

Stationary source emissions — Quality assurance of automated measuring systems

The European Standard EN 14181:2004 has the status of a
British Standard

ICS 13.040.40

National foreword

This British Standard is the official language version of EN 14181:2004. The standard was developed primarily to satisfy the needs of two European directives: The Waste Incineration Directive (2000/76/EC) and the Large Combustion Plant Directive (2001/80/EC), which require the calibration of continuous emission monitors (described in EN 14181 as automated measuring systems — AMSs) to accurate and known standards. However, although this standard must be applied to continuous emission monitoring used on waste incinerators and large combustion plant covered by these directives, it may also have applications to other types of industrial plant, where the relevant parties agree.

This standard includes three different test procedures:

- A procedure (QAL2) to calibrate the continuous emission monitor/AMS following its installation;
- A procedure (QAL3) to maintain and demonstrate the results obtained during normal operations of the monitor;
- A procedure (AST) for annual surveillance tests on the system to ensure that its performance remains as previously determined.

It is assumed that most of the work required in the QAL2 and AST procedures will be carried out by a testing laboratory experienced in carrying out the required tests, with measurements made using Standard Reference Methods. This testing laboratory must also be recognized by the relevant competent authority. Alternatively, the industrial plant operator may carry out this work, provided they are recognized by the competent authority. The QAL3 procedure will normally be carried out by the industrial plant operator.

Users of this standard should also be aware that it has been developed to enable users to interpret the requirements of the above two directives, and that the statistics contained in the standard do not fully conform with the requirements of the ‘Guide to the Estimation of Uncertainty in Measurement’ (ENV 13005, 1999). If users wish to apply this standard outside of the remit of these directives special care should be taken, and users should also understand the limitations of the standard in these respects.

The UK’s participation in the preparation of this standard was entrusted by Technical Committee EH/2, Air quality, to Subcommittee EH/2/4, General air quality issues, which has the responsibility to:

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

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

Cross-references

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

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

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, the EN title page, pages 2 to 59 and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

Amendments issued since publication

Amd. No.	Date	Comments

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 2 December 2004

© BSI 2 December 2004

ISBN 0 580 44881 9

English version

Stationary source emissions - Quality assurance of automated measuring systems

Émission des sources fixes - Assurance qualité des systèmes automatiques de mesure

Emissionen aus stationären Quellen - Qualitätssicherung für automatische Messeinrichtungen

This European Standard was approved by CEN on 3 November 2003.

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

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

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



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

Management Centre: rue de Stassart, 36 B-1050 Brussels

Contents

	Page
Foreword.....	3
Introduction	4
1 Scope	5
2 Normative references	5
3 Terms and definitions	5
4 Symbols and abbreviations	9
5 Principle.....	11
6 Calibration and validation of the AMS (QAL2).....	13
7 Ongoing quality assurance during operation (QAL3).....	21
8 Annual Surveillance Test (AST)	23
9 Documentation.....	27
Annex A (normative) QAL2 and AST functional test of AMS.....	28
Annex B (normative) Test of linearity	32
Annex C (normative) CUSUM Control Charts	34
Annex D (informative) Documentation	40
Annex E (informative) Example of calculation of the calibration function and of the variability test	42
Annex F (informative) Example of calculation of the standard deviation s_{AMS} of the AMS at zero and span level	51
Annex G (informative) Example of using the calibration function and the variability test in the AST.....	54
Annex H (informative) CUSUM charts field form (drift)	58
Bibliography	59

Foreword

This document (EN 14181:2004) has been prepared by Technical Committee CEN/TC 264 “Air quality”, the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by December 2004, and conflicting national standards shall be withdrawn at the latest by December 2004.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association. It supports requirements in the EU Directives 2000/76/EC [1] and 2001/80/EC [2] and may also be applicable for other purposes.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

This standard describes the quality assurance procedures needed to assure that an Automated Measuring System (AMS) installed to measure emissions to air are capable of meeting the uncertainty requirements on measured values given by legislation, e.g. EU Directives [1], [2] or national legislation, and more generally by competent authorities.

Three different Quality Assurance Levels (QAL1, QAL2, and QAL3) are defined to achieve this objective. These Quality Assurance Levels cover the suitability of an AMS for its measuring task (e.g. before or during the purchase period of the AMS), the validation of the AMS following its installation, and the control of the AMS during its ongoing operation on an industrial plant. An Annual Surveillance Test (AST) is also defined.

The suitability evaluation of the AMS and its measuring procedure are described in EN ISO 14956 (QAL1) where a methodology is given for calculating the total uncertainty of AMS measured values. This total uncertainty is calculated from the evaluation of all the uncertainty components arising from its individual performance characteristics that contribute.

