Performance Standards and Test Procedures for Automated Dust Arrestment-Plant Monitors

Certification under MCERTS according to EN 15859

Environment Agency
Version 1.1

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THE ENVIRONMENT AGENCY'S MONITORING CERTIFICATION SCHEME

Record of amendments

Version number	Date	Section	Amendment
1.0	August 2010		First issue
1.1	July 2016	Whole document	Minor editorial changes to increase clarity.
1.1	July 2016	Foreword	Updated addresses and reference to EN ISO/IEC 17065.
1.1	July 2016	1.4	Updated reference to EN ISO/IEC 17065.
1.1	July 2016	6.2	Updated references for revised EU Directives.

Status of this document

This document may be subject to review and amendment following publication. The latest version is available on our website at:

www.mcerts.net

Feedback

If you have any comments on this document please contact Rick Gould at richard.gould@environment-agency.gov.uk

Foreword

We set up our Monitoring Certification Scheme (MCERTS) to provide guidelines on the standards you need to meet to monitor things that affect the environment. MCERTS covers:

- the standards your monitoring equipment must meet
- how qualified your staff must be
- recognising laboratories and inspecting sites in line with European and international standards

This document tells you how well continuous emission monitoring systems (CEMs) used as automated dust-arrestment plant monitors have to work, and describes the requirements that you need to meet to test their performance.

MCERTS for automated dust-arrestment plant monitors is an official certification scheme that comes under the European Standard, EN ISO/IEC 17065. CSA Group, the certification body in this document, runs this scheme for us.

Your equipment must be tested by laboratories and test organisations that have EN ISO/IEC 17025, which is the internationally recognised standard for testing laboratories. CSA Group examines the results of the laboratory tests and field tests using a group of independent experts known as the Certification Committee.

The benefits of this standard

- The standard gives you the support of a certification scheme that is officially recognised in the UK and is accepted internationally.
- Regulators can be confident that monitoring equipment which meets the standard gives them reliable information about emissions.
- You can be confident that the equipment you use to monitor emissions has been thoroughly tested and meets standards that are accepted by UK regulators.
- The standard gives manufacturers an independent approval. This means people will trust their products, which will improve sales in the UK and internationally.
- The standard helps make sure the public gets accurate and reliable information about the quality of air.

If you have any questions about the how the certification process works, or you would like more information on how to apply, please contact CSA Group using the details below.

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If you have any general questions about MCERTS, please contact us.

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You can get more information on MCERTS, including the standards related to CEMs, from our website at www.mcerts.net .

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Performance Standards and Test Procedures for Continuous Automated Dust Arrestment-Plant Monitors

1 Introduction

1.1 Background

This document describes the performance standards, test procedures and general requirements for the testing of continuous emission monitoring systems (CEMs) under MCERTS in compliance with CEN standard EN 15859. There are three classes of particulate-monitoring (PM) CEMs under MCERTS for CEMs. The performance standards and test procedures for Class 1 PM-CEMs are described in a separate document, *MCERTS Performance Standards and Test Procedures for Continuous Emission Monitoring Systems, for gaseous, particulate and flow-rate monitoring systems, Version 3.2*.

This document defines the performance criteria and procedures for performance testing for Class 2 and Class 3 PM-CEMs, also known as automated dust-arrestment plant monitors used on stationary sources. It duplicates and therefore applies the requirements of EN 15859, from Section 4 onwards.

The following two types of dust arrestment plant monitor are covered by this document:

- **Class 2 PM-CEMs** - a Class 2 PM-CEM which can be calibrated in mass concentration units (e.g. mg/m3) and used for dust arrestment control purposes. These are classed as *filter-dust monitors* in EN 15859.

- **Class 3 PM-CEMs** - a Class 3 PM-CEM which indicates a change in the emissions level or a change in the magnitude of the dust pulses created by the cleaning process. Class 3 PM-CEMs are classed as *filter-leakage monitors* in EN 15859.

For the purposes of this document, the term PM-CEM is used to cover both types of dust arrestment plant monitor. The terms Class 2 PM-CEM and Class 3 PM-CEM are only used where it is necessary to distinguish between the two types.

1.2 Processes

Testing consists of a combination of laboratory testing and field-testing. The field-testing of a CEM is ordinarily carried out on the most highly demanding industrial process in the range of applications for which a manufacturer seeks certification. The premise is that if the CEM performs acceptably on this process, then experience has shown that the CEM generally performs well on the majority of other processes.

However, there are always exceptions and it is the responsibility of the manufacturer in conjunction with the user to ensure that the CEM performs adequately on a specific process.

1.3 Performance characteristics

A combination of laboratory and field testing is detailed within this MCERTS standard. Laboratory testing is designed to assess whether a CEM can meet, under controlled conditions, the technical requirements of the relevant performance criteria. Field testing, over a minimum three month period, is designed to assess whether a CEM can continue to work and meet the relevant performance criteria in a real application. Field testing is carried out on an industrial process representative of the intended application for the CEM for which the manufacturer seeks certification.
The main CEM performance characteristics are:

- response or detection time
- influence of ambient conditions
- influence of variations of the waste gas velocity
- susceptibility to physical disturbances
- cross-sensitivity to likely interferents contained in the waste gas
- performance and accuracy of the Class 2 PM-CEM against a standard reference method (SRM), under field conditions
- performance and accuracy of the Class 3 PM-CEM against a certified particulate AMS tested according to EN 15267-3, under field conditions
- drift of automatic internal zero and reference points
- availability and maintenance interval under field conditions
- reproducibility from two CEMs under identical field conditions

Measurements made by CEMs certified to the requirements of this standard do not necessarily fulfil the uncertainty requirements of the EU Directives for Large Combustion Plant and Waste Incineration or the QAL3 functionality of EN 14181.

1.4 Product Certification

Product certification comprises three phases. These are:

- **Laboratory testing** – used to determine performance characteristics, where such testing requires a highly controlled environment.
- **Field testing** – which is at least three months long. The field test is carried out on processes representative of the intended industrial sectors and applications.
- **Surveillance** - initial and continuing – which comprises an audit of the manufacturing process to confirm that the manufacturer has provisions to

ensure manufacturing reproducibility and to control any design changes to ensure that they do not degrade performance below the MCERTS standards.

Test laboratories shall have accredited procedures that comply with the requirements of EN ISO/IEC 17025, EN 15267-3, EN 15859 and the requirements of the MCERTS scheme according to EN ISO/IEC 17065.

1.5 Manufacturing, repairs, maintenance and modifications to certified CEMs

Any spares or replacement parts for certified CEMs must meet the same performance standards as the original parts. Operators and equipment suppliers may be required to provide evidence that the replacement parts meet the required performance standards of the original equipment as specified by the CEM manufacturer.

Modifications to certified CEMs are allowable so long as manufacturers can demonstrate that these design changes do not degrade the performance of the CEM below the MCERTS performance standards. Manufacturers must have a management system which meets the requirements of EN 15267-2. This standards requires manufacturers to keep detailed records and drawings of all design changes to CEMs, and have provisions for design verification, inspection and testing to ensure that the CEMs still meet the required performance standards.

A suitably accredited certification-body will conduct audits of the design changes to CEMs to meet the requirements of product certification. Manufacturers must notify the Certification Body of any modifications to equipment that may have a significant effect on CEM performance. EN 15267-2 provides details of the audit and certification requirements for the manufacturer’s management system.

