence of sample gas flow	u_f	$\frac{0,2\% \times 100}{\sqrt{3}} = 0,12$	0,014 4
Influence of voltage	u_v	$\frac{0,12\% \times 100}{\sqrt{3}} = 0,07$	0,004 9
Cross-sensitivity	u_i	$\frac{0,5}{\sqrt{3}} + \frac{1,2}{\sqrt{3}} = 0,98$	0,960 4
Uncertainty of test gas	u_{tg}	$\frac{2,0\% \times 50}{\sqrt{3}} = 0,58$	0,336 4
Sum	–	–	2,076 0

The combined uncertainty is calculated using Formula (D.8):

$$u_c = \sqrt{u_r^2 + u_{lof}^2 + u_{d,z}^2 + u_{d,s}^2 + u_t^2 + u_p^2 + u_f^2 + u_v^2 + u_i^2 + u_{tg}^2} = \sqrt{2,0760\left(\text{mg/m}^3\right)^2} = 1,44\,\text{mg/m}^3 \quad \text{(D.8)}$$

The expanded uncertainty at a level of confidence of 95 % is then calculated using Formula (D.9):

$$U_{0,95} = 1,96 \times u_c = 1,96 \times 1,44\,\text{mg/m}^3 = 2,82\,\text{mg/m}^3 \quad \text{(D.9)}$$

The relative expanded uncertainty at a level of confidence of 95 % and at ELV is given by Formula (D.10):

$$U_{\text{rel},0,95} = \frac{2,82\,\text{mg/m}^3}{50\,\text{mg/m}^3} = 5,6\,\% \tag{D.10}$$

EN 15058:2016 specifies for the SRM an allowable expanded uncertainty of 6,0 % of ELV at 95 % confidence. As the ELV is 50 mg/m^3, the allowable expanded uncertainty is 3,0 mg/m^3. Therefore, the P-AMS is compliant with these requirements in the performance test.

D.4 Determination of uncertainty contributions by use of sensitivity coefficients

The contribution of a variation of an influence quantity to the total uncertainty of the measured values in a future application of an P-AMS can be calculated from the range of values of the influence quantity in the considered application of the P-AMS and the sensitivity coefficient of this influence quantity determined in the performance test by use of Formula (D.11):

$$u_i = b_i\, u\left(X_i\right) \tag{D.11}$$

where

u_i is the uncertainty contribution to the total uncertainty of the measured values caused by a variation of an influence quantity X_i;

b_i is the sensitivity coefficient of the influence quantity X_i;

$u(X_i)$ is the variation of the influence quantity X_i expressed as a standard uncertainty.

The variation of the influence quantity X_i can be converted to a standard uncertainty by use of the Formulae (D.4) to (D.7).

Annex E
(informative)

Elements of performance testing report

1 General

1.1 Certification proposal

1.2 Unambiguous P-AMS designation

1.3 Measured component(s)

1.4 Device manufacturer together with full address

1.5 Field of application

1.6 Measurement range for performance test

1.7 Restrictions

Restrictions shall be formulated if testing shows that the P-AMS does not cover the full scope of possible application fields.

1.8 Notes

In the event of supplementary or extended testing, reference shall be made to all preceding test reports. Attention shall de drawn to main equipment peculiarities.

1.9 Test laboratory

1.10 Test report number and date of compilation

2 Task definition

2.1 Nature of test

First test or supplementary testing.

2.2 Objective

Specification of which performance criteria were tested;

Bibliography;

Scope of any supplementary tests.

3 Description of the P-AMS tested

3.1 Measuring principle

Description of metrological and scientific relationships.

3.2 P-AMS scope and set-up

Description of all parts of the P-AMS covered in the scope of testing, if possible including a copy of an illustration or flow diagram showing the P-AMS. Statement of technical specifications, if appropriate in tabular form.

4 Test program

Details shall be provided on the test program, in relation to the P-AMS under test.

In the case of supplementary or extended testing, the additional scope of testing shall be detailed and substantiated.

Particularities of the test shall be documented.

4.1 Laboratory test/laboratory inspection

Statement of all test steps involved

4.2 Field test

Details on:

- all test steps involved;

- plant type or test bench on which the field test examinations were carried out;

- P-AMS measurement range to be covered in the test;

- installation conditions and operating conditions for the P-AMS under test.

