
**Corrosion of metals and alloys —
Conventions applicable to
electrochemical measurements in
corrosion testing**

*Corrosion des métaux et alliages — Conventions applicables aux
mesures électrochimiques lors des essais de corrosion*

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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

ISO 17474 was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys*.

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Introduction

Electrochemical test methods are useful for studying corrosion, because it is one particular phenomena of electrochemistry. They can provide quantitative data such as electrode potential, electrochemical current, electrochemical impedance, etc. This International Standard describes how these data are presented, being derived from basic methodology in ASTM G3-89^[1].

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Corrosion of metals and alloys — Conventions applicable to electrochemical measurements in corrosion testing

WARNING — This International Standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1 Scope

This International Standard is intended to provide conventions for reporting and displaying electrochemical corrosion data. Conventions for potential, current density and electrochemical impedance, as well as conventions for graphical presentation of such data, are included.

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.

ISO 8044, *Corrosion of metals and alloys — Basic terms and definitions*

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8044 apply.

4 Significance and use

This practice provides guidance for reporting, displaying and plotting electrochemical corrosion data and includes recommendations on signs and conventions. Use of this practice will result in the reporting of electrochemical corrosion data in a standard format, facilitating comparison between data developed at different laboratories or at different times. The recommendations outlined in this International Standard may be utilized when recording and reporting corrosion data obtained from electrochemical tests, such as potentiostatic and potentiodynamic polarization, polarization resistance, electrochemical impedance, galvanic corrosion, and open-circuit potential measurements.

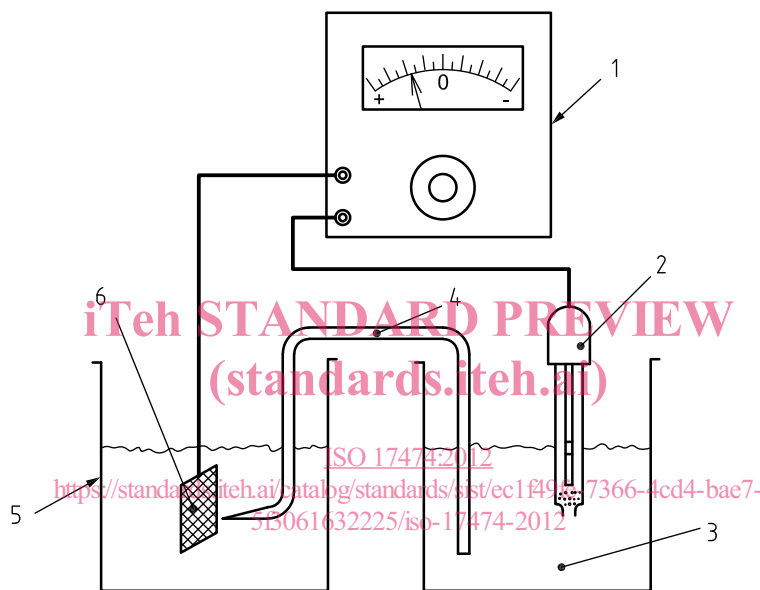
5 Sign convention for electrode potential

5.1 In this convention, the positive direction of electrode potential implies an increase in oxidizing condition at the electrode in question. The positive direction also denotes a noble direction because the corrosion potentials of most noble metals, such as platinum, are more positive than the other non-passive base metals. On the other hand, the negative direction is associated with an increase in the reducing condition, and also denotes an active direction since corrosion potentials of active metals, such as potassium, are more negative than the other metals used. This convention was adopted unanimously by the 1953 International Union of Pure and Applied Chemistry^[1] as the standard for electrode potential.

5.2 To measure a potential of a specimen electrode in an aqueous electrolyte, an experimental set-up may be composed of an electrometer, a reference electrode, an electrochemical cell, the electrolyte, etc. as shown in Figure 1. If the electrometer reads on scale in the negative range, the specimen electrode potential is negative to the reference electrode. Conversely, if the electrometer reads on scale in the positive range, the specimen potential is positive to the reference electrode.

In cases where the polarity of a measuring instrument is in doubt, a simple verification test can be performed as follows: connect the measuring instrument to a dry cell with the lead previously on the reference electrode to the negative battery terminal, and the lead previously on the specimen electrode to the positive battery terminal. The meter deflection shall be in the direction of positive potential. The corrosion potential of magnesium or zinc shall be negative in a 1 N NaCl solution if measured against, for example, a KCl-saturated silver/silver chloride electrode (KCl (sat.)/AgCl/Ag: sat. SSCE).

