



Performance Standards for Continuous Ambient Air Quality Monitoring Systems

**Environment Agency
Version 6
December 2008**



Foreword

We set up our Monitoring Certification Scheme (MCERTS) to provide a framework of standards you can use to monitor things that affect the environment. MCERTS covers:

- the standards of performance that your monitoring equipment must meet;
- the level your staff must be qualified to; and
- accrediting laboratories and inspecting sites in line with European and International standards.

This document sets out the performance standard for equipment that monitors pollution in the ‘ambient’ air (by this we mean the air that we breathe). In this document we refer to this equipment as ‘continuous ambient air-quality monitoring systems’ (CAMs).

This standard is based on International and European standards. The pollutants covered include:

- nitrogen monoxide (NO);
- nitrogen dioxide (NO₂);
- sulphur dioxide (SO₂);
- carbon monoxide (CO);
- ozone (O₃);
- particulate matter (PM₁₀ and PM_{2.5})
- benzene and other organic compounds.

MCERTS for CAMs is a formal certification scheme under European Standard EN 45011. Sira runs this scheme on our behalf.

Your equipment must be tested by laboratories and test organisations that are accredited to EN ISO/IEC 17025, which is the internationally recognised standard for testing laboratories. These organisations must also be capable of meeting the MCERTS performance standards for testing, which are set out in the relevant EN Standards and documents^(6,7,8,9,10,11). Sira assesses the results of the laboratory and field tests, using a group of independent experts known as the Certification Committee.

The benefits of this standard

- The standard gives you a certification scheme that is formally recognised in the UK and is accepted internationally.
- Regulators can be confident that monitoring equipment which meets the standard provides reliable information about air pollution.
- You can be confident that the equipment you use to monitor air pollution has been thoroughly tested and meets standards that are accepted by UK regulators.
- The standard gives manufacturers an independent approval of the equipment they produce, which will improve their access to international markets and increase their sales in the UK.
- The standard helps make sure the public are given accurate and reliable information about air quality.

If you have any questions about the certification process, or would like more information about how to apply, please contact:

Sira Certification Service
12 Acorn Industrial Park
Crayford Road
Crayford
Dartford
Kent
DA1 4AL.

Phone: 01322 520508
Fax: 01322 520501
E-mail: mcerts@siraenvironmental.com

If you have any general questions about MCERTS, please contact:

Environment Agency
National Monitoring Services
PO Box 519
Preston
PR5 8GD.

Phone: 01772 714361
Fax: 01772 714360

You can get more information on MCERTS, including the standards related to monitoring pollution in ambient air, from our website at www.mcerts.net.

Plain English Campaign's Crystal Mark applies to the foreword only.



Record of amendments

Version number	Date	Amendment
Version 4	July 2005	Alignment with the requirements of the Ambient Air Quality Standards: BS EN 14212:2005, BS EN 14625:2005 BS EN 14211:2005, BS EN 14626:2005
Version 4	July 2005	Introduction of the methodology introduced by the EC Working Group on Guidance for Demonstration of Equivalence of Ambient Air Monitoring Methods into ambient dust monitoring equipment test requirements. Removal of wind tunnel and artificial dust generation based testing methods.
Version 4	August 2005	Modification of field repeatability calculation criteria for lower concentration scenarios reflecting reducing levels of ambient pollution for some species. Introduction of consistent criterion of unchanging test stringency.
Version 4	August 2005	Allowing for performance testing with the Kalman filter always switched on for single chamber nitrogen oxides monitors if they are intended for use in this mode of operation only.
Version 5	May 2007	Introduction of laboratory test performance requirements for particulate matter monitors in accordance with draft TC 264 WG22 document - Certification of Automatic Measuring Systems, Part 4: Performance specifications and test procedures for automated measuring systems for monitoring ambient air quality.
Version 5	May 2007	Modification of pass-fail criteria for particulate matter monitors.
Version 6	October 2008	Detailed distinction between different types of instrumentation and modification of assessment criteria in accordance with EN Demonstration of Equivalence of Ambient Air Monitoring Methods. Removal of the sections dealing with PAHs and metals. Modification of requirements for benzene and other organic compounds.

Status of this document

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

www.mcerts.net

Feedback

If you have any comments on this document please contact John Tipping at john.tipping@environment-agency.gov.uk .

CONTENTS

1	Introduction.....	1
2	EU legislative requirements for certification of CAMs	2
2.1	Acceptance for use	2
2.2	Air quality limit values	2
2.3	Combined performance characteristic	2
2.4	Operational conditions	4
3	References.....	6
4	Definitions of performance characteristics and other terms	7
5	General instrument requirements	8
5.1	General requirements for CAMs submitted for testing.....	8
5.2	Response times	9
5.3	Averaging times.....	9
5.4	Certification range	10
5.5	Zero and span drift	11
5.6	NO _x analysers	12
5.7	Sampling line, sampling manifold and particulate filter.....	12
5.8	Cross-sensitivity to interfering substances	12
5.9	Lack of fit.....	12
6.	Determinand specific requirements	13
6.1	Certification of CAMs	13
6.2	Performance standards for CAMs measuring SO ₂ , NO _x , CO and O ₃	13
6.3	Field testing of CAMs measuring SO ₂ , NO _x , CO and O ₃	14
6.4	Performance standards for CAMS measuring PM ₁₀ and PM _{2.5}	18
6.5	Laboratory tests for CAMs using oscillating microbalances, β-attenuation or light scattering	18
6.6	Laboratory tests for particulate monitoring CAMs using a modified EN Standard Reference Method.....	20
6.7	Field testing of CAMs measuring PM ₁₀ and PM _{2.5}	21
6.8	Evaluation of data from particulate matter certification tests	23
6.9	Performance standards for benzene monitoring systems	24
	Appendix 1: Recommendations for sampling lines and manifolds	31

1 Introduction

1.1 This document describes the MCERTS Performance Standards for certain categories of continuous ambient air quality monitoring systems (CAMs). The testing procedures applied for the determination of instrument performance characteristics shall follow the type testing guidance given in the relevant standards.

1.2 For the purpose of this document, CAMs are instrumental systems that either:

- continuously monitor ambient pollutant concentrations in situ and automatically produce results; or
- sample ambient air over an extended period (hours, days or weeks) onto a filter or a similar device, which is subsequently analysed in the laboratory. Such samplers may be used to obtain a continuous, or a discontinuous, longer-term average value of the pollutant concentration, by carrying out sequential sampling over time. For these instruments, the performance standards cover only the sampling stage of the measurement process.

Open-path instruments are covered by a separate MCERTS performance standard.

1.3 The following air pollutants are covered: nitrogen monoxide (NO), nitrogen dioxide (NO₂), sulphur dioxide (SO₂), carbon monoxide (CO), ozone (O₃), particulate matter (PM₁₀ and PM_{2.5}), benzene and benzene-like VOCs.

1.4 The main instrument performance characteristics (not all of them applicable to a particular type of instrument) against which a CAM will be assessed by a combination of laboratory and field testing are:

- response time, consisting of rise lag time, rise time, fall lag time and fall time (where applicable);
- laboratory repeatability standard deviation;
- zero and span drifts;
- accuracy of sample collection in the case of certain particulate CAMs;
- detection limit;
- averaging of short-term fluctuations in determinand concentration (where applicable);
- lack of fit;
- cross-sensitivity to interfering substances;
- NO_x converter efficiency test (where applicable);
- carry-over (where applicable);
- flow accuracy and stability (where applicable);
- influence of atmospheric sample pressure and temperature;
- susceptibility to physical disturbances (where required);
- field performance of the CAM against a reference method where this is available, and/or against another CAM;
- field repeatability;
- long-term zero and span drift;
- availability (maintenance interval).

- 1.5 The definitions of the performance characteristics (and other terms used in this document) are given in Section 4.
- 1.6 The general requirements and the performance standards to be met by CAMs are presented in this document in Sections 5 and 6, respectively.
- 1.7 The MCERTS Performance Standards have been defined so that MCERTS-certified CAMs are capable of meeting the requirements of both the EC Framework Directive 96/62 (EC “Ambient Air Quality Assessment and Management”)⁽¹⁾ and its associated Air Quality Daughter Directives. The total allowable uncertainties at the specified limit values for CAMs monitoring sulphur dioxide, oxides of nitrogen and PM₁₀ particulates are now published in the EC Air Quality Daughter Directive⁽²⁾. In addition, a Daughter Directive has been prepared to cover benzene and carbon monoxide and this also specifies the total allowable uncertainties at the limit values for these pollutants⁽³⁾. The Ambient Air Quality CEN Standards define the technical requirements for monitoring of the pollutants covered by the Directives. The central objective in defining the MCERTS Performance Standards is that they are fully compatible with the CEN standards.
- 1.8 Throughout this document the terms “MCERTS certificate” and “certificate” refer to the MCERTS product-conformity certificate.

2 EU legislative requirements for certification of CAMs

2.1 Acceptance for use

- 2.1.1 The EC Ambient Air Quality Directives require that CAMs used to report air quality results undergo product certification or type approval before they are accepted for use. The MCERTS scheme is designed to meet these requirements and is recognised by the Department for Environment, Food and Rural Affairs (Defra) as a vehicle to deliver such product certification.

2.2 Air quality limit values

- 2.2.1 The performance standards specified in this document are generally expressed as measurement results from which the values of standard uncertainties can be derived. Table 2.1 gives the European Union air-quality limit values in the relevant concentration units. The limit values that have been used to derive the performance characteristics specified in this document are given in Table 2.2.
- 2.2.2 Where certification of CAMs is required in scenarios where no limit value is specified, 70-90% of the certification range shall be used as the value at which the performance characteristics are defined.

