

BS EN 14181:2014



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Stationary source emissions — Quality assurance of automated measuring systems

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National foreword

This British Standard is the UK implementation of EN 14181:2014. It supersedes BS EN 14181:2004 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EH/2/1, Stationary source emission.

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

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Emissionen aus stationären Quellen - Qualitätssicherung für automatische Messeinrichtungen

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Foreword

This document (EN 14181:2014) 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of an identical text or by endorsement, at the latest by May 2015 and conflicting national standards shall be withdrawn at the latest by May 2015.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 14181:2004.

Annex J provides details of significant technical changes between this European Standard and the previous edition.

The first edition of this document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association to support requirements in the EU Directives 2000/76/EC [1] and 2001/80/EC [2], which have been replaced by EU Directive 2010/75/EU [3], and may also be applicable for other purposes.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, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

This European 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], [3] or national legislation, or 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 (QAL1) of the AMS and its measuring procedure are described in EN 15267-3 and EN ISO 14956 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 European 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 European Standard is designed to be used after the AMS has been certified in accordance with the series of European Standards EN 15267.

2 Normative references

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

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

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

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

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

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

3 Terms and definitions

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

3.1

automated measuring system

AMS

measuring system permanently installed on site for continuous monitoring of emissions or measurement of peripheral parameters

Note 1 to entry: An AMS is a method which is traceable to a reference method.

Note 2 to entry: 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, water vapour removal devices, converters, diluters). This definition also includes testing and adjusting devices that are required for regular functional checks.

3.2

extractive AMS

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

3.3

in-situ AMS

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

3.4

peripheral AMS

AMS used to gather the data required to convert the AMS measured value to standard conditions

Note 1 to entry: A peripheral AMS is used to measure e.g. water vapour, temperature, pressure and oxygen.

3.5

reference method

RM

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

[SOURCE: EN 15259:2007]

3.6

standard reference method

SRM

reference method prescribed by European or national legislation

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

[SOURCE: EN 15259:2007]

3.7

peripheral SRM

SRM used to gather the data required to convert the SRM measured values to AMS or standard conditions

Note 1 to entry: A peripheral SRM is used to measure e.g. water vapour, temperature, pressure and oxygen.

3.8

standard conditions

conditions to which measured values have to be standardized to verify compliance with emission limit values

Note 1 to entry: Standard conditions are specified e.g. in EU Directives [1], [2] and [3].

3.9

emission limit value

ELV

limit value related to the maximum permissible uncertainty

Note 1 to entry: For the EU Directives [1], [2] and [3] it is the daily emission limit value that relates to the uncertainty requirement.

3.10

maximum permissible uncertainty

uncertainty requirement on AMS measured values given by legislation or competent authorities

3.11

legislation

directives, acts, ordinances or regulations

3.12

competent authority

organization or organizations which implement the requirements of EU Directives and regulate installations which shall comply with the requirements of this European Standard

3.13

calibration function

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

Note 1 to entry: For dust measuring AMS, a quadratic calibration function can be used as described in EN 13284-2.

3.14

standard deviation

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

Note 1 to entry: The number of degrees of freedom is the number of measurements minus 1.

3.15

confidence interval

interval estimator (T_1 , T_2) for the parameter θ with the statistics T_1 and T_2 as interval limits and for which it holds that $P[T_1 < \theta < T_2] \geq (1 - \alpha)$

[SOURCE: ISO 3534-1:2006]

Note 1 to entry: The two-sided 95 % confidence interval of a normal distribution 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.