Design modifications or extensions to the range of application of a CEM may require renewed testing. The extent of this renewed testing will depend upon the nature of the modifications to the CEM.

If there is evidence that a modification has only limited effects on the performance of the CEM, then it would not be necessary to retest a CEM completely. In such cases, only a supplementary test would be required to the applicable MCERTS performance standards.

In the case of modifications to software – particularly in measuring instruments –documentation must be presented to the Certification Body indicating the nature of the modification as well as resultant effects on operation and functionality. The Certification Body will then decide if further testing is required.

A CEM is certified with a specified type of sampling system. If the analyser is used with components for the sampling system which differ from those which were originally tested, there must be verifiable evidence from a suitable third party test laboratory to demonstrate that the alternative sampling system still enables the CEM to meet the MCERTS performance requirements.

NOTE: The requirements for certification are covered in BS EN 15267-1, and the requirements for the manufacturer's quality-management system for manufacturing and design control are covered in BS EN 15267-2. The certification body applies the requirements of these standards.

1.6 Previous performance tests

Manufacturers that have test reports to demonstrate compliance with the requirements of the type-approval scheme of the Umweltbundesamt (the German national environmental regulator) for their CEMs are invited to submit test reports along with their application for MCERTS certification. We have a formal procedure, *MCERTS - Guidance on the Acceptance of German Type Approval Test Reports for CEMs*, for assessing the test results for compliance with the MCERTS performance standards.

NOTE: Test reports produced to demonstrate compliance with other national schemes may also be acceptable.

1.7 Certificate validity

Certificates are valid indefinitely, subject to the satisfactory control of manufacturing processes and design changes, and compliance with the requirements of BS EN 15267-1, BS EN 15267-2, BS EN 15267-3 and prEN 15859. The certification body keeps the validity of the certification of the CEM under continuous review, taking into account the reports from technical changes to the CEM, post-certification surveillance as defined in BS EN 15267-1, any changes in the technical requirements notified by the Environment Agency, and complaints from users.

2 Normative references

The following referenced documents are indispensable for the application of this document. For all references, the latest edition of the referenced document (including any amendments) applies.

EN 15267-1	Air quality - Certification of automated measuring systems - Part 1: General aspects.
EN 15267-2	Air quality - Certification of automated measuring systems - Part 2: Minimum requirements for product quality assurance, initial assessment and on-going surveillance.
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 15859	Air quality - Certification of automated dust arrestment-plant monitors – Performance criteria and test procedures.
EN 13284-1	Stationary source emissions – Determination of low range mass concentration of dust – Part 1: Manual gravimetric method.
EN 14181	Stationary source emissions – Quality assurance of automated measuring systems.
EN 15259	Air Quality – Measurement of stationary source emissions – Requirements for measurement sections and sites and for the measurement objective, plan and report.
EN 50160	Voltage characteristics of electricity supplied by public distribution systems.
EN 60529	Specification for degrees of protection provided by enclosures (IP code).
EN ISO 14956	Air quality – Evaluation of the suitability of a measurement method by comparison with a stated measurement uncertainty.
EN ISO/IEC 17025	General requirements for the competence of testing and calibration laboratories.

3 Terms and definitions

3.1 Dust

Particles, of any shape, structure or density, dispersed in the gas phase at the sampling point conditions which may be collected by filtration under specified conditions after representative sampling of the gas to be analysed

NOTE Derived from EN 13284-1, 3.1.

3.2 Dust arrestment plant monitor

Class 2 PM-CEM or Class 3 PM-CEM and additional devices for obtaining a result

NOTE Apart from the actual measuring device (the analyser), a CEM may include further components, like purge air blowers or external displays.

3.3 Instrument

dust arrestment plant monitor

NOTE: Also known as a CEM.

3.4 Class 2 PM-CEM

CEM, which can be calibrated in mass concentration units and used for dust arrestment control purposes, but does not fulfil the uncertainty demands according to EN 14181, or does not have reference materials for linearity test and QAL3 procedure according to EN 14181

NOTE A mass concentration unit is e.g. mg/m3.

3.5 Class 3 PM-CEM

CEM, which indicates a possible problem with the dust arrestment plant

NOTE These CEMs may either monitor a change in the emissions level or a change in the magnitude of the dust pulses created by the cleaning process.

3.6 Reference method (RM)

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

NOTE 1 A reference method is fully described.

NOTE 2 A reference method can be a manual or an automated method.

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

[EN 15259:2007, 2.8]

3.7 Standard reference method (SRM)

reference method prescribed by European or national standard.

NOTE Standard reference methods are used e.g. to calibrate and validate CEM and for periodic measurements to check compliance with limit values.

[EN 15259:2007, 2.9]

3.8 Measurement

set of operations having the object of determining a value of a quantity
[VIM:1993, 2,1]

3.9 Paired measurement

simultaneous recording of results of measurement at the same measurement point

NOTE Derived from EN 15267-3, 3.5.

3.10 Measurand

particular quantity subject to measurement
[VIM:1993, 2.6]

NOTE The measurand is a quantifiable property of the waste gas under test, for example mass concentration of a measured component, temperature, velocity, mass flow, oxygen content and water vapour content.

3.11 Measured component

constituent of the waste gas for which a defined measurand is to be determined by measurement
[EN 15259:2007, 2.6]

NOTE Measured component is also called determinand.

3.12 Interferent

substance or phenomenon present in the waste gas under investigation, other than the measured component, that affects the response

NOTE Derived from EN 15267-3, 3.8.

3.13 Calibration

determination of a calibration function with (time) limited validity applicable to a CEM at a specific measurement site

NOTE Derived from EN 15267-3, 3.9.

3.14 Calibration function

relationship between the values of the SRM and the CEM with the assumption of a constant residual standard deviation

NOTE 1 Derived from EN 15267-3, 3.10.

NOTE 2 The calibration function describes the statistical relationship between the starting variable (measured signal) of the measuring system and the associated result of measurement (measured value) simultaneously determined at the same point of measurement using a SRM.

3.15 Automatic internal zero point

output of the CEM in response to an internally generated function, intended to represent absence of the measured component

3.16 Automatic internal reference point

output of the CEM in response to an internally generated function, intended to represent a defined amount of the measured component

3.17 Measured signal

output from a CEM in analogue or digital form which is converted into the measured value with the aid of the calibration function

NOTE Derived from EN 15267-3, 3.15.

3.18 Output

reading, or digital or analogue electrical signal generated by a CEM in response to a measured object

NOTE Derived from EN 15267-3, 3.16.

3.19 Independent reading

reading that is not influenced by a previous individual reading by separating two individual readings by at least four response times
[EN 15267-3:2007, 3.17]

3.20 Individual reading

reading averaged over a time period equal to the response time of the CEM

NOTE Derived from EN 15267-3, 3.18.

3.21 Performance characteristic

quantity assigned to a CEM in order to define its performance

NOTE 1 Derived from EN 15267-3, 3.19.

NOTE 2 A performance characteristic is described by values, tolerances and ranges.

3.22 Accuracy

closeness of agreement between a single measured value of the measurand, and the true value (or an accepted reference value)
[EN 15267-3:2007, 3.20]

3.23 Availability

fraction of the total monitoring time for which data of acceptable quality have been collected
[EN 15267-3:2007, 3.21]

3.24 Averaging time

period of time over which an arithmetic or time-weighted average of concentrations is calculated
[EN 15267-3:2007, 3.22]

3.25 Interference

negative or positive effect that a substance or phenomenon has upon the output of the CEM, when that substance or phenomenon is not the measured component

NOTE Derived from EN 15267-3, 3.24.