2.3 Combined performance characteristic

- 2.3.1 MCERTS includes an overall measure of the performance of the CAM by combining together statistically all the relevant performance characteristics. This is known as a

Table 2.1 European Union air quality limit values

Pollutant	Period	Limit	Number of permissible exceedances	Date to be met
SO ₂	1 hour ^a	350 µg/m ³	not to be exceeded > 24 times per calendar year	1 Jan 2005 ^b
	24 hours	125 µg/m ³	not to be exceeded > 3 times per calendar year	1 Jan 2005
	calendar year & winter	20 µg/m ³	rural areas	E.I.F. ^c + 24 months
NO ₂	1 hour	200 µg/m ³	not to be exceeded > 18 times per calendar year	1 Jan 2010 ^b
NO _x	calendar year	40 µg/m ³		1 Jan 2010 ^b
	calendar year	30 µg/m ³	rural areas	E.I.F. + 24 months
PM ₁₀	24 hours	50 µg/m ³	not to be exceeded > 35 times per calendar year	1 Jan 2005 ^b
	calendar year	40 µg/m ³		1 Jan 2005
	24 hours	50 µg/m ³	not to be exceeded > 7 times per calendar year	1 Jan 2010
	calendar year	20 µg/m ³		1 Jan 2010 ^b
Pb	calendar year	0.5 µg/m ³	None	1 Jan 2005 ^d
Benzene	calendar year	5 µg/m ³ ^e	None	1 Jan 2010 ^b
CO	rolling 8-hour mean	10 mg/m ³ ^e	None	1 Jan 2005
O ₃	8 hour mean	120 µg/m ³	25 exceedances	1 Jan 2010
Arsenic	Annual average	6 ng/m ³	Total content in the PM ₁₀ fraction averaged over calendar year	31 Dec 2012
Cadmium	Annual average	5 ng/m ³	Total content in the PM ₁₀ fraction averaged over calendar year	31 Dec 2012
Nickel	Annual average	20 ng/m ³	Total content in the PM ₁₀ fraction averaged over calendar year	31 Dec 2012
Benzo(a)pyrene	Annual average	1 ng/m ³	Total content in the PM ₁₀ fraction averaged over calendar year	31 Dec 2012

^a Formed from 10-minute averages or 15-minute averages (UK)

^b A decreasing margin of tolerance is applicable until this date.

^c E.I.F. = entry into force (of EU Directive).

^d Or 2010 at industrial sites contaminated with lead

^e Currently proposed values

Table 2.2 Limit values used for MCERTS performance standards

Pollutant	Limit value ^a
Sulphur dioxide	350 µg/m ³
Nitrogen dioxide	200 µg/m ³
Ozone	120.0 µg/m ³
Carbon monoxide	10 mg/m ³
Particulate matter (PM ₁₀)	50.0 µg/m ³
Benzene	5 µg/m ³

^a When expressing pollutant concentrations in µg/m³ or mg/m³ the volume shall be standardised at a temperature of 273 K and pressure of 101.3 kPa.

combined performance characteristic U_c . Only those performance characteristics that influence directly the uncertainty of the measurements produced by the CAM will be used to derive the combined performance, which shall be expressed as an expanded uncertainty with the level of confidence of 95%. The methodology used is based on the ISO Guide to the Expression of Uncertainty in Measurement (GUM)⁽⁴⁾ and on ISO Standard 14956⁽⁵⁾. It is calculated by summing, in quadrature, the individual standard uncertainties u_i , determined for each relevant performance characteristic.

- 2.3.2 The standard uncertainty u is determined by measurement and in the case of a normal distribution is usually taken as the standard deviation of the mean X_{bar} , as shown in Figure 1. The expanded uncertainty U is defined by multiplying the standard uncertainty u by a coverage factor to obtain a 95% confidence level. Therefore the 95% confidence interval for X lies within the limits defined by $\pm U$. The performance standards are defined in terms of measurement results and should be understood as being \pm values. The numbers included in relevant tables are given as absolute values.

$$u_c = \sqrt{\sum_{i=1}^n u_i^2} \quad (2.1)$$

The combined performance characteristic U_c , expressed at the 95% confidence level, is derived from the combined standard uncertainty u_c by multiplying it by a coverage factor dependent on the total number of degrees of freedom.

- 2.3.2 The combined expanded uncertainties are compared against the MCERTS combined performance standards. The CAM must satisfy this requirement as well as meeting the performance standards specified for all individual performance characteristics. The combined performance standard will not be met if all individual performance characteristics contributing to the combined standard uncertainty are at their individual limits specified by MCERTS. Some of the individual performance characteristics have to be better than the corresponding performance standards if the combined performance standard requirement is to be met. On average, a CAM should have individual performance characteristics equal to half of the corresponding MCERTS performance standards, in order to meet this combined performance characteristic. Combined performance characteristic for CAMs monitoring CO, NO_x, SO₂, O₃ and particulates shall be calculated for an averaging period of one hour.

2.4 Operational conditions

- 2.4.1 CAM systems should be assessed under conditions which are representative of the most challenging intended application for which certification is sought. In rural and remote sites, very low concentration levels may be encountered, and CAMs should have low detection limits and minimal zero and span drift characteristics. In urban locations, including kerbside sites, CAMs are expected to monitor rapidly varying concentrations, over a wide dynamic range. Also these locations are likely to have higher levels of cross-interferent species which could have a greater effect on the CAM. CAMs are generally expected to measure under both of the above conditions and they will therefore be tested against the most challenging criteria.

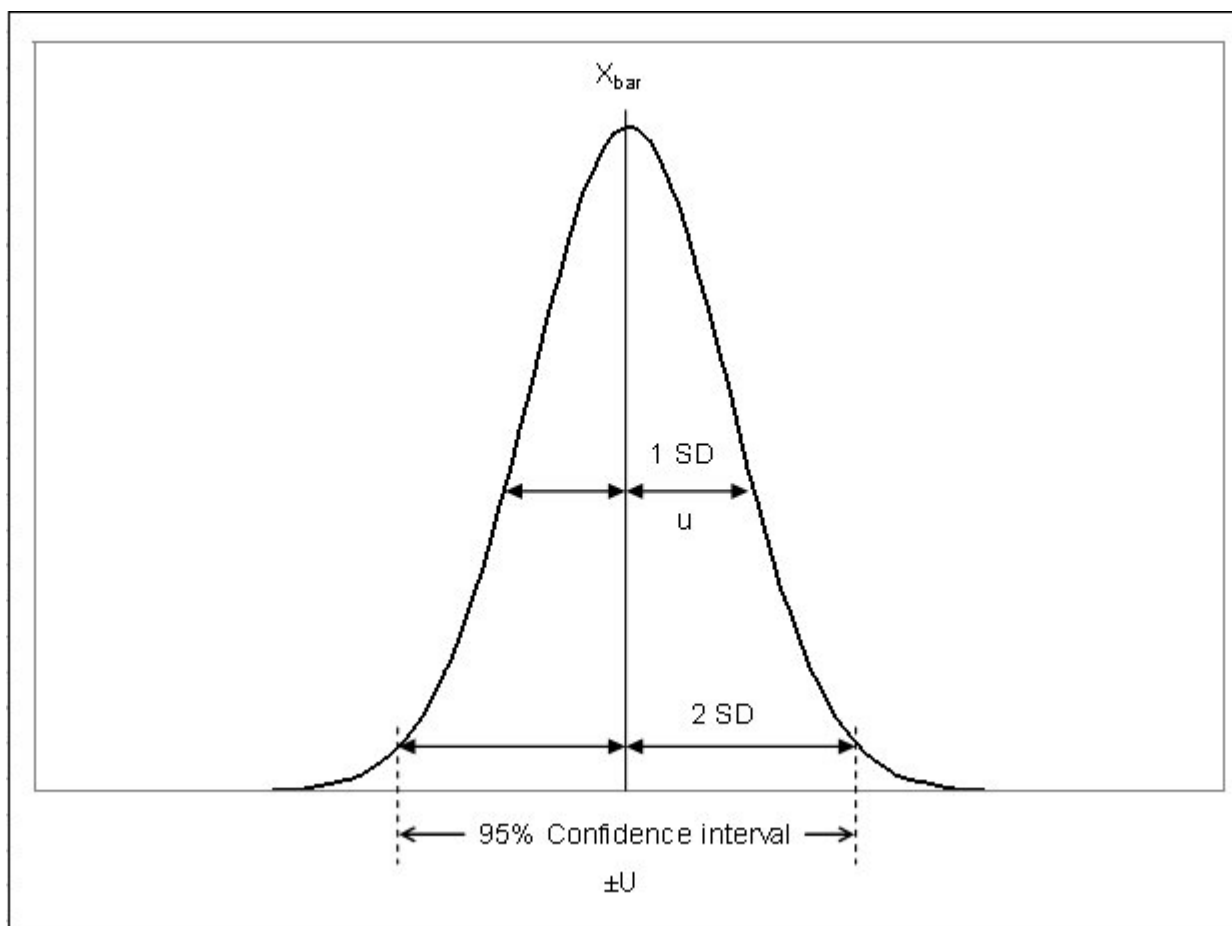


Figure 1

2.4.2 Typical levels of pollutant concentrations measured in the UK are given in Table 2.3.

Table 2.3: Typical concentration values of the determinands covered in this document

Pollutant	Rural		Kerbside	
	Short term	Long term	Short term	Long term
Nitrogen dioxide	25 ppb hourly average	15 ppb annual average	55 ppb hourly average	40 ppb annual average
Sulphur dioxide	10 ppb hourly average	5 ppb annual average	30 ppb hourly average	15 ppb annual average
Carbon monoxide	200 ppb hourly average	100 ppb annual average	4 ppm hourly average	2 ppm annual average
Ozone	70 ppb hourly average	35 ppb annual average	40 ppb hourly average	15 ppb annual average
Particulates (PM ₁₀)	35 µg/m ³ hourly average	25 µg/m ³ annual average	35 µg/m ³ annual average	25 µg/m ³ annual average
Benzene	N/A	0.5 ppb annual average	N/A	2 ppb annual average