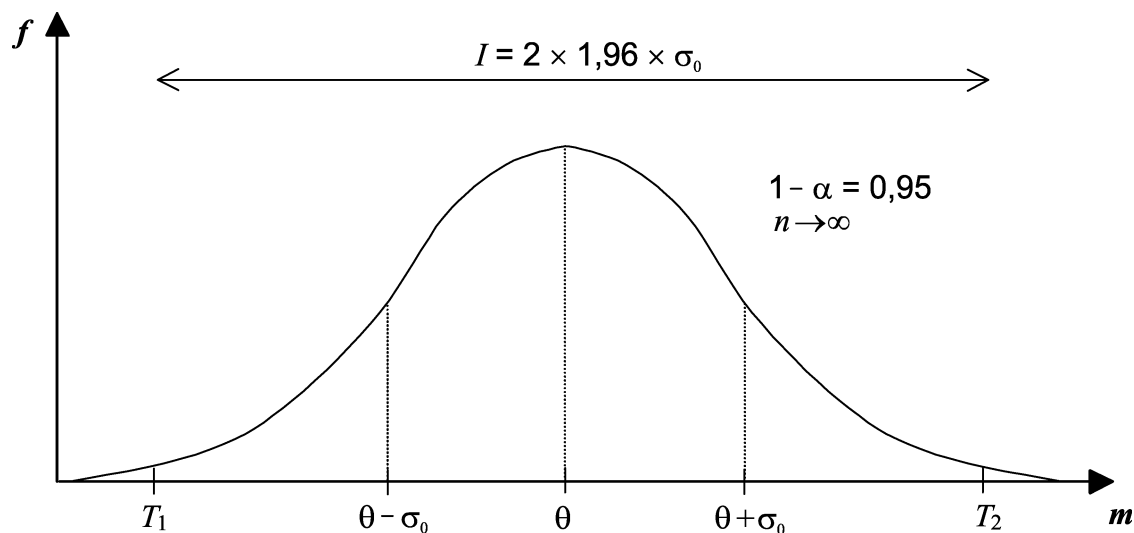


Figure 1 — Illustration of the 95 % confidence interval of a normal distribution

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

Note 2 to entry: In some EU Directives (see [1], [2], [3]) the uncertainty of the AMS measured values is expressed as half of the length of a 95 % confidence interval as a percentage P of the emission limit value E . Then, in order to convert this uncertainty to a standard deviation, the appropriate conversion factor is $\sigma_0 = P E / 1,96$.

3.16 variability

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

3.17 uncertainty

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

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

3.18 measurand

particular quantity subject to measurement

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

Note 1 to entry: A measurand can be e.g. the mass concentration of a measured component or the waste gas velocity, pressure or temperature.

3.19 measured component

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

[SOURCE: EN 15259:2007]

3.20

peripheral parameter

specified physical or chemical quantity which is needed for conversion of measured values to specified conditions

3.21

measured value

estimated value of the measurand derived from a measured signal

Note 1 to entry: This usually involves calculations related to the calibration process and conversion to required quantities.

Note 2 to entry: A measured value is a short-term average. The averaging time can be e.g. 10 min, 30 min or 1 h.

3.22

instrument reading

measured signal directly provided by the AMS without using the calibration function

3.23

zero reading

instrument reading on simulation of the input parameter at zero concentration

3.24

span reading

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

3.25

instability

change in the measured signal comprised of drift and dispersion over a stated maintenance interval

Note 1 to entry: Drift and dispersion specify the monotonic and stochastic change with time of the measured signal, respectively.

3.26

drift

monotonic change of the calibration function over stated maintenance interval, which results in a change of the measured signal

3.27

precision

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

3.28

response time

t_{90}

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

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

3.29

maintenance interval

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

3.30

reference material

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

3.31

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

3.32

EWMA chart

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

Note 1 to entry: The EWMA chart averages the data in a way that gives less and less weight to data as they are further removed in time.

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 SRM measured value y_i and calibrated AMS measured value $\hat{y}_i$
$\bar{D}$	average of D_i
E	emission limit value
k_v	test value for variability (based on a χ^2 -test, with a β -value of 50 %, for N numbers of paired measurements)
N	number of paired samples in parallel measurements
P	percentage value
s_{AMS}	standard deviation of the AMS used in QAL3
s_D	standard deviation of the differences D_i in parallel measurements
$t_{0,95; N-1}$	value of the t distribution for a significance level of 95 % and a number of degrees of freedom of $N - 1$
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
y_i	i^{th} measured value obtained with the SRM
$\bar{y}$	average of the SRM measured values y_i
$y_{i,s}$	SRM measured value y_i at standard conditions
$y_{s,\min}$	lowest SRM measured value at standard conditions
$y_{s,\max}$	highest SRM measured 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
$\hat{y}_{s,\max}$	best estimate for the "true value", calculated from the maximum value of the AMS measured signals x_i at standard conditions
Z	offset (the difference between the AMS zero reading and the zero)
α	significance level
ε_i	deviation between y_i and the expected value
σ_0	standard deviation associated with the uncertainty derived from requirements of legislation

4.2 Abbreviations

AMS	automated measuring system
AST	annual surveillance test
CUSUM	cumulative sum
DAHS	data acquisition and handling system
ELV	emission limit value
EWMA	exponentially weighted moving-average
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 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 15267-1 EN 15267-2, EN 15267-3 and EN ISO 14956. Using these standards, 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.

In case of new installations of AMS, the AMS shall have been certified in accordance with EN 15267-1, EN 15267-2, and EN 15267-3.

In case of AMS already installed at plants which have not been certified according to EN 15267-1, EN 15267-2, and EN 15267-3, or AMS already installed at plants which were certified according to EN 15267-1, EN 15267-2, and EN 15267-3 but where the ELV and the uncertainty requirement have subsequently changed, the procedure described in H.2 may be applied. However, H.2 does not apply to new installations of old AMS which have not been certified according to EN 15267-1, EN 15267-2 and EN 15267-3.

NOTE 1 SRM measurements, influences by peripheral parameters and the sampling site can contribute to the uncertainty of the AMS measured values determined in QAL2.

