BRITISH STANDARD

BS EN 60746-1:2003

Expression of performance of electrochemical analyzers —

Part 1: General

The European Standard EN 60746-1:2003 has the status of a British Standard

ICS 71.040; 19.040

British Standards

National foreword

This British Standard is the official English language version of EN 60746-1:2003. It is identical with IEC 60746-1:2003. It supersedes BS 6438-1:1984 which is withdrawn.

The UK participation in its preparation was entrusted by Technical Committee GEL/65, Industrial — Process measurement and control, to Subcommittee GEL/65/4, Process instruments for gas and liquid analysis, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

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

Cross-references

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

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EUROPEAN STANDARD **EN 60746-1**

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English version

Expression of performance of electrochemical analyzers
Part 1: General
(IEC 60746-1:2003)

Expression des qualités
de fonctionnement des analyseurs
électrochimiques
Partie 1: Généralités
(CEI 60746-1:2003)

Angabe zum Betriebsverhalten
von elektrochemischen Analysatoren
Teil 1: Allgemeines
(IEC 60746-1:2003)

This European Standard was approved by CENELEC on 2003-02-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

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

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CENELEC
European Committee for Electrotechnical Standardization
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Foreword

The text of document 65D/89A/FDIS, future edition 2 of IEC 60746-1, prepared by SC 65D, Analysing equipment, of IEC TC 65, Industrial-process measurement and control, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60746-1 on 2003-02-01.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2003-11-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2006-02-01

Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, annex ZA is normative and annex A is informative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60746-1:2003 was approved by CENELEC as a European Standard without any modification.

CONTENTS

INTRODUCTION

This standard specifies the statements which manufacturers should make to describe analyzers so that users may compare the performance characteristics of any analyzer to their requirements. It includes the terminology and definitions of the terms to be used in such statements. It describes the tests that are applicable to all types of electrochemical analyzers, which may be used to determine these performance characteristics by either the manufacturer or the user.

This standard is applicable to electrochemical analyzers used for the determination of certain properties of (generally aqueous) solutions such as pH value, electrical conductivity, dissolved oxygen content, the concentration of specified ions and redox potential. Other standards in this series describe those aspects that are particular to specific types of analyzer, for example IEC 60746-2*.* It is in accordance with the general principles set out in IEC 60359 and takes into account documents specifying methods for evaluating performance, IEC 60770 and IEC 61298.

This standard is applicable to analyzers specified for installation in any location and to analyzers having either flow-through or immersible type sensors. It is applicable to the complete analyzer when supplied by one manufacturer as an integral unit comprised of all mechanical, electrical and electronic portions. It also applies to sensor units alone and electronic units alone when supplied separately or by different manufacturers. For the purposes of this standard, any regulator for mains-supplied power or any non-mains power supply, provided with the analyzer or specified by the manufacturer, is considered part of the analyzer whether it is integral with the analyzer or housed separately.

It does not apply to accessories used in conjunction with the analyzers, such as chart recorders or data acquisition systems. However, when multiple analyzers are combined and sold with a single electronic unit for measurements of several properties in parallel, that read-out unit is considered to be part of the analyzer. Similarly, e.m.f.-to-current or e.m.f.-to-pressure converters that are not an integral part of the analyzer are not included.

Safety requirements are dealt with in IEC 61010.

Standard ranges of analogue d.c. current and pneumatic signals used in process control systems are dealt within IEC 60381-1, and IEC 60382.

Specifications for values of influence quantities for the testing of performance characteristics can be found in IEC 60654-1 and methods of testing in IEC 60068.

Requirements for documentation to be supplied with instruments are dealt with in some National Standards and also IEC 61187.

General principles concerning quantities, units and symbols are dealt with in ISO 1000. See also ISO 31, Parts 0 to 13.

EXPRESSION OF PERFORMANCE OF ELECTROCHEMICAL ANALYZERS –

Part 1: General

1 Scope

This standard is intended:

– to specify the terminology and definitions of terms related to the performance characteristics of electrochemical analyzers used for the continuous determination of certain aspects of (generally aqueous) solutions;
– to specify uniform methods to be used in making statements on the performance characteristics of such analyzers;
– to specify general test procedures to determine and verify the performance characteristics of electrochemical analyzers, taking into account the differences of approach in IEC documents specifying test methods (IEC 60359, IEC 60770, IEC 61298);
– to provide basic documents to support the application of standards of quality assurance: ISO 9001, ISO 9002 and ISO 9003.

2 Normative references

The following referenced documents are indispensable for the application 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.

IEC 60068-1, *Environmental testing – Part 1: General and guidance*

IEC 60359:2001, *Electrical and electronic measurement equipment – Expression of performance*

IEC 60381-1, *Analogue signals for process control systems – Part 1: Direct current signals*

IEC 60382, *Analogue pneumatic signal for process control systems*

IEC 60654-1, *Industrial-process measurement and control equipment – Operating conditions – Part 1: Climatic conditions*

IEC 60770-1, *Transmitters for use in industrial-process control systems – Part 1: Methods for performance evaluation*

IEC 61298, *(all parts): Process measurement and control devices – General methods and procedures for evaluating performance*

ISO 9001, *Quality management systems – Requirements*

ISO 9002, *Quality systems – Model for quality assurance in production, installation and servicing*

ISO 9003, *Quality systems – Model for quality assurance in final inspection and test*

3 Terms and definitions

For the purposes of this standard, the following definitions apply. These definitions are based on those in IEC 60359. Additional definitions from IEC 60770 are included for performance characteristics appropriate to electrochemical analyzers. The definitions have, in some cases, been clarified and directed towards relevance to electrochemical analyzers. The reconciliation of the quantities used to define performance characteristics in this document with those referred to in IEC 60359, IEC 60770 and IEC 61298 is discussed in clause 4.

