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**Corrosion of metals and alloys —  
General principles for corrosion testing**

*Corrosion des métaux et alliages — Principes généraux 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.

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](http://www.iso.org/directives)).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

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

This second edition cancels and replaces the first edition (ISO 11845:1995), which has been technically revised. The main changes compared with the previous edition are as follows:

- the format has been changed;
- [Annex A](#) has been added with general requirements for corrosion tests under constant immersion.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).



## Introduction

The existence of a wide range of corrosion tests, partly as a function of the various materials and corrosive media in existence, calls for guidance in the general procedures that should be used. Corrosion tests, if they are to evaluate and give comparable results, are carried out in accordance with established conditions. Conditions deviating from these conditions are precisely quoted, taking into account all the details given in this document. The most relevant results on corrosion behaviour of metals can normally be obtained from long-term tests under conditions close to those obtained in practice.





# Corrosion of metals and alloys — General principles for corrosion testing

## 1 Scope

This document specifies general principles for carrying out corrosion tests under conditions of constant immersion. Some of these general principles are applicable to other types of corrosion testing.

This document does not cover important procedures for stress corrosion testing, such as those given in ISO 7539 (all parts).

## 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.

ISO 8044, *Corrosion of metals and alloys — Vocabulary*

ISO 8407, *Corrosion of metals and alloys — Removal of corrosion products from corrosion test specimens*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8044 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 <http://www.electropedia.org/>

## 4 General principles

**4.1** Corrosion tests are generally carried out as comparative tests, i.e. a number of materials or corrosive media are compared under the given test conditions. It is, however, also advisable to include reference materials or reference solutions in which the behaviour under practical conditions of attack are known. It is important to have a clear understanding of the objectives of any corrosion testing programme and to make a judicious choice of the most practical methods in order to evaluate corrosion damage.

**4.2** During the tests, the degree of attack as a function of time is observed and, as far as possible, quantitatively recorded. The objective of most types of testing should be to determine the state of the specimens on more than three separate occasions apart from the start of the test. The duration of tests should be such that, on completion of the test, a clear result is obtained concerning the behaviour of the material and, where applicable, the reference material under the given test conditions. If necessary, additional tests extending beyond the time originally planned should be required.

**4.3** Because results often exhibit considerable scatter, a single value provides little useful information. For this reason, whenever possible, every test result should be verified by taking the mean of at least three tests per measurement point. For this purpose, each specimen should be used only once.



**4.4** The test conditions should, as far as possible, be matched to the practical conditions under which the material and the corrosive media will be used, except for short-duration tests as detailed in [4.5](#). This applies:

- a) to the material, in relation to its shape, surface condition, grain structure, etc., for details see [Clause 5](#);
- b) to the corrosive medium, in relation to concentration, temperatures, etc., for details see [Clause 7](#).

**4.5** In the case of short-duration corrosion tests, the object is to achieve usable results in the shortest possible time by intensifying the attack conditions. However, intensification of the attack conditions, e.g. by increasing the temperature or concentration of the corrosive medium, often gives results that do not correspond to behaviour under practical conditions. Care shall therefore be exercised when applying such results in practice.

**4.6** Particular care is necessary when applying the results of accelerated corrosion tests to practical conditions since, with this type of corrosion test, corrosion media differing from those occurring in practice are often used.

**4.7** For the specific purpose, the material, the corrosive medium, the ratio of solution volume to surface area, the surface area, the temperature, the agitation, the test duration, the evaluation, and the corrosion form should be in accordance with the International Standards given in [Annex A](#).