NOTE 2 EN 15267-3 requires that the total uncertainty of the AMS measured values determined in the performance test should be at least 25 % below the maximum permissible uncertainty specified e.g. in applicable regulations to provide a sufficient margin for the uncertainty contributions from the individual installation of the AMS to pass QAL2 and QAL3 successfully.

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 maximum permissible 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 the standard reference method (SRM). The variability of the measured values obtained with the AMS is then evaluated against the maximum permissible 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 uncertainty of the measured values obtained from the AMS still meet the 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.

NOTE 3 There are several concentration ranges relevant to the application of this European Standard:

- certification range

This is the range over which the AMS has been certified. It is generally recommended that this range be related to the ELV given in relevant EU Directives of the processes under which the AMS will be used. EN 15267-3 requires that the certification range be no greater than 1,5 times the daily ELV for waste incineration plants and 2,5 times the daily ELV for large combustion plants. Where there is a choice, the daily ELV is used.

- calibration range

This is the range over which the AMS has been calibrated under the QAL2 procedure.

- measuring range

This is the range at which the AMS is set to operate during use. There are usually requirements from national competent authorities that the range encompasses the maximum short-term ELV. The measuring range can be greater than the certification range.

5.2 Limitations

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

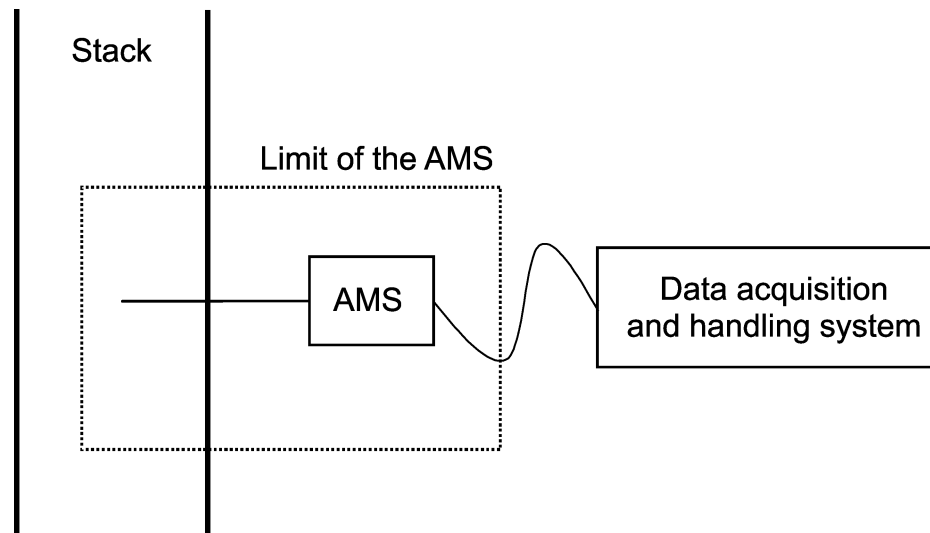


Figure 2 — Limits for the QA of the AMS excluding the data acquisition and handling system

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

NOTE 2 The performance of the data acquisition and handling system (DAHS) 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. A European Standard on quality assurance of DAHS is currently under preparation.

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 alternatively 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.

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. EN 15259 describes a procedure to identify the best sampling location for the AMS, in order to provide representative measurements. It also defines the optimum location for undertaking parallel SRM measurements for the QAL2.

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 and the working platform used to perform the SRM measurements shall be in accordance with the requirements of EN 15259. The sampling ports for measurements with the SRM shall be placed in such a location to avoid mutual interference between SRM and AMS in order to achieve comparable measurements between AMS and SRM.

NOTE Lack in the fulfilment of these conditions can result in higher measurement uncertainties, potentially resulting in nonconformity with the requirements given by EU Directives.

It is necessary to have good access to the AMS to enable inspections to take place and also to minimize 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 be accredited for this task according to EN ISO/IEC 17025, or shall be approved directly by the relevant competent authority.

NOTE CEN/TS 15675 provides clarification and additional information on the application of EN ISO/IEC 17025 to periodic measurements used e.g. for the calibration of AMS.

6 Calibration and validation of the AMS (QAL2)

6.1 General

QAL2 covers the following items:

- functional test of the AMS including check of correct installation;
- parallel measurements with the SRM;
- data evaluation;
- determination of the calibration function of the AMS and its range of validity;
- calculation of variability of the AMS measured values;
- test of variability of the AMS measured values;
- reporting.