3.26 Cross-sensitivity

response of the CEM to substances and phenomena other than those that it is designed to measure

NOTE See interference.

3.27 Drift

monotonic change of the calibration function over a stated period of unattended operation, which results in a change of the measured value
[EN 15267-3:2007, 3.26]

3.28 Internal zero drift

change in the automatic internal zero point over a stated period of unattended operation

3.29 Internal reference drift

change in the automatic internal reference point over a stated period of unattended operation

3.30 Maintenance interval

maximum admissible interval of time for which the performance characteristics remain within a pre-defined range without external servicing, e.g. refill, calibration, adjustment

NOTE This is also known as the period of unattended operation.

[EN 15267-3:2007, 3.29]

3.31 Response time, t_{90}

time interval between the instant of a sudden change in the value of the input quantity to a CEM and the time as from which the value of the output quantity is reliably maintained above 90 % of the correct value of the input quantity

NOTE 1 Derived from EN 15267-3, 3.31.

NOTE 2 The response time is also referred to as the 90 % time or t90 time.

3.32 Detection time

time interval between the onset of an event, and the CEM providing the defined change in output.

3.33 Reproducibility, 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
[EN 15267-3:2007, 3.33]

NOTE Reproducibility is determined by means of two identical CEMs operated side by side. It is a CEM performance characteristic for describing the production tolerance specific to that CEM. The reproducibility is calculated from the half-hour averaged output signals (raw values as analogue or digital outputs) during the three-month field test.

3.34 Uncertainty

parameter associated with the result of a measurement, which characterises the dispersion of the values that could reasonably be attributed to the measurand
[ENV 13005:1999, B.2.18]

3.35 Test laboratory

laboratory accredited to EN ISO/IEC 17025 for carrying out the tests defined in this standard

NOTE 1 Derived from EN 15267-3, 3.37.

NOTE 2 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.

3.36 Field test

test for at least three months on a plant appropriate to the field of application of the CEM

NOTE Derived from EN 15267-3, 3.38.

3.37 Certification range

range over which the Class 2 PM-CEM is tested and certified for compliance with the relevant performance criteria

NOTE Derived from EN 15267-3, 3.39.

3.38 Emissions limit value (ELV)

limit values given in regulations such as EU Directives, ordinances, administrative regulations, permits, licences, authorisations or consents

NOTE 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.

[EN 15267-3:2007, 3.40]

3.39 Plant

installation or industrial facility on which an instrument is installed

NOTE Derived from EN 15267-3, 3.41.4

4 Symbols and abbreviations

4.1 Symbols

b_f	sensitivity coefficient of sample gas flow
b_t	sensitivity coefficient of ambient temperature
b_v	sensitivity coefficient of supply voltage
n	number of measurements, number of parallel measurements
r_1	nominal flow rate
r_2	lowest specified flow rate
R_f	reproducibility under field conditions
R^2	determination coefficient of calibration function
s_D	standard deviation from paired measurements
s_r	repeatability standard deviation of the measurement
σ_0	uncertainty requirement
$t_{n-1;\,0,95}$	two-sided Student *t*-factor at a confidence level of 95 % with a number of degrees of freedom $n - 1$
t_d	is the relative difference between the response times determined in rise and fall mode
t_r	response time determined in rise mode
t_f	response time determined in fall mode
t_o	outage time
t_tot	total operating time
T	temperature (absolute)
T_i	*i*th temperature
U_1	minimum voltage specified by the manufacturer
U_2	maximum voltage specified by the manufacturer
V	availability
x	measured signal
x_i	*i*th measured signal; average of the measured signals for substance *i*
$x_{1,i}$	*i*th measured signal of the first measuring system
$x_{2,i}$	*i*th measured signal of the second measuring system
$\bar{x}$	average of measured signals x_i

4.2 Abbreviations

AST	annual surveillance test
CEM	continuous emission monitoring system
CR	certification range
ELV	emission limit value
QAL	quality assurance level
QAL1	first quality assurance level
QAL2	second quality assurance level
QAL3	third quality assurance level
SRM	standard reference method

5 General Requirements

5.1 Application of performance criteria

The test laboratory shall test at least two identical instruments. All instruments tested shall meet the performance criteria specified in this document.

5.2 Ranges to be tested

5.2.1 General

The test laboratory shall test the instrument over a specified certification range and, if applicable, over supplementary ranges.

Note: The ranges of a Class 3 PM-CEM can be expressed in units defined by the manufacturer.

5.2.2 Certification range for Class 2 PM-CEM

The certification range over which the instrument is to be tested shall consist of minimum and maximum values and the coverage shall be fit for the intended application of the instrument.

The minimum value of the certification range shall be the detection limit certified during the test. A Class 2 PM-CEM shall be able to measure instantaneous values in a range that is at least two times the upper limit of the certification range, in order to measure the half-hour values correctly. If it is necessary to use more than one range setting of the instrument to achieve this requirement, supplementary ranges require additional testing (see 5.2.3).

Note: Manufacturers can choose other ranges for different applications.

The test laboratory shall state the certification range(s) and the performance criteria tested for each range in the test report.

The test laboratory shall choose for the field test an industrial plant with challenging measuring conditions. This means that the instrument can also be used in less demanding measuring conditions.

5.2.3 Supplementary ranges for Class 2 PM-CEMs

If a manufacturer wishes to demonstrate performance over one or more supplementary ranges larger than the certification range, then some limited additional testing is required over all the supplementary ranges. This additional testing shall at least include evaluations of the response time as specified in 10.8.

The supplementary range(s) and the performance criteria tested for these ranges shall be stated on the certificate.

5.2.4 Type of arrestment plant for Class 3 PM-CEMs

The manufacturer shall agree with the test laboratory the type of arrestment plant for which the certification application is intended. This shall be stated on the test certificate and shall include the type of filter (e.g. electrostatic precipitator or bagfilter) and in the case of arrestment plant monitors also include whether the instrument operation requires a change in the magnitude of the dust pulses created by the cleaning process to operate or a change in the emissions level. Also for arrestment plant monitors, the manufacturer shall agree with the test laboratory the type of bagfilter cleaning mechanisms for which the instrument is applicable.

Note 1: The bagfilter cleaning mechanism influences the dynamic dust profile from a bagfilter. For example bagfilter which are cleaned with a compartment off line have a different dust emission profile to a single compartment bagfilter which is cleaned on line.

Note 2: The test laboratory shall choose a field test location which reflect the type of arrestment plant.

5.2.5 Expression of performance criteria with respect to ranges

The performance criteria presented in Clause 08 are expressed in terms of a percentage of the upper limit of the certification range. A performance criterion is a value that corresponds to the largest permitted deviation allowed for each test, regardless of the sign of the deviation determined in the test.

5.2.6 Ranges of optical in-situ instrument with variable optical length (cross-stack)

The certification range for optical in-situ instrument with variable optical length (cross-stack) shall be defined in units of the dust concentration multiplied by the length of the optical path, e.g. mgm^{-3} per metre of path length.

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

5.3 Manufacturing consistency and changes to instrument design

Certification is specific to the instrument version, which has undergone performance testing. Subsequent design modifications that might affect the performance of the instrument can invalidate the certification.