## 5 Materials

**5.1** Test specimens shall be clearly identified. The following information should be given, when applicable:

- a) chemical composition of the material and the appropriate designation, according to the relevant international, regional or national standards;
- b) condition of the material and fabrication details (e.g. presence of welds, sand cast, gravity die cast, pressure die cast, hot rolled, cold rolled, forged, heat-treatment, whether naturally or artificially aged);
- c) form of material (sheet, wire, tube, solid bars or similar);
- d) position and orientation of the specimens in the original material (with a sketch if necessary);
- e) dimensions (exact size, shape, area) and mass of specimens;
- f) condition of the surface of the material (with or without rolling skin, thickness of rolling skin, pickled, ground, polished, or other pretreatment);
- g) mechanical properties of the material;
- h) structure of the material, including any chemical or mechanical pretreatment;
- i) protective layers and coatings (type, composition and thickness).

**5.2** The method of producing the specimens from the test piece should be documented. Specimens should preferably be taken from the test piece in such a manner as to exclude the effect of any significant additional mechanical cold working and any substantial temperature rise at the cut edges during machining. Any burr at the cut edges produced when the specimen is obtained should be removed. In general, it is necessary to protect the edges where it is likely that unwanted effects on the corrosion behaviour of the material being tested should originate at the edges (e.g. in the case of coated specimens).



**5.3** In the case of corrosion tests under conditions close to those obtained in practice, the surface condition of the specimens should be the same as that found in practical application.

**5.4** In general, specimens should be cleaned and degreased. The choice of suitable cleaning or degreasing agents depends on the material being tested. Only products that do not alter the surface of the part being tested should be used. In most cases, organic solvents are used. The cleaning agent used should be reported.

**5.5** If the specimen surface has to be mechanically pretreated, this should preferably be done by grinding, with each step removing damage from the previous step. The grade of the final abrasive used should be reported. Machining is preferable to grinding for soft metals.

**5.6** Specimens should be clearly marked, for example by stamping with numbers or letters. Since the mechanical stress resulting from stamping with numbers or letters can initiate local corrosion, in the case of particularly sensitive materials, and under defined test conditions, it is desirable to use a method of marking which does not involve any cold working, e.g. electro-mechanical marking or notching of specimens. It should be necessary to carry out heat treatment of the specimen after marking.

## **6 Corrosive medium**

**6.1** The corrosive medium shall be clearly described. In particular, the origin, composition, method of preparation and condition of the corrosive medium should be quoted.

**6.2** The information on the origin of the corrosive medium should state whether the solutions used are of natural origin, normally occurring in technical processes or whether they are specially manufactured.

**6.3** Where the quantitative chemical composition of the medium is not known, it should be determined by analysis and the analysis should also take into account small amounts of admixtures or impurities.

**6.4** In the case of aqueous solutions, the pH value and, if possible, the redox potential should be given.

**6.5** In the case of solutions, the results are often influenced by the amount of dissolved gases contained; in the case of gases, by the moisture and solid matter contained; in the case of solids, by the moisture content. Hence, these components also should be taken into account.

**6.6** If the corrosive medium is significantly altered as a result of the corrosion reaction, evaporation or condensation it should be replaced or replenished during the test so that the environmental conditions remain constant. The test report should state whether, how often and to what extent the corrosive medium has been replaced or replenished.

## **7 Test procedure**

**7.1** For general requirements for corrosion tests under constant immersion, the material, the corrosive medium, the ratio of solution volume to surface area, the surface area, the temperature, the agitation, the test duration, the evaluation, and the corrosion form should be in accordance with the International Standards given in [Annex A](#).

**7.2** The quantity of the corrosive medium shall be a defined ratio of volume to surface area of the specimen. This ratio should normally be at least 5 ml/cm<sup>2</sup>.

**7.3** In order to exclude the effect of irregularities as far as possible, the total exposed surface area of each specimen should normally be not less than 25 cm<sup>2</sup> except where smaller surface areas are specified in special test regulations. The total exposed surface area for electrochemical testing is usually much less.



For the testing of specimens taken from castings, approximately twice this surface area is recommended. For specimens containing weldments in which the influence of the surrounding parent material on the heat affected zone or weld metal is to be taken into consideration, the parent material area either side of the weld should each be at least twice the weld area.