3 References

1. European Air Quality Framework, Framework Directive, 96/62 EC, OJ L296, 21/11/1996.
2. European Air Quality Framework and First Daughter Directives, Framework Directive, 96/62 EC, Daughter Directive for SO₂, NO₂, PM₁₀ and Lead, 1999/30/EC, 22 April 1999.
3. Council Directive relating to limit values for benzene and carbon monoxide in ambient air, Directive 2000/69/EC, 16 November 2000.
4. Guide to the Expression of Uncertainty in Measurement, ISBN 92-67-10188-9, 1st ed, Geneva, Switzerland, ISO, 1993.
5. EN ISO 14956, Evaluation of the Suitability of a Measurement Method by Comparison with a Stated Measurement Uncertainty.
6. BS EN 14212:2005 Ambient air quality - Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence.
7. BS EN 14626:2005 Ambient air quality- Standard method for the measurement of carbon monoxide concentrations in ambient air by non-dispersive infrared spectroscopy.
8. BS EN 14211:2005 Ambient air quality- Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence.
9. BS EN 14625:2005 Ambient air quality- Standard method for the measurement of the concentration of ozone by ultraviolet photometry.
10. BS EN 14662-3:2005 Ambient Air Quality- Standard method for the Measurement of Benzene Concentrations. Part 3: Automated pumped sampling with in situ gas chromatography.
11. EN 12341:1999 Air quality – Determination of the PM₁₀ fraction of suspended particulate matter – Reference method and field test procedure to demonstrate reference equivalence of measurement methods.
12. EN 14907:2005 Ambient air quality - Reference gravimetric measurement method for the determination of the PM 2.5 mass fraction of suspended particulate matter.
13. Guide to the demonstration of equivalence of ambient air monitoring methods- Report by an EC Working Group on Guidance for the Demonstration of Equivalence, October 2008.

4 Definitions of performance characteristics and other terms

Availability: Fraction of the total time period for which valid measurement data of the ambient air concentrations is available from an analyser (excluding servicing and calibrations).

Averaging effect: Measure of the uncertainty in CAMs results caused by short term fluctuations in the input concentrations within the time scale shorter than the averaging time T_a .

Averaging time: Period of time over which an arithmetic or time weighted average of concentrations is calculated [T_a – is the averaging period used by the CAMs; T_{ra} is the required data averaging period, e.g. prescribed by legislation].

Combined standard uncertainty: Calculation result of combining the uncertainties determined for all performance characteristics specified for a given type of instrument.

Converter efficiency: Efficiency with which the internal converter unit of a NO_x analyser reduces NO_2 to NO .

Cross-sensitivity: Response of the CAM to determinands other than those that it is designed to measure.

Detection limit: The concentration value of determinand gas above which there is at least a 95 % degree of confidence that the measured value is different from zero.

Drift (short-term) – zero and span: Short-term zero and span drift is a measure of the drift in the output signal over the time period during which other performance characteristics are to be determined.

Effect of sample pressure change: Effect of sample gas pressure on the output signal of the CAM expressed in units of concentration per unit of pressure increment.

Effect of sample temperature change: Effect of sample temperature on the output signal of the CAM expressed in units of concentration per unit of temperature increment.

Expanded uncertainty: An interval about the measurement result that is expected to encompass a specific fraction of the distribution of values attributable to the determinand.

Field repeatability: Expanded uncertainty calculated from the standard deviation of differences between measurements made by two co-located identical analysers over the test period.

Flow-rate accuracy: The difference between the flow measured using a traceable standard and the mean flow rate.

Flow-rate stability: Assessment of statistical variations of flow in the sampling train during the test defined as a ratio of the standard deviation of the measured flow and the mean flow rate.

Lack of fit: Measure of fit of the instrument's response across its measurement range to a straight line using a number of samples of approximately equally distributed concentrations of a pollutant and a zero concentration.

Maintenance interval: Time in the operating environment in the field over which the CAM zero and span drifts remain within specific limits.

Repeatability: Repeatability is a measure of the variation between successive measurements made maintaining the input span gas and all influence variables as constant as practicable.

Response time: A measure of the dynamic response of the CAM to a step change in the pollutant concentration [RT_{rise} is response time to a positive step change in pollutant concentration; RT_{fall} is response time to a negative step change in pollutant concentration].

5 General instrument requirements

5.1 General requirements for CAMs submitted for testing

5.1.1 Manufacturers are required to submit the following:

- two identical, complete air quality monitoring systems (CAMs);
- calibration gases (where appropriate);
- for gaseous CAMs, all components required for the connection to a sampling manifold (but not the sampling manifold itself);
- all necessary components for operation under field conditions;
- for particulate monitors, all sampling components (including the sampling head).

5.1.2 The CAM submitted for testing shall have analogue or digital outputs that allow the provision of negative readings with respect to zero of at least 15% of the certification range, to ensure that the instrument performance tests carried out around the zero reading are valid (e.g. tests of zero drift, detection limit and cross-interference), and not truncated at the CAM's zero reading.

5.1.3 The determinand concentrations measured by a CAM are generally expressed either in density units (mass of determinand per unit volume of the ambient atmosphere) or in volume fraction units (volume of determinand per unit volume of the ambient atmosphere), although other units may also be used. The first of these units (density) is directly dependent on the temperature and pressure of the ambient atmosphere, while the second of these (volume fraction) may also have a weak dependence. Nationally traceable calibration gas mixtures, however, are generally defined in units of mole fraction, which are independent of gas temperature and pressure. Conversion factors between these different units may be calculated, but there may be uncertainties in some of the parameters in the conversion calculations. The CAM manufacturer or

supplier shall inform the relevant MCERTS Certification Committee and the test house(s) as to which concentration units are being used, and the test house shall take these conversion calculations and any uncertainties into account when carrying out relevant tests. The test house and the MCERTS Certification Committee shall, where required, provide comments on the validity of any such algorithm employed by the CAM supplier or manufacturer, to ensure its proper subsequent use. It is therefore essential that the measurement units used by the CAM and any conversions to reference conditions applied (e.g. gas pressure and temperature) are clearly and unambiguously identified by the manufacturer. Results reported in units of mass per unit volume shall be expressed at standard temperature and pressure (temperature of 293 K, pressure of 101.3 kPa).

- 5.1.4 The CAM submitted for testing shall be in conformity with all applicable EC Directives. These include the Electro-magnetic Compatibility Directive 89/336/EEC, and its amendments 92/31/EEC and 93/68/EEC, and the Directive 72/23/EEC covering electrical equipment designed for use within certain voltage limits, and its amendment 93/68/EEC. Equipment within the scope of the Hazardous Atmospheres Directives falls outside the scope of this ambient MCERTS document. CAM manufacturers or suppliers shall supply declarations of conformity to all relevant Directives applicable to the equipment.

5.2 Response times

- 5.2.1 The response times RT_{rise} and RT_{fall} (as defined in Section 4) shall be determined as a part of the performance tests. A minimum performance requirement is that the CAMs shall have response times RT_{rise} and RT_{fall} less than 25% of the required averaging period. Table 5.1 lists examples of the averaging times used in the UK for collecting ambient air quality information. The performance standards for the response time take account of the residence times in a typical manifold, as these are not tested under the MCERTS Scheme. The minimum performance requirements for manifolds and/or sampling lines etc are given in Appendix 1.
- 5.2.2 CAMs shall have response times to positive and negative step changes in concentration that are within 10% (see Table 6.1) to ensure fast fluctuations of air quality concentrations are averaged correctly.
- 5.2.3 Some CAMs use adaptive filters for data smoothing. When testing the response times, the tests shall be performed with the filter enabled if this is the intended mode of operation. The response times measured shall be used to compare with the performance standards.
- 5.2.4 When testing NO_x CAMs, the response time shall be determined using both NO and NO_2 as the test gas. The response time for both gases will be compared with the performance standard.

5.3 Averaging times

- 5.3.1 Most of the performance requirements given in this document apply to results produced by CAMs that are averaged values of the pollutant concentration over a period defined as the averaging time T_a . In cases where the CAM internally produces

averaged results and where the averaging time T_a is selectable, then it shall be selected by the CAM manufacturer or supplier, in consultation with the MCERTS Certification Committee and the test house(s). In most cases the averaging times specified for air quality monitoring given in Table 5.1 should be used. The averaging times actually used will be stated on the MCERTS certificate.

Table 5.1 Examples of averaging times used for sampling and reporting in the UK

Pollutant	Typical averaging time (T_a^a) (also sampling time for benzene))
Carbon monoxide	15 minutes
Nitrogen dioxide	15 minutes
Ozone	15 minutes
Particulates (PM ₁₀)	15 minutes
Sulphur dioxide	15 minutes
Benzene	1 hour

^adefined in Section 4.

5.4 Certification range

- 5.4.1 The CAM's manufacturer or supplier shall specify and agree with the MCERTS Certification Committee, for each pollutant concentration to be measured, a certification range of concentrations over which the CAM is to be tested for each determinand.
- 5.4.2 Each certification range shall be generally between zero and a maximum value of the pollutant concentration. These values shall be agreed by the MCERTS Certification Committee as being fit for the intended purpose.
- 5.4.3 Typical values of the certification range for CAMs are given in Table 5.2. These ranges are recommended unless the CAM manufacturer or supplier and the Certification Committee agree that there is a strong justification for selecting different ranges. Where no limit value is given, the compliance with the performance standards shall be verified at 70-90% of the certification range. If a manufacturer or supplier wishes to demonstrate performance over different ranges, additional testing will be required for each range.
- 5.4.4 Where the CAM has user-selectable settings, range for example, these would be chosen by the CAM manufacturer or supplier and agreed with the Certification Committee in conjunction with the test house(s), to be appropriate for the certification range. In practice, the CAM range selected is likely to be similar to the certification range, although this is not essential. However, the CAM will be tested only over the certification range. The CAM settings, once chosen, will not be altered during the tests.

