



BSI Standards Publication

Ambient air — Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence

National foreword

This British Standard is the UK implementation of EN 14212:2024. It supersedes BS EN 14212:2012, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee EH/2/3, Ambient atmospheres.

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Ambient air - Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence

Air ambiant - Méthode normalisée pour le mesurage de la concentration en dioxyde de soufre par fluorescence U.V.

Außenluft - Messverfahren zur Bestimmung der Konzentration von Schwefeldioxid mit Ultraviolett-Fluoreszenz

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European foreword

This document (EN 14212:2024) 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of an identical text or by endorsement, at the latest by June 2025, and conflicting national standards shall be withdrawn at the latest by June 2025.

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

This document supersedes EN 14212:2012.

The technical modifications in comparison with the previous edition are listed in Annex J of this document.

Any feedback and questions on this document should be directed to the users’ national standards body. A complete listing of these bodies can be found on the CEN website.

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

1 Scope

This document specifies a continuous measurement method for the determination of the concentration of sulfur dioxide present in ambient air based on the ultraviolet fluorescence measuring principle. This document describes the performance characteristics and sets the relevant minimum criteria required to select an appropriate ultraviolet fluorescence analyser by means of type testing. It also includes the evaluation of the suitability of an analyser for use in a specific fixed site so as to meet the data quality requirements (see Annex I of Directive 2008/50/EC [1] for additional information) and requirements during sampling, calibration and quality assurance for use.

The method is applicable to the determination of the mass concentration of sulfur dioxide present in ambient air up to 1000 $\mu\text{g}/\text{m}^3$. This concentration range represents the certification range for sulfur dioxide for type testing.

NOTE 1 It is possible to use other ranges depending on the levels present in ambient air.

NOTE 2 Exemplar uncertainty budget calculations are given in Annexes E to H referring to Directive 2008/50/EC [1]. In the event that the Limit Values are updated in future iterations of Directive 2008/50/EC [1], the user can use these new values to calculate measurement uncertainties.

The method covers the determination of ambient air concentrations of sulfur dioxide in zones classified as rural areas, urban-background areas, traffic-oriented locations and locations influenced by industrial sources.

The results are expressed in $\mu\text{g}/\text{m}^3$ (at 20 °C and 101,3 kPa).

NOTE 3 1 000 $\mu\text{g}/\text{m}^3$ of SO_2 corresponds to 376 nmol/mol of SO_2 .

This document contains information for different groups of users.

Clause 5 to Clause 7 and Annex C and Annex D contain general information about the principles of sulfur dioxide measurement by ultraviolet fluorescence analyser and sampling equipment.

Clause 8 and Annex E are specifically directed towards test houses and laboratories that perform type testing of sulfur dioxide analysers. These sections contain information about:

- type testing conditions, test procedures and test requirements;
- analyser performance requirements;
- evaluation of the type testing results;
- evaluation of the associated uncertainty of the measurement performed by the sulfur dioxide analyser based on the type testing results.

Clause 9 to Clause 11 and Annex F, Annex G and Annex H are directed towards monitoring networks performing the practical measurements of sulfur dioxide in ambient air. These sections contain information about:

- initial installation of the analyser in the monitoring network and acceptance testing;
- ongoing quality assurance/quality control;
- calculation and reporting of measurement results;
- evaluation of the uncertainty of the measurement results under practical monitoring conditions.

This document represents an evolution of earlier editions (EN 14212:2005 and EN 14212:2012).

NOTE 4 Analysers type tested prior to the publication of this document can still be used for regulated monitoring purposes. As newer versions of analysers tested under this document become available, discontinue the use of older reference analysers.

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 15267-1, *Air quality - Assessment of air quality monitoring equipment - Part 1: General principles of certification*

EN 15267-2, *Air quality - Assessment of air quality monitoring equipment - Part 2: Initial assessment of the manufacturer's quality management system and post certification surveillance for the manufacturing process*

EN ISO 6142, *Gas analysis — Preparation of calibration gas mixtures — Gravimetric method (ISO 6142)*

EN ISO 6143, *Gas analysis - Comparison methods for determining and checking the composition of calibration gas mixtures (ISO 6143)*

EN ISO 6144, *Gas analysis - Preparation of calibration gas mixtures - Static volumetric method (ISO 6144)*

EN ISO 6145-6, *Gas analysis - Preparation of calibration gas mixtures using dynamic methods - Part 6: Critical flow orifices (ISO 6145-6)*

EN ISO 6145-7, *Gas analysis - Preparation of calibration gas mixtures using dynamic methods - Part 7: Thermal mass-flow controllers (ISO 6145-7)*

EN ISO 6145-10, *Gas analysis - Preparation of calibration gas mixtures using dynamic volumetric methods - Part 10: Permeation method (ISO 6145-10)*

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

EN ISO 19229, *Gas analysis - Purity analysis and the treatment of purity data*

3 Terms and definitions

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

ISO and IEC maintain terminological 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

adjustment of a measuring system

set of operations carried out on a measuring system so that it provides prescribed indications corresponding to given values of a quantity to be measured

Note 1 to entry: Types of adjustment of a measuring system include zero adjustment of a measuring system, offset adjustment, and span adjustment (sometimes called gain adjustment).

Note 2 to entry: Adjustment of a measuring system should not be confused with calibration, which is a prerequisite for adjustment.

Note 3 to entry: In the context of this document, adjustment is generally performed on measurement data rather than on the analyser.

[SOURCE: JCGM 200:2012, 3.11 [2]]

3.2

ambient air

outdoor air in the troposphere where provisions concerning health and safety at work apply and to which members of the public do not have regular access

Note 1 to entry: This excludes workplaces as defined by Directive 89/654/EEC.

[SOURCE: Council Directive 2008/50/EC [1]]

3.3

analyser

measuring system that provides an output signal which is a function of the concentration or partial pressure of one or more components in a gas mixture and flow or temperature of this gas mixture

3.4

availability of the analyser

fraction of the time period for which valid measuring data of the ambient air concentration is available from an analyser

3.5 calibration

operation that, under specified conditions, in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an indication

Note 1 to entry: A calibration may be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it may consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.

Note 2 to entry: Calibration should not be confused with adjustment of a measuring system, often mistakenly called “self-calibration”, nor with verification of a calibration.

Note 3 to entry: Often, the first step alone in the above definition is perceived as being calibration.

Note 4 to entry: In the context of this document, calibration is a comparison of the analyser response to a known gas concentration with a known uncertainty when the information obtained from the comparison is used for the successive adjustment (if needed) of the analyser.

[SOURCE: JCGM 200:2012, 2.39 [2]]

3.6 certification range

concentration range for which the analyser is type tested

3.7 check

verification that the analyser is still operating within specified performance limits

3.8 combined standard uncertainty

standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms, the terms being the variances or co-variances of these other quantities weighted according to how the measurement result varies with changes in these quantities

[SOURCE: JCGM 100:2008, 2.3.4 [3]]

3.9 coverage factor

numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

[SOURCE: JCGM 100:2008, 2.3.6 [3]]

3.10 competent body

organization which can demonstrate its competence for a specific task to the national competent authority of the Member State

3.11**detection limit**

smallest concentration of a measurand that can be reliably detected by a specific measurement process

Note 1 to entry: The detection limit is calculated as $3,3 \times (s_{r,z}/B)$ where $s_{r,z}$ is the standard deviation of analyser response at zero measurand concentration (see 8.4.5) and B is the slope of the calibration function [4].

3.12**expanded uncertainty**

quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

Note 1 to entry: The fraction can be viewed as the coverage probability or level of confidence of the interval.