3.1
electrochemical analyzer
measuring instrument that provides an indication of a specific property of a medium by use of a sensor which responds to ions from electrolytes (or ions generated from reactions with non-electrolytes) in that medium

NOTE The analyzer may comprise of separate parts, see below.

3.2
sensor
that part of the electrochemical analyzer (which may be a separate unit) which is in contact with the medium in which the property is to be measured

NOTE In general an electrical output related to that property of the sample which is to be measured is derived from this part of the analyzer. Examples of electrochemical sensors are: pH, ion-sensitive and redox potentiometric cells, dissolved oxygen cells, conductance cells.

3.3
electronic unit
device converting the electrical signal from the sensor to a defined, scaled, output signal

3.4
simulator
device which provides well-defined electrical properties similar to a specific type of sensor

NOTE It may therefore be used to determine the performance characteristics of the electronic unit alone. It must exhibit uncertainties that are negligible in comparison with the specifications of performance characteristics to be determined.

3.5
calibration solution
solution of known value of the property being measured, used for periodic calibration and for various performance tests.

NOTE 1 The value should be expressed in SI units compatible with ISO 31.

NOTE 2 For the purposes of this Standard, the value of this solution represents the conventional true value (see 3.8) against which the indicated value is compared.

NOTE 3 The values of calibration solutions should be traceable to reference material according to international or national standards, or agreed upon by the manufacturer and the user, and the uncertainty of the conventional true values shall be stated.

3.6
test solution
solution of approximately known value of the property being measured, which is stable in value over an extended period of time

3.7
true value
value of a quantity which is defined with no uncertainty.

NOTE The true value of a quantity is an ideal concept and, in general, cannot be known exactly.

3.8
conventional true value
value approximating to the true value of a quantity such that, for the purpose for which that value is used, the difference between the two will be regarded as negligible

NOTE 1 Since the "true value" cannot be known exactly, for the sake of simplicity and where no ambiguity exists, the term "true value" may be used where the term "conventional true value" is meant.

NOTE 2 See 3.1.13 of IEC 60359.

3.9
performance characteristic
one of the quantities assigned to an apparatus in order to define its performance by values, tolerances, ranges, etc.

3.10
influence quantity
any quantity, which is not the subject of the measurement but which influences the indication of the measuring equipment

NOTE Influence quantities may interact in their effect on the measuring equipment.

3.11
variation
difference between the values indicated by an analyzer for the same value of the property being measured when a single influence quantity assumes successively two different values

3.12
rated value
value assigned to a performance characteristic of the analyzer by the manufacturer

NOTE See 3.3.8 of IEC 60359.

3.13
range
domain between the upper and lower limits of the quantity under consideration

NOTE 1 The term "range" is usually used with a modifier. It may apply to a performance characteristic or an influence quantity, etc. For example, the Rated Measuring Range is the set of values of the property to be measured, corresponding to the Output Signal Range of the analyzer (for example 4 mA - 20 mA, etc).

NOTE 2 See 3.3.2 of IE 60359.

3.14
span
difference between the upper and lower limits of the rated measuring range

3.15
performance
quality with which the intended functions of the equipment are accomplished

3.16
reference conditions
appropriate set of influence quantities, with reference values with their tolerances and reference ranges, with respect to which intrinsic uncertainty is specified

3.17
reference value
specified value of one of a set of reference conditions

NOTE A tolerance may be specified for a reference value.

3.18
reference range
specified range of values of one of a set of reference conditions

3.19
specified operating range
range of values of a single influence quantity which forms part of the rated operating conditions

3.20
specified measuring range
set of values of the property to be measured for which the uncertainty of the analyzer is intended to lie within specified limits

NOTE 1 An instrument can have several specified measuring ranges.

NOTE 2 The specified measuring range can be smaller than the range of values which can be indicated, for example, on the scale.

NOTE 3 This term used to be known as "effective range".

3.21
rated operating conditions
set of operating ranges for influence quantities and associated ranges of performance characteristics within which the variations of an analyzer are specified by the manufacturer

3.22
limit conditions of operation
extreme conditions which an operating instrument can withstand without resulting in damage or degradation of performance when it is afterwards operated under rated operating conditions

3.23
storage and transport conditions
extreme conditions which an non-operating instrument can withstand without resulting in damage or degradation of performance when it is afterwards operated under rated operating conditions

3.24
uncertainty (of measurement)
dispersion of values that may be attributed to the measured quantity

NOTE See 3.1.4 of IEC 60359.

3.25
intrinsic uncertainty
uncertainty when used under reference conditions (see 3.16)

NOTE See 3.1.10, 3.1.11, 3.1.12 of IEC 60359.

3.26
operating uncertainty
uncertainty when used under rated operating conditions (see 3.21)

NOTE See also 3.2.11 of IEC 60359.

3.27
relative uncertainty
ratio of the uncertainty to the conventional true value (when expressed in the same units)

NOTE See 3.3.4 of IEC 60359.

3.28
interference uncertainty
uncertainty caused by substances other than those affecting the measured property being present in the sample

3.29
linearity uncertainty
maximum deviation between indicated values and a linear function of indicated value versus the true value of the property being measured, which includes indicated values near the upper and lower limits of the rated range

NOTE Linearity is a property of the electronic unit and may be verified with a simulator (see 3.4).

