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Stationary source emissions — Quality assurance of automated measuring systems

Émission des sources fixes — Assurance qualité des systèmes automatiques de mesurage

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by the European Committee for Standardization (CEN) (as EN 14181:2014) and was adopted, without modification by Technical Committee ISO/TC 146, *Air quality,* Subcommittee SC 1, *Stationary source emission*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document describes the quality assurance procedures needed to ensure that an automated measuring system (AMS) installed to measure emissions to air are capable of meeting the uncertainty requirements on measured values e.g. given by legislation[1],[2],[3] 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 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.

Stationary source emissions — Quality assurance of automated measuring systems

1 Scope

This document 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 document 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 document is designed to be used after the AMS has been certified in accordance with the series of documents EN 15267.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. 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*

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

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

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 document

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.

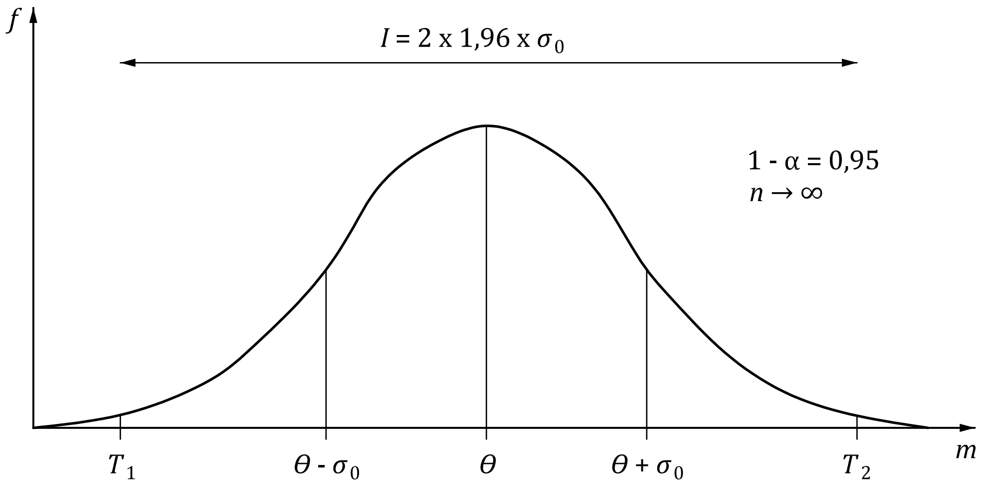

Figure 1 — Illustration of the 95 % confidence interval of a normal distribution

In this document, 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 characterizes 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 abbreviated terms

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
$y_{i,\mathrm{s}}$	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 Abbreviated terms

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 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 document:

— 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 document.

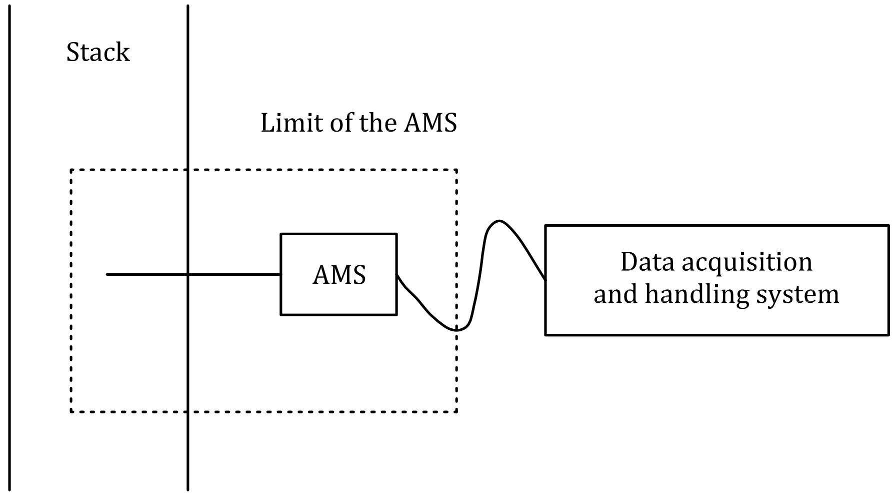

Figure 2 — Limits for the QA of the AMS excluding the data acquisition and handling system

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 document 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 organization(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