Note: Design modifications apply to both hardware and software.

The requirements for manufacturing consistency and changes to instrument design are described in EN 15267-2.

5.4 Qualifications of test laboratories

Test laboratories must be accredited to EN ISO/IEC 17025 and the appropriate test standards for carrying out the tests defined in this standard. Test laboratories must know and understand the uncertainties attributed to the individual test procedures applied during performance testing.

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.

6 Performance characteristics for laboratory testing

6.1 Instrument for testing

All instruments submitted for testing shall be complete and in their entirety. These specifications do not apply to the individual parts of an instrument. The report shall be issued for a specified instrument with all its parts listed.

6.2 CE labelling

The CEM submitted for testing shall be in conformity with all applicable EC Directives. As of April 2016, these include the Electro-magnetic Compatibility Directive 2014/30/EU (formerly 2004/108/EC), and the Low Voltage Directive 2014/35/EU (formerly 2006/95/EC), covering electrical equipment designed for use within certain voltage limits. Equipment within the scope of the Hazardous Atmospheres Directive, 2014/34/EU (formerly 94/9/EC) falls outside the scope of this MCERTS document. CEM manufacturers or suppliers shall supply declarations of conformity to all relevant Directives applicable to the equipment.

6.3 Security

The instrument shall have a means of protection against unauthorised access to control functions.

6.4 Output ranges and zero-point

The instrument shall have a data output signal such that both negative and positive readings can be displayed.

Analogue output shall have a live zero point.

The instrument shall have a display that shows the measurement response. The display may be external to the instrument.

6.5 Additional outputs on Class 3 PM-CEMs

Class 3 PM-CEMs shall be provided with at least two alarm outputs, with alarm delay capability in addition to the data output.

6.6 Display of operational status signals

The instrument shall have a means of displaying its operating status.

Note: Status signals cover, for example, normal operation, stand-by, maintenance mode, malfunctions.

The instrument shall also have a means of communicating the operational status to a data handling and acquisition system.

6.7 Degrees of protection provided by enclosures

CEMs limited to be mounted in ventilated rooms or cabinets, where any kind of precipitation cannot reach the instrument, shall meet at least IP40 specified in EN 60529.

CEMs shall meet at least IP54 specified in EN 60529 when mounted in areas, where some kind of shelter against precipitation is in place, e.g. a porch roof, but precipitation may reach the instrument due to environmental factors such as wind and rain.

CEMs which are designed to be used in the open air and without any weather protection shall at least meet the requirements of standard IP65 specified in EN 60529.

6.8 Response time

A Class 2 PM-CEM shall meet the performance criteria for response time specified in Table 1.

6.9 Detection time

A Class 3 PM-CEM shall meet the performance criteria for detection time specified in Table 1.

6.10 Repeatability standard deviation at automatic internal zero point

The CEM shall meet the performance criteria for repeatability standard deviation at the automatic internal zero point specified in Clause 8.

6.11 Repeatability standard deviation at automatic internal reference point

The CEM shall meet the performance criteria for repeatability standard deviation at the automatic internal reference point specified in Clause 8.

6.12 Automatic internal zero and reference point checks

The manufacturer shall provide a description of the technique used by the instrument to determine the automatic internal zero and reference points.

The test laboratory shall assess that the mechanisms for determining the automatic internal zero and reference points are as comprehensive as is practical for the measurement technique used, but does not necessarily check the complete measurement path.

The manufacturer shall provide details in the manual which describe the correct operation of the parts of the measurement path not tested by the automatic internal zero and reference point checks.

6.13 Influence of ambient temperature

The deviations of the instrument readings at the automatic internal zero and reference points shall not exceed the performance criteria specified in Clause 8 when the ambient temperature varies from –20 °C to +50 °C, unless assemblies are installed indoors where the temperatures do not fall below +5 °C or rise above +40 °C, in which case the test range shall be +5 °C to +40 °C.

The manufacturer submitting an instrument for testing may specify wider ambient temperature ranges to those cited above.

NOTE Temperature ranges tested are indicated in the certificate.

6.14 Influence of sample gas flow for extractive instrument

The deviation of the CEM reading at the automatic internal reference point shall not exceed the performance criterion specified in Table 1, 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 voltage variations

The deviation of the CEM reading at the automatic internal zero and reference points shall not exceed the performance criterion specified in Table 1, when the voltage supply to the instrument varies from –15 % to +10 % from the nominal value of the supply. The instrument shall be capable of operating at a voltage which meets the requirements of EN 50160.

6.16 Influence of vibration

The instrument shall be unaffected by the levels of vibration typically expected during installation at an industrial plant. The influence of vibration is acceptable if the deviations of the instrument readings at the automatic internal zero and reference points do not exceed the performance criteria specified in Table 1.

6.17 Cross-sensitivity

The manufacturer shall describe any known sources of interference. The test laboratory shall assess and report on relevant interferents.

6.18 Excursion of measurement beam of cross-stack in situ instruments

In the event of an excursion of the measurement beam within an instrument, the deviation of the instrument reading shall not exceed the performance criterion specified in Table 1 for the maximum allowable deviation angle specified by the manufacturer. This shall not be smaller than 0.3°.

6.19 Detection limit

The detection limit of the Class 2 PM-CEM shall be determined, assessed and documented in the test report.

The detection limit should be lower than 25 % of the normal emission concentration from the type of arrestment plant for which certification is requested.

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.

7 Performance characteristics for field testing

7.1 Calibration function for Class 2 PM-CEMs

The calibration function shall be determined by parallel measurements carried out using a SRM. The calibration function shall have at least a determination coefficient R^2 of the regression as specified in Table 2.

The variability attached to the calibration function and determined in accordance with EN 14181 shall meet the performance criterion in Table 2.

Note: This test involves regression analysis of 15 paired measurements at the beginning and end of the field test and an assessment of the change in the calibration function using the AST criterion.

7.2 Functional test of Class 3 PM-CEM

7.2.1 General

During the field test, instruments shall be tested after typical arrestment plant for which certification is sought. The test laboratory shall select a suitably demanding installation.

Two Class 3 PM-CEMs and a particulate AMS shall be installed on the same outlet from the arrestment plant and the outputs recorded for the duration of the field test.

The particulate AMS shall be certified in accordance with EN 15267-3 for the field test application conditions and adjusted to a suitably short averaging time, enabling it to follow the fast changes in dust concentration, associated with arrestment plant dynamics.

7.2.2 Plant failure detection test

The Class 3 PM-CEM shall detect any failure that occurs during the field test (as confirmed by the AMS).

For instruments monitoring mean emission level, failure is deemed to have occurred if emissions reach the plant emission limit value.

For instruments monitoring the change in dust pulse magnitude, failure is deemed to have occurred if pulse height increases by a factor agreed between the manufacturer and test laboratory.

The Class 3 PM-CEM shall discriminate between failure conditions and normal operation.

7.2.3 Simulated filter failure test

The instruments tested in 7.2.2 shall be subjected to a simulated arrestment plant failure condition lasting for 5 minutes at least five times over the field test. No more than three tests shall be conducted on one day and the tests should be conducted at both the beginning and end of the field test period.

Simulated failure conditions shall be applicable to the instrument under test and shall meet the criteria specified in 7.2.2.

7.3 Maintenance interval

The minimum maintenance interval of the instrument shall meet the performance criterion specified in Table 2.