Table 5.2 Typical certification ranges for CAMs

	Rural and remote sites (Category 1)		Urban background/centre, suburban, kerbside, roadside and industrial sites (Category 2)	
	Scale min.	Scale max.	Scale min.	Scale max.
NO	0.0 ppb	400 ppb	0.0 ppb	2000 ppb
NO ₂	0.0 ppb	400 ppb	0.0 ppb	2000 ppb
SO ₂	0.0 ppb	400 ppb	0.0 ppb	2000 ppb
CO	0.0 ppm	10 ppm	0.0 ppm	50 ppm
O ₃	0.0 ppb	500 ppb	0.0 ppb	500 ppb
PM ₁₀	0.0 µg/m ³	1000 µg/m ³	0.0 µg/m ³	1500 µg/m ³
PM _{2.5}	0.0 µg/m ³	1000 µg/m ³	0.0 µg/m ³	1500 µg/m ³
Benzene	N/A	N/A	0.0 µg/m ³	50.0 µg/m ³

5.4.5 Auto-ranging CAMs will not have their ranges adjusted in any way by the test house(s) during the tests. The certificate will state that the performance tests have been carried out in auto-range mode. The certificate will show only the certification range tested and will not mention any internal range settings to which the CAM may have switched during the tests. If the CAM manufacturer or supplier wishes to certify the CAM at specific internal range settings, separate tests shall be performed, using agreed certification ranges. Where the output of an auto-ranging CAM is not converted to air quality units, or to a normalised scale, then an output must be available to flag which internal range setting applies to the output data signal.

5.4.6 The certificate will list all the ranges certified and the CAM settings used, and will state explicitly the performance characteristics tested.

5.5 Zero and span drift

5.5.1 During the field tests the measurement of long-term drift will be made by supplying certified zero and calibration gases externally to the sampling port of the CAM.

5.5.2 In addition, the CAM will have associated with it, where possible, a methodology using either an automated or a manual method to measure the zero drift and span drift of the complete system. The CAM supplier or manufacturer shall provide a description of the methodology used to determine these drifts. This will be assessed during the field tests.

5.5.3 During the laboratory and field tests the settings of the monitor shall be as the manufacturer requires. All settings shall be noted in the test report.

5.6 NO_x analysers

- 5.6.1 NO₂ is not directly measured by most current NO_x CAMs, but instead is obtained by subtracting the measured NO concentration from the measured NO_x concentration.
- 5.6.2 When the NO₂ concentrations approach the limit value in an urban background/centre scenario, the accompanying concentrations of NO are typically 5 - 6 times the NO₂ concentrations. Therefore testing of the CAM's performance characteristics with NO test gas shall be done at a NO concentrations as indicated in EN14211⁽⁸⁾.

5.7 Sampling line, sampling manifold and particulate filter

- 5.7.1 Sampling manifolds will not be tested under the MCERTS Scheme. However, Appendix 1 provides recommended minimum requirements for the design of manifolds and sample lines.
- 5.7.2 For gaseous CAMs, a particulate filter is generally installed to precondition the sample before it enters the analytical unit of the CAM. This particulate filter shall retain all particulate matter likely to alter the performance of the CAM analytical unit or contaminate its internal components. The filter housing shall be so constructed that it does not retain or convert the determinand(s) of interest. Tests of the CAM will be carried out with this particulate filter included.

5.8 Cross-sensitivity to interfering substances

- 5.8.1 The CAM's response to interferent gases shall be tested. The interferent gas concentrations shall be set at levels indicated in the EN Standards^(6,7,8,9).
- 5.8.2 Cross-sensitivity tests shall be performed using binary mixtures of each interferent gas with the determinand gas at the concentration indicated in the EN Standards^(6,7,8,9).

5.9 Lack of fit

- 5.9.1 This performance standard is to be specified as the percentage of the measured value. Linearity shall be assessed at six points approximately equally spaced across the measurement range, with one point at zero concentration. The differences between the best-fit line and an average at each point expressed as percentages of the measured value will be compared with the performance standard.
- 5.9.2 When deciding on the NO concentrations to be used for the test of linear fit for NO_x CAMs, the lowest non-zero test concentration shall be at or below the NO₂ limit value concentration.

6. Determinand specific requirements

6.1 Certification of CAMs

6.1.1 CAMs submitted for certification may fall into one of three categories:

- systems based on EN standard methods (for example, UV fluorescence, chemiluminescence, UV absorption, IR GFC);
- systems using a different method (for example, chemiluminescence for ozone, β -attenuation for particulates);
- previously certified CAMs with modifications that may affect performance.

6.1.2 A CAM submitted for certification based on an EN standard method is subjected to the programme of performance testing specified in the relevant standard^(6,7,8,9,10). A particulate monitor based on the EN standard methods^(11,12) is tested following the guidance in the Guide to the demonstration of equivalence of ambient air monitoring methods⁽¹³⁾.

6.1.3 Any other CAMs are treated as “black box” measurement systems and are tested to determine whether their individual performance characteristics and the overall expanded uncertainty meet the pass-fail criteria. The field testing procedures of such CAMs include determination of field repeatability (between two identical systems) and comparison with a certified reference analyser (based on the EN standard method). The measurement results shall be used to calculate systematic differences between the standard reference method and the paired instruments under test. The collected data shall be evaluated using the formula and assessment criteria specified in the EC document Guide to the demonstration of equivalence of ambient air monitoring methods⁽¹³⁾.

6.1.4 If a CAM is a modification to an existing approved CAM then only the laboratory performance characteristics that are affected by the modification are tested and their standard uncertainties as well as the new combined uncertainty are calculated.

6.1.5 The performance standards are expressed in terms of measurement results from which standard uncertainties can be derived, in keeping with international procedures.

6.1.6 Testing is required on two identical systems.

6.2 Performance standards for CAMs measuring SO₂, NO_x, CO and O₃

6.2.1 CAMs used for monitoring SO₂, NO_x, CO and O₃ draw in a sample of ambient air, usually from a manifold, into an analytical system where the concentration of the relevant pollutant is measured. For NO_x monitoring systems, however, a catalytic converter is used to reduce NO₂ to NO, and two measurements of NO are made, with and without the converter, to allow the NO₂ concentration to be determined by difference.

6.2.2 The certification procedure for CAMs measuring SO₂, NO_x, CO and O₃ is shown in Figure 2.

6.2.3 The performance standards are given in Table 6.1.

6.3 Field testing of CAMs measuring SO₂, NO_x, CO and O₃

6.3.1 The test sites shall be representative of the typical conditions for which certification is being sought including possible episodes of high concentrations. For CAMs not based on a standard reference method a minimum of four comparisons of one month duration each shall be performed with emphasis on the following factors:

- air composition including high and low concentrations and potential interferences;
- range of air humidity and temperature representative of the monitoring site;
- range of wind speeds representative of the monitoring site.

6.3.2 During the tests the following information shall be recorded:

- calibration procedures and equipment used including information on standard traceability;
- air pressure and temperature;
- specific events and situations that may have a bearing upon the performance of instruments.

6.3.3 Of the full data set, 20% of results shall be greater or equal to the upper assessment threshold specified in the relevant Daughter Directive. Data ratification is allowable but measurement results can only be removed when sound technical reasons can be found to do so. If this requirement cannot be fulfilled due to difficulty in finding an appropriate measurement site, the site acceptability shall be decided by the Certification Committee.