3.30
limits of uncertainty
maximum values of uncertainty assigned by the manufacturer to the indicated values of an analyzer operating under specified conditions

NOTE See 3.3.6 of IEC 60359.

3.31
repeatability
spread of the results of successive measurements at short intervals of time of identical test material, carried out by the same method, with the same measuring instruments, by the same observer, in the same laboratory, in unchanged environmental conditions and with no adjustments made by external means to the analyzer under test

NOTE 1 The spread of results should be included in the intrinsic uncertainty (see 3.25).

NOTE 2 A time interval equal to about ten times the 90 % response time of the analyzer may be considered a short interval between successive measurements.

3.32
hysteresis
difference in indicated values when the same value of the property being measured is applied but preceded by a lower then a higher value

NOTE If repeatability is specified or measured using approaches from both upscale and downscale direction, it may include an amount due to hysteresis, i.e., which is not a truly random event. However, the contribution may be considered to be random when the analyzer is to be applied to applications where the indicated value may be approached from either direction with equal probability.

3.33
drift
change of indication of an analyzer, for a given value of the property being measured, over a stated period of time, under reference conditions which remain constant and without any adjustment to the analyzer by external means

NOTE The rate of change of uncertainty with time should be derived by linear regression.

3.34
output fluctuation
peak-to-peak deviations of the output measured with constant input and constant influence quantities

3.35
minimum detectable change
change in value of the property to be measured equivalent to twice the output fluctuation

3.36
delay time, T_{10}
time interval from the instant a step change in the value of the property being measured occurs to the instant when the change in the indicated value passes (and remains beyond) 10 % of its steady-state amplitude difference. For cases where the rising delay time and falling delay time differ, the different delay times should be specified.

3.37
rise (fall) time, T_r, T_f
difference between the 90 % response time and delay time

3.38
90 % response time, T_{90}
time interval from the instant a step change occurs in the value of the property being measured to the instant when the change in the indicated value passes (and remains beyond) 90 % of its steady-state amplitude difference, i.e., $T_{90} = T_{10} + T_r$(or T_f). For cases where the rising and falling response times differ, the different response times should be specified.

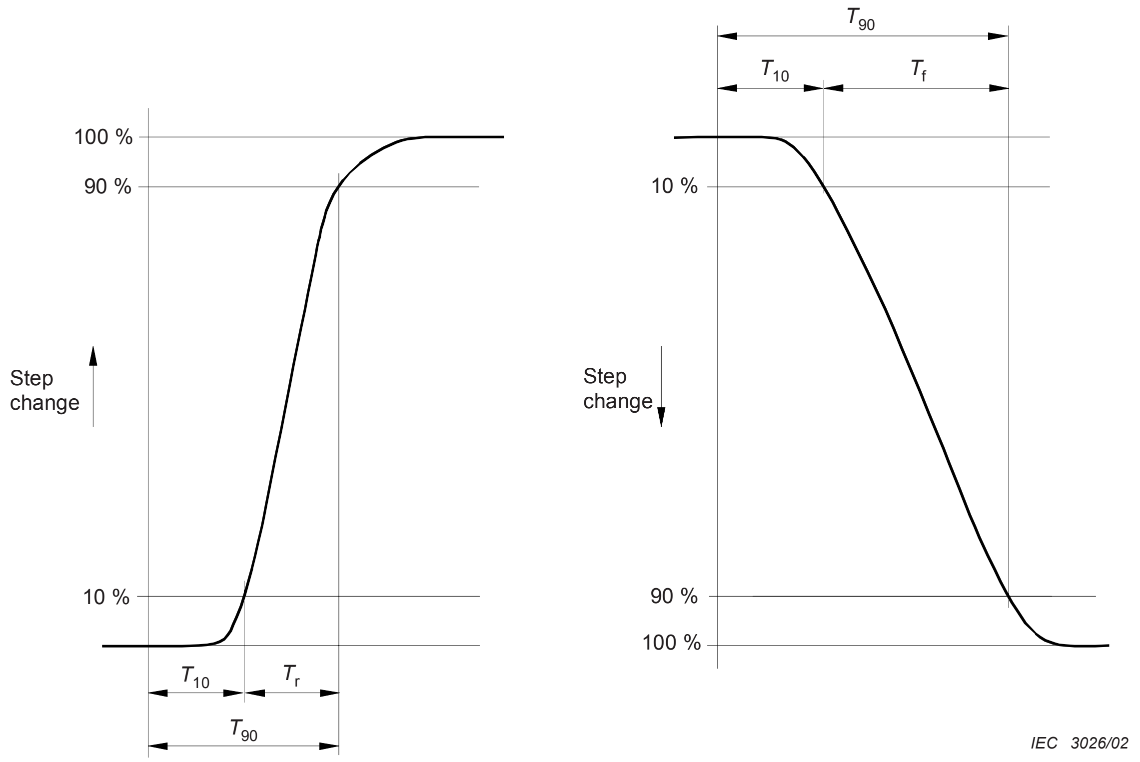

Figure 1 – Relationship between T_{10}, T_r, (T_f) and T_{90}

3.39
warm-up time
time interval after switching on the power, under reference conditions, necessary for a unit or analyzer to comply with and remain within specified limits of uncertainty

NOTE The limits of uncertainty may appropriately be specified equal to the rated intrinsic uncertainty.