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

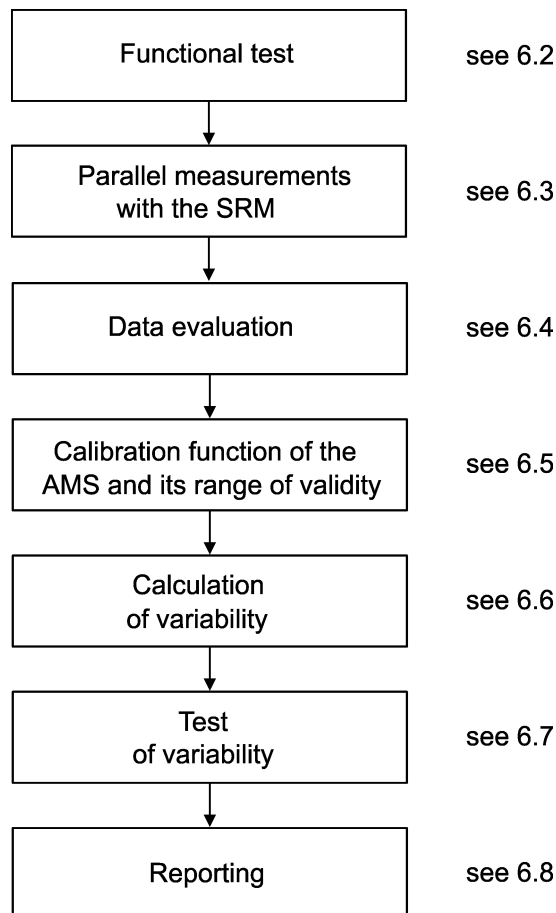


Figure 3 — Flow diagram for the calibration and variability tests

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;

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 implemented within six 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.

NOTE In some EU member countries the local authorities allow in individual cases the continued use of the previous calibration function if it can be proven by use of a specified statistical procedure that the new calibration function does not significantly differ from the previous one.

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 6.3 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 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. It is recommended to perform the functional test not more than one month before parallel measurements are started. The functional test shall be performed by an experienced testing laboratory, which has been recognised by the competent authority.

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

Since the AMS and SRM measured values are converted to standard conditions by independently determined data sets of the peripheral parameters, the uncertainties in the peripheral parameters are attributed to the AMS of the air pollutant in the variability test. Therefore, it is recommended to perform the relevant steps of the functional test specified in Annex A for measuring systems of the peripheral parameters to minimize uncertainties caused by the peripheral parameters.

6.3 Parallel measurements with the 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 can be possible to establish one calibration function fulfilling the variability requirements that covers the range of conditions within which the plant operates.

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.

NOTE 2 Careful measurement planning can identify the optimum time for the parallel measurements, when the emissions are at their highest or most varied.

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

The SRM shall be used to sample the emissions at a sampling plane in the duct, which fulfils the requirements of EN 15259, and is as close as possible to the AMS.

The presence of the SRM equipment shall not influence or disturb the AMS measurements and vice versa.

NOTE 3 Although EN 15259 allows simplified sampling of gaseous components in cases of homogeneous flue gas or negligible concentration variations, grid measurements can improve the quality of the calibration curve.

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 three days and over each of the measuring days of normally 8 h to 10 h (e.g. not five measurements in the morning and none in the afternoon) and be performed within a period of four weeks.

NOTE 4 The required spread of a minimum of 15 valid measurements over three days is essential in minimizing 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 5 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 6 The requirement that the measurements need to be uniformly spread over at least three days does not imply that the measurements need to be performed within three consecutive days.

If the QAL2 is not the first QAL2 being carried out on the AMS, then an AST may be performed instead of a QAL2 provided that the SRM measured values obtained in the AST and at least 95 % of the AMS measured values at standard conditions obtained since the last AST are less than the maximum permissible uncertainty specified e.g. in the relevant EU Directive.

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 four 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.

NOTE 7 If the emissions are at low levels the SRM measured values can be improved for manual SRM by extending the sampling time.

The time interval between the start of each sample shall be at least 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.