Figure 2 - MCERTS certification of CAMs for gases

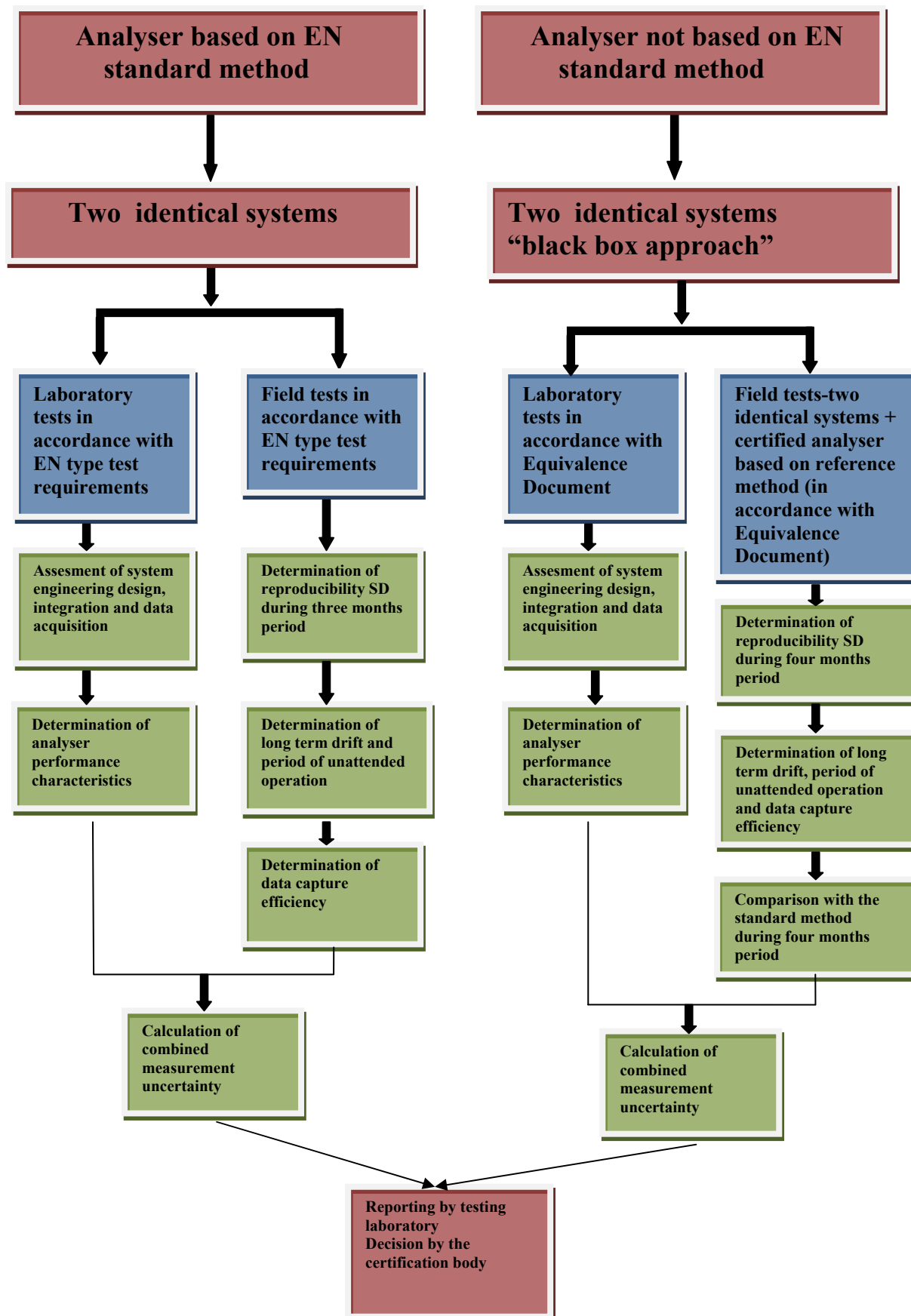


Table 6.1 Analyser performance characteristics and assessment criteria

NOTE nmol/mol = ppb

Item	Performance characteristic	Lab test	Field test	Performance criterion			
				SO ₂	NO _x	CO	O ₃
1	Repeatability at zero	x		≤ 1.0 nmol/mol	≤ 1.0 nmol/mol	≤ 1.0 μmol/mol	≤ 1.0 nmol/mol
2	Repeatability at hourly limit value	x		≤ 3.0 nmol/mol	≤ 3.0 nmol/mol	≤ 3.0 μmol/mol	≤ 3.0 nmol/mol
3	Residual lack of fit at zero	x		≤ 5.0 nmol/mol	≤ 5.0 nmol/mol	≤ 0.2 μmol/mol	≤ 5.0 nmol/mol
4	Lack of fit (largest residual from the linear regression line)	x		≤ 4 % of the measured value ^b	≤ 4 % of the measured value ^b	≤ 4% of the measured value ^b	≤ 4 % of the measured value ^b
5	Sensitivity coefficient to sample gas pressure	x		≤ 3.0 nmol/mol/kPa	≤ 8.0 nmol/mol/kPa ^a	≤ 0.7 μmol/mol/kPa ^a	≤ 2.0 nmol/mol/kPa
6	Sensitivity coefficient to sample gas temperature	x		≤ 1.0 nmol/mol/K	≤ 3.0 nmol/mol/K	≤ 0.3 μmol/mol/K	≤ 1.0 nmol/mol/K
7	Sensitivity coefficient of surrounding air temperature	x		≤ 1.0 nmol/mol/K	≤ 3.0 nmol/mol/K	≤ 0.3 μmol/mol/K	≤ 1.0 nmol/mol/K
8	Sensitivity coefficient of electrical supply voltage	x		≤ 0.3 nmol/mol/V	≤ 0.3 nmol/mol/V	≤ 0.3 μmol/mol/V	≤ 0.3 nmol/mol/V
9	Converter efficiency	x		-----	> 98%	-----	-----
10	Interference by H ₂ O ^c	x		≤ 10 nmol/mol at concentration of 19 mmol/mol ^d	≤ 5 nmol/mol at concentration of 19 mmol/mol ^d	≤ 1μmol/mol at concentration of 19 mmol/mol ^d	≤ 10 nmol/mol at concentration of 19 mmol/mol ^d
11	Interference by H ₂ S ^c	x		≤ 5 nmol/mol at concentration of 200 nmol/mol	-----	-----	-----
12	Interference by NH ₃ ^c	x		≤ 5 nmol/mol at concentration of 200 nmol/mol	≤ 5 nmol/mol at concentration of 200 nmol/mol	-----	-----
13	Interference by NO ^c	x		≤ 5 nmol/mol at concentration of 500 nmol/mol	-----	≤ 0.5 μmol/mol at concentration of 1 μmol/mol	-----
14	Interference by NO ₂ ^c	x		≤ 5 nmol/mol at concentration of 200 nmol/mol	-----	-----	-----
15	Interference by m-xylene ^c	x		≤ 10 nmol/mol at concentration of 1 μmol/mol	-----	-----	≤ 5 nmol/mol at concentration of 0.5 μmol/mol
16	Interference by toluene ^c	x		-----	-----	-----	≤ 5 nmol/mol at concentration of 0.5 μmol/mol
17	Interference by CO ₂ ^c	x		-----	≤ 5 nmol/mol at concentration of 500 μmol/mol	≤ 0.5 μmol/mol at concentration 500 μmol/mol	-----

Table 6.1 Analyser performance characteristics and assessment criteria (continued)

Item	Performance characteristic	Lab test	Field test	Performance criterion			
				SO ₂	NO _x	CO	O ₃
18	Interference by N ₂ O ^c	x		-----	----- --	≤ 0.5 µmol/mol at concentration of 50 nmol.mol	-----
19	Interference by ozone ^c	x		-----	≤ 2 nmol/mol at concentratio n of 200 nmol/mol	-----	-----
20	Averaging effect	x		≤ 7% of the measured value	≤ 7% of the measured value	≤ 7% of the measured value	≤ 7% of the measured value
21	Reproducibility under field conditions ^f		x	≤ 5% of the average over a three months period	≤ 5% of the average over a three months period	≤ 5% of the average over a three months period	≤ 5% of the average over a three months period
22	Long term drift at zero		x	≤ 5 nmol/mol	≤ 5 nmol/mol	≤ 0.5 µmol/mol	≤ 5 nmol/mol
23	Long term drift at span level ^a		x	≤ 5% of maximum of certification range	≤ 5% of maximum of certification range	≤ 5% of maximum of certification range	≤ 5% of maximum of certification range
24	Short term drift at zero	x		≤ 2 nmol/mol over 12 h	≤ 2 nmol/mol over 12h	≤ 0.10 µmol/mol over 12 h	≤ 2 nmol/mol over 12 h
25	Short term drift at span level ^a	x		≤ 6 nmol/mol over 12 h	≤ 6 nmol/mol over 12 h	≤ 0.60 µmol/mol over 12 h	≤ 6 nmol/mol over 12 h
26	Response time (rise)	x		180 s	180 s	180 s	180 s
27	Response time (fall)	x		180 s	180 s	180 s	180 s
28	Difference between rise and fall time	x		≤ 10% or 10 seconds	≤ 10% or 10 seconds	≤ 10% or 10 seconds	≤ 10% or 10 seconds
29	Difference between sampling and calibration port	x		≤ 1%	≤ 1%	≤ 1%	≤ 1%
30	Difference in NO ₂ due to residence time in analyser	x		-----	≤ 4 nmol/mol	-----	-----
31	Period of unattended operation		x	3 months but not less than two weeks	3 months but not less than two weeks	3 months but not less than two weeks	3 months but not less than two weeks
32	Availability of analyser		x	> 90 %	> 90 %	> 90 %	> 90 %
33	Total expanded uncertainty	x	x	15%	15%	15%	15%

^a span level is 70-80% of the certification range

^b and 2 nmol/mol at zero (0.2 µmol/mol for CO analysers)

^c performance criterion is set both at zero and span level

^d H₂O concentration of 19 mmol/mol equals 80% RH at 293 K and 101,3 kPa

^e if relevant

^f if the average concentrations at the monitoring site are less than 0.3 of the LV then 0.3 of the LV shall be used instead of average

6.4 Performance standards for CAMS measuring PM₁₀ and PM_{2.5}

6.4.1 Particulate monitoring CAMs collect particulate material over a defined averaging time (T_a) and either:

- dynamically determine the incremental mass increase; by direct mass measurements, e.g. by using an oscillating microbalance, or by a surrogate technique e.g. a β -attenuation gauge; or
- retain the collected material for subsequent analysis (weighing); or
- apply another measurement principle, such as light scattering.

6.4.2 The sampling system is an inherent component of gravimetric particulate monitors, as they require size-selective sampling heads to collect particulate material preferentially according to its aerodynamic size. Two categories of particulate material are currently monitored, PM₁₀ and PM_{2.5}. These refer to the aerodynamic size of ambient particulates collected with sampling heads for which a 50% cut-off is achieved.

6.4.3 The test procedure for CAMS measuring particulate matter is shown in Figure 3.

6.4.4 The laboratory tests depend on the measurement technique employed by the CAM. The requirements are specified in sections 6.5 and 6.6.