4 Comparison of IEC Standards for Specification and Evaluation

The methods for specification of analyzer performance characteristics used by manufacturers should be compatible with methods for specification of performance requirements by users. For accurate comparison of manufacturers' specifications and users' requirements, the parameters used to define the performance characteristics of the equipment must be selected and defined identically.

An electrochemical sensor has particular characteristics primarily determined by chemical properties, and these can only be slightly modified by constructional techniques. Moreover, the sensor is directly exposed to a working fluid which can exert a range of influence factors on the sensor system. This is in contrast to the operation of the purely electrical measuring devices considered in many other related standards, where the signal is injected electrically into the instrument's circuits and the sensing of that signal is entirely internal. The approach to the determination and statement of performance characteristics used in 6.4.2 of IEC 60359 entitled *Limits of intrinsic instrumental uncertainty with variations for a single influence quantity* was selected as the best basis for defining the performance of electrochemical type analyzers. Therefore, requirements for statements in this document are generally given in accordance with that document, with some performance parameters and test methods based on IEC 60770.

Alternative approaches adopted in other IEC documents are summarized below, for comparison:

IEC 61298, Subclause 3.9: Maximum measured uncertainty

A non-statistical test of instrument conformity, where the maximum and minimum uncertainties are reported from a series of tests. This is particularly appropriate to batch tests where a limited series of tests should yield individual results within the limits of uncertainty specified for the rated operating conditions.

IEC 60770, Evaluating the performance of transmitters for use in industrial-process control systems

Procedures defined in this standard are closely aligned with those in IEC 60359. Both IEC 60359 and IEC 60770 are primarily directed to the evaluation of purely electrical (or pneumatic) systems. Procedures defined in the following clauses are from these two documents but take into account the chemical nature of the sensor. Definitions of terms have all been based on these documents.

5 Procedure for specification

5.1 Specification of values and ranges

Manufacturers specifying the performance of complete analyzers, sensor units or electronic units, shall give statements covering all quantities considered to be applicable performance characteristics.

These statements shall cover the aspects which will be described in the following subclauses.

5.2 General

5.2.1 The reference value (or range) and rated range of use for all influence quantities shall be stated. These should be selected from only one of the usage groups I, II or III in IEC 60359 (see Annex A) or may be from usage groups in IEC 60654-1. Any exceptions to the values given there shall be explicitly and clearly stated by the manufacturer with an indication that they are exceptions.

NOTE 1 The analyzers or electronic units may correspond to one group of rated ranges of use for environmental conditions and to another group for mains supply conditions, but this should be clearly stated by the manufacturer.

NOTE 2 When the sensor and electronic units are separate, the rated range for climatic conditions for the individual units may be different.

NOTE 3 Electrochemical analyzers frequently employ sensors containing or used to measure aqueous solutions, in which case the ambient temperature class I of IEC 60359 will be appropriate to prevent freezing in the sensor and sample lines.

5.2.2 Rated ranges of use shall be stated for sample conditions at the analyzer inlet for an on-line analyzer, or at the sensor unit for an insertion sensor type analyzer. These shall include flow rate (if appropriate), pressure and temperature, as well as the rated maximum rate of change for sample temperature.

5.2.3 The limit conditions of operation shall be stated such that the analyzer, while functioning, will show no damage or degradation of performance when any number of performance characteristics and/or influence quantities assume any value within the limit conditions of operation during a specified time, or, if not specified, for an unlimited time.

NOTE Absence of degradation of performance means that, after re-establishing reference conditions or rated operating conditions, the analyzer again satisfies the requirements concerning its performance.

5.2.4 The limit conditions for storage or transport shall be stated such that the analyzer, while inoperative, will show no permanent damage or degradation of performance, when it has been subjected to conditions where any number of influence quantities assume any value within their storage or transport conditions during a specified time, or, if not specified, for an unlimited time.

NOTE Absence of degradation of performance means that, after re-establishing reference conditions or rated operating conditions, the analyzer again satisfies the requirements concerning its performance.

5.2.5 Constructional materials in contact with the sample shall be stated.

5.2.6 Unless the analyzer system is specified as a complete unit, the manufacturer shall state the values of parameters which are required to make any type of sensor unit(s) compatible with the electronic unit and type of electronics unit(s) compatible with the sensor unit[1]. The steps required to restore accurate operation within the original performance specification when replacing either the sensor unit or electronic unit shall be stated[2].

5.3 Performance characteristics requiring statements of rated values

5.3.1 The manufacturer shall state minimum and maximum rated values for the property to be measured (range or ranges).

5.3.2 Minimum and maximum rated values for output signals corresponding to the rated values as given in 5.3.1.

These signals shall be stated in units of voltage, current or pressure. If stated in units of voltage, the minimum allowable load, in ohms, shall be stated. If stated in units of current, the maximum allowable load, in ohms, shall be stated. If a capacitive or inductive load will influence the output signal, this shall be specified.

Where the analyzer or electronic unit has multiple outputs, the statements above should be made for all outputs.

If the output signal is an electrical current, see also IEC 60381-1; if it is pneumatic, see also IEC 60382.

5.4 Uncertainty limits to be stated for each specified range

These should be in accordance with 6.4.2 in IEC 60359. Wherever appropriate, statements shall be made of the uncertainty limits near the lower and upper ends of each analyzer range.

5.4.1 Limits of intrinsic uncertainty shall be stated for use under reference conditions in a manner which allows them to be inferred over the rated range.