**7.4** The shape of the specimen depends on the method of the corrosion test and on the type of corrosion expected. If a non-uniform or local attack is likely, specimens of sufficient thickness for a determination of the depth of attack should be used. The thickness of the specimen should be measured before the test.

**7.5** The influence of a corrosive attack on the mechanical properties should preferably be measured on specimens of the kind used for testing the mechanical properties.

**7.6** The way the specimens are arranged in the corrosive medium can influence the test results. In the case of flowing corrosive media, the specimens should be arranged in such a manner that the flow is parallel to the long direction of the specimen.

**7.7** The specimens shall be placed in the corrosive medium in such a manner that their entire test surface is subject to the medium except where the effects of phase boundaries are also to be determined.

**7.8** For immersion testing, any slight fluctuations resulting from the operation of the test equipment should be balanced out by re-positioning, at intervals, the specimens in the test environment.

**7.9** Replicated specimens should not be arranged directly adjacent to one another but as far as possible at different parts of the test environment or test vessel. In order to avoid galvanic corrosion, no metallically conducting connection should exist between the specimens themselves or between specimens and a metal vessel.

**7.10** Specimens should be provided with a hole for hanging and attached with a suitable thin synthetic fibre thread or glass hook. Caution is required not to cause crevice attack that would influence the observed corrosion. If the distance between specimens or between the specimens and the vessel is inadequate, the results obtained will not be reproducible.

**7.11** In principle, only specimens of the same type of material should be tested in the same vessel unless it is required to test the interaction of different materials.

**7.12** The vessel shall be of a material which is neither attacked by the corrosive medium nor alters the corrosive medium.

**7.13** The vessels shall be arranged in such a manner that there is no possibility of unwanted external influence on the test conditions.

**7.14** In the case of tests with open vessels, the air shall contain no components capable of disturbing the test procedure.

**7.15** The rate of corrosion is temperature dependent. If temperature fluctuations have to be excluded, the test temperatures should be maintained constant by suitable measures. If the temperature is being varied during the test period, care should be taken to maintain the required heating and cooling periods.

**7.16** If, in practice, there exists a temperature gradient between the corrosive medium and the metallic material, this gradient should also be established in the test procedure.

**7.17** If the corrosive medium moves during the test, this should be mentioned in the test report.



**7.18** Before the mass loss is determined, corrosion products shall be removed from the specimens in accordance with ISO 8407. Specimens should also be weighed before corrosion product removal, and the mass of the corrosion products obtained by difference.

## 8 Test report

The test report should contain the following:

- the date of the test;
- the sample;
- the International Standard used (including its year of publication);
- the method used (if the standard includes several);
- the result(s), including a reference to the clause which explains how the results were calculated;
- any deviations from the procedure;
- corrosive media and concentration (any changes during test);
- volume of test solution;
- temperature (maximum, minimum, average);
- gas purge, e.g. aeration/deaeration (describe conditions or technique);
- agitation (describe conditions or technique);
- type of apparatus used for test;
- duration of each test;
- chemical composition of the material and appropriate designation;
- condition of the material and fabrication details (e.g. presence of welds, sand cast, gravity die cast, pressure die cast, hot rolled, cold rolled, heat-treatment, whether naturally or artificially aged);
- form of material (sheet, wire, tube, solid bars or similar);
- position of the specimens in the test piece (with a sketch if necessary);
- dimensions (exact size, shape and area) and mass of specimens;
- condition of the surface of the material (with or without rolling skin, thickness of rolling skin, pickled, ground, polished or other pretreatment);
- mechanical properties of the material;
- structure of the material, including any chemical or mechanical pretreatment;
- protective layers and coatings (type, composition and thickness);
- treatment used to prepare specimens for test;
- number of specimens of each material tested and whether specimens were tested separately or which specimens were tested in the same container;
- method used to clean specimens after exposure and the extent of any error expected by this treatment;
- initial and final masses and actual reduction in mass and change of thickness for each specimen;