6.5 Laboratory tests for CAMs using oscillating microbalances, β -attenuation or light scattering

6.5.1 Laboratory testing of instruments measuring concentrations of particulate matter in ambient air is limited to parameters related to stability of flow through the filter or measurement cell and the provision of a representative sample. The following parameters shall be tested:

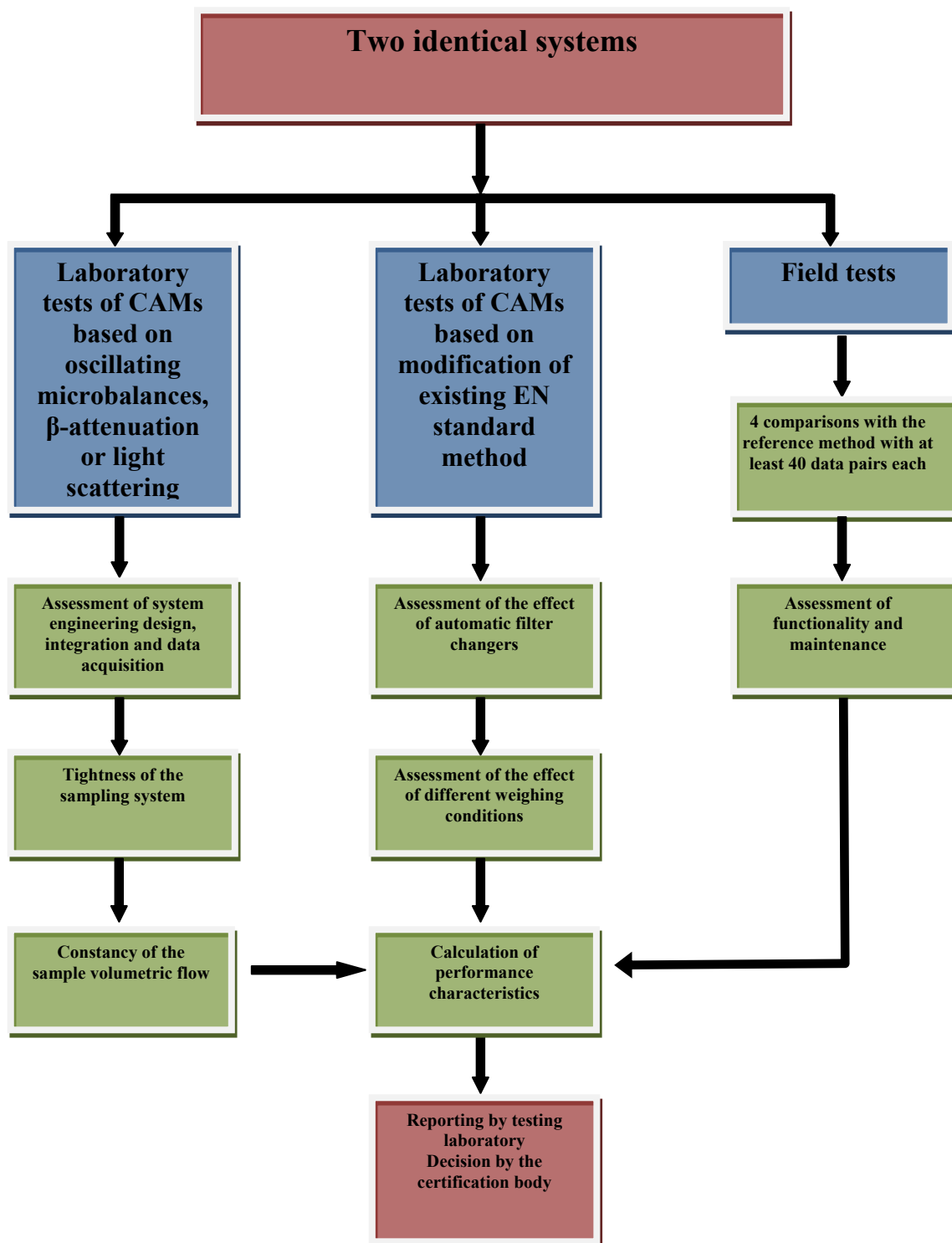
- constancy of sample volumetric flow;
- tightness of the sampling system.

The performance criteria related to the above parameters are given in Table 6.2

Table 6.2 Performance requirements for CAMs measuring PM₁₀ and PM_{2.5} using oscillating microbalances, β -attenuation or light scattering (laboratory tests)

Parameter	Performance requirement
Constancy of sample volumetric flow	Sample volumetric flow averaged over the sampling time to remain constant within $\pm 3\%$ of the rated value. All instantaneous values to remain within $\pm 5\%$ of the rated value.
Tightness of the sampling system	Leakage not to exceed 1 % of the sampled volume.

Figure 3 - MCERTS certification of CAMS for PM10 and PM2.5



6.5.2 Constancy of sample volumetric flow

The testing shall be carried out providing loaded filters, volumetric flow measuring device such as, for example, a mass flow meter and a pressure measuring device. Three pre-loaded filters with the particulate load of approximately 0%, 50%, and 80% of the maximum permissible filter loading shall be used. For each filter the constancy of the sample volumetric flow shall be recorded every 30 minutes as a 3 minute average over the time period of at least 24 hours.

6.5.3 Tightness of the sampling system

The testing is normally carried out with the help of a pressure measuring device and a volumetric flow measuring system. The leak rate of the entire instrument shall be determined if it is feasible. This includes the inlet as well as the whole sampling system and the measuring system. If because of the instrument design the complete system tightness can not be measured the leak rate can be determined separately for the sampling part and the measuring part. The leak rate can be measured by the determination of volume flow at the inlet and outlet of the system or by the pressure drop method. In the latter case the system is sealed at the inlet and evacuated by a built in or separate pump and the pressure increase due to leaks is measured over the period of 5 minutes. The leak rate V_L determination shall be repeated three times. It is calculated from the following formula:

$$V = \frac{\Delta P \cdot V_g}{P_0 \cdot \Delta t}$$

where: ΔP – pressure drop determined over the time interval Δt
 P_0 - pressure at time t_0
 V_g - estimated total volume of the system
 Δt - time interval of the pressure increment

6.6 Laboratory tests for particulate monitoring CAMs using a modified EN Standard Reference Method

6.6.1 The laboratory test programme covers the following modifications of the Standard Reference Method:

- application of automated filter changers leading to filter storage conditions deviating from those prescribed in the reference method;
- use of different weighing conditions from those prescribed in the standard reference method.

6.6.2 Application of automated filter changers

The instruments shall be tested under the worst case conditions envisaged at the monitoring sites. These must reflect the most unfavourable storage temperatures occurring at day and night when semi-volatile materials are expected to be collected

on the filters. A minimum of 40 samples shall be collected under conditions known to produce significant fractions of semi-volatile materials on the filters. These samples shall be removed from the filter and weighed according to the procedure in the EN Standard Method. Subsequently the samples shall be exposed to the established worst case conditions in a temperature controlled cabinet and reweighed following the EN standard procedure. The largest mass loss due to storage shall be determined and used in the uncertainty budget.

6.6.3 Different weighing conditions

Additional uncertainty arising from weighing conditions outside the range specified by the Standard Method shall be assessed for both the blank filters and for samples. A minimum of five blank filters from least two different batches shall be investigated. The maximum mass change due to the weighing conditions shall be used in the uncertainty budget.

6.7 Field testing of CAMs measuring PM₁₀ and PM_{2.5}

6.7.1 General principles

Field tests are performed with the instrument operated side by side with the standard reference method. The purpose of the measurements is to assess the uncertainty between the instruments through the use of two instruments working in parallel and the comparability of the instruments with the standard reference method. Results of existing studies can be used provided that the requirements of the relevant sampling standards have been met.

In order to assess proper functioning of the standard reference method two reference samplers shall be used. The mean squared difference of the results produced by both reference samplers provides an estimate of the random uncertainty of the reference method. Performance criteria for field test results are given in Table 6.3. The tests, calculations of the performance characteristics and calibration procedures shall be conducted in accordance with the Guide to the demonstration of equivalence of ambient air monitoring methods⁽¹³⁾.

6.7.2 Experimental conditions

The test sites selected for the field tests should be representative of the conditions under which the instruments are likely to operate. Occurrences of possible episodes of high concentrations are desirable. A minimum of four comparisons should be carried out with the emphasis on the following variables:

- composition of the PM fraction, preferably including high and low fractions of semi-volatile fractions to be able to cover maximum impact of potential losses;
- high and low air temperature and humidity to cover any conditioning losses of semi-volatiles;
- large variations of wind speed to cover the impact on sampling inlet performance.

Table 6.3 Performance standards for CAMs measuring PM₁₀ and PM_{2.5} (field tests)

Performance characteristic	Performance standard
Between sampler/instrument uncertainty for the standard method	< 2 µg/m ³
Between sampler/instrument uncertainty for the complete data set	< 2.5 µg/m ³
Between sampler/instrument uncertainty for two data sets obtained by splitting the full data set into values below and above 50% of the limit value	< 2.5 µg/m ³
Highest resulting uncertainty estimate comparison against data quality objective	$W_{CM} \leq W_{dqo}$

Note: Calculation algorithms of W_{CM} and W_{dqo} criterion are defined in Guide to the demonstration of equivalence of ambient air monitoring methods⁽¹³⁾.

During the tests the following information should be collected and recorded:

- calibration procedures, equipment and intervals;
- results of the quality assurance checks;
- temperature and pressure of the sampled air;
- humidity and other relevant conditions;
- events likely to affect the measurement results.

A minimum of 40 measurement results, each averaged over a period of 24 hours constitutes a comparison run. Of the full data set at least 20% of the results obtained using the standard method shall be greater than the upper assessment threshold specified for the annual limit values.

6.7.3 Calculation of performance characteristics

The uncertainty between the instruments should be determined:

- for the standard method;
- for the complete data set;
- for two data sets obtained by splitting the whole data set according to PM concentrations; above or below 50% of the limit value.

6.7.4 Comparison with the standard reference method

The performance of the standard reference method can be evaluated by checking the uncertainty between the reference instruments. This uncertainty is satisfactory if the result is $\leq 2 \mu\text{g}/\text{m}^3$.

For the evaluation of uncertainty due to the lack of comparability between the instrument under tests and the standard reference method it is assumed that the relationship between both measurements can be described by a linear function described in the Guide to the demonstration of equivalence of ambient air monitoring methods⁽¹³⁾.