Note 2 to entry: To associate a specific level of confidence with the interval defined by the expanded uncertainty requires explicit or implicit assumptions regarding the probability distribution characterized by the measurement result and its combined standard uncertainty. The level of confidence that may be attributed to this interval can be known only to the extent to which such assumptions may be justified.

Note 3 to entry: For the purpose of this document, the expanded uncertainty is the combined standard uncertainty multiplied by a coverage factor $k = 2$ resulting in an interval with a level of confidence of 95 %.

[SOURCE: JCGM 100:2008, 2.3.5 [3]]

3.13**fall time**

difference between the response time (fall) and the lag time (fall)

3.14**independent measurement**

individual measurement that is not influenced by a previous individual measurement by separating two individual measurements by at least four response times

Note 1 to entry: The largest value of response time (rise) and response time (fall) are intended.

3.15**individual measurement**

measurement averaged over a time period equal to the response time of the analyser

Note 1 to entry: The largest value of response time (rise) and response time (fall) are intended.

Note 2 to entry: This definition differs from the meaning of the concept “individual measurement” in Directive 2008/50/EC [1].

3.16**influence quantity**

quantity that is not the measurand but that affects the result of the measurement

[SOURCE: JCGM 100:2008, B.2.10] [3]

3.17**interferent**

component of the air sample, excluding the measured constituent, that affects the output signal

3.18

lack of fit

maximum deviation from the linear regression line of the average of a series of measurement results at the same concentration

3.19

lag time

time interval from the moment at which a step change of sample concentration occurs at the inlet of the analyser to the moment at which the output reading reaches a level corresponding to a predefined change of the stable output reading

3.20

limit value

level fixed on the basis of scientific knowledge, with the aim of avoiding, preventing or reducing harmful effects on human health and/or the environment as a whole, to be attained within a given period and not to be exceeded once attained

[SOURCE: Council Directive 2008/50/EC [1]]

3.21

long-term drift

difference between zero or span readings over a determined period of time (e.g. period of unattended operation)

3.22

monitoring station

enclosure located in the field in which an analyser has been installed to monitor concentrations of one or more ambient air pollutants

3.23

parallel measurement

measurement from different analysers, sampling with the same sampling system starting at the same time and ending at the same time

Note 1 to entry: sampling can be performed from one and the same sampling manifold or with identical individual sampling lines

3.24

performance characteristic

one of the parameters assigned to equipment in order to define its performance

3.25

performance criterion

limiting quantitative numerical value assigned to a performance characteristic, to which conformance is tested

3.26

period of unattended operation

time period over which the drift complies with the performance criterion for long-term drift

3.27**repeatability of results of measurement**

closeness of the agreement between the results of successive individual measurements of sulfur dioxide carried out under the same conditions of measurement

Note 1 to entry: These conditions include:

- a) the same measurement procedure;
- b) the same observer;
- c) the same analyser, used under the same conditions;
- d) at the same location;
- e) repetition over a short period of time.

3.28**reproducibility under field conditions**

closeness of the agreement between the results of simultaneous measurements with two analysers in ambient air carried out under the same conditions of measurement

Note 1 to entry: These conditions are called field reproducibility conditions and include:

- a) the same measurement procedure;
- b) two identical analysers, used under the same conditions;
- c) at the same monitoring station;
- d) the period of unattended operation.

3.29**residence time inside the analyser**

time period for the sampled air to be transported from the inlet of the analyser to the reaction chamber

3.30**residence time in the sampling system**

time period for the sampled air to be transferred to the inlet of the analyser

3.31**response time**

time interval from the instant at which a step change of sample concentration occurs at the inlet of the analyser to the instant at which the output reading reaches a level corresponding to a predefined change of the output reading

3.32**sampled air**

part of ambient air that is transferred through the sampling inlet and sampling system for subsequent measurement

3.33

sample gas temperature

temperature of the sampled gas at the sample inlet

Note 1 to entry: The term “gas” can refer to a test gas used in type testing or to ambient air transferred to the analyser.

3.34

sampling system

assembly of components needed to transfer ambient air to the analyser

3.35

short-term drift

difference between zero or span readings at the beginning and end of a 12 h period

3.36

standard uncertainty

uncertainty of the result of a measurement expressed as a standard deviation

[SOURCE: JCGM 100:2008, 2.3.1 [3]]

3.37

surrounding temperature

temperature of the air directly surrounding the analyser

3.38

total residence time

sum of the residence time in the sampling system and the residence time inside the analyser

3.39

type testing

examination of two or more analysers of the same design which are submitted by a manufacturer to a competent body including the tests necessary for approval of the design (determination of fitness for purpose of a specific device model / of an unambiguous designated analyser)

Note 1 to entry: In EN 15267-1 and -2, type testing is referred to as performance testing.

3.40

uncertainty of the measurement

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

[SOURCE: JCGM 100:2008, 2.2.3] [3]]

4 Abbreviated terms

AMS	automated measuring system (sometimes referred to as continuous automated measuring system (CAMS))
PFA	perfluoro-alkoxy
PTFE	polytetrafluoroethylene

5 Principle

5.1 General

This document describes the method for measurement of the concentrations of sulfur dioxide in ambient air by means of ultraviolet fluorescence. The requirements, the specific components of the ultraviolet fluorescence analyser and its sampling system are described. A number of performance characteristics with associated minimum performance criteria are given for the analyser. The actual values of these performance characteristics for a specific type of analyser shall be determined in a so-called type test for which procedures have been described. The type testing comprises laboratory tests and field tests. The selection of a type tested analyser for a specific measuring task in the field is based on the calculation of the expanded uncertainty of the measured values obtained by the measurement method. In this expanded uncertainty calculation, the actual values of various performance characteristics of a type tested analyser and the site-specific conditions at the monitoring station are taken into account (see Table 4b and 9.9). The expanded uncertainty of the method shall not exceed the limits (this is also specified in Annex I of Directive 2008/50/EC [1]). Requirements and recommendations for quality assurance and quality control are given for the measurements in the field (see 9.4).

5.2 Measuring principle

UV (ultraviolet) fluorescence is based on the emission of light by sulfur dioxide molecules excited by UV radiation when they return to their ground state:

The first reaction step is:



In the second step the excited SO_2^* molecule returns to its ground state, emitting an energy $h\nu'$ according to the reaction:



The intensity of the fluorescence radiation is proportional to the number of sulfur dioxide molecules in the detection volume and is therefore proportional to the concentration of sulfur dioxide.

Therefore:

$$F = k * c_{\text{SO}_2} \quad (3)$$

Where:

- F is the intensity of fluorescence radiation;
- k is the factor of proportionality;
- c_{SO_2} is the concentration of sulfur dioxide.

Before entering the fluorescence analyser, the air sample is passed through a filter in order to exclude interferences caused by contamination with particles.

The sampled air is scrubbed to remove any interference by aromatic hydrocarbons that may be present. A hydrocarbon scrubber device is used to achieve this.

The sampled air is then introduced into a reaction chamber, where it is irradiated by UV light in the wavelength range between 200 nm and 220 nm. The UV fluorescent light emitted in the wavelength range from 240 nm to 420 nm, is optically filtered and then converted to an electrical signal by a UV detector, for example, a photomultiplier tube.

The response of the analyser is proportional to the number of sulfur dioxide molecules in the reaction chamber. Therefore, temperature and pressure either need to be kept constant, or, if variation of these parameters occurs, the measured values need to be corrected.

The concentration of sulfur dioxide is expressed in the units provided by the calibration standard. The final results for reporting are expressed in $\mu\text{g}/\text{m}^3$ using standard conversion factors (see Clause 10).