For accuracy, an input impedance of the electrometer should be more than $10^{11}\Omega$.



- Key**
- 1 electrometer
 - 2 reference electrode
 - 3 electrolyte
 - 4 salt bridge
 - 5 electrochemical cell
 - 6 specimen electrode

Figure 1 — Schematic diagram of an apparatus to measure electrode potential of a specimen

6 Sign convention for current and current density

A convention for the sign of current and current density, in which anodic and cathodic values are designated as positive and negative, respectively, is recommended. When the potentials are plotted against the logarithm of the current densities, only the absolute values of the latter can be plotted. In such plots, the values which are cathodic should be clearly differentiated from the anodic values, if both are present.

7 Conventions for displaying polarization data

7.1 Sign conventions

The standard mathematical practice for plotting graphs is recommended for displaying electrochemical corrosion data. In this practice, positive values are plotted above the origin on the ordinate (y axis) and to the right of the origin on the abscissa (x axis). In logarithmic plots, the abscissa value increases from left to right and the ordinate value increases from bottom to top.

7.2 Current density-potential plots

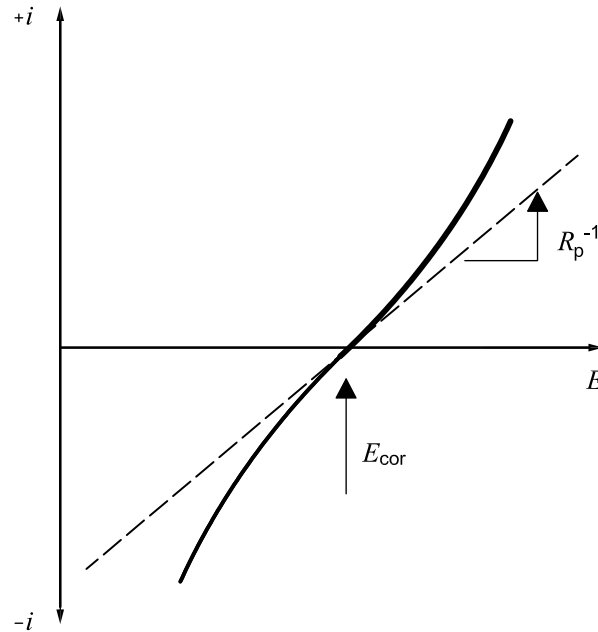
A convention for plotting current density vs. potential data, in which current density is plotted along the ordinate and potential along the abscissa, is recommended. In current density/potential plots, the current density may be plotted on either linear or logarithmic axes. In general, logarithmic plots are used to incorporate wide ranges of current density data and to demonstrate Tafel relationships. Linear plots are used for studies in case the current density or potential range is small, or in case the region of the current density change from anodic to cathodic is assessed. Linear plots are also used for the determination of the polarization resistance R_p , which is defined as the inverse of the slope of a potential-current density plot at the corrosion potential E_{cor} . The relationship between the polarization resistance R_p and the corrosion current density i_{cor} is as follows (References [2][3]):

$$\left[\frac{d(\Delta E)}{di} \right]_{\Delta E=0} = R_p = \frac{b_a b_c}{2,303 (b_a + b_c) i_{cor}} \quad (1)$$

where

b_a is the anodic Tafel slope;

b_c is the cathodic Tafel slope.



Key

- E potential
- i current density
- E_{cor} corrosion potential
- R_p polarization resistance

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Figure 2 — Linear polarization plot

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The solid line in Figure 2 is a plot of current density i versus potential E around the corrosion potential E_{cor} , from which the polarization resistance R_p may be determined as an inverse of the slope of the same curve at the potential E_{cor} .

7.3 Potential reference point

In plots where electrode potentials are displayed, some indication for conversion from the displayed values to the standard hydrogen electrode scale (SHE) shall be shown. Expressing the used reference electrode in such a way as ' $E(V)$ vs. 1M KCl (1M KCl/AgCl/Ag)' is recommended. The electrode potential may be plotted on the abscissa, at the bottom of which is the scale against the reference electrode used, together with that at the top with the converted scale against the standard hydrogen electrode (SHE). If the latter is not shown, a relationship such as the following may be used for the conversion according to Annex A.

$$E \text{ vs. SHE} = E \text{ vs. 1M KCl/AgCl/Ag} + 0,235 \text{ V} \tag{2}$$

where

E vs. SHE represents the electrode potential, in volts, against the standard hydrogen electrode;

$E(V)$ vs. 1M KCl/AgCl/Ag represents the electrode potential, in volts, measured against the silver/silver chloride electrode in 1M KCl.