The equation coefficients are calculated using a regression technique involving symmetrical treatment of both variables. A commonly applied computational technique is that of orthogonal regression. The regression equation is calculated for:

- each of the instruments individually;
- data sets for each individual site;
- for a data sets representing PM concentrations greater than or equal to $28 \mu\text{g}/\text{m}^3$ for PM_{10} or concentrations greater than or equal to $17.5 \mu\text{g}/\text{m}^3$ for $\text{PM}_{2.5}$ provided that the subset contains 40 or more valid data pairs.

6.8 Evaluation of data from particulate matter certification tests

6.8.1 Data evaluation procedures

Evaluation of the collected data involves the following stages:

- Evaluation of suitability of data sets;
- Calculation of performance characteristics including between sampler/instrument uncertainty and comparison with the standard method;
- Calculation of the expanded uncertainty of the sampler/instrument under tests;
- Application of the calibration functions (if required);
- Application of the pass-fail criteria based on the comparison of the highest expanded uncertainty of the test results with the data quality objective.

The highest resulting uncertainty estimate W_{CM} is compared with the expanded relative uncertainty based on the data quality objectives W_{dqo} . The criteria for acceptance or rejection are as follows:

$W_{\text{CM}} \leq W_{\text{dqo}}$ the instrument is accepted as equivalent to the standard reference method.

$W_{\text{CM}} > W_{\text{dqo}}$ the instrument is not accepted as equivalent to the standard reference method.

Data may be removed from the data set when there are sound technical reasons for doing so, such as errors due to manual handling of filters. The calculation procedures and formulae for evaluation of the data sets are given in the Guide to the

demonstration of equivalence of ambient air monitoring methods⁽¹³⁾. The flow chart illustrating the data evaluation process is given in Figure 4.

6.8.2 Summary of acceptable deviations from strict adherence to the Guide to the demonstration of equivalence of ambient air monitoring methods⁽¹³⁾.

Recent UK experience in testing particulate monitoring instrumentation for the purpose of the UK national network has revealed ambiguities in the treatment of data required by the Guide. The MCERTS performance standards accept the following recommendations resulting from this work:

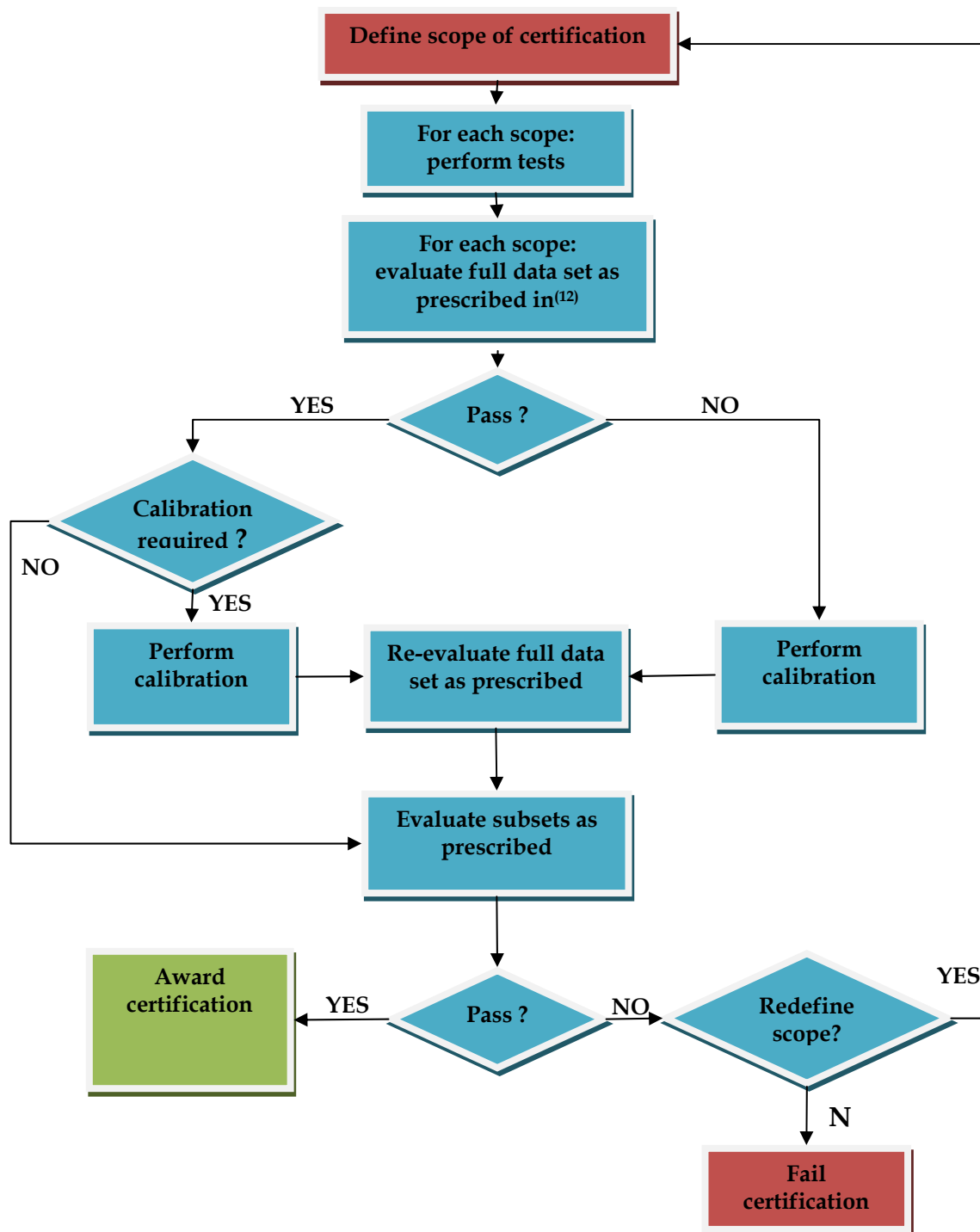
- Significant outliers are sometimes observed when considering the intra-instrument comparison of filter mass based measurements. These outliers are thought to be caused by human errors in the processing of filters and may potentially lead to unjustified failure of the certification process. The outliers shall be identified by repeated application of the Grubbs' test until either a critical value is not exceeded or at most 5% of the data pairs are removed.
- The Guide states that precondition of data acceptance of a dataset is that the slope and intercept should not be significantly different from 1 and zero for any of the individual or combined datasets. These criteria may have the effect of punishing instruments with low scatter while rewarding instruments with relatively large scatter. To avoid these problems data shall be corrected only if the slopes of the data sets are all greater or all less than 1 and/or all the intercepts of the datasets are all greater or all less than zero.
- When an instrument fails on WCM (expanded uncertainty) for the < 50% of the limit value dataset alone either before or after the slope and/or intercept correction this is not sufficient grounds for rejection.
- The requirements of EN 14907 for maximum 15 days filter storage before weighing and filter rejection if the difference between the masses of the two pre-weighings and two post-weighings is greater than 40 and 60 µg, respectively are too restrictive and may result in severe impact on the capture of data. Advice shall be sought from the Certification Committee before application of such criteria.

6.9 Performance standards for benzene monitoring systems

6.9.1 These performance standards apply to cyclic automated CAMs, which draw in a known volume of air through a sorbent medium for a fixed time, and then analyse the amount of benzene trapped using an automated gas chromatograph. The standards are applicable to measurements of airborne benzene vapour in the concentration range from 0 µg/m³ to 50 µg/m³ and the certification is normally carried out for this concentration range.

6.9.2 The standards can also be applied to systems monitoring other organic compounds with the agreement of the Certification Committee. Such organic compounds may be included in the instrument certification with the application of the same testing procedures, performance characteristics and assessment criteria as those formulated for benzene in BS EN 14662-3:2005⁽¹⁰⁾. These compounds include but are not limited to: (in the C2-C6 group) ethane, ethene, propane, propene, iso-butane, n-butane, acetylene, trans-2-butene, 1-butene, cis-2-butene, 2-methyl butane, n-pentane, 1-3 butadiene, trans-2-pentene, 1-pentene, 2-methyl pentane, n-hexane, isoprene and

Figure 4 - Evaluation of data during MCERTS certification of PM10 and PM2.5 samplers/instruments



(in the C6-C12 group) 2,2,4-trimethyl pentane, n-heptane, toluene, n-octane, ethyl benzene, m-xylene, p-xylene, o-xylene, 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene and 1,2,3-trimethyl benzene.

- 6.9.3 A measured volume of the air sampled is drawn through a sorbent tube where benzene is retained. The collected benzene is then thermally desorbed and transferred by an inert gas flow into a gas chromatograph equipped with a capillary column and a flame ionization detector or other suitable sensor where it is analysed. Before entering the column a sample is concentrated either by a cryo-trap or by a pre-column where higher boiling hydrocarbons are removed by back-flush.
- 6.9.4 Two types of instrumentation are in use; one equipped with a single sampling trap and the other equipped with two or more traps. Multi-trap instruments have the advantage of providing uninterrupted sample analysis. Typical cycling times vary between 15 minutes and 1 hour. The certification procedure is shown in Figure 5.
- 6.9.5 Certification assessment

The analysers tested shall comply with:

- the requirements given in Table 6.4 for each individual performance characteristic during the laboratory tests;
 - the requirements given in Table 6.5 for each individual performance characteristic during the field tests ;
 - the expanded measurement uncertainty, calculated from the combination of the relevant performance characteristics, shall be less than the maximum allowable value prescribed in the relevant directive.
- 6.9.6 The calculation of total expanded uncertainty is based on the procedures laid down in CR 14377⁽¹⁴⁾. The calculation is performed in two steps:
- Calculation of total uncertainty using the values of performance characteristics determined in the laboratory tests;
 - Re-calculation of the total uncertainty determined as above replacing the short term drift found in the laboratory tests by the long term drift determined in the field and replacing the repeatability found in the laboratory tests with reproducibility found in the field tests.
- 6.9.7 The uncertainty of the measurement result given by the analyser is influenced not only by its performance characteristics but also by site specific conditions which are not known in advance. The default values listed in Table 6.6 shall be used in the calculation of total uncertainty for the purpose of certification.