5.3 Type testing

The type test is based on the evaluation of performance characteristics determined under a prescribed series of tests. In this document, test procedures are described for the determination of the actual values of the performance characteristics for at least two analysers of the same type in a laboratory and the same analysers in the field, operated in parallel in both cases. The laboratory tests shall not include the sampling inlet, sampling system and external data acquisition system, but shall include analyser sampling line and filter. The field tests may include a sampling inlet and a sampling system. However, the influence of these components on the test results shall be minimized by proper maintenance.

A competent body shall perform these tests. The evaluation for type testing of an analyser is based on the calculation of the expanded uncertainty in the measuring result based on the numerical values of the tested performance characteristics and compared with a prescribed maximum uncertainty.

The type testing of an analyser and subsequent QA and QC procedures provide evidence that the specified requirements concerning data quality (see Annex I of Directive 2008/50/EC [1] for more information) can be satisfied.

Appropriate experimental evidence shall be provided by:

- type tests performed under conditions of intended use of the specified method of measurement; and
- calculation of expanded uncertainty of results of measurement by reference to JCGM 100 [3].

5.4 Field operation and quality control

Prior to the installation and operation of a type-tested analyser at a monitoring station, an expanded uncertainty calculation shall be performed with the actual values of the performance, obtained during the type tests, and in accordance with the site-specific conditions at that monitoring station. This calculation shall be used to demonstrate that the type-tested analyser meets the requirements for all applicable limit values under the actual conditions present at that specific monitoring station.

After the installation of the type tested analyser at the monitoring station, its correct functioning shall be tested.

Requirements for quality assurance and quality control are given in Clause 9 for the operation and maintenance of the sampling system, as well as for the analyser, to ensure that the associated uncertainty of measurements obtained in the field is not compromised.

6 Sampling

6.1 General

Depending on the installation of the ultraviolet fluorescence analyser at a monitoring station, a single sampling line for the analyser may be chosen. Sampling can take place :

- from a sampling inlet with an individual sampling line specific to the analyser; or
- from a common sampling inlet with a sampling manifold to which analysers and equipment may be attached.

Conditions and layout of the sampling system will contribute to the uncertainty of the measurement; to minimize this contribution to the expanded uncertainty, requirements for the sampling equipment are given in the following subclauses.

NOTE In Annex B, different arrangements of the sampling equipment are schematically presented.

The following factors may, through decrease or increase in the concentration of sulfur dioxide, contribute to the uncertainty of the measurement when considering the sampling as an integral part of the measurement:

- loss of sulfur dioxide in the sampling system;
- loss of sulfur dioxide in the particle filter.

These factors are recognized to be relevant, but currently cannot be quantified for lack of appropriate assessment methods. As a consequence, the contributions of these factors are not considered in the uncertainty assessment applied in this document. The effect of these factors is minimized through minimum requirements (see 6.3) and application of appropriate QA/QC measures (see 9.4 to 9.6) and maintenance (see 9.7).

6.2 Sampling location

The location where the ambient air shall be sampled and analysed is not specified as this depends strongly on the category of a monitoring station (such as measurements taken in e.g. a rural area or background area).

NOTE More information on guidance and criteria for micro scale sampling points are given in Annex III of Directive 2008/50/EC [1] and Amendment 2015/1480/EC [5].

6.3 Sampling system

6.3.1 Construction

The sampling system shall include a sampling inlet and may include the following components:

- a dedicated sampling line to the analyser or manifold;
- a particle filter placed between the sampling line or manifold and the analyser;
- a sampling pump in case a sampling manifold is used.

The sample inlet shall be constructed in such a way that ingress of rainwater into the sampling line or manifold is prevented. The sampling line or manifold shall be as short as practical to minimize the residence time (see also 6.3.3).

In the case where a sampling manifold is used, an additional pump is necessary with sufficient capacity to fulfil the sampling requirements stated in the previous subclauses (see also 6.5 and Annex B).

The material of the sample inlet as well as the sampling line or manifold can influence the composition of the sample. In practice, the best materials, such as polytetrafluoroethylene (PTFE), perfluoro-alkoxy (PFA), borosilicate glass, silicon-coated or 316L stainless steel, shall be used. The influence of the material of the sampling inlet and line or manifold on the measured concentrations of sulfur dioxide due to losses shall be $\leq 2,0$ %.

NOTE 1 When using polymeric materials consider their permeability to gases and in particular to water vapour. This effect can be avoided by increasing the thickness of the sampling line or manifold.

NOTE 2 This value can be achieved when the quality assurance and quality control requirements (see Clause 9) are followed.

The sampling line or manifold may be moderately heated to avoid condensation, which may occur in the case of high ambient temperature and/or humidity in presence of cold surfaces.

The influence of the pressure drop on the measurement concentration along the sampling inlet, line, manifold and the particle filter on the measured concentrations shall be considered (see 9.6.3).

6.3.2 Particle filter

A particle filter shall be placed between the sampling line or manifold and the inlet of the analyser. The filter shall retain all particles likely to alter the performance of the analyser. It shall be made of PTFE. The material of the filter housing shall be chemically inert to sulfur dioxide.

The filter may be internal to the analyser (see 7.8) or external. In case the analyser contains a built-in filter, an external filter is not necessary.

NOTE 1 A pore size of the filter of 5 μm usually fulfils this requirement.

NOTE 2 Suitable materials for the filter housing are for example PTFE, PFA, 3161, stainless steel, or borosilicate glass.

The particle filter shall be conditioned before used in measurements (6.3.4.). The filter shall be changed periodically depending on the dust loading at the sampling site (as indicated in 9.7). The filter housing shall be cleaned at least every six months. Overloading of the filter can cause loss of sulfur dioxide by adsorption on the particle matter and can increase the pressure drop in the sampling line.

6.3.3 Loss of sulfur dioxide

Depending on the location of the particle filter, the sampling system can be contaminated by deposition of dust. This can induce losses of sulfur dioxide. The sampling system shall be cleaned (as stated in 9.4.2) with a frequency which is dependent on the site-specific conditions.

6.3.4 Conditioning

The sampling system and the particle filter shall be conditioned (at initial installation and after each cleaning) to avoid temporary decreases in the measured sulfur dioxide concentrations by sampling ambient air for a period of at least 30 min at the nominal sample flow rate. Conditioning may also be done in the laboratory before installation.

These conditioning periods shall not be included in the calculation of the availability of the analyser during the type test (8.5.7).

NOTE Conditioning during field operation is considered a part of normal maintenance..

6.4 Control and regulation of sample flow rate

The sample flow rate into the analyser shall be maintained within the specifications of the manufacturer of the analyser.

6.5 Sampling pump for the manifold

When a sampling manifold is used, a pump (or similar device, e.g. a blower) is necessary for sampling ambient air and suction of the sampled air through the sampling manifold. The inlet of the sampling pump for the sampling manifold shall be located at the end of the sampling manifold (see Annex B). The sampling pump shall have sufficient rating to ensure that all analysers connected to the manifold are supplied with the required amount of air and to ensure that the residence time fulfils the requirement (see 9.4.5.3). To verify the functioning of this pump, it is recommended to install a flow alarm system. An example of a sampling manifold is given in Annex B.

The influence of the pressure drop induced by the manifold sampling pump on the measured concentration shall be $\leq 1,0 \%$.

7 Analyser equipment

7.1 General

A schematic diagram of a UV fluorescence analyser is given in Annex C.

A UV fluorescence analyser consists of the principal components which are described in 7.2 to 7.6.

7.2 Selective traps for interfering agents

One or more selective traps shall be used before the fluorescence cell to remove interfering gases such as aromatic hydrocarbons.

These selective traps shall not retain any sulfur dioxide, and shall be replaced regularly in accordance with the manufacturer's instructions.

If high concentrations of H_2S are expected in the ambient air, a selective scrubber shall be used.

7.3 Optical assembly

The optical assembly consists of a UV lamp, a fluorescence cell, a reference sensor and a UV detector.