7.4 Drift of automatic internal zero point and automatic internal reference point

The drift of automatic internal zero point and automatic internal reference point within the maintenance interval shall not exceed the performance criteria specified in Table 2.

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

7.5 Availability

The instrument shall have an availability which meets the requirements of applicable regulations, and in any case the performance criterion specified in Table 2, during the field test.

If the instrument is not measuring the measurand, then it is not considered as being available. The instrument can be unavailable due to malfunctions, servicing and any kind of internal zero and reference point evaluation and correction. Periods when the monitored process is not operating are excluded.

7.6 Reproducibility

Instrument shall meet the performance criterion for reproducibility under field conditions specified in Table 2.

For Class 3 PM-CEMs reproducibility shall be calculated between the two Class 3 PM-CEMs and not include the particulate AMS.

8 Performance criteria

This section specifies the performance criteria to be achieved during laboratory and field testing. The values for individual parameters given in these sections are expressed as a percentage of the upper limit of the certification range of the CEM under test, with the exception of availability and calibration function.

Where regulations specify uncertainty requirements, the instrument shall meet both the individual performance criteria specified in this document and the uncertainty requirements required by the applicable regulations.

The maximum allowable deviations (as absolute values) of the measured signals are given as percentages of the upper limit of the certification range.

Table 1 details the performance criteria that are tested in the laboratory. Table 2 details the performance criteria that are tested during the three month field test.

Table 1 — Performance criteria for laboratory tests

Performance characteristic	Class 2 PM-CEM	Class 3 PM-CEM	Test in
Response time	≤ 200 s	not applicable	6.8
Detection time	not applicable	≤ 200 s	6.9
Repeatability standard deviation at automatic internal zero point	≤ 2.0 % [a]	≤ 2.0 % [a]	6.10
Repeatability standard deviation at automatic internal reference point	≤ 2.0 % [a]	≤ 2.0 % [a]	6.11
Influence of ambient temperature change from 20 °C within specified range	≤ 5.0 % [a]	≤ 5.0 % [a]	6.13
Influence of sample gas flow (extractive systems only)	≤ 2.0 % [a]	≤ 2.0 % [a]	6.14
Influence of voltage at –15 % and at +10 % from nominal supply voltage	≤ 2.0 % [a]	≤ 2.0 % [a]	6.15
Influence of vibration	≤ 2.0 % [a]	≤ 2.0 % [a]	6.16
Influence of misalignment (cross-stack instruments only)	≤ 2.0 % [a]	≤ 2.0 % [a]	6.18
Detection limit	to be reported	not applicable	6.19

[a] Percentage of the upper limit of the certification range.

Table 2 — Performance criteria for field tests

Performance characteristic	Class 2 PM-CEM	Class 3 PM-CEM	Test in
Determination coefficient of calibration function, R^2 a) for concentrations > 20 mg/m^3 b) for concentrations ≤ 20 mg/m^3	 ≥ 0.70 ≥ 0.60	not applicable	7.1
Uncertainty, σ_0	≤ 30 % [a]	not applicable	7.1
Success rate in detecting failure condition	not applicable	100 %	7.2.2, 7.2.3
False alarm rate	not applicable	0 %	7.2.2
Minimum maintenance interval	8 days	8 days	7.3
Drift of automatic internal zero point during maintenance interval	≤ 3.0 %[a]	≤ 3.0 %[a]	7.4
Drift of automatic internal reference point during maintenance interval	≤ 3.0 %[a]	≤ 3.0 %[a]	7.4
Availability	≥ 95.0 %	≥ 95.0 %	7.5
Reproducibility, R_f a) for concentrations > 20 mg/m^3 b) for concentrations ≤ 20 mg/m^3	 ≤ 2.0 %[a] ≤ 3.3 % [a]	≤ 10.0 % [a]	7.6

[a] Percentage of the upper limit of the certification range.

9 General test requirements

The test laboratory shall perform all relevant tests on two identical instruments. These two instruments have to be tested in the laboratory and field.

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 instrument 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, 1013 hPa, dry gas).

The test laboratory shall evaluate the performance of the instruments at the lowest certification range possible for the intended application, which is chosen by the manufacturer. If the instrument is to be used for industrial plants requiring assurance over higher measurement ranges, then the test laboratory shall perform selected additional tests to demonstrate satisfactory performance over higher ranges.

Note 1: 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 instruments, followed by measured component specific test requirements. They include:

- description of the test method
- evaluation procedure
- assessment of performance against the relevant performance criterion
- where appropriate, information on any specialised test equipment

If a test requires two or more test cycles and the instruments 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 test laboratory does not have to perform the tests in the numerical order in this document, as the selection of tests and their order depend on the characteristics and type of individual CEM.

Note 2: The field test is usually carried out after all laboratory tests are passed.

Note 3: A short-term drift test performed after the response time test can show that drift is not influencing the results of the other tests. As a guideline, a short-term drift test could be 24 hours long, where a drift at zero point of more than 2 % of the upper limit of the certification range indicates that the CEM will not be sufficiently stable for the remainder of the tests.

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

10 Test procedures for laboratory tests

10.1 CEM for testing

The test laboratory shall check whether the CEMs are complete and identical, by examining the appropriate parts, as specified in the manufacturer's documentation.
The test laboratory shall check that extractive CEMs have appropriate provisions for effective control of liquid water entering the system.

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

Note 1: In addition to the analyser, a CEM can include the sampling probe, the sampling hose, any special test components and the operating instructions.

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

Note 2: Minor repairs needed to perform the test but without influence on the CEMs performance can be carried out, and the test be continued.

10.2 CE labelling

If the CEM 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 Security

The CEMs shall be set up according to the operating instructions. The test laboratory shall then activate the security mechanisms provided by the CEM manufacturer to prevent inadvertent and unauthorised maladjustment. A check shall then be carried out to establish whether the security mechanisms operate effectively.

Note 1: Adjustment can include zero adjustments, deletion of data sets, changing averaging times and altering ranges.

Note 2: Security mechanisms can include a key or security codes, which are keyed into the CEMs before adjustments are permitted.

10.4 Output ranges and zero point

The test laboratory shall check whether the output ranges on the CEM can be changed and whether such ranges are appropriate for the intended applications.

The test laboratory shall check that the indicated zero point on the measurement display and output of the CEMs is a true live zero, and that the CEM can display both positive and negative readings.

10.5 Additional outputs on Class 3 PM-CEMs

The test laboratory shall verify that the Class 3 PM-CEM is equipped with at least two alarm outputs and that these alarms function correctly.

Note: The two alarms are normally used to provide advance warning of, and indication of, arrestment plant failure.

10.6 Display of operational status signals

The test laboratory shall assess that the CEM has a means of displaying and providing data for recording the relevant operational status (e. g. standby, service, malfunction), and that it is operating correctly.

10.7 Degrees of protection provided by enclosures

The CEM 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 6.7.

10.8 Response time

The test laboratory shall determine the response time of the Class 2 PM-CEM by the use of surrogates.