1 Scope

This European Standard specifies procedures for establishing quality assurance levels (QAL) for automated measuring systems (AMS) installed on industrial plants for the determination of the flue gas components and other flue gas parameters.

This standard specifies:

- a procedure (QAL2) to calibrate the AMS and determine the variability of the measured values obtained by it, so as to demonstrate the suitability of the AMS for its application, following its installation;
- a procedure (QAL3) to maintain and demonstrate the required quality of the measurement results during the normal operation of an AMS, by checking that the zero and span characteristics are consistent with those determined during QAL1;
- a procedure for the annual surveillance tests (AST) of the AMS in order to evaluate (i) that it functions correctly and its performance remains valid and (ii) that its calibration function and variability remain as previously determined.

This standard is designed to be used after the AMS has been accepted according to the procedures specified in EN ISO 14956 (QAL1).

This standard is restricted to quality assurance (QA) of the AMS, and does not include the QA of the data collection and recording system of the plant.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text, and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

EN ISO 14956, *Air quality - Evaluation of the suitability of a measurement procedure by comparison with a required measurement uncertainty* (ISO 14956:2002).

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

3 Terms and definitions

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

3.1

air quality characteristic

one of the quantifiable properties relating to an air mass under investigation, for example, concentration of a constituent

[ISO 6879:1995]

3.2

automated measuring system AMS

measuring system permanently installed on site for continuous monitoring of emissions

NOTE 1 An AMS is a method which is traceable to a reference method.

NOTE 2 Apart from the analyser, an AMS includes facilities for taking samples (e.g. sample probe, sample gas lines, flow meters, regulators, delivery pumps) and for sample conditioning (e.g. dust filter, moisture removal devices, converters, diluters). This definition also includes testing and adjusting devices, that are required for regular functional checks.

3.3 calibration function

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

3.4 competent authority

organisation or organisations which implement the requirements of EU Directives and regulate installations which must comply with the requirements of this European Standard

3.5 confidence interval (two-sided)

when T_1 and T_2 are two functions of the observed values such that, θ being a population parameter to be estimated, the probability $P_r(T_1 \leq \theta \leq T_2)$ is at least equal to $(1 - \alpha)$ [where $(1 - \alpha)$ is a fixed number, positive and less than 1], the interval between T_1 and T_2 is a two-sided $(1 - \alpha)$ confidence interval for θ

[ISO 3534-1:1993]

NOTE The 95 % confidence interval is illustrated in Figure 1, where:

$T_1 = \theta - 1,96 \sigma_0$	is the lower 95 % confidence limit;
$T_2 = \theta + 1,96 \sigma_0$	is the upper 95 % confidence limit;
$I = T_2 - T_1 = 2 \times 1,96 \times \sigma_0$	is the length of the 95 % confidence interval;
$\sigma_0 = I / (2 \times 1,96)$	is the standard deviation associated with a 95 % confidence interval;
n	is the number of observed values;
f	is the frequency;
m	is the measured value.