The UV lamp emission may be pulsed electronically or mechanically in order to enable synchronous detection and amplification of the signal. The lamp shall have a stabilized power supply to ensure a stable emission of light. An optical filter is used to restrict the wavelengths to a range which allows excitation of the sulfur dioxide molecule and minimizes the interferences due to water vapour, aromatic hydrocarbons or nitrogen monoxide. This filter shall remove radiation at wavelengths longer than 600 nm, to minimize any interference produced by the UV fluorescence of unsaturated hydrocarbons, which radiate at these wavelengths.

The reference sensor in the extension of the beam path behind the reaction chamber checks the constancy of the UV lamp and is used to correct the fluorescence signal or to control the UV lamp.

The fluorescence cell shall be made of material inert to sulfur dioxide and UV radiation. The cell shall be heated to a constant temperature above the water vapour dew point to avoid water condensation and to minimize temperature changes. An optical trap in the fluorescence cell shall be used to prevent reflection of the UV radiation.

The UV detector, for example a photomultiplier tube, detects the fluorescence light emitted by the sulfur dioxide molecules in the fluorescence cell. A selective optical filter placed in front of the photomultiplier tube reduces the signal due to scattering of incident light.

The optical assembly shall be placed in a heated temperature-controlled enclosure.

7.4 Pressure measurement

The output signal of the analyser is proportional to the density of sulfur dioxide (number of sulfur dioxide molecules) present in the reaction chamber and depends on the pressure in the chamber. Variations of internal pressure shall be measured and the signal corrected.

The signal shall be corrected also for external pressure and temperature fluctuations. Significant pressure variations are due to synoptic meteorological changes (up to $\pm 3\%$) or by the altitude of the measurement site (e.g. approximately 10 % decrease in pressure for an 800 m rise in altitude).

NOTE One of the main causes of a reduced pressure in the reaction chamber is a pressure drop in the sample line.

7.5 Flow rate indicator

A flow rate indicator shall be included in the analyser.

It is recommended that the flow rate be kept constant by means of a flow controller.

7.6 Sampling pump for the analyser

The sampling pump is situated at the outlet of the analyser, and draws the sample through the analyser. It can be separate or a part of the analyser. In any case, it shall be capable of operating within the specified flow requirements of the manufacturer of the analyser and pressure conditions required for the reaction chamber.

If the use of the UV lamp produces ozone, it is recommended to vent this ozone outside the monitoring station and away from the sampling inlet. A suitable charcoal filter may be used for trapping ozone.

7.7 Internal sulfur dioxide span source

Some analysers are equipped with an internal span source. This span source shall not be used for calibration purposes. The concentrations generated by this internal span source may be used for functional tests only.

7.8 Particle filter

An analyser will generally contain an internal particle filter (see 6.3.2). This filter shall be considered an integral part of the analyser in type testing.

8 Type testing of ultraviolet fluorescence sulfur dioxide analysers

8.1 General

The determination of the concentration of sulfur dioxide in ambient air shall fulfil the requirement of a maximum uncertainty in the measured values. In order to achieve an uncertainty less than (or equal to) this required uncertainty, the ultraviolet fluorescence analyser shall fulfil all the criteria for a number of performance characteristics which are given in this document. The values of the selected performance characteristics shall be evaluated by means of laboratory tests and field tests. By combining uncertainties derived from the values of the selected performance characteristics in the expanded uncertainty calculation, a judgement shall be made whether or not the ultraviolet fluorescence analyser meets the criterion of maximum uncertainty.

This process of assessment (type testing) of the values of the performance characteristics comprises laboratory tests and field tests and the calculation of the expanded uncertainty. Test procedures are described for the determination of the actual values of the performance characteristics for at least two analysers identical in hardware, firmware and software. The same analysers shall be evaluated in the laboratory and field tests,, operated in parallel in both cases.

If a measuring system fails irreparably, the performance test shall be continued with a measuring system of the same type after reconciliation with the competent body responsible for the declaration of suitability.

The test procedure shall fulfil the requirements laid down in EN 15267-1 and EN 15267-2. A competent body shall perform the type testing.

NOTE 1 It is advisable that the organisations performing the type testing are accredited according to an internationally accepted standard. EN ISO/IEC 17025 [6] is the harmonized international standard that usually applies.

NOTE 2 A formal accreditation by a member body of the European Accreditation Organization to EN ISO/IEC 17025 [6] is a demonstration of conformity.

EN 15267-1 specifies the general principles of the product certification of automated measuring systems (AMS) for monitoring emissions from stationary sources and ambient air quality. This product certification consists of the following sequential stages:

- a) performance testing of an AMS type;
- b) initial assessment of the AMS manufacturer's quality management system;
- c) certification;
- d) post-certification product-surveillance.

EN 15267-2 covers the supplementary requirements for an AMS manufacturer's management system to EN ISO 9001 [7] for the control of design and manufacturing of AMS. This document also serves as a reference document for auditing the AMS manufacturer's management system.

8.2 Relevant performance characteristics and criteria

The performance characteristics which shall be determined during a laboratory and field test, and their related performance criteria, are given in Table 1. Table 1 applies to those ranges that are specified as normative in the scope of this document. When type testing is performed on analysers with other certification ranges, the performance criteria stated in absolute units such as nmol/mol/K may need to be modified in order to meet the uncertainty criteria.

NOTE Directive 2008/50/EC Annex I provided further information about the uncertainty criteria

The determination of the value of the performance characteristics stated in Table 1 shall be performed during the laboratory test and field test by a competent body according to the procedures described in 8.4, 8.5 and Annex A.

Table 1 — Relevant performance characteristics and criteria

Nr	Performance characteristic	Symbol	Section	Lab test	Field test	Performance criterion for SO ₂
1	Repeatability standard deviation at zero	$s_{r,z}$	8.4.5	X		≤ 1,0 nmol/mol
2	Repeatability standard deviation at concentration c_t	$s_{r,ct}$	8.4.5	X		≤ 3,0 nmol/mol
3	Lack of fit (residual from the linear regression function)		8.4.6			
3a	Largest residual from the linear regression function at concentrations higher than zero	$r_{\max}$		X		≤ 4,0 % of the measured value
3b	Residual at zero	r_z		X		≤ 5 nmol/mol
4	Sensitivity coefficient of sample gas pressure	b_{gp}	8.4.7	X		≤ 2,0 nmol/mol/kPa
5	Sensitivity coefficient of sample gas temperature	b_{gt}	8.4.8	X		≤ 1,0 nmol/mol/°C
6	Sensitivity coefficient of surrounding temperature	b_{st}	8.4.9	X		≤ 1,0 nmol/mol/°C
7	Sensitivity coefficient of electrical voltage	b_v	8.4.10	X		≤ 0,3 nmol/mol/V
8	Interferents at zero and at concentration c_t (at a level of the hourly limit) ^a		8.4.11			
8a	H ₂ O with concentration 19 mmol/mol _b	$x_{H_2O,z,ct}$		X		≤ 10 nmol/mol
8b	H ₂ S with concentration 200 µmol/mol	$x_{H_2S,z,ct}$		X		≤ 5,0 nmol/mol
8c	NH ₃ with concentration 200 nmol/mol	$x_{NH_3,z,ct}$		X		≤ 5,0 nmol/mol