- methods of evaluation of corrosion damage if other than general, such as crevice corrosion, pit x) depth and distribution, and results of microscopic examination or mechanical tests;
- corrosion rates for each specimen; recommended units are  $\text{mm}\cdot\text{a}^{-1}$  or  $\mu\text{m}\cdot\text{a}^{-1}$  for thickness loss and  $\text{mg}\cdot\text{dm}^{-2}\cdot\text{d}^{-1}$  or  $\text{g}\cdot\text{m}^{-2}\cdot\text{h}^{-1}$  or  $\mu\text{g}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$  for mass loss;
- minor occurrences or deviations from the proposed test programme, if known, as these can often have significant effects.

Statistical methods can be a valuable tool for analysing the results from test programmes designed to generate adequate data and should be used where appropriate.



**Annex A**  
(informative)

**General requirements for corrosion tests under constant  
immersion for a specific purpose**



**Table A.1 — General requirements for corrosion tests under constant immersion for a sp**

International Standard		Material	Corrosive medium	Ratio of solution volume to surface area	Surface area	Temperature	Agitation	Test dura
ISO 3651-1		austenitic and ferritic-austenitic stainless steels	65 % ± 0,2 % nitric acid	at least 20 ml/cm <sup>2</sup>	not specified	boiling	not specified	5 periods of 4
ISO 3651-2	Method A	ferritic, austenitic and ferritic-austenitic stainless steels	Dissolve 100 g of copper(II) sulfate pentahydrate CuSO <sub>4</sub> 5H <sub>2</sub> O in 700 ml of distilled water. Then add 184 g (100 ml) of sulfuric acid and make up to 1 000 ml with distilled water	at least 8 ml/cm <sup>2</sup>	15 cm <sup>2</sup> to 35 cm <sup>2</sup> a maximum thickness of 6 mm	boiling	not specified	20 h ± 5
	Method B		Add carefully 250 ml of sulfuric acid to 750 ml of distilled water. Dissolve 110 g copper(II) sulfate pentahydrate in the warm solution	at least 10 ml/cm <sup>2</sup>		boiling		20 h ± 5
	Method C		Add carefully 280 ml of sulfuric acid to 720 ml of distilled water. Dissolve 25 g ferric sulfate(III) in the warm solution	at least 10 ml/cm <sup>2</sup>		boiling		20 h ± 5
ISO 3651-3		low-Cr ferritic stainless steels	0,5 % H <sub>2</sub> SO <sub>4</sub> + 24 % CuSO <sub>4</sub>	a minimum 8 ml/cm <sup>2</sup>	5 cm <sup>2</sup> to 20 cm <sup>2</sup> (recommended)	boiling	not specified	15 h ± 3
ISO 6509-1		copper alloys with zinc	Dissolve 12,7 g of copper(II) chloride dihydrate in deionized water and make up the volume to 1 000 ml	240 ml/cm <sup>2</sup> to 300 ml/cm <sup>2</sup>	approximately 1 cm <sup>2</sup>	75 °C ± 5 °C	not specified	24 h ± 30



Table A.1 (continued)