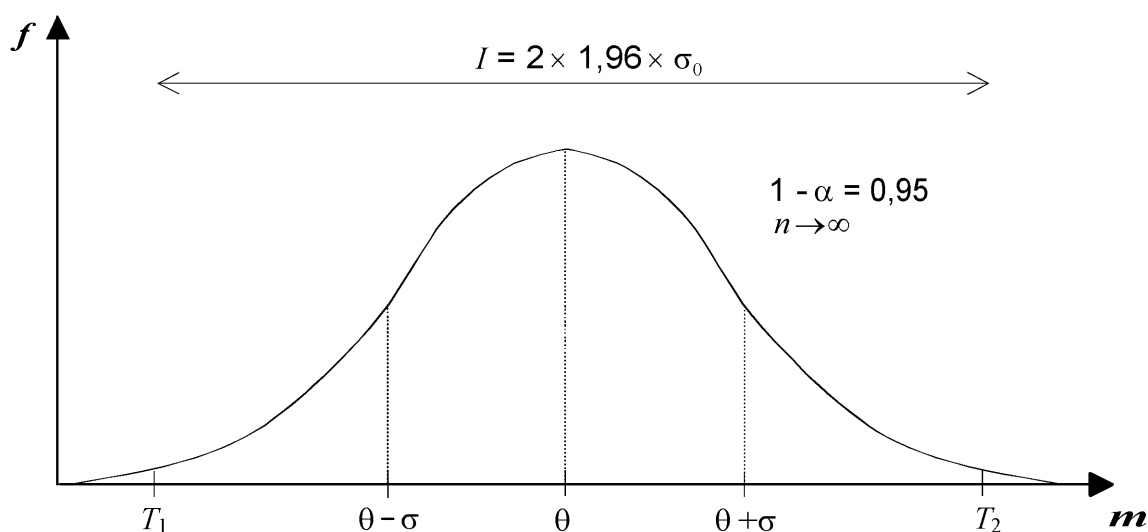


Figure 1 — Illustration of the 95 % confidence interval of a normal distribution

In this European Standard, the standard deviation σ_0 is estimated in QAL2 by parallel measurements with a SRM. It is assumed that the requirement for σ_0 , presented in terms of an allowable uncertainty budget i.e. variability, is provided by the regulators (e.g. in some EU Directives). In the procedures of this standard, the premise is that the required variability is given as σ_0 itself, or as a quarter of the length of the full 95 % confidence interval.

3.6

CUSUM chart

calculation procedure in which the amount of drift and change in precision is compared to the corresponding uncertainty components which are obtained during QAL1

3.7

drift

monotonic change of the calibration function over stated period of unattended operation, which results in a change of the measured value

3.8

emission limit value

limit value related to the uncertainty requirement

NOTE For the EU directives [1] and [2] it is the daily emission limit value that relates to the uncertainty requirement.

3.9

extractive AMS

AMS having the detection unit physically separated from the gas stream by means of a sampling system

3.10

instability

change in the measured value comprised of drift and dispersion resulting from the change in the calibration function over a stated period of unattended operation, for a given value of the air quality characteristic. Drift and dispersion specify the monotonic and stochastic change with time of the output signal, respectively

[ISO 6879:1995]

3.11

instrument reading

indication of the measured value directly provided by the AMS without using the calibration function

3.12

legislation

directives, Acts, ordinances and regulations

3.13

measurand

particular quantity subject to measurement

[ENV 13005:1999]

3.14

measured value

estimated value of the air quality characteristic derived from an output signal; this usually involves calculations related to the calibration process and conversion to required quantities

[ISO 6879:1995]

3.15

non-extractive AMS

AMS having the detection unit in the gas stream or in a part of it

3.16

period of unattended operation

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

[ISO 6879:1995]

3.17

peripheral AMS or SRM

measuring system or SRM used to gather the data required to convert the measured values to standard reference conditions, i.e. AMS or SRM for moisture, temperature, pressure and oxygen

3.18

precision

closeness of agreement of results obtained from the AMS for successive zero readings and successive span readings at defined time intervals

3.19

reference material

material simulating a known concentration of the input parameter, by use of surrogates and traceable to national standards

NOTE Surrogates normally used are calibration gases, gas cells, gratings or filters.

3.20

response time

time taken for an AMS to respond to an abrupt change in value of the air quality characteristic

[ISO 6879:1995]

3.21

span reading

instrument reading of the AMS for a simulation of the input parameter at a fixed elevated concentration.

NOTE 1 This simulation should test as much as possible all the measuring elements of the system, which contribute significantly to its performance.

NOTE 2 The span reading is approximately 80 % of the measured range.

3.22

standard conditions

conditions as given in the EU-directives to which measured values have to be standardised to verify compliance with the emission limit values

3.23

standard deviation

positive square root of: the mean squared deviation from the arithmetic mean divided by the number of degrees of freedom

NOTE The number of degrees of freedom is the number of measurements minus 1.

3.24

Standard Reference Method SRM

method described and standardised to define an air quality characteristic, temporarily installed on site for verification purposes

NOTE Also known as a reference method.

3.25**uncertainty**

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

[ENV 13005:1999]

3.26**variability**

standard deviation of the differences of parallel measurements between the SRM and AMS

3.27**zero reading**

instrument reading of the AMS on simulation of the input parameter at zero concentration

NOTE This simulation should test as much as possible all the measuring elements of the AMS, that contribute significantly to its performance

4 Symbols and abbreviations

4.1 Symbols

a	intercept of the calibration function
$\hat{a}$	best estimate of a
b	slope of the calibration function
$\hat{b}$	best estimate of b
D_i	difference between measured SRM value y_i and calibrated AMS value $\hat{y}_i$
$\overline{D}$	average of D_i
D_{adjust}	amount by which the AMS has to be adjusted, in the case that drift is detected
d_t	difference between actual instrument reading of the AMS and the reference value
d_{t-1}	difference between previous instrument reading of the AMS and the reference value
E	emission limit value
h_s	test value for detection of a decrease in precision
h_x	test value for detection of drift
k_s	constant in the calculation in the provisional sum for standard deviation
k_v	test value for variability (based on a χ^2 -test, with a β -value of 50 %, for N numbers of paired measurements)
k_x	constant in the calculation in the provisional sum for positive and negative differences and in the calculation of the required adjustment of the AMS
N	number of paired samples in parallel measurements
$N(s)$	number of readings since the standard deviation was different from zero
$N(\text{pos})$	number of readings since a positive difference was detected
$N(\text{neg})$	number of readings since a negative difference was detected
P	percentage value
s_p	provisional normalised sum of the standard deviations of the AMS (QAL3)

