INTERNATIONAL STANDARD

**ISO
16773-1**

Second edition
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Electrochemical impedance spectroscopy (EIS) on coated and uncoated metallic specimens —

Part 1:
Terms and definitions

Spectroscopie d'impédance électrochimique (SIE) sur des éprouvettes métalliques revêtues et non revêtues —
Partie 1: Termes et définitions

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 35, *Paints and varnishes*, Subcommittee SC 9, *General test methods for paints and varnishes*.

This second edition cancels and replaces the first edition (ISO 16773-1:2007), which has been technically revised. The main changes are the following:

a) the introductory element of the title, *Paints and varnishes*, has been omitted because the scope is broadened to include metals and alloys and the main element of the title has been changed to: *Electrochemical impedance spectroscopy (EIS) on coated and uncoated metallic specimens*;

b) a reference to ISO/TR 16208 has been added;

c) the terms are listed in alphabetical order;

d) the definition for working electrode has been implemented from ISO/TR 16208;

e) the units and symbols have added where applicable.

ISO 16773 consists of the following parts, under the general title *Electrochemical impedance spectroscopy (EIS) on coated and uncoated metallic specimens*:

— *Part 1: Terms and definitions*

— *Part 2: Collection of data*

— *Part 3: Processing and analysis of data from dummy cells*

— *Part 4: Examples of spectra of polymer-coated and uncoated specimens*

Introduction

ISO 16773 describes the application of electrochemical impedance spectroscopy (EIS). Although this International Standard was originally developed for coatings and major sections are specific for coatings, the general guidelines can be used also for uncoated samples. For uncoated samples extra information can be found in ISO/TR 16208.

This part of ISO 16773 defines terms used in electrochemical impedance spectroscopy.

ISO 16773-2 describes an experimental procedure for testing laboratory instrumentation for collecting and presenting EIS data collected under potentiostatic control with a focus on high-impedance organic coatings on metal surfaces. ISO 16773-2 specifies a dummy cell that models the properties of a high-impedance system. It gives a test procedure and set-up parameters for the collection of impedance data from the dummy cell and the coated metal specimens. It outlines a procedure for comparing the recorded spectra with the theoretical data for the dummy cell in order to establish guidelines for acceptable instrumental accuracy and limitations. It does not provide any guidance on data interpretation.

ISO 16773-3 specifies the procedure used for the evaluation of the experimental results obtained from dummy cells which simulate high-impedance coated samples and it gives acceptance criteria for the values obtained.

ISO 16773-4, which is informative in nature, includes some background on impedance spectra of coated metal specimens and some typical examples of spectra from actual coatings.

ISO/TR 16208 describes basic principles of electrochemical impedance spectroscopy (EIS) specially focusing on the corrosion of metallic materials. It also deals with how to use electrochemical apparatus, set up and connect electrical instruments, present measured data, and analyse results.

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Electrochemical impedance spectroscopy (EIS) on coated and uncoated metallic specimens —

Part 1:
Terms and definitions

1 Scope

This part of ISO 16773 defines terms for electrochemical impedance spectroscopy (EIS) for use in the other parts of ISO 16773.

2   Terms and definitions

2.1
peak-to-peak amplitude
$2U_0$
maximum value between maximum and minimum excitation of the applied a.c. perturbation signal

Note 1 to entry: The peak-to-peak amplitude is usually expressed in millivolts.

2.2
rms amplitude
U_{rms}
root-mean-square (i.e. effective) value of the applied a.c. perturbation signal

Note 1 to entry: This is the peak-to-peak value of the a.c. amplitude, divided by $2 \times \sqrt{2}$.

2.3
Bode plot
curves of (a) *phase angle* (2.36) versus the logarithm of the applied frequency and (b) the logarithm of the *magnitude of the impedance* (2.28) |Z| versus the logarithm of the applied frequency

2.4
charge transfer resistance
R_{ct}
resistance of the resistor representing the metal-electrolyte interface characteristics in the *equivalent circuit* (2.18)

Note 1 to entry: The charge transfer resistance is usually expressed in ohms. The specific charge transfer resistance is usually expressed in ohms times square centimetres.

2.5
coating
layer formed from a single or multiple application of a coating material to a substrate

[SOURCE: ISO 4618:2014, 2.50.1]

2.6
coating
process of applying a coat

Note 1 to entry: The use of the term "coating" for "coating material" is deprecated.