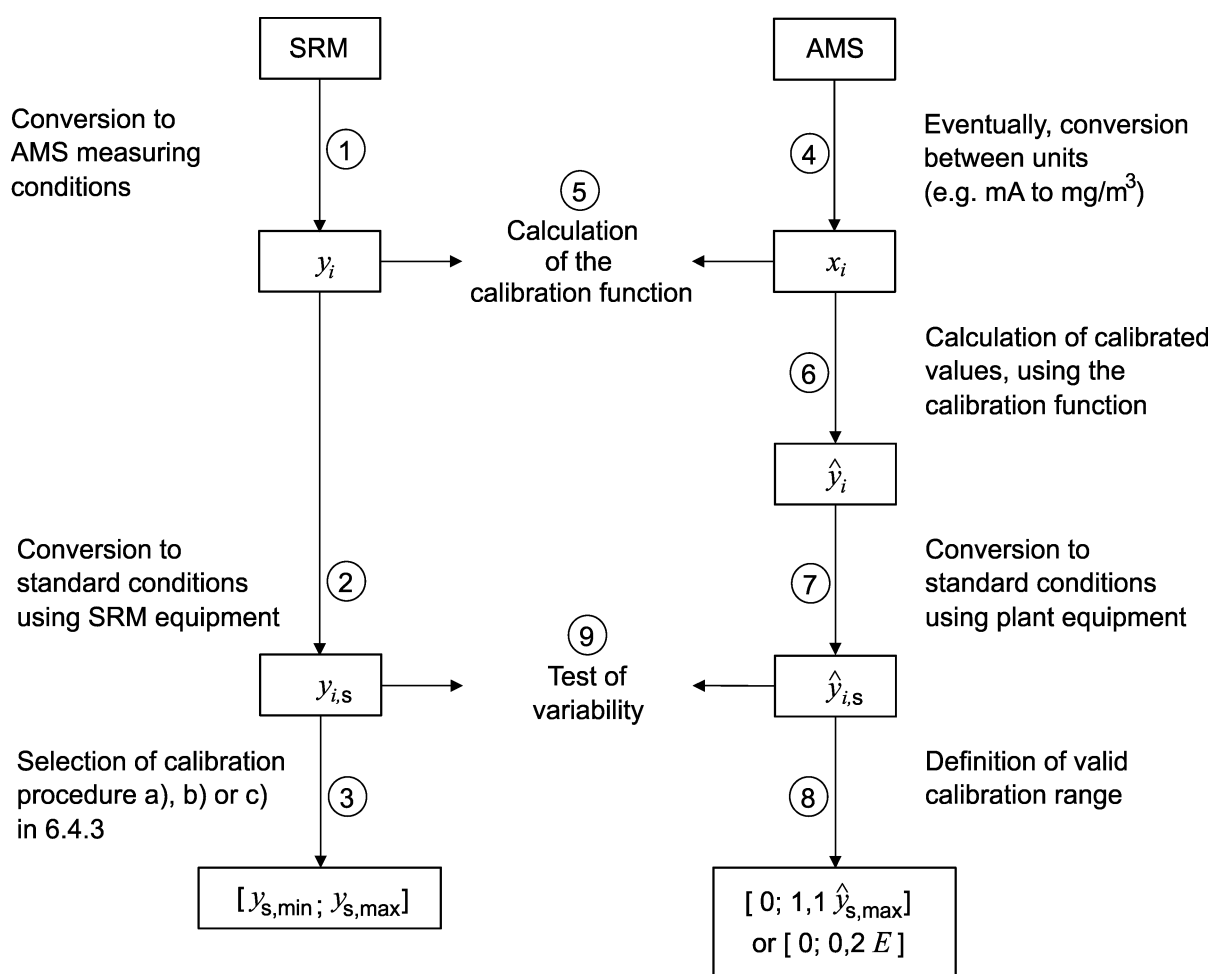
EXAMPLE If the AMS measures gaseous HCl in units of mg/m^3 in stack gas containing water vapour, then the SRM measured values are expressed in the same units (e.g. mg/m^3 in the stack gas with the same water vapour concentration).

In order to fulfil the requirement that the calibration of the AMS is valid over as large a range as possible, and that it covers most operational situations, parallel measurements over three days are required. However, this requires several manual SRM measurements of the water vapour concentration. If calibrated AMS measured values for water vapour are available, these may be used to convert the SRM data to dry or wet basis. When wet abatement techniques are used, the exhaust gas is saturated and therefore the water vapour concentration is often nearly constant. In such cases an extended measurement of the water vapour concentration is of little purpose. In those situations, conversion of SRM data to dry or wet basis may be carried out using calculated water vapour values.

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.



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

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

The AMS shall be calibrated at the condition of the flue gas as measured by the AMS. Therefore, the SRM measured 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 in-situ AMS, that measure the gas directly, the calibration function is reported at the operating conditions. For extractive AMS measuring at specified conditions, the calibration function is reported at these specified conditions.

The data sets obtained in the parallel measurements shall be checked for possible outliers. The method used to assess outliers and reasons for excluding outliers shall be given in the QAL2 report. Outliers shall be reported and identified in the calibration data tables and diagrams.

This standard requires at least 15 valid data points for a QAL2 calibration function. If points are excluded e.g. through the use of outlier tests, this requirement can be failed. It is therefore recommended that additional data points be taken, to allow for the exclusion of outliers. If this is not done the QAL2 can be invalid. All data points shall be used to form the calibration function, unless excluded through the use of outlier tests or have been shown to be invalid.

6.4.2 Selection of data points from automated SRM

In the case of data sets produced from an automated SRM, which may produce a high number of data points, any selection of points shall be justified and documented.

6.4.3 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):

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

where

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

y_i is the i^{th} SRM measured value; $i = 1$ 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 can 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 the maximum permissible uncertainty, other (similar) procedures are given below for high level clusters (procedure b) and for low level clusters (procedure c).

NOTE 1 In some EU Directives (see [1], [2], [3]) the maximum permissible uncertainty of the AMS measured values is expressed as half of the length of a 95 % confidence interval as a percentage P of the emission limit value E . In this case the maximum permissible uncertainty corresponds to an expanded uncertainty.