For example:
"$\pm x$ % of span"
"±0,1pH units"
"The greatest of $\pm x$ % of range or $\pm y$ % of true value"
"±1 display digit $\pm y$ % of true value"

5.4.2 For an analyzer or electronic unit, the linearity uncertainty shall be stated separately. Where a non-linear output is provided, the manufacturer shall accurately state the relationship between the output value and the measured parameter.

NOTE Deviation from linearity is strictly considered as an uncertainty only if a linear output is claimed. For analyzers having non-linear outputs, the term "conformity" may be used.

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1 For example: "sensor model XXX for use with electronics unit YYY".

2 For example: "when replacing the sensor unit, recalibrate the analyzer using calibration solutions….", or "when replacing the electronics unit, enter the following parameters as data …".

5.4.3 The manufacturer shall state which possible sample components are known to have interference effects in the application under consideration, whether the interference is positive or negative and its magnitude. The choice of interfering components, their concentration levels and test methods may, where appropriate, be made by agreement between the manufacturer and the user except where other Parts of the IEC 60746 series state specific requirements.

5.4.4 The manufacturer shall state the repeatability and the basis on which it was calculated.

5.4.5 The drift shall be stated by the manufacturer for at least one time interval chosen from the list in 6.2.5. The time interval(s) chosen should be relevant to the intended application (see note of 6.2.5). The warm-up time is always excluded from the time interval.

5.5 Other performance characteristics

Although no statements of uncertainty limits are required for the performance characteristics listed below, the manufacturer shall state their values or ranges for each specified measuring range.

5.5.1 Output fluctuation.

5.5.2 Minimum detectable change.

5.5.3 Delay and 90 % response times for both upscale and downscale changes.

5.5.4 Warm-up time.

5.5.5 The quantitative effect on indicated value of the property to be measured produced by variation of the sample temperature.

NOTE This may be given as part of the statement of the rated operating conditions, in that at the limits of sample temperature, the specified maximum variation for this influence quantity has been reached.

5.5.6 The quantitative effects on indicated value of the property to be measured produced by changes in other influence quantities may not be known, but where there are reasons to believe simple coefficients exist, these should be stated for sample flow-rate, sample pressure and ambient temperature.

NOTE These may be given as part of the statement of the rated operating conditions, in that at the limits of the influence quantities, the specified maximum variations have been reached.

6 Verification of values

In order to determine or verify the rated values stated by the manufacturer, uniform test procedures are necessary. These will enable the statements made with respect to different analyzers for similar applications to be strictly comparable. It will also enable the user to demonstrate compliance of an analyzer with his performance requirements fairly and by similar means to those which the manufacturer used to determine its rated performance. This clause gives general test procedures to determine the values of the various performance characteristics defined. Later parts of the IEC 60746 series will give more specific procedures appropriate to particular types of analyzer. In the case of special circumstances, where these tests are not appropriate, additional test procedures may be agreed upon between manufacturer and user.

6.1 General

6.1.1 Tests shall be performed with the analyzer (including accessories) ready for use after warm-up time and after performing all necessary adjustments according to the manufacturer’s instructions.

6.1.2 Unless otherwise specified, the influence quantities shall be at reference conditions during the tests concerned and during the tests, the analyzer shall be supplied with its rated voltage and frequency.

6.1.3 The sensor shall be in optimal condition as specified by the manufacturer. The flow conditions and other relevant influence factors (sample flow-rate, pressure, temperature, etc.) at the sensor shall be according to the manufacturer's instructions.

6.1.4 When measuring the intrinsic uncertainty, the combination of values and/or ranges of influence quantities shall remain within the reference conditions which include relevant tolerances on reference values.

6.1.5 When measuring variation of a performance characteristic due to an influence quantity, all other quantities shall remain within reference conditions. The value of the property to be measured in the test solution applied and the range of the influence quantity may assume any value within their rated operating ranges.

6.1.6 During tests, adjustments by external means may be repeated at the intervals prescribed by the manufacturer or at any suitable interval, if such adjustment does not interfere with the uncertainty to be checked.

Adjustments shall also be performed when uncertainty values have expressly been quoted to be valid only after such adjustment. Measurements shall be made immediately after such adjustment so that any drift will not influence them.

6.1.7 In principle, the uncertainties in measurements made with test instruments should be negligible in comparison with the uncertainties to be determined. Refer to local standards defining quality assurance procedures and also 6.1.8.

6.1.8 When the uncertainty of any test instrument is not negligible, the following rule should apply:

If an analyzer is tested against a reference instrument which has a known uncertainty n and the uncertainty determined is n_1 the actual uncertainty e of the analyzer shall be stated as $e = n_1 - n$. If the performance of the analyzer is subsequently checked by another party using a test instrument with a known uncertainty m and the uncertainty determined is m_1, it may only legitimately be claimed that this indicates that the analyzer is not exhibiting its stated performance if $m_1 - m > e$.

NOTE The above represents a very simplistic treatment of uncertainty based on consideration of instrument systematic uncertainty only. In order to be completely rigorous in the treatment of claimed uncertainties and deviations from stated performance, strict statistical examination of the results would be necessary. This would probably require calculation of *t* or *f* test parameters and the use of statistical tables to demonstrate the significance of the claims.