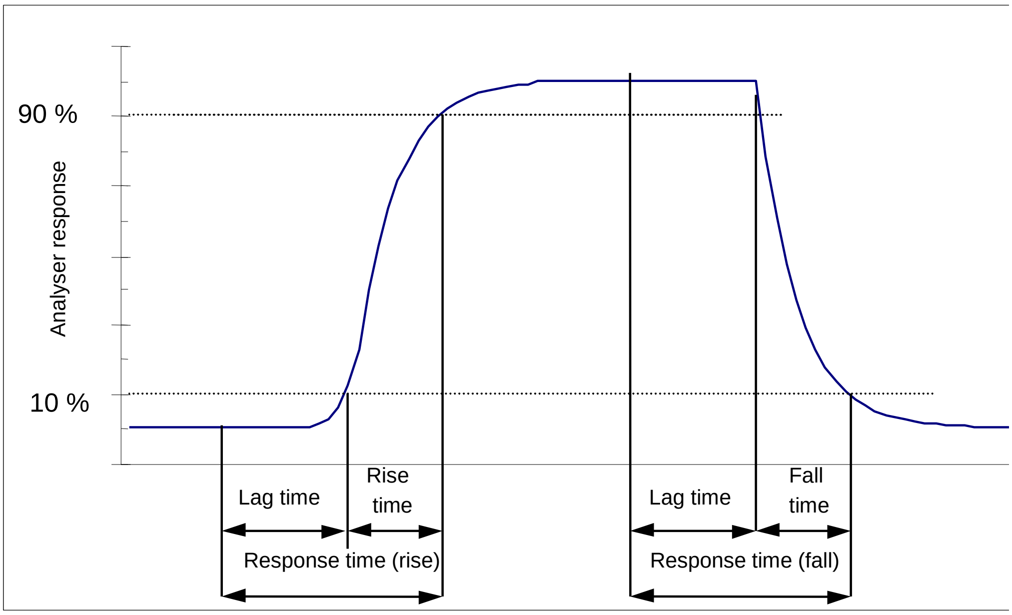
Note: This test provides the initial stabilisation period, which is then used in other tests described in this European Standard.

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

The whole cycle shall be repeated four times with a time elapsed between two experiments of four times the response time. If the CEM 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 value of the response time (rise) and the response time (fall) shall be used as the response time of the CEM and be compared with the applicable performance criteria specified in Table 1.



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 Equation (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 in rise mode

t_f is the response time in fall mode

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

10.9 Detection time

The test laboratory shall determine the detection time of the Class 3 PM-CEM by the use of surrogates.

Note: This test provides the initial stabilisation period, which is then used in other tests described in this European Standard.

The elapsed time (detection time) between the start of the step change and the CEM providing the defined response shall be determined for both the rise and fall modes.

The whole cycle shall be repeated four times with a time elapsed between two experiments of four times the detection time. If the CEM 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 detection times (rise) and the average the detection times (fall) shall be calculated.

The larger value of the detection time (rise) and the detection time (fall) shall be used as the detection time of the CEM and be compared with the applicable performance criteria specified in Table 1.

10.10 Repeatability standard deviation at automatic internal zero and reference points

The measured signals of the CEM at zero and reference points shall be determined after application of the internal reference by waiting the time equivalent to one independent reading and then recording 20 consecutive individual readings in each case.

These data are then used to determine the repeatability standard deviation at automatic internal zero and reference points using Equation (2):

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

where

- s_r is the repeatability standard deviation
- x_i is the *i*th 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 automatic internal zero and reference points shall meet the performance criterion specified in Clause 8.

The individual readings and the repeatability standard deviation at automatic internal zero and reference points shall be reported.

10.11 Influence of ambient temperature

The test laboratory shall determine how the automatic internal zero point and automatic internal reference point values of the CEM are influenced by changes in ambient temperature by using a climatic chamber which can control ambient temperature from –20 °C to +50 °C, within limits of ±1.0 C.

If a measurement at zero is possible, this may be used instead of the automatic internal zero point.

In the case of CEM installed outdoors, the following temperatures shall be set in the climatic chamber in the given order of sequence:

20 °C → 0 °C → -20 °C → 20 °C → 50 °C → 20 °C.

In the case of CEM installed at temperature-controlled locations, the following temperatures shall be set in the given order of sequence:

20 °C → 5 °C → 20 ° C → 40 °C → 20 °C.

After a sufficient equilibration period, the measured signals of the CEMs at automatic internal zero point and at automatic internal reference point shall be determined at each temperature 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 laboratory shall wait at least six hours between each temperature change in the environmental chamber, to allow the CEM to equilibrate, before taking further readings.

Alternatively, the test laboratory may monitor the reading from the CEM following each temperature change. If the CEM stabilises in less than six hours, then the test laboratory may reduce the equilibration period. However, the test laboratory shall record objective and verifiable evidence to support this.

The CEMs shall remain switched on when varying the ambient temperature in the environmental chamber.

The deviations between the average reading at each temperature and the average reading at 20 °C shall be determined. The deviations shall meet the applicable performance criteria specified in Clause 8 for all temperatures.

The test shall be repeated three times. If the CEM 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 temperature as well as the maximum deviation at automatic internal zero point and at automatic internal reference 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 Equation (3):

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

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 sample gas flow for extractive CEMs

The CEM 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 CEM, since in situ CEM 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 at the automatic internal reference 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 Table 1. This test shall be repeated three times at the automatic internal reference point. If the CEM 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 Equation (4):

$$b_f = \frac{(x_2 - x_1)}{(r_2 - r_1)} \qquad (4)$$

where

b_f is the sensitivity coefficient of sample gas flow
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

10.13 Influence of voltage variations

The supply voltage to the CEM 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 Table 1. The measured signals of the CEM at automatic internal zero point and at automatic internal reference 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.

If a measurement at zero is possible, this may be used instead of the automatic internal zero point.

Note: After changes in voltage the CEM can need time to stabilize.

The deviations between the average reading 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. If the CEM 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 automatic internal zero point and at automatic internal reference 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 Equation (5):

$$b_V = \frac{(x_2 - x_1)}{(U_2 - U_1)} \tag{5}$$

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 internal reference point shall be taken.

10.14 Influence of vibration

The CEM shall be examined in the laboratory and in the field in respect of whether normal vibrations affect the performance of the CEM. If the conditions of use specified by the manufacturer demand that a vibration test be performed, the measured signals of the CEM at automatic internal zero point and at automatic internal reference 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.

If a measurement at zero is possible, this may be used instead of the automatic internal zero point.

The vibration test, if required, shall be applied to duct-mounted parts of the CEM only and shall be made with reference to IEC 60068-1 and the appropriate sections of IEC 60068-2. The CEM shall be subjected to vibration on three perpendicular axes in turn, with a swept range of frequencies from 10 Hz to 160 Hz at one octave per minute and at a vibration acceleration chosen by the manufacturer and assessed by the test laboratory to be proper for the application for which the CEM is intended.

If any resonant frequencies are observed, a vibration test shall be carried out at each observed frequency for a period of two minutes. If no resonant frequencies are observed, a vibration test shall be made at a frequency of 25 Hz for a period of two minutes.

The vibration test shall be followed by a functional test. Any influence on the CEM from vibrations and from the service position 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 Table 1.

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

10.15 Cross-sensitivity

The nature and magnitude of relevant interferents shall be assessed by the test laboratory and included on the test report. At least the following interferents shall be considered:

- influence from duct gas velocity
- influence of particle material
- influence from particle static charge
- influence from particulate grain size
- influence from moisture in the duct gas (water vapour)
- influence from aerosols in the duct gas (water droplets)
- influence from duct gas temperature

10.16 Excursion of measurement beam of cross-stack in situ CEMs

The test laboratory shall gradually and precisely deflect the transmitter and receiver assemblies of the CEM in the horizontal and vertical planes, and then record the measured signals using reference materials.