If the concentration range is slightly bigger than the maximum permissible uncertainty, and if procedure a) results in an inadequate calibration function (e.g. a function with negative slope), procedure b) or c) may be used instead. The justification shall be given in the QAL2 report.

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 the maximum permissible uncertainty, the parameters of the calibration function shall be calculated according to Formula (4) and Formula (5):

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

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

- b) If ($y_{s,\max} - y_{s,\min}$) is smaller than the maximum permissible uncertainty and $y_{s,\min}$ is greater than or equal to 15 % of the ELV, the parameters of the calibration function shall be calculated according to Formula (6) and Formula (7):

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

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

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

NOTE 2 For several AMS the offset is 4 mA.

For procedure b) it is essential that, prior to the parallel measurements, it is proven that the AMS gives a reading at or below detection limit (as demonstrated in QAL1) at a zero concentration (as stated in 6.2).

- c) If ($y_{s,\max} - y_{s,\min}$) is smaller than the maximum permissible uncertainty and $y_{s,\min}$ is smaller than 15 % of the ELV, the parameters of the calibration function shall be determined as follows:

If appropriate reference materials at zero and close to the ELV are available, these shall be used to obtain two data pairs (AMS measured signal and reference value) one at zero and one close to the ELV. The data pairs shall be converted to AMS measuring conditions by use of the average of the AMS measuring conditions in the parallel measurements with the SRM. A combined data set consisting of the results of the parallel measurements and of the data pairs obtained by use of the reference materials shall be formed. The combined data set shall be used to calculate the quantities according to Formula (2)

and Formula (3) as well as the parameters of the calibration function according to Formula (4) and Formula (5).

NOTE 3 If appropriate data pairs are available from the functional test they can be used.

If appropriate reference materials at zero and close to ELV are not available, alternative procedures for the establishment of calibration function can be used, subject to approval by the competent authority. The procedure applied shall be agreed by both the plant operator and the competent authority and be completely documented in the QAL2 report.

The results shall be plotted on an x-y graph in order to show explicitly the calibration function and the valid calibration range.

6.5 Calibration function of the AMS and its validity

The calibration function is given by Formula (8):

$$\hat{y}_i = \hat{a} + \hat{b} x_i \quad (8)$$

where

$\hat{y}_i$ is the calibrated AMS measured value;

x_i is the AMS measured signal.

Each AMS measured signal x_i shall be converted to a calibrated value $\hat{y}_i$ by means of the above calibration function.

It is recommended that this calibration function is incorporated into the data processing system of the plant.

NOTE $\hat{y}_i$ is the calibrated measurement result obtained from the AMS. According to certain EU Directives (see [1], [2], [3]) the maximum permissible uncertainty should be subtracted from that result before comparisons are made with the emission limit value. That procedure is outside the scope of this standard. The calibrated result $\hat{y}_i$ of the AMS is without subtraction of the maximum permissible uncertainty.

The calibration function is valid when the plant is operated within the valid calibration range. This valid calibration range is either the calibration range from zero to the maximum value $\hat{y}_{s,max}$ of the calibrated AMS measured values at standard conditions, determined during the QAL2 procedure, plus an extension of 10 % of $\hat{y}_{s,max}$, or to 20 % of ELV, whichever is greater.

For measurements outside the valid calibration range, however, the calibration curve shall be extrapolated in order to determine the concentration values, which exceed the valid calibration range.

If greater confidence in the performance of the AMS at ELV is required when the plant is emitting outside its calibration range determined above, reference materials at zero and at a concentration close to ELV shall be used, where available, as part of the calibration procedure to confirm the suitability of the linear extrapolation. In this case, calculate the deviation between the calibrated measured value of the AMS at zero and ELV and the corresponding SRM measured values. The deviation at ELV should be less than the maximum permissible uncertainty specified by legislation. The deviation at zero should be less than 10 % of the ELV. If these criteria are not fulfilled then further investigations shall be performed to establish the reasons for this.

The validity of the valid calibration range shall be evaluated by the plant owner on a weekly basis (Monday to Sunday). A full new calibration (QAL2) shall be performed, reported and implemented within 6 months, if any of the following conditions occur:

- more than 5 % of the number of AMS measured values calculated over this weekly period (based on standardized calibrated values) are outside the valid calibration range for more than 5 weeks in the period between two AST;
- more than 40 % of the number of AMS measured values calculated over this weekly period (based on standardized calibrated values) are outside the valid calibration range for one or more weeks.

If the plant is not operated continuously then the percentage values may be calculated from the last 168 operational hours (representing one week in operation).

If exceedances of the valid calibration range are caused by plant failures, a full new calibration (QAL2) is not needed after fixing the plant failure.