s_t	provisional normalised sum of the standard deviations of the AMS at time t (QAL3)
s_{t-1}	provisional normalised sum of the standard deviations of the AMS at time $t-1$ (QAL3)
s_D	standard deviation of the differences D_i in parallel measurements
u_{inst}	uncertainty due to instability (expressed as a standard deviation)
u_{temp}	uncertainty due to influence of temperature (expressed as a standard deviation)
u_{pres}	uncertainty due to influence of pressure (expressed as a standard deviation)
u_{volt}	uncertainty due to influence of voltage (expressed as a standard deviation)
u_{others}	any other uncertainty that may influence the zero and span reading (expressed as a standard deviation)
x_i	i^{th} measured signal obtained with the AMS at AMS measuring conditions
$\bar{x}$	average of AMS measured signals x_i
x_t	reference value at time t (QAL3)
y_i	i^{th} result obtained with the SRM
$\bar{y}$	average of the SRM results y_i
$y_{i,s}$	SRM value y_i at standard conditions
$y_{s,\text{min}}$	lowest SRM value at standard conditions
$y_{s,\text{max}}$	highest SRM value at standard conditions
$\hat{y}_i$	best estimate for the "true value", calculated from the AMS measured signal x_i by means of the calibration function
$\hat{y}_{i,s}$	best estimate for the "true value", calculated from the AMS measured signal x_i at standard conditions
y_t	actual instrument reading of the AMS at time t (QAL3)
Z	offset (the difference between the AMS zero reading and the zero)
$\Sigma(\text{pos})_p$	provisional normalised sum of the positive drift of the AMS
$\Sigma(\text{pos})_t$	normalised sum of the positive drift of the AMS at time t
$\Sigma(\text{pos})_{t-1}$	previous normalised sum of the positive drift of the AMS (at time $t-1$)
$\Sigma(\text{neg})_p$	provisional normalised sum of the negative drift of the AMS
$\Sigma(\text{neg})_t$	normalised sum of the negative drift of the AMS at time t
$\Sigma(\text{neg})_{t-1}$	previous normalised sum of the negative drift of the AMS (at time $t-1$)
s_{AMS}	standard deviation of the AMS used in QAL3
α	significance level
ε_i	deviation between y_i and the expected value
σ_0	uncertainty derived from requirements of legislation

4.2 Abbreviations

AMS	Automated Measuring System
AST	Annual Surveillance Test
ELV	Emission Limit Value
QA	Quality Assurance

QAL	Quality Assurance Level
QAL1	First Quality Assurance Level
QAL2	Second Quality Assurance Level
QAL3	Third Quality Assurance Level
QC	Quality Control
SRM	Standard Reference Method

5 Principle

5.1 General

An AMS to be used at installations covered by EU Directives, e.g. [1] and [2], shall have been proven suitable for its measuring task (parameter and composition of the flue gas) by use of the QAL1 procedure, as specified by EN ISO 14956. Using this standard, it shall be proven that the total uncertainty of the results obtained from the AMS meets the specification for uncertainty stated in the applicable regulations. In QAL1 the total uncertainty required by the applicable regulation is calculated by summing in an appropriate manner all the relevant uncertainty components arising from the individual performance characteristics.

The QAL2 and AST procedures involve testing laboratories, whereas the QAL3 procedures involve the plant operators.

QAL2 is a procedure for the determination of the calibration function and its variability, and a test of the variability of the measured values of the AMS compared with the uncertainty given by legislation. The QAL2 tests are performed on suitable AMS that have been correctly installed and commissioned. A calibration function is established from the results of a number of parallel measurements performed with a Standard Reference Method (SRM). The variability of the measured values obtained with the AMS is then evaluated against the required uncertainty.

The QAL2 procedures are repeated periodically, after a major change of plant operation, after a failure of the AMS or as required by legislation.

QAL3 is a procedure which is used to check drift and precision in order to demonstrate that the AMS is in control during its operation so that it continues to function within the required specifications for uncertainty. This is achieved by conducting periodic zero and span checks on the AMS – based on those used in the procedure for zero and span repeatability tests carried out in QAL1 – and then evaluating the results obtained using control charts. Zero and span adjustments or maintenance of the AMS, may be necessary depending on the results of this evaluation.