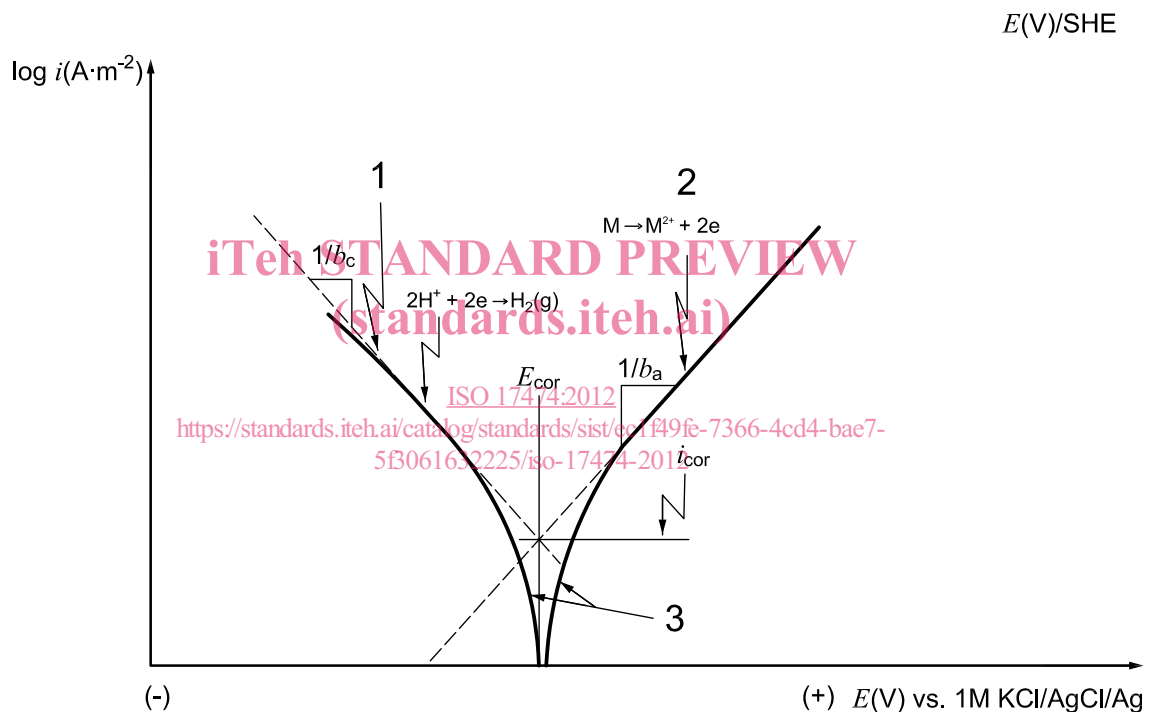
NOTE A table of potentials for various common reference electrodes is given in Annex A.

7.4 Units

The recommended unit of potential is volt (V). If only small potential ranges are covered, millivolts (mV) or microvolts (μV) may be used. The SI units for current density are amperes per square metre ($\text{A}\cdot\text{m}^{-2}$) or amperes per square centimetre ($\text{A}\cdot\text{cm}^{-2}$). Units expressed in milli-amperes per square centimetre ($\text{mA}\cdot\text{cm}^{-2}$), and microamperes per square centimetre ($\mu\text{A}\cdot\text{cm}^{-2}$) are still in use.

7.5 Sample polarization curves

Sample polarization plots employing these recommended practices are shown in Figures 2 to 6. Figures 3 and 4 are hypothetical curves showing active and active-passive anode behaviours, respectively. Figures 5 and 6 are actual anodic polarization data for Type 430 stainless steel (UNS 43000)^[4] and cathodic polarization data of Type 2024-T3 aluminium alloy^[5]. The purpose of Figures 3 and 4 is to illustrate the location of various points used in discussion of electrochemical methods for corrosion testing. The purpose of Figures 5 and 6 is to show how various types of electrode behaviours are plotted in accordance with this convention.



Key

- 1 cathodic branch
- 2 anodic branch
- 3 observed polarization plot
- b_a anodic Tafel slope
- b_c cathodic Tafel slope
- E electrode potential
- E_{cor} corrosion potential
- i current density
- i_{cor} corrosion current density

Figure 3 — Hypothetical cathodic and anodic polarization diagram