If the best estimate of the true value $\hat{y}_{i,s}$ is outside the valid calibration range but below 50 % of ELV, then the competent authority can allow the plant to perform an AST instead of the QAL2. If the AST demonstrates that the existing calibration function is valid beyond the existing valid calibration range, the competent authority can allow the plant to extend the valid calibration range up to the maximum measured concentration determined during the AST plus an extension of 10 % of this value, but the valid calibration range shall not exceed 50 % of ELV.

The existing calibration function shall be used until the new calibration function has been implemented.

Data from previous calibrations shall not be combined with data from a new calibration exercise when calculating the calibration function.

Only calibrated values should be used when reporting to the authorities.

6.6 Calculation of variability

Identify the stated maximum permissible uncertainty for the AMS measured values. Verify the exact definition of this uncertainty (e.g. is it expressed as a 95 % confidence interval, an expanded uncertainty, a standard deviation, or any other statistical formulation). If necessary, convert the maximum permissible uncertainty in terms of an absolute standard deviation σ_0 .

In the case where the expanded uncertainty is expressed at a level of confidence of 95 %, the value of an absolute standard deviation shall be determined by using a factor of 1,96 as the value for the coverage factor.

EXAMPLE In some EU Directives (see [1], [2], [3]) the maximum permissible uncertainty of the AMS measured values is expressed as half of the length of a 95 % confidence interval as a percentage P of the emission limit value E . Then, in order to convert this uncertainty to a standard deviation, the appropriate conversion factor is $\sigma_0 = P E / 1,96$.

The variability test shall be based on the results of the parallel measurements and shall not include data obtained by use of reference materials or alternative procedures for the determination of the calibration function.

The variability test shall be performed on the measured values (calibrated values) of the AMS. Hence, for every parallel measurement the AMS measured value $\hat{y}_i$ shall be calculated using the calibration function (see 6.5).

Where the requirements on the data quality are specified under standard conditions (as e.g. in the relevant EU Directives [1], [2] and [3]), the variability test shall be performed using concentrations under these conditions.

The AMS measured values should be standardized by use of the calibrated measured values of the peripheral AMS for oxygen and water vapour. These peripheral AMS can be calibrated by use of the data sets obtained in the parallel measurements according to 6.3. The calibration function of the peripheral AMS can be established in line with 6.4.3.

NOTE 1 Since the AMS and SRM measured values are converted to standard conditions by independently determined data sets of the peripheral parameters, the uncertainties in the peripheral parameters are attributed to the AMS of the air pollutant in the variability test.

When calculating the variability, the peripheral parameters (e.g. water vapour content, temperature and oxygen concentration) used to standardize the measurements shall be taken from:

- a) the SRM instrumentation for standardizing the SRM measured values;
- b) the plant instrumentation for standardizing the AMS measured values, or in case these do not exist, the default values used by the plant.

NOTE 2 The purpose of this procedure is to ensure that the standardization procedure carried out in the plant's data recording and processing system is included in the variability test.

Examples of Formulae for the conversion of values are given in Annex E.

If the AMS fails the variability test due to error arising from measurements in the peripheral parameters obtained from the plant instrumentation, it is permissible to repeat the variability test using the parameters obtained by the test laboratory from their peripheral SRM. This is only permitted if measures are taken to correct the faulty plant instrumentation.

For each data set (minimum 15 pairs) for a given calibration function, the following parameters shall be calculated, where $y_{i,s}$ is the SRM measured value at standard conditions and $\hat{y}_{i,s}$ the calibrated AMS measured value (the best estimate for the "true value"), calculated from the AMS measured signal x_i at standard conditions:

$$D_i = y_{i,s} - \hat{y}_{i,s} \quad (9)$$

$$\bar{D} = \frac{1}{N} \sum_{i=1}^N D_i \quad (10)$$

$$s_D = \sqrt{\frac{1}{N-1} \sum_{i=1}^N (D_i - \bar{D})^2} \quad (11)$$

6.7 Test of variability

The AMS passes the variability test when:

$$s_D \leq \sigma_0 k_v \quad (12)$$

Values for k_v which shall be applied for different number of parallel measurements are given in Annex I.

NOTE 1 The k_v values are the test values from a χ^2 -test, with a β -value of 50 %.

NOTE 2 The variability obtained includes uncertainty components associated with the repeatabilities of both the AMS and the SRM, but not the overall uncertainty of the SRM (therefore an imprecise implementation of the SRM can result in an apparent poorer variability of the AMS and could result in its false rejection during the variability test). The procedure for determination of variability is not in accordance with GUM (ISO/IEC Guide 98-3).

NOTE 3 This method implies that the quality of the application of the SRM will influence the result of the test. It will be noted, however, that it is the result, which determines a pass or failure and that in some cases a better application of the SRM could change the result from fail to pass.

The measured values of the AMS may be used to demonstrate compliance with the emission limit value only if the AMS has passed the variability test.

When the AMS passes the variability test, for compliance with legislation, the AMS then complies with the uncertainty requirement at the emission limit value, since the variability is deemed as constant throughout the range.