Nr	Performance characteristic	Symbol	Section	Lab test	Field test	Performance criterion for SO ₂
8d	NO with concentration 500 nmol/mol	$x_{NO_2,z,ct}$		X		≤ 5,0 nmol/mol
8e	NO ₂ with concentration 200 nmol/mol	$x_{NO_2,z,ct}$		X		≤ 5,0 nmol/mol
8f	m-xylene with concentration 1 µmol/mol	$x_{yl,z,ct}$		X		≤ 10,0 nmol/mol
9	Averaging effect	E_{av}	8.4.12	X		≤ 7,0 % of the measured value
10	Reproducibility standard deviation under field conditions	$s_{r,f}$	8.5.5		X	≤ 5,0 % of the average of a three-month period
11	Long-term drift at zero level	$D_{l,z}$	8.5.4		X	≤ 4,0 nmol/mol
12	Long-term drift at span level ^c	$D_{l,s}$	8.5.4		X	≤ 5,0 %
13	Short-term drift at zero level	$D_{s,z}$	8.4.4	X		≤ 2,0 nmol/mol over 12 h
14	Short-term drift at span level ^c	$D_{s,s}$	8.4.4	X		≤ 6,0 nmol/mol over 12 h
15	Response time (rise)	t_r	8.4.3	X		≤ 180 s
16	Response time (fall)	t_f	8.4.3	X		≤ 180 s
17	Difference between rise time and fall time	t_d	8.4.3	X		≤ 10 s
18	Difference sample/calibration port ^d	Δx_{sc}	8.4.13	X		≤ 1,0 %
19	Period of unattended operation		8.5.6		X	3,0 months or less if manufacturer indicates a shorter period, but not less than 2 weeks
20	Availability of the analyser	A_a	8.5.7		X	≥ 90 %

^a Performance criterion is set both at zero and test gas concentration level.

^b H₂O-concentration of 19 mmol/mol equals 80 % RH at 20 °C and 101,3 kPa.

^c Span level is 70 % to 80 % of the certification range.

^d If relevant.

NOTE µmol/mol = ppm (parts per million); nmol/mol = ppb (parts per billion)

8.3 Design change

When the manufacturer makes design changes, the manufacturer shall notify the test laboratory, unless the manufacturer has evidence to show that the analyser still meets the performance stated in the original analyser certificate. The following three classes of changes to a type tested analyser are defined as follows:

- Type 0: changes that have no measurable influence to the performance of the analyser;
- Type 1: changes that can have an influence on the performance of the analyser, but where subsequent tests prove that such changes do not have a significant influence;
- Type 2: changes that have a significant influence on the performance of the analyser.

A significant influence modifies the performance of the analyser compared to that recorded in the certificate for the stipulated performance characteristics. The manufacturer shall evaluate and document all changes to a type tested analyser. It is essential that the manufacturer documents all changes and evaluations in accordance with the requirements of EN ISO 9001 [7] and EN 15267-2 in such a way that they can be audited. Where changes are identified, the procedures documented in EN 15267-1 and -2 shall be followed.

8.4 Procedures for determination of the performance characteristics during the laboratory test

8.4.1 General

The performance characteristics shall be determined in the laboratory as a part of the type testing. The quality of the materials and equipment used in the described test procedures shall be in accordance with the requirements given in this document. The tests shall be performed on at least two analysers of the same type in the laboratory test.

8.4.2 Test conditions

8.4.2.1 General

Before operating the analyser, the operating instructions of the manufacturer shall be followed particularly with regard to the set-up of equipment and the quality and quantity of the consumable products necessary.

The analyser shall be allowed to warm up during the time specified by the manufacturer before undertaking any tests. If the warm-up time is not specified, a minimum of 4 h is required.

If auto rescaling and self-correction for drift are optional to the analyser, then these functions shall be disabled during the laboratory tests.

If an auto-rescaling function or self-correction function are not optional and are considered “normal operational condition”, then the times and magnitudes of any self-correction shall be available to the test laboratory. The magnitude of the auto zero and the auto span drift corrections both have the same restrictions as laid down in the performance characteristics.

When applying test gases to the analyser, the test gas system shall be operated sufficiently long before starting the tests in order to stabilize the concentrations applied to the analyser. The analyser shall be tested with the particle filter installed.

Most analyser systems are able to give an output signal as a moving average over an adjustable period of time and some systems automatically change this integration time as a function of the frequency of the fluctuations in concentration of the detected pollutant. These options are typically used in order to smooth output data. It needs no demonstration that the set value for the averaging time or the use

of an active filter will influence the result of the averaging test and response time test. During laboratory and field tests for the type testing, the settings of the monitor shall be as the manufacturer requires. Auto zeroing and auto-scaling capabilities shall be disabled during the lab tests; during field tests the monitor shall be in the configuration as used. All settings shall be noted in the test report.

8.4.2.2 Parameters

During the test for each individual performance characteristic, the values of the following parameters shall be stable within the specified range given in Table 2.

Table 2 — Set points and stability of test parameters

Parameter	Set points	Stability
Sample gas pressure	Manufacturer's specification (except for the sample gas pressure test, see 8.4.7)	$\pm 0,2$ kPa
Sample gas temperature	20 °C to 23 °C (except for the sample gas temperature test, see 8.4.8)	± 2 °C
Surrounding temperature	20 °C to 23 °C (except for the temperature of the surrounding air test, see 8.4.9)	± 2 °C
Electrical voltage a	At nominal line voltage and within manufacturer's specifications (except for the voltage dependence test, see 8.4.10)	± 1 %
Sample flow to the analyser	Manufacturer's specification	± 1 %
^a For an analyser operating on direct current the type testing of voltage variation shall be carried out over the range of ± 10 % of the nominal voltage.		

8.4.2.3 Test gases

For the determination of the various performance characteristics, test gases traceable to (inter)nationally accepted standards shall be used unless otherwise stated in this document. Various methods for the generation of test gases are given in Table 3.

Table 3 — Methods for preparation of test gases

Method	Description	Standard(s) to be used
Cylinder	Gas mixture of SO ₂ in (synthetic) air (for direct use)	EN ISO 6142 EN ISO 6143
Dynamic dilution	Dynamic blending of high concentration SO ₂ (Cylinder mixture in either synthetic air or nitrogen) with (synthetic) zero air free of interferents	EN ISO 6145-6 or EN ISO 6145-7
Permeation tubes	Determination of the mass loss of a permeation tube containing SO ₂	EN ISO 6145-10
Static dilution	Preparation by means of injecting known amounts of SO ₂ into a known volume of air	EN ISO 6144

The maximum permitted expanded uncertainty (95 % confidence) in the concentration of gases used for laboratory tests is 3 %.

Possible contamination of zero and span gas shall not significantly influence the results of laboratory tests. Therefore, the span gases and zero gas shall meet the specifications given in Table 4 to Table 6.

The specifications for the purity of test gases and zero gases shall be assessed using EN ISO 19229.

Table 4 — Specification for purity of test gas

Pollutant	Concentration
H ₂ S	≤ 0,1 µmol/mol
NH ₃	≤ 2,0 nmol/mol
NO	≤ 1,0 nmol/mol
NO ₂	≤ 1,0 nmol/mol
m-xylene	≤ 1,0 nmol/mol
water	≤ 150 µmol/mol
NOTE For field operation and ongoing quality control (see 9.5.3), it is possible to relax the impurity specifications in the gases.	

Table 5 — Specification for purity of zero gas for interferents testing [9]

Pollutant	Concentration
H ₂ S	≤ 0,1 µmol/mol
NH ₃	≤ 2,0 nmol/mol
NO	≤ 1,0 nmol/mol
NO ₂	≤ 1,0 nmol/mol
m-xylene	≤ 1,0 nmol/mol
water vapour	≤ 150 µmol/mol
SO ₂	≤ 1,0 nmol/mol
NOTE For field operation and ongoing quality control (see 9.5.3), it is possible to relax the impurity specifications in the gases.	