International Standard		Material	Corrosive medium	Ratio of solution volume to surface area	Surface area	Temperature	Agitation	Test duration
ISO 6509-2		copper alloys with a mass fraction of zinc more than 15 %	Dissolve 12,7 g of copper(II) chloride dihydrate in deionized water and make up the volume to 1 000 ml	240 ml/cm <sup>2</sup> to 300 ml/cm <sup>2</sup>	approximately 1 cm <sup>2</sup>	75 °C ± 5 °C	not specified	24 h ± 30 min
ISO 11130		metals with or without coatings	35 g/l ± 1 g/l, NaCl	not less than 30 ml/cm <sup>2</sup>	90 mm x 120 mm x 1 mm	25 °C ± 2 °C	not specified	20 days to 90 days, test cycle is immersion and drying
ISO 11846	Method A	heat-treatable aluminium alloys without protective coatings	57 g/l ± 1 g/l of sodium chloride and 10 ml ± 1 ml of hydrogen peroxide	not less than 5 ml/cm <sup>2</sup>	4 cm <sup>2</sup> to 20 cm <sup>2</sup>	30 °C ± 3 °C	not specified	6 h
	Method B		30 g/l sodium chloride and 10 ml ± 1 ml of hydrochloric acid			room temperature	not specified	24 h
ISO 11881	1	aluminium alloys	20 g/l K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> + 9 g/l HCl	10 ml/cm <sup>2</sup>	at least 50 mm x 75 mm (37,5 cm <sup>2</sup> )	18 °C to 25 °C	not specified	7 d
	2		234 g/l NaCl + 50 g/l KNO <sub>3</sub> + 4,4 g/l HNO <sub>3</sub>	15 ml/cm <sup>2</sup>		25 °C ± 3 °C		2 d to 4 d
	3		54 g/l HN <sub>4</sub> NO <sub>3</sub> + 20 g/l NH <sub>4</sub> NO <sub>3</sub> + 2 g/l (NH <sub>4</sub> ) <sub>2</sub> C <sub>4</sub> H <sub>2</sub> O + 3 g/l H <sub>2</sub> O <sub>2</sub>	10 ml/cm <sup>2</sup>		65 °C ± 1 °C		1 d
	4		20 g/l K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> + 13,5 g/l HCl	10 ml/cm <sup>2</sup>		18 °C to 25 °C		7 d
	5		10 g/l K <sub>2</sub> Cr <sub>2</sub> O <sub>7</sub> + 234 g/l NaCl + 50 g/l KNO <sub>3</sub> + 4,4 g/l HNO <sub>3</sub>	15 ml/cm <sup>2</sup>		25 °C ± 3 °C		2 d to 4 d
	6		234 g/l NaCl + 61 g/l KNO <sub>3</sub> + 5,4 g/l AlCl <sub>3</sub> 6H <sub>2</sub> O	20 ml/cm <sup>2</sup>		25 °C ± 3 °C		4 d
ISO 18069		stainless steels and nickel-based alloys	the intended liquids	at least 5 ml/cm <sup>2</sup>	at least 20 cm <sup>2</sup>	the intended temperature	stirring	three sequential 24 h, 72 h, and 168 h



## Bibliography

- [1] ISO 3651-1, *Determination of resistance to intergranular corrosion of stainless steels — Part 1: Austenitic and ferritic-austenitic (duplex) stainless steels — Corrosion test in nitric acid medium by measurement of loss in mass (Huey test)*
- [2] ISO 3651-2, *Determination of resistance to intergranular corrosion of stainless steels — Part 2: Ferritic, austenitic and ferritic-austenitic (duplex) stainless steels — Corrosion test in media containing sulfuric acid*
- [3] ISO 3651-3, *Determination of resistance to intergranular corrosion of stainless steels — Part 3: Corrosion test for low-Cr ferritic stainless steels*
- [4] ISO 6509-1, *Corrosion of metals and alloys — Determination of dezincification resistance of copper alloys with zinc — Part 1: Test method*
- [5] ISO 6509-2, *Corrosion of metals and alloys — Determination of dezincification resistance of copper alloys with zinc — Part 2: Assessment criteria*
- [6] ISO 7539 (all parts), *Corrosion of metals and alloys — Stress corrosion testing*
- [7] ISO 11130, *Corrosion of metals and alloys — Alternate immersion test in salt solution*
- [8] ISO 11846, *Corrosion of metals and alloys — Determination of resistance to intergranular corrosion of solution heat-treatable aluminium alloys*
- [9] ISO 11881, *Corrosion of metals and alloys — Exfoliation corrosion testing of aluminium alloys*
- [10] ISO 18069, *Corrosion of metals and alloys — Method for determination of the uniform corrosion rate of stainless steels and nickel based alloys in liquids*