Note 1: This test typically applies to cross-stack in-situ optical techniques. The test also applies to extractive CEM with separate transmitter and receiver assemblies.

Note 2: This testing requires calibration standards (e.g. reference filters) and an optical bench.

Note 3: Typically the experimental path length for this test is 2 m to 3 m, although the test should be performed at the maximum path length practical.

Deflections shall be carried out for the zero point over two typical measurement path lengths. The deflection is to be performed in incremental steps of approximately 0.05° in the angle range demanded.

The range of deflection shall be equal to at least twice the angle specified by the manufacturer. It should also be tested as far as the deflection limit permitted by the assemblies - if necessary in larger increments.

The efficiency of any manual optical adjustment facilities shall be examined at least in qualitative terms. Automatic adjustment processes shall be activated and included in the test.

The measured signals obtained for the various test steps shall be included in tabular form in the test report. These measured signals shall be paired up with the deflection angles.

The maximum permissible deflection angles shall be stated within which the CEM satisfies the performance criterion. In the case of an automatically aligning CEM, the manner of operation shall be described and verified by means of test results.

10.17 Detection limit

The measured signals of the Class 2 PM-CEM at zero point shall be determined after simulating a zero dust concentration by waiting the time equivalent to one independent reading and then recording 20 consecutive independent individual readings.
These data are then used to determine the repeatability standard deviation at zero point using Equation (2).

The detection limit of the Class 2 PM-CEM shall be calculated by multiplying the repeatability standard deviation at zero point with a factor of two, and shall be assessed and documented in the test report.

11 Requirements for field tests

11.1 Provisions

The field test is an endurance test on an industrial facility appropriate to the CEM's field of application. When selecting the industrial facility, the test laboratory shall ensure that the mass concentrations of the measured component are available in a concentration sufficient to assess the measurement results. This is usually the case if the mass concentration is in the range of 20 % to about 50 % of the certification range to be tested.

The measurement site shall be selected in accordance with EN 15259.

Note: Compliance with EN 15259 for the selection of the CEM sampling point eliminates or at least minimises any systematic deviation caused by spatial and temporary lack of homogeneity in the mass concentration or volumetric concentration of individual measured components.

The field test shall be performed with two complete and identical CEMs. In the case of a Class 3 PM-CEM, a certified particulate AMS, tested according to EN 15267-3 is also required. The CEMs and the AMS, if required, shall be mounted so that they will measure the same concentration.

Any additional equipment required is specified in the various test procedures.

11.2 Field test duration

The field test duration shall be at least three months and shall not be interrupted. Only in exceptional cases, which shall be justified (e.g. in the case of operation-related interruptions or change of site); shorter testing periods may be included in the field test. The total duration of the shorter testing periods shall be at least three months. During the field test, the performance criteria shall be determined under near-practice and realistic conditions.

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

12 Test procedures for field tests

12.1 Calibration function for Class 2 PM-CEM

The test laboratory shall determine the calibration function of the Class 2 PM-CEM during the field test, by performing parallel measurements with the SRM. The calibration function shall be determined on the basis of at least 15 parallel measurements in accordance with EN 14181.

The calibration function shall be determined twice, once at the beginning and once again at the end of the field test. Both calibration functions shall meet the performance criterion for the uncertainty specified in Table 2. The variability shall be assessed according to of EN 14181. The peripheral parameters (e.g. moisture content, temperature and oxygen content) used to standardise the measured results should be the same for dust monitor and SRM measured values to calculate the variability only for the tested dust monitor without influence of peripheral parameters. Furthermore, the validity of the second calibration function shall be assessed according to EN 14181 by use of all results of the parallel measurements.

Note: It is advantageous to use the zero point in the calibration in order to avoid an inadequate calibration function.

If any effects of waste gas temperature and pressure are observed during the field tests, the test laboratory shall note these effects in the test report.

12.2 Functional test of Class 3 PM-CEM

12.2.1 Plant failure detection test

The test laboratory shall record the output from the Class 3 PM-CEM and the particulate CEM and assess that the Class 3 PM-CEM has detected any failure that occurred during the field test (as confirmed by the CEM).

For CEMs monitoring mean emission level, failure is deemed to have occurred if emissions reach the plant emission limit value.

For CEMs monitoring the change in dust pulse magnitude, failure is deemed to have occurred if pulse height increases by a factor agreed between the manufacturer and test laboratory.

The test laboratory shall assess that the dust arrestment plant monitor does not give false signals during the field test.

12.2.2 Simulated filter failure test

The test laboratory shall subject the Class 3 PM-CEM to a simulated arrestment plant failure condition lasting for five minutes at least five times over the field test. No more than three tests shall be conducted on one day and the tests should be conducted at both the beginning and end of the field test period. The test laboratory shall assess that the CEM detects all simulated filter conditions

Simulated failure conditions shall be applicable to the CEM under test.

Note: Failure conditions can be simulated by one of the following procedures:

- injection of particulate
- using a defective bag
- changing voltage on EP plates
- opening a bypass around the filter

12.3 Maintenance interval

The test laboratory shall determine the maintenance work that is necessary for the CEM to work properly as well as the intervals at which such maintenance work shall be performed. The recommendations of the CEM manufacturer should be taken into account.

The procedure given by the manufacturer to ensure the correct operation of the parts of the measurement path not tested by the internal zero and reference point checks shall be evaluated by the test laboratory.

If the CEM does not require any service, the maintenance interval is determined by the drift behaviour.

In order to determine drift behaviour, the CEM shall be adjusted at the start of testing. The CEMs shall be checked at regular intervals (e. g. once a week) during the further course of testing. The maintenance interval shall be defined as the time period between the start of the test and the last time when the deviation remained within the permissible drift.

The maintenance interval shall be derived from the shortest interval between the requisite maintenance work operations. This also includes manual as well as automatic checks.

The maximum allowable maintenance interval for a three-month field test shall be one month. Extending the maintenance interval to one year necessitates long-term studies as specified in Table 3. The test laboratory has to describe the minimum amount of maintenance work to be performed within the maintenance interval.

Table 3 — Maximum allowable maintenance intervals

Field test duration	Maximum allowable maintenance interval
3 months	1 month
6 months	3 months
12 months	6 months
24 months	12 months

12.4 Drift of automatic internal zero point and automatic internal reference point

The test shall be performed using two CEMs of identical design as part of the field test in the form of paired measurements in the smallest measuring range tested. The position of the automatic internal zero point and of the automatic internal reference point shall be determined 10 times manually on a pollutant-free measurement section, if necessary using the test standard provided with the CEM, at intervals of a maximum of four weeks over the period of the field test. A different interval may also be selected in substantiated cases.

In the case of CEMs with recording of automatic internal zero point and automatic internal reference point drift, the display readings shall also be acquired and recorded over the period intended for the maintenance interval as well as over the period of the field test.

Manual re-adjustment to the CEM characteristic at the automatic internal zero point or at the automatic internal reference point shall only be permissible if the test laboratory establishes that the permissible level of drift is exceeded during an inspection interval. The maintenance work operations defined by the manufacturer of the CEM shall be performed at the prescribed intervals and included in the test.

All manually determined zero point and reference point values shall be used for the purpose of evaluation and presented in tabular form together with the associated times. CEM-internal control values issued automatically by the CEM as signal values shall be checked for adherence to the permissible levels of drift.