6.1.9 Test equipment shall include all of the necessary test solutions (see 3.5, 3.6)

6.1.10 Test equipment shall also include appropriate simulators for testing electronic units in those cases where such units are supplied separately from sensor units. In these cases, 6.1.7 and 6.1.8 apply to the simulators. Specifications for appropriate simulators vary from one type of analyzer to another and are located in the other Parts of the IEC 60746 series dealing with specific analyzers

NOTE Sensor units supplied separately are tested with suitable calibration or test solutions (see 3.5, 3.6), using an appropriate electronic unit, which may be that of the considered analyzer, provided it has been previously tested.

6.2 Test procedures

Tests of the complete analyzer or sensor unit alone will normally be carried out. In this case, intrinsic uncertainty shall be determined by use of a series of applications of calibration or test solutions with a reference method. Variations shall be determined while applying stable test solution(s). Tests may also be of the electronics unit alone, in which case a simulator of known performance characteristics would be used to apply signals equivalent to the particular sensor. Tests should be repeated for each specified measuring range.

6.2.1 Intrinsic uncertainty

With all influence quantities at their reference values, the output reading of the unit shall be recorded in the units of the property to be measured. Values shall be applied giving indications near the upper and lower limits of the measuring range and at least one other point within the range. This procedure shall be performed at least six times to calculate the mean value of intrinsic uncertainty at the three chosen points.

6.2.2 Linearity uncertainty

At least five measurements shall be taken, approximately uniformly distributed across the range and with two near the limits of the measuring range. A straight line shall be fitted to the readings using the least squares method.

The maximum deviation between the recorded values and this straight line is the linearity uncertainty. It is expressed in terms of the units of the property to be measured.

NOTE Where the output signal is a non-linear function of the measured parameter, the manufacturer's linear transform function should be applied to the signal prior to data analysis. The deviation from the fitted line, as defined above, is the "(independent) conformity".

6.2.3 Repeatability

The results obtained as in 6.2.1 shall be used to calculate the repeatability at each applied value as the standard deviation of the indications at that level.

6.2.4 Output fluctuation

An applied value approximately representing the mid-scale value of the measuring range shall be applied for a period of at least five minutes (or ten times the 90 % response time if greater) and the maximum peak-to-peak value of the random, or regular, deviation from the mean output determined.

In the case of the electronic unit or analyzer having variable time constants in the output circuit, the output fluctuation shall be determined using the same time constant as referred to in the statement of delay and 90 % response times.

NOTE For the purposes of this standard, any spikes which can be positively identified as being caused by the influence of external electromagnetic fields or by supply mains transients are considered as due to changes in influence quantities and may therefore be ignored in the determination of output fluctuation.

6.2.5 Drift

The test procedure shall be used to determine the drift characteristics under reference conditions, over at least one time interval and for at least one point in the measuring range.

If only one point is used, a value near the 50 % span should be used as the test point.

The analyzer should be fully warmed up, calibrated according to the manufacturer's instructions, and operated continuously and in accordance with manufacturer's instructions during the test. At no time after the start of the test may the analyzer be adjusted by external means.

The appropriate input shall be applied continuously to the analyzer, if practicable, or until a stable indication is obtained at the beginning, end, and at a minimum of six, approximately evenly spread, time intervals within the test interval.

The time interval for which the stability limits are determined should be chosen appropriately for the specific application from the following values:

15 minutes	7 days
1 h	30 days
3 h	3 months
7 h	6 months
24 h	1 year

The results shall be analyzed by linear regression with respect to time. The slope of the linear regression (for each input value) shall be used to report drift (for example, as *x* pH units per month).

NOTE Drift measured over periods of up to 24 h are usually referred to as short-term. For on-line analyzers, long term drift values will also normally be required referring to periods of 7 days to 3 months.

6.2.6 Delay (T_{10}) and 90 % (T_{90}) response times

Signals representing the minimum and maximum of the measuring range shall be applied successively until constant readings are obtained on a recording device (a chart recorder or data logger) which also accurately records time intervals.

The values for delay times (T_{10}) for both increasing and decreasing step changes and 90 % response times (T_{90}) for both increasing and decreasing step changes may be determined from the data record. See Figure 1.

6.2.7 Warm-up time

The electronic unit shall be switched off and all of its components allowed to cool to ambient temperature (for example, overnight). A stable signal representing between 75 % and 95 % of the span shall be applied. The analyzer shall be switched on and the reading recorded. Recording shall be continued until the response has reached and remained within the specified intrinsic uncertainty band (taking account of repeatability) for a period of 15 min.

The warm-up time is the interval from the time the electronic unit was switched on until the beginning of this 15 min period.

6.2.8 Variations

Uncertainties caused by changes in influence quantities are variations. The most common, relevant influence quantities are listed in 6.2.9 and 6.2.10, but not all sources of uncertainty are relevant to all applications. The procedure is very similar for measuring the effects of each influence quantity.

Uncertainties shall be determined at two points near the lower and upper ends of the measuring range; a single point in the range may be sufficient where the influence quantity is an event, (for example, electrical transient, drop, etc.). Starting with all parts of the analyzer under reference conditions, the variation in indication caused by changing the influence quantity to the lower limit of its rated range shall be determined. This shall be followed by a return to reference conditions, then the variation in indication caused by changing the influence quantity to the upper limit of its rated range shall be determined, followed by a return to reference conditions.

Analyzers can incorporate automatic or manual compensation for some physical parameters. This compensation can be for both the properties of the sensor and of the measured parameter in the working fluid, and refer back to a reference value of the influence quantity[3]. Where compensation functions can be manually adjusted or disabled, the indications should be noted for both the compensated and uncompensated value. The correct operation of the compensation function can then be assessed.