5 Standard reference method

5.1 Method of measurement

It is necessary to specify the standard reference method employed. Variations from any method acknowledged as Standard Reference Method of measurement as described in European, international or national standards shall be documented. Only validated methods shall ever be used and, as such, a statement on validation shall be made. The uncertainty of the standard reference method shall be stated.

5.2 Test stand set-up

Description of the sampling probe, any dust filters used for particle separation in the measurement of gaseous substances, details on the sample gas line (length, material, size) and on sample gas conditioning.

6 Test results

Comparison of the performance criteria placed on P-AMS in the performance test with the results attained.

The information below shall be stated for each individual test point in the following order of sequence:

Consecutive number and short title of performance criteria as heading.

6.1 Citation of performance criterion

6.2 Equipment

6.3 Method

6.4 Evaluation

6.5 Assessment

6.6 Detailed presentation of test results allowing for the respective section of the documentation

7 Maintenance work

8 Results of the equivalence test

Annex A Values measured and computed

Annex B Operating instructions

The operating instructions should also be enclosed with the report in electronic form (e.g. as a PDF file).

Annex F
(informative)

European standard reference methods

Table F.1 — Examples of European standard reference methods

Measured component	Standard
Particulate matter	EN 13284–1
Mercury	EN 13211
Hydrogen chloride	EN 1911
Hydrocarbons	EN 12619
Oxygen	EN 14789
Water-vapour	EN 14790
Sulfur dioxide	EN 14791
Nitrogen monoxide	EN 14792
Carbon monoxide	EN 15058

Bibliography

[1] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control)

[2] Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community and amending Council Directive 96/61/EC

[3] Directive 2004/108/EC of the European Parliament and of the Council of 15 December 2004 on the approximation of the laws of the Member States relating to electromagnetic compatibility and repealing Directive 89/336/EEC

[4] Directive 2014/35/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits

[5] EN 1911, *Stationary source emissions - Determination of mass concentration of gaseous chlorides expressed as HCl - Standard reference method*

[6] EN 12619, *Stationary source emissions - Determination of the mass concentration of total gaseous organic carbon - Continuous flame ionisation detector method*

[7] EN 13211, *Air quality - Stationary source emissions - Manual method of determination of the concentration of total mercury*

[8] EN 13284-1, *Stationary source emissions - Determination of low range mass concentration of dust - Part 1: Manual gravimetric method*

[9] EN 14181:2014, *Stationary source emissions - Quality assurance of automated measuring systems*

[10] EN 14789:2017, *Stationary source emissions — Determination of volume concentration of oxygen — Standard reference method: Paramagnetism*

[11] EN 14790:2017, *Stationary source emissions — Determination of the water vapour in ducts — Standard reference method*

[12] EN 14791:2017, *Stationary source emissions — Determination of mass concentration of sulphur oxides — Standard reference method*

[13] EN 14792:2017, *Stationary source emissions — Determination of mass concentration of nitrogen oxides — Standard reference method: chemiluminescence*

[14] EN 15058:2017, *Stationary source emissions — Determination of the mass concentration of carbon monoxide — Standard reference method: non-dispersive infrared spectrometry*

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

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

[17] EN 15267-3, *Air quality - Certification of automated measuring systems - Part 3: Performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources*

[18] EN 50160, *Voltage characteristics of electricity supplied by public electricity networks*

[19] EN 50379-1, *Specification for portable electrical apparatus designed to measure combustion flue gas parameters of heating appliances - Part 1: General requirements and test methods*

[20] EN 50379-2, *Specification for portable electrical apparatus designed to measure combustion flue gas parameters of heating appliances - Part 2: Performance requirements for apparatus used in statutory inspections and assessment*

[21] EN 50379-3, *Specification for portable electrical apparatus designed to measure combustion flue gas parameters of heating appliances - Part 3: Performance requirements for apparatus used in non-statutory servicing of gas fired heating appliances*

[22] EN ISO 9169, *Air quality - Definition and determination of performance characteristics of an automatic measuring system (ISO 9169)*

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

[24] EN ISO/IEC 17043, *Conformity assessment - General requirements for proficiency testing (ISO/IEC 17043)*

[25] CEN/TS 15675, *Air quality - Measurement of stationary source emissions - Application of EN ISO/IEC 17025:2005 to periodic measurements*

[26] ISO 5725-2, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

[27] ISO/IEC Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

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389 Chiswick High Road London W4 4AL UK

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