

INTERNATIONAL STANDARD

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Second edition
2002-06

Expression of performance of electrochemical analyzers –

Part 3: Electrolytic conductivity

*Expression des qualités de fonctionnement
des analyseurs électrochimiques –*

*Partie 3:
Conductivité électrolytique*

[IEC 60746-3:2002](#)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**EXPRESSION OF PERFORMANCE
OF ELECTROCHEMICAL ANALYZERS –**
Part 3: Electrolytic conductivity

FOREWORD

- 1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 60746-3 has been prepared by subcommittee 65D: Analyzing equipment, of IEC technical committee 65: Industrial-process measurement and control.

This second edition cancels and replaces the first edition, published in 1985, and constitutes a technical revision.

This standard shall be used in conjunction with IEC 60746-1.

The text of this standard is based on the following documents:

FDIS	Report on voting
65D/85/FDIS	65D/87/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annex C forms an integral part of this standard.

Annexes A, B and D are for information only.

IEC 60746 consists of the following parts, under the general title *Expression of performance of electrochemical analyzers*:

Part 1: General

Part 2: pH value

Part 3: Electrolytic conductivity

Part 4: Dissolved oxygen in water measured by membrane covered amperometric sensors

Part 5: Oxidation-reduction potential or redox potential

Part 6: Conductivity effect of foreign ions in ultrapure waters, from combined conductivity and pH¹⁾

The committee has decided that the contents of this publication will remain unchanged until 2007. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

The contents of the corrigendum of January 2003 have been included in this copy.

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¹⁾ Under consideration.

EXPRESSION OF PERFORMANCE OF ELECTROCHEMICAL ANALYZERS –

Part 3: Electrolytic conductivity

1 Scope

This part of IEC 60746 is intended

- to specify terminology, definitions and requirements for statements by manufacturers for analyzers, sensor units, and electronic units used for the determination of the electrolytic conductivity of aqueous solutions;
- to establish performance tests for such analyzers, sensor units and electronic units;
- to provide basic documents to support the applications of quality assurance standards.

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 60746-1, *Expression of performance of electrochemical analyzers – Part 1: General*

3 Definitions

For the purpose of this part of IEC 60746, the definitions of IEC 60746-1 apply, together with the following definitions.

3.1

electrolytic conductance

current divided by the potential difference in the case of ionic charge transport within an electrolytic solution filling a conductivity cell:

$$G = \frac{I}{U}$$

where

I is the current through the electrolyte, in amperes (A);

U is the potential difference applied across the electrodes, in volts (V);

G is the electrolytic conductance, in siemens (S).

Electrolytic resistance is the reciprocal of electrolytic conductance with the ohm (Ω) as the unit of measurement

3.2 electrolytic conductivity

formerly called specific conductance, is defined by the equation:

$$\kappa = \frac{j}{E}$$

where

j is the electric current density, in $\text{A}\cdot\text{m}^{-2}$;

E is the electric field strength, in $\text{V}\cdot\text{m}^{-1}$.

The unit of electrolytic conductivity, κ , is siemens per metre ($\text{S}\cdot\text{m}^{-1}$). Electrolytic resistivity is the reciprocal of electrolytic conductivity with the unit of ohmmeter ($\Omega\cdot\text{m}$)

NOTE In practical use, the most commonly employed conductivity unit is microsiemens per centimetre ($\mu\text{S}\cdot\text{cm}^{-1}$) or the corresponding resistivity unit, megohm per centimetre ($\text{M}\Omega\cdot\text{cm}$)

$$1 \mu\text{S}\cdot\text{cm}^{-1} = 10^{-4} \text{S}\cdot\text{m}^{-1} = 1 \text{M}\Omega\cdot\text{cm}.$$

3.3 cell constant of the sensor unit

an electrolytic conductor of a uniform cross-section X and length L is defined by the equation:

$$K_{\text{cell}} = \frac{L}{X}$$

where K_{cell} is the cell constant, in m^{-1} (see Note 1).

It is usual to measure electrolytic conductivity by means of cells without a uniform cross-section, in which case the K_{cell} should be determined by means of a reference solution of known electrolytic conductivity.

The relationship between electrolytic conductance and electrolytic conductivity is defined by the equation:

$$\kappa = K_{\text{cell}} \times G$$

where

κ is the electrolytic conductivity, in $\text{S}\cdot\text{m}^{-1}$;

G is the electrolytic conductance, in S ;

K_{cell} is the cell constant, in m^{-1} .

NOTE 1 In practical use, K_{cell} is generally expressed in cm^{-1} , κ in $\mu\text{S}\cdot\text{cm}^{-1}$ and G in μS (see 3.2).

NOTE 2 The cell constant will normally have a constant value over a stated range (see 4.1). Outside this range, it should be expected that polarization or other effects will produce errors (see 3.4 and annex D).