The AST is a procedure which is used to evaluate whether the measured values obtained from the AMS still meet the required uncertainty criteria – as demonstrated in the previous QAL2 test. It also determines whether the calibration function obtained during the previous QAL2 test is still valid. The validity of the measured values obtained with the AMS is checked by means of a series of functional tests as well as by the performance of a limited number of parallel measurements using an appropriate SRM.

5.2 Limitations

Figure 2 illustrates the components of the AMS covered by this standard.

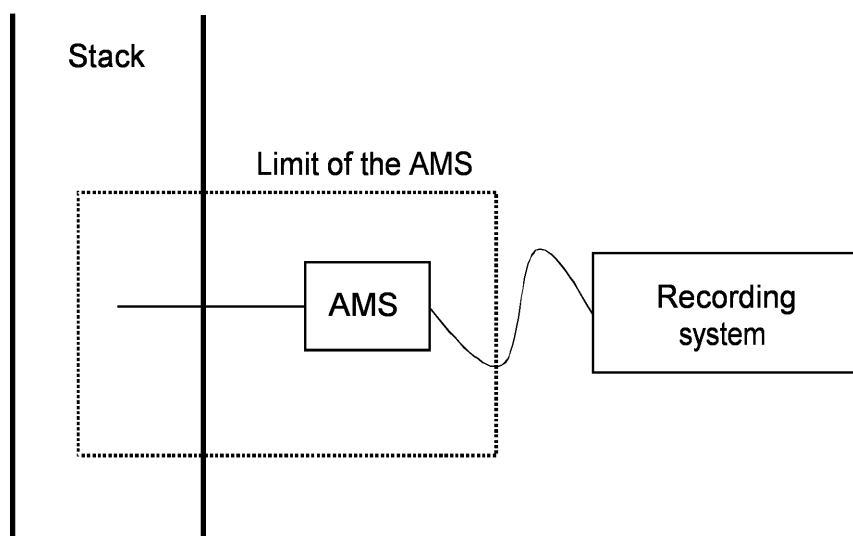


Figure 2 — Limits for the QA of the AMS excluding the data recording system

NOTE 1 The influence of the uncertainty of the measurement results, which arise from the data acquisition recording and handling system of the AMS or of the plant system, and its determination, are not covered from this standard.

NOTE 2 The performance of the data collection and recording system can be as influential as the AMS performance in determining the quality of the results obtained from the whole measuring system/process. There are different requirements for data collection recording and presentation in different countries.

When conducting parallel measurements, the measured signals from the AMS shall be taken directly from the AMS (e.g. expressed as analogue or digital signal) during the QAL2 and AST procedures specified in this standard, by using an independent data collection system provided by the organisation(s) carrying out the QAL2 and AST tests. All data shall be recorded in their uncorrected form (without corrections e.g. for temperature and oxygen). A plant data collection system with ongoing quality control can additionally be used to collect the measured signal from the AMS.

5.3 Measurement site and installation

The AMS shall be installed in accordance with the requirements of the relevant European and/or international standards. Special attention shall be given to ensure that the AMS is readily accessible for regular maintenance and other necessary activities.

NOTE The AMS should be positioned as far as practical in a position where it measures a sample that is representative of the stack gas composition.

All measurements shall be carried out on a suitable AMS and peripheral AMS installed within an appropriate working environment.

The working platform used to access the AMS shall readily allow parallel measurements to be performed using an SRM. The sampling ports for measurements with the SRM shall be placed as close as possible, but not more than three times the equivalent diameter up- or down-stream of the location of the AMS, in order to achieve comparable measurements between AMS and SRM.

It is necessary to have good access to the AMS to enable inspections to take place and also to minimise the time taken to implement the quality assurance procedures of this standard. A clean, well-ventilated and well-lit working space around the AMS is required to enable the staff to perform this work effectively. Suitable protection is required for the personnel and the equipment, if the working platform is exposed to the weather.

5.4 Testing laboratories performing SRM measurements

The testing laboratories performing the measurements with the SRM shall have an accredited quality assurance system according to EN ISO/IEC 17025, or shall be approved directly by the relevant competent authority. They shall also have sufficient experience in performing the measurements using the appropriate SRM. The SRM used shall be a European Standard, if available. If such a standard does not exist, international or national standards shall apply so as to ensure the provision of data of an equivalent scientific quality.

6 Calibration and validation of the AMS (QAL2)

6.1 General

Testing shall cover the following items:

- installation of the AMS;
- calibration of the AMS by means of parallel measurements with a SRM;
- determination of the variability of the AMS, and the check of compliance with the required uncertainty.