The time between two test intervals in which drift is exceeded shall, if necessary, be established. This is based on the levels of drift permitted under current performance criteria.

Both the manually determined automatic internal zero point and automatic internal reference point values as well as any control values displayed automatically by the CEM shall be assessed. The minimum and maximum deviation from rated value shall be documented.

In the case of CEM with automatic zero point and reference point correction facility, the maximum technically permissible amount of correction shall be specified or determined from the test results. The drift of the automatic internal zero point shall be related to the relevant measuring range and the drift of the automatic internal reference point to the rated value.

12.5 Availability

The test laboratory shall determine the availability of the CEM by recording the duration of the field test and all interruptions to the normal monitoring functionality of the CEM.

Note: Interruptions include e.g. malfunctions, servicing work and automatic internal zero and reference point checks.

The availability *V* in per cent shall be determined using Equation (6) with the aid of the total operating time t_{tot} and the outage time t_o:

$$V = \frac{t_{tot} - t_o}{t_{tot}} \times 100\,\% \qquad (6)$$

The results shall be summarised in tabular form. Table 4 provides an example.

Table 4 — Summary of availability test results

		CEM 1	CEM 2
Total operating time t_{tot}	h		
Outage time t_o – CEM internal setting times – CEM malfunction and repairs – Maintenance, adjustment	 h h h		
Availability V	%		

The test records with the raw data and results shall be documented.

12.6 Reproducibility

Reproducibility shall be determined during the three-month field test from simultaneous, continuous measurements by means of two identical CEMs at the same measurement point (paired measurements) and an electronic data recording system with a memory capacity of at least four weeks and a sampling rate of at least four times during the averaging period.

The test shall be carried out in the smallest measuring range under test. When selecting the plant, it is preferable that in the range of 30 % to about 100 % of the upper limit of the certification range the mass concentrations of the measured component are available in a concentration sufficient to assess the measured results.

The measured signals of both CEMs (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 half-hour mean values, provided that for each half-hour at minimum 20 min are covered by individual values. Measured signals from malfunction, maintenance or test cycles taking place in the CEM 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 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 test, the reproducibility shall be calculated on the basis of all valid paired values, i.e. the condensed measured signals from the CEM, accrued throughout the entire period of the field test with both CEM in accordance with Equation (7) using the standard deviation of the difference of the paired measurements as given by Equation (8) and with a statistical confidence of 95 % for the *t*-distribution (two-sided):

$$R_f = t_{n-1;\,0,95} \times s_D \tag{7}$$

$$s_D = \sqrt{\frac{\sum_{i=1}^{n}\left(x_{1,i} - x_{2,i}\right)^2}{2n}} \tag{8}$$

where

R_f is the reproducibility under field conditions

$t_{n-1;\,0,95}$ is the two-sided Student *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

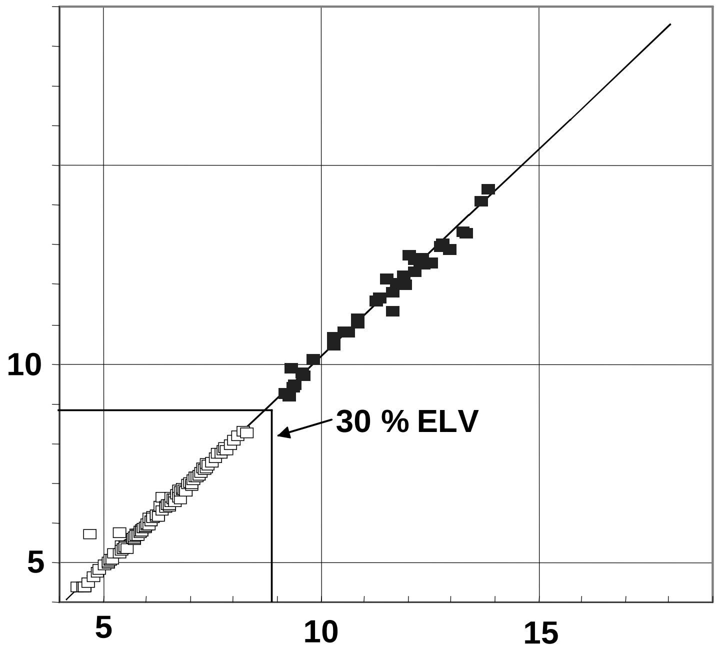
n is the number of parallel measurements

Note: The determination of the reproducibility under field conditions is in accordance with ISO 5725-2. In the report, the paired values shall be plotted on a graph in accordance with Figure 2. In the graph, the measured value pairs below 30 % of the certification range shall be identified separately.

The reproducibility calculation results shall deliver the following information in tabular form:

- concentration range of value pairs (e. g. in $mg.m^{-3}$)
- number of value pairs above 30 % of the upper limit of the certification range
- number of value pairs below 30 % of the upper limit of the certification range
- total number of valid value pairs in the test period
- reproducibility under field conditions, related to the measuring signal range (e. g. 4 mA to 20 mA for analogue outputs)
- certification range (e. g. signal range: 4 mA to 20 mA, concentration range: 0 $mg.m^{-3}$ to 50 $mg.m^{-3}$)

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



Key

$x_{1,i}$, $x_{2,i}$	measured signals from the first and second CEM
CR	certification range (4 mA to 20 mA)
–	regression line
□	measured signals < 30 % CR
■	measured signals > 30 % CR

Figure 2 — Graphical representation of measured signals used for determination of reproducibility under field conditions

13 Test report

The test report shall provide a comprehensive and detailed account of the testing and CEM performance.

Annex A gives an example of a suitable test report.

Note: The test report is part of the documentation of the certified CEM.

Annex A
(informative)

Elements of recommended performance testing report

1. General

1.1 Certification proposal

1.2 Unambiguous CEM designation

1.3 Measured component(s)

1.4 Device manufacturer together with full address

1.5 Field of application

For example, the type of arrestment plant, its cleaning mechanism, and the possible presence of water droplets.

1.6 Measuring range for suitability test

1.7 Restrictions

For example if testing shows that the CEM does not cover the full scope of possible application fields.

1.8 Notes

Any preceding test reports and any 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

Details of performance criteria tested;

Bibliography;

Scope of any supplementary tests.

3 Description of the CEM tested

3.1 Measuring principle

Description of metrological and scientific relationships.

3.2 CEM scope and set-up

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

3.3 Manual Quality Control Procedures

Description of any manual procedures necessary to ensure correct operation of the entire CEM.

4 Test programme

Test programme, in relation to the CEM under test and in the case of supplementary or extended testing, the additional scope of testing Particularities of the test

4.1 Laboratory test / laboratory inspection

Statement of all test steps involved

4.2 Field test

Details on:

– all test steps involved;

– plant type on which the field test examinations were carried out;

– type of dust arrestment used during the test;

– CEM measuring range to be covered in the test;

– installation conditions and operating conditions for the CEM under test.

5 Standard reference method

5.1 Method of measurement

Variations from any method acknowledged as a standard reference method of measurement and described in European, international or national standards.

6 Test results

Comparison of the performance criteria placed on continuous emission CEM in the suitability test with the results attained.

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

Annex A Values measured and computed

Annex B Operating instructions

Bibliography

CEN/TS 15675, Air quality – Measurement of stationary source emissions – Application of EN ISO/IEC 17025:2005 to periodic measurements

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

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