3.4 polarization

effect which occurs at electrode surfaces in an electrolytic solution when the current between the electrodes is such as to produce electrolysis and consequent partial insulation of the electrode surface

To avoid this uncertainty, different measuring methods can be applied (see 3.7, 3.8 and annex D):

- a) a.c. measurements with a frequency high enough to avoid polarization effects;
- b) four or six electrode measurements with separated current transporting and potential measuring electrodes;
- c) inductive or capacitive measurements by coupling between the electrolytic conductor and the electrical measuring circuit through non-conductive media.

In each case, the relationship between the electrolytic conductivity and the measured output quantity is established by the cell constant.

3.5 temperature coefficient

relative increase (or decrease) of the electrolytic conductivity of a solution per kelvin temperature change. The temperature coefficient is dependent on the reference temperature and the nature of the solution.

The following approximate equation can be applied for strong electrolyte solutions where $\kappa > 10^{-4} \text{ S}\cdot\text{m}^{-1}$ ($1 \mu\text{S}\cdot\text{cm}^{-1}$)

$$\kappa_t = \kappa_{tr} \times (1 + \alpha \Delta t)$$

where

κ_t is the electrolytic conductivity at temperature t ;

κ_{tr} is the electrolytic conductivity at reference temperature tr ;

Δt is the temperature difference $t - tr$;

α is the temperature coefficient.

In practice, this formula is sufficiently accurate over a small temperature range. For large temperature ranges, it is usually necessary to add higher terms of a polynomial series (such as $\beta(\Delta t)^2 + \gamma(\Delta t)^3 + \dots$) to the above equation, to obtain sufficient accuracy. The percentage temperature coefficient, which is the percentage relative deviation per kelvin from the reference value κ_{tr} , is often used so that

$$\alpha (\%) = 100 \alpha$$

NOTE The manufacturer's literature should be consulted for details of sample temperature compensation technique(s) applied.

3.6 simulator

a series of non-inductive resistors (preferably step-variable, e.g., a decade resistance box), used for the performance tests of conductimetric electronic units, simulating two- and three-electrode sensors

NOTE The minimum step should preferably be $0,01 R$, where R is the reciprocal value of the nominal full range conductivity value. Analogously, the highest resistance value should correspond to the lower limit of the measuring range: if the range begins at zero, the resistance value should be at least $10 R$ for testing at 10 % of the range.

For multi-electrode sensor simulator design, the manufacturer must be consulted.

The temperature sensor may be simulated by another variable precision resistor, e.g., a variable decade resistance box.

3.7 cell capacitance

produced by the electrostatic field existing between the sensor's measuring electrodes due to the high dielectric constant of water. Its value is inversely proportional to the cell constant and expressed by the approximate relationship:

$$C_{\text{cell}} \Psi \frac{7}{K_{\text{cell}}}$$

where

C_{cell} is the cell capacitance, in picofarads (pF: $1 \text{ pF} = 10^{-12} \text{ F}$);

K_{cell} is the cell constant, in cm^{-1} ;

C_{cell} may disturb low conductivity measurements made with two- or three-electrode cells when too high a frequency is used. The effect can be reduced by means of phase discrimination within the electronic unit.

3.8 leakage currents

a.c. currents at the measuring frequency flowing from the cell electrodes to local conductive parts in contact with the sample solution.

They effectively alter the cell constant causing measuring uncertainties and arise principally in symmetrical cells, i.e., with similar electrodes side by side.

4 Procedure for specification

See clause 5 of IEC 60746-1, plus the following.

4.1 Additional statements on sensor units

- a) Type, i.e., flow-through, dip or insertion unit, number of electrodes, if electrodeless whether inductive or capacitive cell (common types of cell are described in annex D).
- b) Cell constant, tolerance and corresponding range of measurement (see 4.3a)).
- c) Type of temperature compensator (for example, Pt100).
- d) Sensor dimensions, mounting and connection details.

4.2 Additional statements on electronic units

- a) Measuring frequency/frequencies.
- b) Cell constant adjustment range.
- c) Type of temperature compensator sensor to which the electronic unit can be connected and maximum permitted resistance of compensator plus connection leads.
- d) Reference temperature adjustment range; if fixed, state temperature.
- e) Range of temperature coefficient adjustment and details of sample temperature compensation that may be applied. If fixed, state value.
- f) Installation details.

4.3 Additional statements on complete analyzers

- a) Measuring ranges (rated and effective).

NOTE Some analyzers employ concentration units, for example, mass % NaCl, g NaOH per litre, etc. For such analyzers, the rated range should be specified on the measurement unit as well as the corresponding conductivity at the rated reference temperature.

- b) Reference temperature for the measurement.
- c) Installation details.

5 Recommended standard values and ranges of influence quantities affecting the performance of electronic units

See annex A of IEC 60746-1.

6 Verification of values

See clause 6 of IEC 60746-1