The sequence of the combined tests is shown in Figure 3.

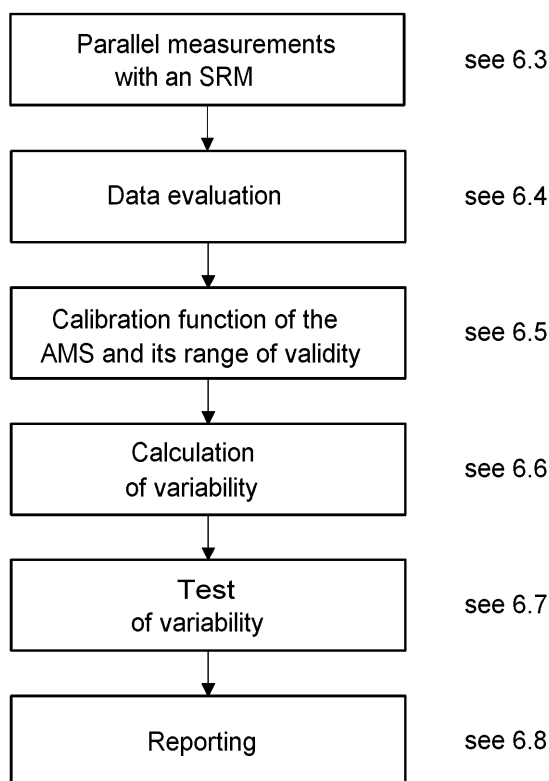


Figure 3 — Flow diagram for the calibration and variability tests

A QAL2 procedure shall be performed for all measurands:

- at least every 5 years for every AMS or more frequently if so required by legislation or by the competent authority (e.g. the EU Directive 2000/76/EC on the Incineration of Waste [1] specifies parallel measurements every 3 years);

Furthermore, a QAL2 shall be performed for all the measurands influenced by:

- any major change in plant operation (e.g. change in flue gas abatement system or change of fuel), or
- any major changes or repairs to the AMS, which will influence the results obtained significantly.

The results of QAL2 shall be reported within 6 months after the changes. During the period before a new calibration function has been established the previous calibration function (where necessary with extrapolation) shall be used.

Examples of calculation of the calibration function and of the variability test are given in annex E.

6.2 Functional test

The requirements for installation and the measurement site as specified in 5.3 shall be fulfilled.

Before calibration (see 6.4 and 6.5) and the test for variability (see 6.6 and 6.7) are performed, it shall be proven that the AMS is commissioned satisfactorily, e.g. as specified by the AMS supplier and/or manufacturer. It shall also be shown and documented that the AMS gives a zero reading on a zero concentration.

NOTE 1 For some AMS it is difficult to achieve a zero reading. In those situations, the AMS can be removed from the stack, and zeroed using a test bench or similar. As an alternative, a measuring path, which enables this zero test to be carried out, can be installed in the stack.

The functional test before calibration shall be performed according to annex A.

NOTE 2 The specific precautions to be taken should depend on the individual location. Special attention should be made for particulate measurements.

6.3 Parallel measurements with an SRM

Parallel measurements shall be performed with the AMS and SRM in order to calibrate and validate the AMS by use of an independent method.

It is not sufficient to use reference materials alone to obtain the calibration functions and this is therefore not permitted. This is because these reference materials do not replicate sufficiently the matrix stack gas, they cannot be used to establish that the sampling point(s) of the AMS are representative, and they are not used with the sampling system in all cases. However, if there are limited variations in the results obtained in the AMS/SRM tests, and the measured concentrations are well below the ELV, an extrapolation of the calibration function to the ELV may be verified by the use of appropriate reference materials, taking into account the effects of interfering substances on the AMS, where appropriate.

If clear and distinct operating modes of the plant process are part of its normal operation (for example changes of fuel), additional calibrations shall be performed and a calibration function established for each operational mode.

NOTE 1 It is recommended that a preliminary test be carried out in order to evaluate if a full calibration over the whole concentration range can be performed. Otherwise a competent authority should judge, if, based on its experience, it is reasonable to establish one calibration function that covers all normal changes in the process.

In order to ensure that the calibration function is valid for the range of conditions within which the plant will operate, the concentrations during the calibration shall be varied as much as possible within the normal operations of the plant. This shall ensure that the calibration of the AMS is valid over as large a range as possible, and also that it covers most operational situations.

The test for variability shall be performed (see 6.7) for each calibration function, i.e. for each operating mode of the plant.

An SRM shall be used to sample the emissions at a sampling plane in the duct, which is as close as possible to the AMS, without the results obtained by each being influenced by the other.