Table 6 — Specification for purity of zero gas for other tests [9]

Pollutant	Concentration
H ₂ S	≤ 0,1 µmol/mol
NH ₃	≤ 10 nmol/mol
NO	≤ 1,0 nmol/mol
NO ₂	≤ 1,0 nmol/mol
m-xylene	≤ 1,0 nmol/mol
water vapour	≤ 150 µmol/mol
SO ₂	≤ 1,0 nmol/mol
NOTE For field operation and ongoing quality control (see 9.5.3), it is possible to relax the impurity specifications in the gases.	

It is advisable to perform the field tests with the same set of cylinders and zero air generators, exclusively reserved for the tests. The stability of both the zero air and the span gas should be guaranteed over a period longer than the test period.

NOTE Suitable stability criteria will be achieved by sourcing traceable gas mixtures that are certified to a relevant standard, for example EN ISO 17034 [9].

8.4.3 Response time

8.4.3.1 General requirements

The response time of the analyser shall be determined at the nominal sample flow rate specified by the manufacturer.

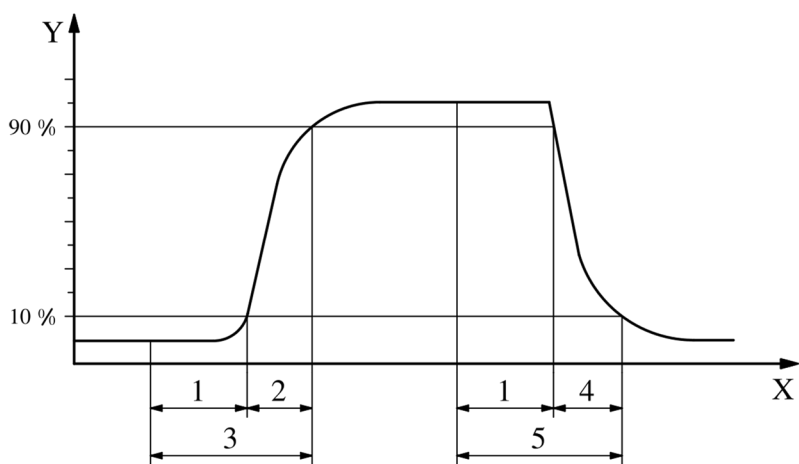
The sample flow rate shall be kept constant within the requirements as given in 8.4.2 ($\pm 1\%$) during the test.

8.4.3.2 Test procedure

The determination of the response time shall be carried out by applying to the analyser a step function in the concentration from less than 20 % to about 80 % of the maximum of the certification range of sulfur dioxide and vice versa (see Figure 1).

NOTE Usually zero gas and span gas are used for this test.

The change from zero gas to span gas and vice versa needs to be made almost instantaneously, with the use of a suitable valve. The valve outlet shall be mounted direct to the inlet of the analyser, and both zero gas and span gas shall have the same amount of gas in excess, which is vented by the use of a tee. The gas flows of both zero gas and span gas shall be chosen in such a way that the dead time in the valve and tee can be neglected compared to the lag time of the analyser system. The step change is made by switching the valve from zero gas to span gas. This event needs to be timed and is the start ($t = 0$) of the (rise) lag time according to Figure 1. When the reading over 5 min is stable to within $\pm 2\%$ of the test gas (span) concentration, the span gas can be changed to zero gas again; this event is the start ($t = 0$) of the (fall) lag time. When the reading over 5 min is stable to within 3 nmol/mol of the zero gas concentration the whole cycle as shown in Figure 1 is complete.



- Key**
- X time
 - Y analyser response
 - 1 lag time
 - 2 rise time
 - 3 response time (rise)
 - 4 fall time
 - 5 response time (fall)

Figure 1 — Diagram illustrating the response time

The elapsed time (response time) between the start of the step change and reaching 90 % of the analyser final stable reading of the applied concentration shall be measured. The whole cycle shall be repeated four times. The average of the four response times (rise) and the average of the four response times (fall) shall be calculated.

The difference in response times shall be calculated according to Formula (4):

$$t_d = \bar{t}_r - \bar{t}_f \tag{4}$$

where

- t_d is the difference between response time (rise) and response time (fall), in s;
- $\bar{t}_r$ is the response time (rise) (average of the four response times - rise), in s;
- $\bar{t}_f$ is the response time (fall) (average of the four response times - fall), in s.

The times t_d , $\bar{t}_r$ and $\bar{t}_f$ shall comply with the performance criteria in Table 1.

8.4.4 Short-term drift

After the required stabilization period (8.4.2.1), the analyser shall be adjusted at zero and span level (around 70 % to 80 % of the maximum of the certification range of sulfur dioxide). Wait the time equivalent to one independent reading and then record 20 individual measurements, first at zero and then at span concentration. From these 20 measurements, the average is calculated for zero and span level.

The analyser shall be kept running under the laboratory conditions (8.4.2.2) while analysing ambient air. After a period of 12 h, zero and span gas is fed to the analyser. Wait the time equivalent to one

independent reading and then record 20 individual measurements, first at zero and then at span concentration. The averages for zero and span level shall be calculated.

The short-term drift at zero and span level shall be calculated as follows:

$$D_{s,z} = C_{z,2} - C_{z,1} \quad (5)$$

where

- $D_{s,z}$ is the 12-h drift at zero, in nmol/mol;
- $C_{z,1}$ is the average concentration of the measurements at zero at the beginning of the drift period, in nmol/mol;
- $C_{z,2}$ is the average concentration of the measurements at zero at the end of the drift period, in nmol/mol.

The 12-h drift at zero $D_{s,z}$ shall comply with the performance criterion in Table 1.

$$D_{s,s} = (C_{s,2} - C_{s,1}) - D_{s,z} \quad (6)$$

where

- $D_{s,s}$ is the 12-h drift at span, in nmol/mol;
- $C_{s,1}$ is the average concentration of the measurements at span level at the beginning of the drift period, in nmol/mol;
- $C_{s,2}$ is the average concentration of the measurements at span level at the end of the drift period, in nmol/mol.

The 12-h drift at zero $D_{s,s}$ shall comply with the performance criterion in Table 1.

NOTE Compliance with this test shows that drift is not the dominant factor in any of the test results.

8.4.5 Repeatability standard deviation

After waiting the time equivalent of one independent reading, 20 individual measurements both at zero concentration and at a test concentration c_t similar to the hourly limit value shall be performed.

From these measurements, the repeatability standard deviation s_r at zero concentration and at concentration c_t (hourly limit value) shall be calculated according to Formula (7):

$$s_r = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}} \quad (7)$$

where

- s_r is the repeatability standard deviation, in nmol/mol;
- x_i is the i th measurement, in nmol/mol;
- $\bar{x}$ is the average of the 20 measurements, in nmol/mol;
- n is the number of measurements, $n = 20$.

The repeatability standard deviation shall be calculated separately for both series of measurements (zero gas and concentration c_t).

The repeatability standard deviation s_r shall comply with the performance criterion in Table 1, both at zero and at the test gas concentration c_t (hourly limit value).

The repeatability standard deviation at zero is used in combination with the slope of the calibration function determined in 8.4.6 to calculate the detection limit of the analyser according to [4] as shown in Formula (8):

$$l_{\text{det}} = 3,3 \frac{s_{r,z}}{B} \quad (8)$$

where

- l_{det} is the detection limit of the analyser, in nmol/mol;
- $s_{r,z}$ is the repeatability standard deviation at zero, in nmol/mol;
- B is the slope of the calibration function determined according to Annex A using the data from 8.4.6.

NOTE Detection limit values are used for data treatment or reporting, see 9.8.

8.4.6 Lack of fit of linearity of the calibration function

The lack of fit of linearity of the calibration function of the analyser shall be tested over the range of 0 % to 95 % of the maximum of the certification range of sulfur dioxide, using at least seven concentrations (including the zero point). The analyser shall be adjusted at a concentration of about 80 % of the maximum of the certification range. At each concentration (including zero) at least five individual measurements shall be performed.