6.8 QAL2 report

The QAL2 report shall contain at least the following information:

- a) a description of the plant and its sampling location(s);
- b) a description of the operating condition of the plant, and the fuel(s) used at the plant during the tests;
- c) the names of the testing laboratory and of the personnel conducting the tests;
- d) details of the EN ISO/IEC 17025 accreditation of the testing laboratory, or details of approval by the relevant competent authority;
- e) a description of the AMS used – including the measurands covered, its principle, type, operating range, and its location;
- f) a description of the SRM used: its principle, type, operating range, repeatability and/or measurement uncertainty, and its EN or ISO reference number where appropriate;
- g) dates and times of the parallel measurements;
- h) detailed data of all the measured values obtained from the AMS and the SRM, averaged over relevant periods;
- i) method used to assess outliers and reasons for excluding outliers;
- j) the calibration function and the valid calibration range including the procedure for the determination of the calibration function and all data used for calculating the calibration function and performing the variability test;
- k) the x-y plot of parallel measurements, including the valid calibration range;
- l) any deviation from the procedures described in this European Standard, and their possible influence on the results obtained presented;
- m) the results of the last functional test (see Annex A).

7 Ongoing quality assurance during operation (QAL3)

7.1 General

AMS can drift or become less precise during routine operation. Drift can be due to, for example, changes in the AMS, such as contamination of an optical surface, gradual failure of a component or blockage in a filter. Such changes can cause systematic deviations in the AMS data. On the other hand, AMS are also subject to short-term variations due to influence factors such as changes in ambient temperature. These variations can cause random deviations. The magnitude of the random deviations is assessed during the certification process of the AMS (QAL1).

After the acceptance and calibration of the AMS, further quality assurance and quality control procedures shall be followed so as to ensure that the measured values obtained with the AMS meet the maximum permissible uncertainty on a continuous basis (also described as *ongoing quality control*). The implementation and performance of the QAL3 procedures given in this standard are the responsibility of the plant owner (i.e. the owner of the AMS). It is also the responsibility of the plant owner to assure that the AMS is operating inside the valid calibration range (see 6.5). The procedures shall be implemented and be in place at the same time that the collection of emission data by means of the AMS is mandatory for reporting to the authorities. It is recommended, however, that these procedures commence as soon as possible after the installation of the AMS in order to gain as much information on the performance of the AMS as possible. This may begin before the AMS has to be calibrated with the SRM in order to fulfil the QAL2 procedure requirements.

A special case may be applied if the plant is operating two independent parallel AMS, measuring the same measured component, standardizing and registering the two outputs independently in the DAHS of the plant, a situation commonly known as a hot spare. In this case if the measurement quality is monitored by an online continuous monitoring of the difference between the output of the two AMS, giving alarm if the difference between the two independent AMS measured values exceeds 5 % of the short-term ELV for more than five consecutive measurements, then the intervals for QAL3 procedures may be extended to one year. If, for whatever reason, the redundant AMS is not working for more than half of the maintenance period of the AMS in question, a QAL3 procedure shall be implemented again immediately after this point in time. In order to control the entire sampling system the two independent AMS should have separate extraction systems and separate zero and span gas supplies for automatic control cycles. It is also recommended that they use separate instruments for monitoring of all peripheral parameters.

7.2 Procedures to maintain ongoing quality

The aim of the procedure is to maintain and demonstrate the quality of the AMS, so that requirement for the stated zero and span repeatability and drift values are met during ongoing operation and the AMS is maintained in the same operational condition as when installed and calibrated in QAL2. This shall be achieved by confirming that the drift and precision determined during the QAL1 remain under control. A suitable methodology shall either:

- a) determine the combined drift and precision of the AMS, or
- b) separately determine the drift and precision.

Both procedures shall identify when an adjustment or maintenance (e.g. by the manufacturer) is necessary.

These operations shall be achieved by the use of control charts which plot the drifts (zero and span) against the time. In both procedures reference materials of known quantity and quality are needed.

In case a), the combined drift and precision obtained in the field shall be compared against specified control limits. This method (e.g. Shewhart control chart) is simple, but does not have the benefit of allowing the AMS to be externally adjusted when it is demonstrated to be out of control.

In case b), a more sophisticated method (e.g. CUSUM control chart) shall be used, which allows separate determination of drift and precision and gives more flexibility by determining if and by how much the zero and span of the AMS need to be externally adjusted.

Control charts require regular and ideally frequent measurements at zero and span points. The needed frequency of the QAL3 is at least once within the period of the maintenance interval, which is defined during the certification process of the AMS in accordance with EN 15267-3. Control charts show trends in the zero and span point measurements and can help the operator by making adjustments to the AMS only when required.

Therefore, QAL3 requires plant operators to have a procedure which describes the requirements for

- measuring zero and span values,