The presence of the equipment specified in the SRM shall not influence or disturb the AMS measurements.

For each calibration a minimum of 15 valid parallel measurements shall be made with the plant operating normally. These measurements shall be uniformly spread both over at least 3 days and over each of the measuring days of normally 8 h to 10 h (e.g. not 5 measurements in the morning and none in the afternoon) and be performed within a period of four weeks.

NOTE 2 The required spread of a minimum of 15 valid measurements over three days is essential in minimising the effect of influences of the subsequent measurement results (i.e. to avoid auto-correlation between the calculated differences in the results of the AMS and SRM). The alternative of performing more measurements within a shorter time interval can lead to the establishment of an invalid calibration function.

NOTE 3 A minimum of 15 valid measurements can in practice require that more than 15 samples be taken, since some samples may be deemed to be invalid during subsequent analysis because of inadequate quality.

NOTE 4 The requirement that the measurements need to be uniformly spread over at least 3 days does not imply that the measurements need to be performed within 3 consecutive days.

A set of measurements is valid when all of the requirements below are fulfilled:

- the SRM measurements are performed according to the accepted standard;
- the time period of each AMS measured signal, is larger than 90 % of the averaging time (excluding all of the measured signals which are above 100 % or below 0 % of the measuring range of the AMS, signals obtained during internal checks (auto calibration), and signals obtained during any other malfunctioning of the AMS).

During the parallel measurements with the AMS and SRM, each result is considered as a measurement pair (one AMS measured signal and one SRM measured value) and these shall cover the same time period.

The sampling time for each of the parallel measurements shall be at least 30 min, or at least 4 times the response time of the AMS, including the sampling system (as determined during the response time measurements carried out during QAL1), whichever is the greater. In general the sampling time should equal the shortest averaging time, which is required by the ELV specification. The recording system shall have an averaging time significantly shorter than the response time of the AMS.

If the sampling time is shorter than 1 h, then the time interval between the start of each sample shall be longer than 1 h.

The results obtained from the SRM shall be expressed under the same conditions as those measured by the AMS (e.g. conditions of pressure, temperature, etc.). In order to establish the calibration function and perform the variability test all additional parameters and values included in the corrections to AMS conditions and standard conditions shall be obtained for each measurement pair.

EXAMPLE If the AMS measures gaseous HCl in units of mg/m^3 in stack gas containing water vapour, then the SRM results are expressed in the same units (e.g. mg/m^3 in the stack gas with the same water vapour concentration).

6.4 Data evaluation

6.4.1 Preparation of data

The steps for providing data required for establishing the calibration function and performing the test of variability are illustrated in Figure 4.