The concentrations shall be applied in the following sequence: 80 %, 10 %, 40 %, 0 %, 60 %, 20 % and 95 % with a tolerance of $\pm 1.5\%$ at each point. After each change in concentration, at least four response times shall be taken into account before the next measurement is performed.

NOTE The design of the test (number of concentrations and number of repetitions) is such that the deviation from a linear function can be determined with sufficient accuracy. The test is also sufficiently robust to detect the case of nonlinearity in the range from zero to some concentration at the lower end of the range as well as nonlinearity from that lower end of the range to the higher end of the range.

Calculation of the linear regression function and residuals shall be performed according to Annex A. All the (relative) residuals from the linear regression function shall fulfil the criteria as stated in Table 1.

The largest value of the relative residuals is reported as r_{max} and shall be taken into account in demonstrating compliance with type testing requirements.

8.4.7 Sensitivity coefficient to sample gas pressure

Measurements are taken at a concentration of about 70 % to 80 % of the maximum of the certification range of sulfur dioxide at an absolute pressure of about $(90 \pm 0,2)$ kPa and at an absolute pressure of about $(110 \pm 0,2)$ kPa. Changes in pressure shall be achieved by modifying the applied calibration gas pressure at the sample inlet. At each pressure after waiting the time equivalent to one independent reading, three individual measurements are recorded. From these three measurements, the averages at each pressure are calculated.

Measurements at different pressures shall be separated by at least four response times.

The pressure sensitivity coefficient shall be evaluated with regard to the following key requirements:

- instrument manufacturers shall describe in detail how pressure correction is implemented in their instrument, and the exact locations of the pressure sensors used for these calculations;
- option 1: If the pressure compensation hardware is completely contained within the sample tubing and measurement cell, the instruments will be tested in the lab by varying the sample inlet pressure

in the range from 90 kPa to 110 kPa. If an instrument has multiple flow paths the inlet pressure for those particular paths shall be varied identically and concurrently with the pressure in the main sample flow path;

- option 2: If manipulation of the inlet pressure of the sample flow paths or the additional flow paths is technically not possible or if the pressure compensation is based on other pressure sensors outside of the impacted flow paths, the instruments shall be tested at a suitable pressure test stand. An example is described in Annex I. The instruments will be tested in the lab by varying the sample inlet pressure in the range from 90 kPa to 110 kPa.

NOTE Performance of the analyser can be affected if the instrument is operated in an ambient gas pressure outside of the tested 90 kPa to 110 kPa range (for example at high altitude).

The sample gas pressure influence is calculated by Formula (9):

$$b_{gp} = \left| \frac{(C_{P2} - C_{P1})}{(P_2 - P_1)} \right| \quad (9)$$

where

- b_{gp} is the sample gas pressure sensitivity coefficient, in nmol/mol/kPa;
- C_{P1} is the average concentration of the measurements at sampling gas pressure P_1 , in nmol/mol;
- C_{P2} is the average concentration of the measurements at sampling gas pressure P_2 , in nmol/mol;
- P_1 is the minimum sampling gas pressure, in kPa;
- P_2 is the maximum sampling gas pressure, in kPa.

The sample gas pressure sensitivity coefficient b_{gp} shall comply with the performance criterion in Table 1.

8.4.8 Sensitivity coefficient to sample gas temperature

Measurements shall be performed at sample gas temperatures of $T_{G,1} = 5\text{ °C}$ and $T_{G,2} = 40\text{ °C}$. A concentration around 70 % to 80 % of the maximum of the certification range of sulfur dioxide shall be applied. Wait the time equivalent to one independent measurement and record three individual measurements at each temperature. The sample gas temperature, measured at the inlet of the analyser, shall be held constant for at least 30 min.

The influence of sample gas temperature is calculated from Formula (10):

$$b_{gt} = \left| \frac{(C_{GT,2} - C_{GT,1})}{(T_{G,2} - T_{G,1})} \right| \quad (10)$$

where

- b_{gt} is the sample gas temperature sensitivity coefficient, in nmol/mol/K;
- $C_{GT,1}$ is the average concentration of the measurements at sample gas temperature $T_{G,1}$, in nmol/mol;
- $C_{GT,2}$ is the average concentration of the measurements at sample gas temperature $T_{G,2}$, in nmol/mol;

$T_{G,1}$ is the minimum sample gas temperature, in °C;

$T_{G,2}$ is the maximum sample gas temperature, in °C.

The sample gas temperature sensitivity coefficient b_{gt} shall comply with the performance criterion in Table 1.

8.4.9 Sensitivity coefficient to the surrounding temperature

The sensitivity of the analyser readings to the surrounding temperature shall be determined by performing measurements at the following temperatures (or within the specifications of the manufacturer):

- a) at the minimum temperature $T_{S,1} = 5$ °C;
- b) at the surrounding temperature $T_{S,0}$: see Table 2;
- c) at the maximum temperature $T_{S,2} = 40$ °C.

For these tests, a climate chamber is necessary.

If the manufacturer specifies temperatures other than these, these shall be fully documented in the test report.

A concentration around 70 % to 80 % of the maximum of the certification range of sulfur dioxide shall be applied. At each temperature setting after waiting the time equivalent to one independent measurement, three individual measurements at zero and at span shall be recorded.

At each temperature setting, the criteria for warm-up or stabilization time are to be met according to 8.4.2.1.

The sequence of test temperatures is as follows: $T_{S,0}$, $T_{S,1}$, $T_{S,0}$ and $T_{S,0}$, $T_{S,2}$, $T_{S,0}$.

At the first temperature ($T_{S,0}$), the analyser shall be adjusted at zero and at span level (70 % to 80 % of the maximum of the certification range). Then three individual measurements are recorded after waiting the time equivalent to one independent reading at $T_{S,0}$, at $T_{S,1}$ and again at $T_{S,0}$. This measurement procedure shall be repeated at the temperature sequence of $T_{S,0}$, $T_{S,2}$, and at $T_{S,0}$.

A stabilization time of 4 h is recommended after changing the temperature of the surrounding air.

In order to exclude any possible drift due to factors other than the surrounding temperature, the measurements at $T_{S,0}$ are averaged, which is taken into account in the following formula for calculation of the sensitivity coefficient to surrounding temperature:

$$b_{st} = \left| \frac{x_T - \frac{x_1 + x_2}{2}}{T_S - T_{S,0}} \right| \quad (11)$$

where

b_{st} is the surrounding temperature sensitivity coefficient at zero or span and at $T_{S,1}$ or $T_{S,2}$, in nmol/mol/K;

x_T is the average of the measurements at $T_{S,1}$ or $T_{S,2}$, in nmol/mol;

x_1 is the first average of the measurements at $T_{S,0}$, in nmol/mol;

x_2 is the second average of the measurements at $T_{S,0}$, in nmol/mol;

T_s	is the extreme surrounding temperature at which the test is performed, in °C;
$\overline{T_{s,0}}$	is the average of the surrounding temperatures at set point (see Table 2), in °C;
$T_{s,1}$	is the minimum surrounding temperature, in °C;
$T_{s,2}$	is the maximum surrounding temperature, in °C.

For reporting the surrounding temperature dependence, the higher value is taken of the two calculations of the temperature dependence at $T_{s,1}$ and $T_{s,2}$.

The surrounding temperature sensitivity coefficient b_{st} shall comply with the performance criterion in Table 1.