6.2.8.1 Interference uncertainty

This is a specific example of a variation which can only be realistically determined for the entire analyzer or sensor unit, not for the electronics unit alone. Interference uncertainty should be determined for components which are known to affect the sensor and are expected to be present in the sample. The uncertainties shall be determined at two points near the lower and upper ends of the measuring range.

Generally a test solution is applied first without, then with the interfering substance present. The interfering component should be introduced at the highest expected concentration[4] and at approximately half of that level. Each test should be repeated three times and the mean variation for each applied parameter value reported as the interference uncertainty at that value.

6.2.9 Primary influence quantities

These influence quantities are normally important, and shall be tested whenever relevant:

- ambient temperature;
- humidity;
- supply voltage;
- a.c. supply frequency;
- sample flow rate;
- sample temperature;
- sample pressure;
- sample outlet pressure;
- interfering substances;
- radio frequency interference (see local standards);
- vibration (see IEC 60068).

6.2.10 Other influence quantities

These should also be specified and tested where relevant. Test procedures can be found in IEC 60068, IEC 60770 and IEC 61298. The following list is not exhaustive.

- attitude (“tilt”);
- a.c. supply ripple;
- d.c. supply impedance;
- electrical supply transients;
- electrical supply interruption;
- shock (drop test);

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[3] For example, pH sensors are normally corrected for the Nernstian temperature response of the sensor. A correction for properties of the solution to a reference temperature, often 25 °C, may also be applied as a slope in terms of pH/°C.

[4] This may be chosen with consideration to an application, or simply to establish the rated operating range for that component.

- sound pressure;
- ventilation;
- sand and dust;
- liquid water;
- salt water;
- barometric pressure;
- contaminating dust or vapour;
- ionizing radiation;
- electrical grounding requirements;
- effect of particulates.

Annex A
(informative)

Recommended standard values of influence – Quantities affecting performance from IEC 60359

The rated ranges of use of the influence quantities below have been divided into the following three usage groups:

I: for indoor use under conditions which are normally found in laboratories and factories and where apparatus will be handled carefully.

II: for use in environments having protection from full extremes of environment and under conditions of handling between those of Groups I and III.

III: for outdoor use and in areas where the analyzer may be subjected to rough handling.

NOTE These influence quantities generally affect the electronic units directly and apply specifically to them. The sensor units, being immersed in the sample are affected primarily by the sample conditions and these influence quantities may not relate to them. For *in situ* analyzers, where both sensor units and electronic units are immersed in the sample, the sample conditions, rather than these influence quantities, may relate to the electronic unit also. The effects of the external environment on the sensor unit may need to be stated separately.

A.1 Climatic conditions

A.1.1 Ambient temperature

– Reference value (to be chosen from): 20 °C, 23 °C, 25 °C or 27 °C.

– Tolerance on reference value ±2 °C.

– Rated ranges of use:

Usage group I: +5 °C to +40 °C;

Usage group II: –10 °C to +55 °C;

Usage group III: –25 °C to +70 °C.

– Limit range for storage and transport: -40 °C to +70 °C.

NOTE Many sensors need protection from freezing conditions.

A.1.2 Relative humidity of the air

Because extreme values of both temperature and humidity are not likely to occur simultaneously, the manufacturer may specify the time limit over which these may be applied and should specify the limitations of the combination, if any, for continuous operation.

– Reference range at 20 °C, 23 °C, 25 °C or 27 °C: 45 % to 75 %.

– Rated ranges of use:

Usage group I: 20 % to 80 % excluding condensation;

Usage group II: 10 % to 90 % including condensation;

Usage group III: 5 % to 95 % including condensation.

A.1.3 Barometric pressure

– Reference value: existing local barometric pressure.

– Rated ranges of use:

Usage group I: 70,0 kPa to 106,0 kPa (up to 2 200 m);

Usage groups II and III: 53,3 kPa to 106,0 kPa, (up to 4 300 m)

- Limit range of operation: equal to the rated range of use unless otherwise stated by the manufacturer.
- Limit range for storage and transport: to be stated by the manufacturer.

A.1.4 Heating effect due to solar radiation

- Reference value: no direct irradiation.
- Rated ranges of use:

  Usage groups I and II: no direct irradiation;

  Usage group III: the combined effect of solar radiation plus the ambient temperature should never cause the surface temperature to exceed that which is obtained at an ambient temperature of 70 °C alone.
- Limit range of operation: equal to the rated range of use unless otherwise stated by the manufacturer.
- Limit range for storage and transport: to be stated by the manufacturer.

A.1.5 Velocity of the ambient air

- Reference range: 0 m/s to 0,2 m/s.
- Rated ranges of use:

  Usage groups I and II: 0 m/s to 0,5 m/s;

  Usage group III: 0 m/s to 5 m/s.
- Limit range of operation: equal to the rated range of use unless otherwise stated by manufacturer.

A.1.6 Sand and dust contents of the air

- Reference value: no measurable contents.
- Rated ranges of use:.

  Usage groups I and II: negligible contents (i.e. will have negligible effect on the analyzer);

  Usage group III: to be stated by the manufacturer.
- Limit range of operation: equal to the rated range of use unless otherwise stated by manufacturer.
- Limit range for storage and transport: to be stated by manufacturer.

A.1.7 Salt contents of the air

- Reference value: no measurable contents.
- Rated ranges of use:

  Usage groups I and II: negligible contents;

  Usage group III: to be stated by the manufacturer.
- Limit range of operation: to be stated by the manufacturer.
- Limit range of storage and transport: to be stated by the manufacturer.