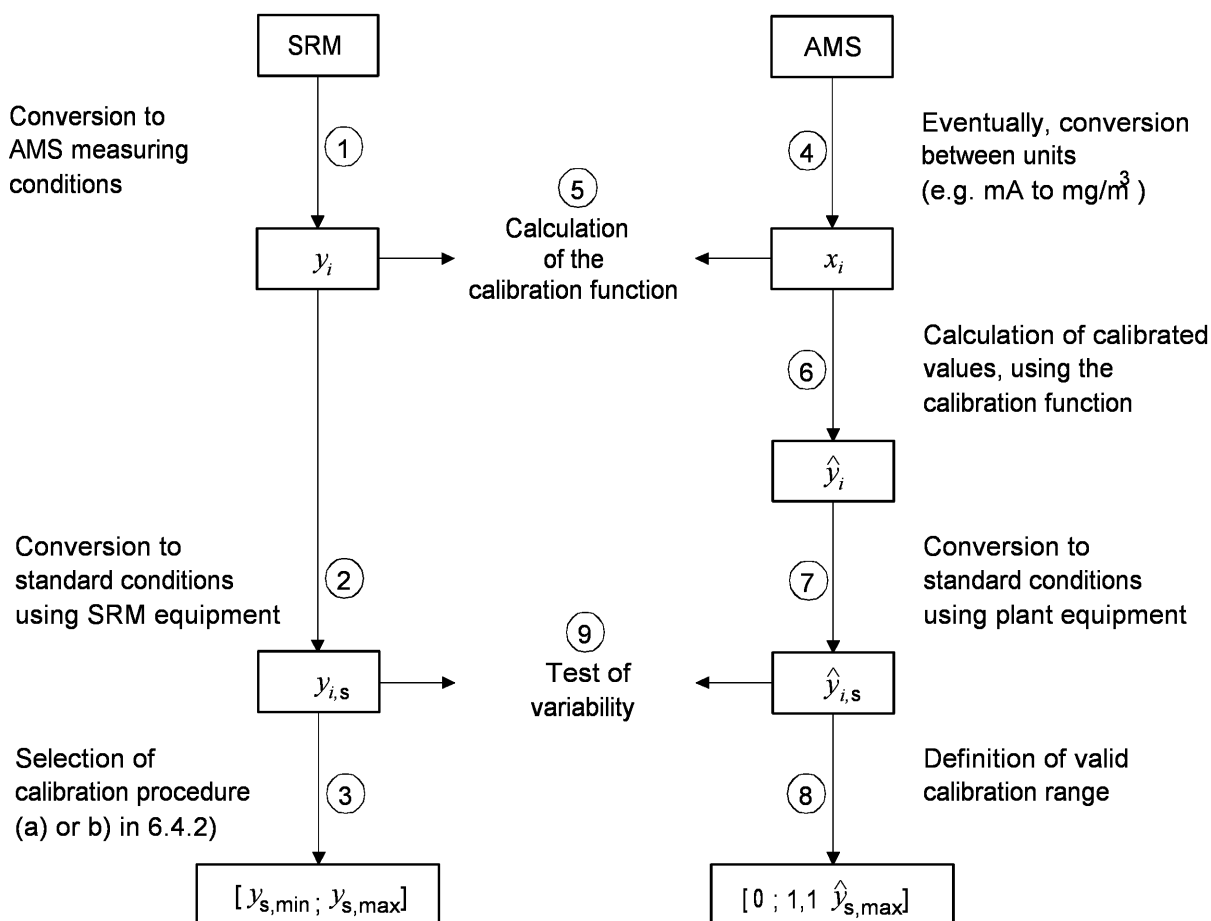


Figure 4 — Flow chart describing the steps in calibration procedure and test for variability¹.

The AMS shall be calibrated at the condition of the exhaust gas as measured by the AMS. Therefore, the SRM values shall be converted to AMS measuring conditions, if necessary, giving SRM measured values y_i to be expressed in concentration units (e.g. mg/m³).

The measured signals from the AMS x_i can be either a signal in an electrical unit (e.g. mA or Volt) or in a concentration unit (e.g. mg/m³).

NOTE For a non-extractive AMS, that measures the gas directly, the calibration function reported should be at the operating conditions. For an extractive AMS measuring at specified conditions, the calibration function is reported at these specified conditions.

6.4.2 Establishing the calibration function

It is presupposed in the standard that the calibration function is linear and has a constant residual standard deviation. The calibration function shall be described by the model below (see ISO 11095):

¹ The figure in the circles indicates the sequence of the steps.

$$y_i = a + b x_i + \varepsilon_i \quad (1)$$

where

x_i is the i^{th} result of the AMS; $i = 1$ to N ; $N \geq 15$;

y_i is the i^{th} result of the SRM; $i = 1$ to N ; $N \geq 15$;

ε_i is the deviation between y_i and the expected value;

a is the intercept of the calibration function;

b is the slope of the calibration function.

The general procedure requires a sufficient range of the measured concentrations to give a valid calibration of the AMS for the complete range of concentrations encountered during normal operations. As stated in 6.3 it is essential that the concentration range is as large as possible within the normal operation of the plant to allow for a valid calibration function to be obtained. However, at a large number of plants, it may be difficult under normal operating conditions to achieve a sufficiently large concentration range. In such cases, in which the concentration range (measured with the SRM) is less than 15 % of the emission limit value, another (similar) procedure is given below (procedure b).

NOTE 1 If the concentration range is slightly bigger than 15 %, and if procedure a) results in an inadequate calibration function (e.g. a function with negative slope), procedure b) can be used instead.

The following quantities shall be calculated:

$$\bar{x} = \frac{1}{N} \sum_{i=1}^N x_i \quad (2)$$

$$\bar{y} = \frac{1}{N} \sum_{i=1}^N y_i \quad (3)$$

The difference ($y_{s,\max} - y_{s,\min}$) between the highest and lowest measured SRM concentration at standard conditions shall be calculated.

a) If ($y_{s,\max} - y_{s,\min}$) is greater than or equal to 15 % of the ELV, calculate:

$$\hat{b} = \frac{\sum_{i=1}^N (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^N (x_i - \bar{x})^2} \quad (4)$$

$$\hat{a} = \bar{y} - \hat{b} \bar{x} \quad (5)$$

b) If ($y_{s,\max} - y_{s,\min}$) is smaller than 15 % of the ELV, calculate:

$$\hat{b} = \frac{\bar{y}}{\bar{x} - Z} \quad (6)$$

$$\hat{a} = -\hat{b} Z \quad (7)$$

where the offset Z is the difference between the AMS zero reading and zero.