8.4.10 Sensitivity coefficient to electrical voltage

The sensitivity coefficient of electrical voltage shall be determined at both ends of the voltage range specified by the manufacturer, V_1 and V_2 , at zero concentration and at a concentration around 70 % to 80 % of the maximum of the certification range of sulfur dioxide. After waiting the time equivalent to one independent measurement, three individual measurements at each voltage and concentration level shall be recorded.

The voltage dependence is calculated from Formula (12):

$$b_v = \left| \frac{(C_{V2} - C_{V1})}{(V_2 - V_1)} \right| \quad (12)$$

where

b_v	is the voltage sensitivity coefficient, in nmol/mol/V;
C_{V1}	is the average concentration reading of the measurements at voltage V_1 , in nmol/mol;
C_{V2}	is the average concentration reading of the measurements at voltage V_2 , in nmol/mol;
V_1	is the minimum voltage in V specified by the manufacturer;
V_2	is the maximum voltage in V specified by the manufacturer.

For reporting the dependence on voltage, the higher value of the result at zero and span level shall be taken.

The voltage sensitivity coefficient b_v shall comply with the performance criterion in Table 1.

For an analyser operating on direct current, the type testing of voltage variation shall be carried out over the range of ± 10 % of the nominal voltage.

8.4.11 Interferents

The analyser response to certain interferents, which are to be expected to be present in ambient air, shall be tested. The interferents can give a positive or negative response. The test shall be performed at zero and at a test concentration (c_i) of sulfur dioxide similar to the hourly limit value.

The concentration of the mixtures of the test gases with the interferent shall have an expanded uncertainty of ≤ 5 % and shall be traceable to (inter)nationally accepted standards. The interferents to be tested and their respective concentrations are given in Table 1. The influence of each interferent shall be determined separately. A correction on the concentration of the measurand shall be made for the dilution effect due to addition of an interferent (e.g. water vapour).

After adjustment of the analyser at zero and span level, the analyser shall be fed with a mixture of zero gas and the interferent to be investigated with the concentration as given in Table 1. With this mixture, one independent measurement of sulfur dioxide followed by two individual measurements of sulfur dioxide shall be carried out. This procedure shall be repeated with a mixture of the measurand at concentration c_t and the interferent to be investigated. The influence quantities at zero and concentration c_t are calculated from:

$$X_{\text{int},z} = x_z \quad (13)$$

$$X_{\text{int},c_t} = x_{c_t} - c_t \quad (14)$$

where

- $X_{\text{int},z}$ is the influence quantity of the interferent at zero, in nmol/mol;
- x_z is the average of the measurements at zero, in nmol/mol;
- X_{int,c_t} is the influence quantity of the interferent at concentration c_t , in nmol/mol;
- x_{c_t} is the average of the measurements at concentration c_t , in nmol/mol;
- c_t is the sulfur dioxide test gas concentration at the level of the hourly limit value, in nmol/mol.

The influence quantities of the interferents shall comply with the performance criteria in Table 1, both at zero and at concentration c_t .

8.4.12 Averaging test

The averaging test gives a measure of the uncertainty in the averaged values caused by short-term concentration variations in the sampled air shorter than the time scale of the measurement process in the analyser. In general, the output of an analyser is a result of the determination of a reference concentration (normally zero) and the actual concentration which takes a certain time.

For the determination of the uncertainty due to the averaging, the following concentrations are applied to the analyser and readings are taken at each concentration (see Figure 2): a stepwise varied concentration of sulfur dioxide between zero and a concentration c_t of sulfur dioxide similar to the hourly limit value.

The time period t_c of the constant sulfur dioxide concentration shall be at least equal to a period necessary to obtain four independent readings (which is equal to at least sixteen response times). The time period t_v of the varying sulfur dioxide concentration shall be at least equal to a period to obtain four independent readings. The time period t_{SO_2} for the sulfur dioxide concentration shall be 45 s followed by a period t_{zero} of 45 s of zero concentration.

Further:

- c_t is the test concentration, in nmol/mol;
- t_v is a time period including a whole number of t_{SO_2} and t_{zero} pairs, and contains a minimum of 3 such pairs, in s.

The change from t_{SO_2} to t_{zero} shall be within 0,5 s. The change from t_c to t_v shall be within one response time of the analyser under test.

The averaging effect E_{av} is calculated according to Formula (15):

$$E_{av} = \frac{C_{av,c} - 2C_{av,v}}{C_{av,c}} \cdot 100 \quad (15)$$

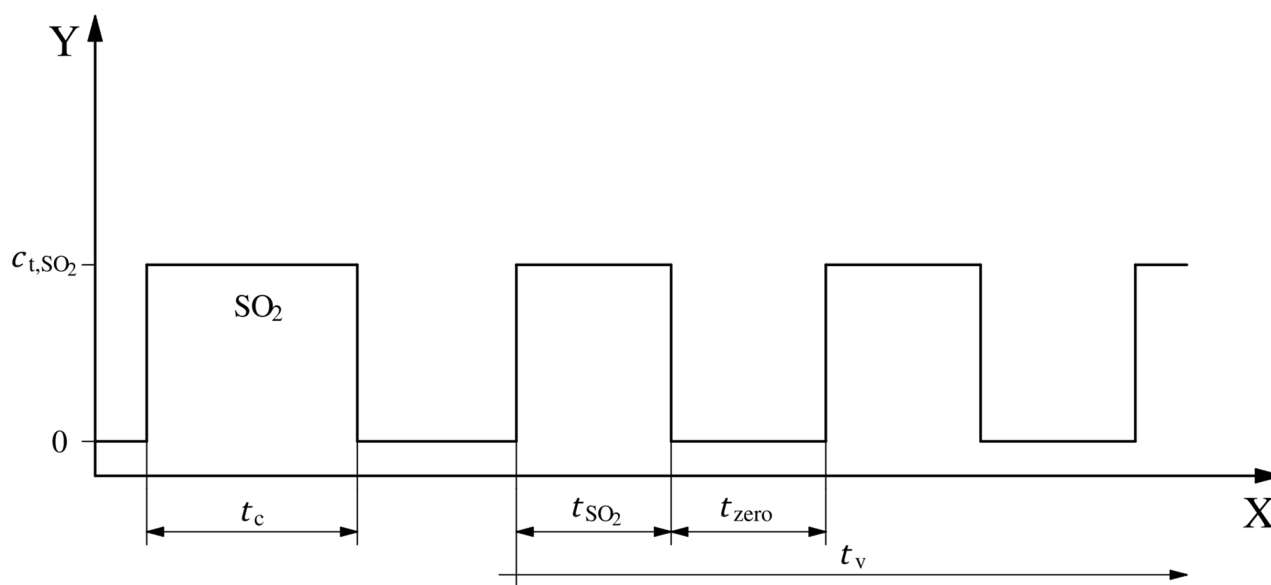
where

E_{av} is the averaging effect, in %;

$C_{av,c}$ is the average of the at least four independent measurements during the constant concentration period t_c , in nmol/mol;

$C_{av,v}$ is the average of the at least four independent measurements during the variable concentration period t_v , in nmol/mol.

The test sequence shall be repeated at least three times. The average of the results for E_{av} shall be reported.



Key

X time

Y concentration (nmol/mol)

Figure 2 — Concentration variations for the averaging effect test

8.4.13 Difference sample/calibration port

If the analyser has different ports for feeding sample gas and calibration gas, the difference in response of the analyser to feeding through the sample or calibration port shall be tested. The test shall be carried out by feeding the analyser with a test gas with a concentration of 70 % to 80 % of the maximum of the certification range of sulfur dioxide through the sample port. The test shall consist of one independent measurement followed by two individual measurements. After a period of at least four response times, the test shall be repeated using the calibration port. The difference shall be calculated according to Formula (16):

$$\Delta x_{sc} = \frac{x_{sam} - x_{cal}}{c_t} \cdot 100 \quad (16)$$