[SOURCE: ISO 4618:2014, 2.50.2]

2.7
coating capacitance
C_c
capacitance of the capacitor representing the electrical capacitance of the *coating* (2.5) in the *equivalent circuit* (2.18)

Note 1 to entry: The coating capacitance is usually expressed in nanofarads. The specific coating capacitance is usually expressed in nanofarads per square centimetre.

Note 2 to entry: For coatings which do not have ideal capacitance, the constant phase element (CPE) is frequently used. The use of a constant phase element does not have a physical meaning.

2.8
coating resistance
R_c
resistance (2.40) of the resistor representing the electrical resistance of the *coating* (2.5) in the *equivalent circuit* (2.18)

Note 1 to entry: The coating resistance is usually expressed in gigaohms. The specific coating resistance is usually expressed in gigaohms times square centimetres.

2.9
corrosion potential
U_{cor}
potential of a corroding surface at which the rate of oxidation (corrosion) and the rate of reduction of the one or more oxidants are equal

Note 1 to entry: This is also known as the mixed potential or the rest potential.

Note 2 to entry: This potential is measured relative to a *reference electrode* (2.39) under open-circuit conditions.

Note 3 to entry: The corrosion potential is usually expressed in volts.

2.10
corrosion rate
amount of metal lost in unit time

Note 1 to entry: The corrosion rate is usually expressed in millimetres per year.

2.11
counter electrode
CE
inert electrode in the *electrochemical cell* (2.15) through which the current passes from or to the *working electrode* (2.46)

2.12
double-layer capacitance
C_{dl}
capacitance of the capacitor representing the metal-electrolyte interface characteristics in the *equivalent circuit* (2.18)

Note 1 to entry: The double-layer capacitance is usually expressed in microfarads. The specific double-layer capacitance is usually expressed in microfarads per square centimetre.

2.13
dummy cell
printed-circuit board with mounted electrical components representing the *equivalent circuit* (2.18) and with connection points to the measuring instrument

2.14
electrical zero-reference
voltage with respect to which all voltages within the electrochemical equipment are referenced

2.15
electrochemical cell
system consisting of at least two electrodes in an electrolyte

2.16
electrochemical impedance spectroscopy
EIS
electrochemical technique which allows the impedance spectrum of an electrochemical system to be recorded as a function of the frequency of the applied signal, and the spectrum thus obtained to be analysed by transfer function analysis

2.17
electromagnetic noise
electrical noise in the current and/or voltage signal in a circuit whose origin is stray electromagnetic radiation from nearby electrical devices

2.18
equivalent circuit
electrical circuit modelling the *impedance* (2.23) of the specimen under test

Note 1 to entry: For example, this could be a network, consisting of elements such as a resistor, a capacitor and an inductor, which has the same impedance spectrum (i.e. the same response to a perturbation) as the electrochemical system.

2.19
error estimate
percentage deviation from zero of the recorded data, or the percentage deviation of the data from the absolute values of the elements of the dummy cell used

Note 1 to entry: The percentage deviation from zero of the recorded data is determined by subtracting the data from the theoretical equivalent-circuit data and dividing it by the latter. This method is only suitable for dummy cell measurements.

Note 2 to entry: The percentage deviation from the absolute values of the elements of the dummy cell used is determined by calculating the values of the equivalent-circuit elements from the recorded spectra. It is expressed as the percentage deviation from the absolute values of the elements of the dummy cell.

2.20
Faraday cage
metallic cabinet, used to reduce electromagnetic interference to the *electrochemical cell* (2.15) (or circuit), that completely encases the cell and is grounded to the instrument earth

2.21
galvanostat
electronic instrument which controls the current through the *working electrode* (2.46) and *counter electrode* (2.11) and which measures the resulting potential at the working electrode with respect to a *reference electrode* (2.39)

2.22
ground
electronic reference point

Note 1 to entry: Voltage in the circuit is measured with respect to this reference point. In an electrochemical system, there could be several types of ground:

a)   Earth ground, which is a connection to earth. The "protective ground pin" in a.c. receptacles is connected to earth. The chassis of a desktop computer connected to the a.c. mains will be grounded in this way.

b)   Floating ground, which in an electrochemical system (instrumentation and cell) is one which is not actually connected to earth.

c)   Signal ground, which is the reference point in the electronic circuit of a *potentiostat* (2.38). A signal ground can be earthed or floating, depending upon the potentiostat design.