A.1.8 Contaminating gas or vapour contents of the air

- Reference value: no measurable contents.
- Rated ranges of use: usage groups I to III: to be stated by the manufacturer.
- Limit range of operation: to be stated by the manufacturer.
- Limit range for storage and transport: to be stated by the manufacturer.

A.1.9 Liquid water contents of the air

- Reference value: no measurable contents.
- Rated ranges of use:

  Usage group I: negligible contents;

  Usage group II: drip water;

  Usage group III: splash water.
- Limit range of operation: to be stated by the manufacturer.
- Limit range for storage and transport: to be stated by the manufacturer.

A.2 Mechanical conditions

A.2.1 Operating position

- Reference value: position as stated by the manufacturer.
- Tolerance on reference: ±1°.
- Rated ranges of use:

  Usage groups I and II: reference position ±30°;

  Usage group III: reference position ±90°.
- Limit range of operation: to be stated by the manufacturer.
- Limit range for storage and transport: to be stated by the manufacturer.

NOTE These rated ranges of use should be understood only for the electronic units without orientation-sensitive indicators. For electronic units with built-in orientation-sensitive indicators, the manufacturer should make suitable statements.

A.2.2 Ventilation

- Reference value: ventilation not obstructed.
- Rated ranges of use:

  Usage groups I and II: negligibly obstructed;

  Usage group III: the obstruction of the ventilation plus ambient temperature should never cause the surface temperature to exceed that which is obtained at an ambient temperature of 70 °C alone, with the ventilation not obstructed.
- Limit range of operation: to be stated by the manufacturer.

A.2.3 Vibration

- Reference value: no measurable value.
- Rated ranges of use:

  Usage group I: negligible;

  Usage groups II and III: to be stated by the manufacturer.

- Limit range of operation: to be stated by the manufacturer.
- Limit range for storage and transport: to be stated by the manufacturer.

A.3 Mains supply conditions

A.3.1 Mains supply voltage (considering a distorted waveform)

	d.c. and a.c. (r.m.s.)	*a.c. (peak)*
– Reference value:	Rated value	Rated value
– Tolerance on reference value:	+1 %	±2 %
– Rated ranges of use:		
Usage group I :	±10 %	±12 %
Usage group II:	–12 % to +10 %	–17 % to +15 %
Usage group III:	–20 % to +15 %	–30 % to +25 %

- Limit range of operation: equal to the rated range of use unless otherwise stated by the manufacturer.

A.3.2 Mains supply frequency

- Reference value: rated frequency.
- Tolerance on reference value: 1 %.
- Rated range of use:
  - Usage groups I and II: ±5 %
  - Usage group III: ±10 %
- Limit range of operation: to be stated by the manufacturer.

A.3.3 Distortion of a.c. mains supply

The distortion is determined by a factor, β, in such a way that the waveform is inside an envelope formed by:

$$Y_1 = (1 + \beta) \text{ A sin } \omega t, \text{ and}$$

$$Y_2 = (1 - \beta) \text{ A sin } \omega t$$

- Reference value $\beta = 0$ (sine-wave).
- Tolerance on reference value: $\beta = 0{,}05$
- Rated ranges of use:
  - Usage group I: $\beta = 0{,}05$;
  - Usage groups II to III: $\beta = 0{,}10$.
- Limit range of operation: to be stated by the manufacturer.

The values of β are valid when the analyzer is connected to the supply mains.

NOTE 1 The above formulae may be applied over the half cycle or a full cycle depending on whether the zero crossings are equally spaced or not.

NOTE 2 If the a.c. peak voltage exceeds the values stated in A.3.1, the mains supply under consideration cannot be used.

A.3.4 Ripple of d.c. supply

– Reference value 0 % of supply voltage
– Rated ranges of use

Usage group I:	0,5 % of supply voltage
Usage group II:	1,0 % of supply voltage
Usage group III:	5,0 % of supply voltage

– Limit range of operation: 5,0 % of supply voltage

The values given are peak to peak values of the ripple voltage expressed as a percentage of the average d.c. supply voltage.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60068-1	- [1]	Environmental testing Part 1: General and guidance	EN 60068-1	1994 [2]
IEC 60359	2001	Electrical and electronic measurement equipment - Expression of performance	EN 60359	2002
IEC 60381-1	- [1]	Analogue signals for process control systems Part 1: Direct current signals	HD 452.1 S1	1984 [2]
IEC 60382	- [1]	Analogue pneumatic signal for process control systems	EN 60382	1993 [2]
IEC 60654-1	- [1]	Industrial-process measurement and control equipment - Operating conditions Part 1: Climatic conditions	EN 60654-1	1993 [2]
IEC 60770-1	- [1]	Transmitters for use in industrial-process control systems Part 1: Methods for performance evaluation	EN 60770-1	1999 [2]
IEC 61298	Series	Process measurement and control devices - General methods and procedures for evaluating performance	EN 61298	Series
ISO 9001	- [1]	Quality management systems - Requirements	EN ISO 9001	2000 [2]
ISO 9002	- [1]	Quality systems - Model for quality assurance in production, installation and servicing	EN ISO 9002	1994 [2]

[1] Undated reference.

[2] Valid edition at date of issue.

Publication	Year	Title	EN/HD	Year
ISO 9003	- [1)]	Quality systems - Model for quality assurance in final inspection and test	EN ISO 9003	1994 [2)]

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