Figure 5 - MCERTS certification of CAMS for benzene

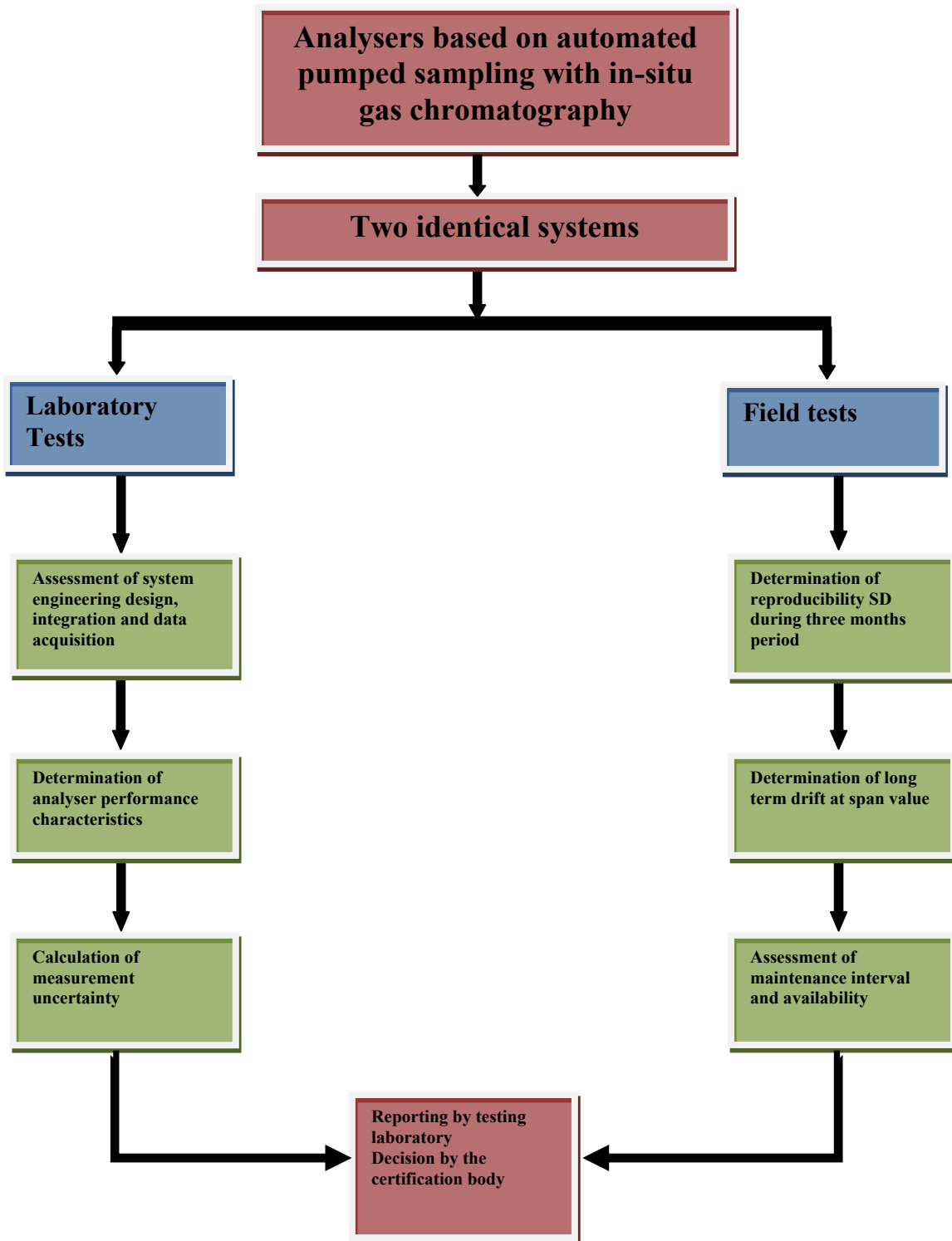


Table 6.4 Performance standards for benzene CAMs (laboratory tests)

Performance characteristic	Performance standard
1. Lack of fit, largest residual	< ± 5%
2. Repeatability at 0.5 µg/m ³	< ± 0.3 µg/m ³
3. Repeatability at limit value	< ± 5%
4. Interference by ozone	< ± 5%
5. Interference from the sum of possible organic compounds at span value	< ± 5%
6. Effect of relative humidity	< ± 4%
7. Sensitivity coefficient of the surrounding air temperature effect at span	< ± 0.2%/K
8. Sensitivity coefficient of the ambient pressure effect at span	< ± 1%/kPa
9. Sensitivity coefficient of voltage effect at span	< ± 0.2%/V
10. Short term (24h) drift at span	< ± 5%
11. Carry over	< 10% of the limit value for the first analysis after the response time
Parameters 1 and 3-9 are used in the calculation of combined uncertainty of the measured value. Where the performance criterion is expressed as a percentage its value should be calculated as 100u/C, where u is the uncertainty component in µg/m ³ calculated using the relevant formula and C is the highest concentration used in the test in µg/m ³ . The values of the performance criteria should be calculated using the formula and procedures given in EN 14662-3 ⁽¹⁰⁾ .	

Table 6.5 Performance standards for benzene CAMs (field tests)

Performance characteristic	Performance standard
1. Reproducibility standard deviation	± 0.25 µg/m ³
2. Long term drift at span (14 days)	± 10%
3. Maintenance interval	> 14 days
4. Availability	> 90%
Parameters 1 and 2 are used in the calculation of combined uncertainty. The values of the performance criteria should be calculated using the formula and procedures given in EN 14662-3 ⁽¹⁰⁾ .	

Table 6.6 Default values and limiting conditions

Parameter	Default values used for the calculation of uncertainty	Limiting conditions for the laboratory tests
Surrounding air temperature variations	278 K and 308 K	293±2 K
Sampling gas pressure variations	± 5 kPa	Ambient ±0.2 kPa
Voltage variations	± 20 V (about 10% of the line voltage)	230 ± 2.5 V
Relative humidity of sample	20 % and 80%	(50 ± 10) %

6.9.8 Interfering compounds

Possible interference from organic compounds should be investigated by generation of a gas mixture of the species listed in Table 6.7 at the concentrations of about 3-10 µg/m³ for each compound (except humidity and ozone).

Table 6.7 Possible interfering compounds

Compound
methylcyclopentane
2,2,3- trimethylbutane
2,4 - dimethylpentane
tetrachloromethane
cyclohexane
2,3 - dimethylpentane
2- methylhexane
3- ethylpentane
trichloroethylene
n-heptane
water vapour
ozone

6.9.9 Selection of the field site

Selection of a monitoring site for the field test is based on the following criteria:

- Location: Urban – 4 to 5 metres from the kerbside
- Monitoring station facilities: Sufficient capacity of the sampling manifold, enough space for two complete analysers together with the calibration equipment, air conditioning, access to telemetry-telephone, accessibility.

Appendix 1: Recommendations for sampling lines and manifolds

- A1.1 The sample intake should be constructed in such a way that suction of rain water into the sample line (or CAM system) is prevented. The material of the sample intake as well as the sample line (or CAM system) can influence the composition of the gas in the sampling line. Materials such as polytetrafluoroethylene (PTFE), perfluoroethylene-propylene (FEP), glass or stainless steel may be used. Copper or copper-based alloys should not be used. If condensation due to high ambient temperatures and/or humidity occurs, the sample lines may be moderately heated.
- A1.2 In the case of NO_x measuring CAMs, in order to avoid disturbance of the nitrogen monoxide-nitrogen-dioxide-ozone equilibrium in the sample line (or system), the residence time in the sample system (or line) from the sampling inlet to the monitor should be such that the increase of the nitrogen dioxide content in the sample is less than 2%. The influence of the pressure drop along the complete sampling system, including any filter, should be such that it causes an apparent concentration change of less than 1% of the signal output of the analyser.
- A1.3 The increase of the sampled nitrogen dioxide is due to the effect of the reaction of ambient ozone with nitric oxide in the sampling line. The influence of the residence time on the increase of nitrogen dioxide in the sampling line can be estimated by the following formula:

$$[O_3]_0 = \frac{b \cdot [O_3]_t}{[O_3]_t - [NO]_t \cdot e^{(b \cdot k \cdot t)}} \quad (A4.1)$$

where:

- [O₃]₀ is the ozone concentration at the sample manifold inlet;
- [O₃]_t is the ozone concentration after t seconds of residence time in the sampling line;
- [NO]_t is the nitric oxide concentration after t seconds of residence time in the sampling line;
- b is the concentration difference between [O₃]_t and [NO]_t: b = [O₃]_t - [NO]_t with b ≠ 0;
- k is the rate constant for the reaction of O₃ with NO: k = 4.43x10⁻⁴ ppb⁻¹s⁻¹ at 25°C;
- t is the residence time in seconds,

and

$$[O_3]_0 - [O_3]_t = [NO]_0 - [NO]_t$$

where

- [NO]₀ is the NO concentration at the sample manifold inlet

Example

Assuming a residence time of 2 seconds in the manifold and the following concentrations measured after the sampling manifold:

$$[O_3]_t = 22 \text{ ppb}$$

$$[NO]_t = 100 \text{ ppb}$$

Equation (A4.1) will give an ozone concentration at the sample inlet, $[O_3]_0$, of 24.1 ppb and therefore a NO concentration at the sample inlet of 97.9 ppb. This would result in an increase of 2.1 ppb of NO_2 due to the reaction of NO and O_3 in the sampling manifold and a loss of 2.1 ppb of NO.