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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

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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.

International Standard ISO 11845 was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys.*

Annex A of this International Standard is for information only.

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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 which should be utilized. Corrosion tests, if they are to evaluate and give comparable results, must be carried out according to established conditions. Conditions deviating from these must be precisely quoted, taking into account all the details given in this International Standard. 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

1.1 This International Standard contains the most important general guidelines for carrying out corrosion tests under conditions of constant immersion. However some of these general principles may also be applicable to other types of corrosion testing.

1.2 This International Standard does not cover important procedures for stress corrosion testing such as those given in ISO 7539. (See annex A.)

2 Normative reference

The following standard contains provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the edition indicated was valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 8407:1991, *Corrosion of metals and alloys — Removal of corrosion products from corrosion test specimens.*

3 General principles

3.1 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 whose 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.

3.2 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 may be required.

3.3 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.

3.4 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 3.5. This applies:

a) to the material, in relation to its shape, surface condition, grain structure, etc., for details see clause 4;

b) to the corrosive medium, in relation to concentration, temperatures, etc., for details see clause 9).

3.5 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 which do not correspond to behaviour under practical conditions. Care must therefore be exercised when applying such results in practice.

3.6 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 Material

4.1 Test specimens must be clearly identified. The following information should be given, when applicable:

a) chemical composition of the material and appropriate designation, e.g.: BS, DIN, UNS, etc., where applicable;

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, etc.);

c) form of material (sheet, wire, tube, solid bars or similar);

d) position and orientation of the specimens in the original material (with 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).

4.2 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 may originate at the edges (e.g. in the case of coated specimens).

4.3 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.

4.4 In general, specimens should be cleaned and degreased. The choice of suitable cleaning or degreasing agents depends on the material being tested. Only products which 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.

4.5 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.

4.6 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 may be necessary to carry out heat treatment of the specimen after marking.

5 Corrosive medium

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

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

5.3 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.

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

5.5 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.

5.6 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.

6 Test procedure

6.1 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 10 ml/cm^2.

6.2 In order to exclude the effect of irregularities as far as possible, the total exposed surface area of each specimen should be not less than 25 cm^2 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.

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

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

6.5 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. In atmospheric testing, results may be influenced by angle of exposure to the ground, position relative to geographic poles, prevailing winds and whether the skyward or ground-facing surfaces are under consideration.

6.6 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.

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

6.8 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.

6.9 Specimens may 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 which may 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.

6.10 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.

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

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

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

6.14 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.

6.15 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.

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

6.17 Before the mass loss is determined, corrosion products must be removed from the specimens according to ISO 8407. Specimens may also be weighed before corrosion product removal, and the mass of the corrosion products obtained by difference.

7 Reporting the data

7.1 The importance of reporting as much data as possible cannot be over-emphasized.

7.2 Expansion of the testing programme in the future or correlating the results with tests of other investigators will be possible only if all pertinent information is properly recorded.

7.3 The following checklist is a recommended guide for reporting all important information and data.

7.3.1 Corrosive media and concentration (any changes during test).

7.3.2 Volume of test solution.

7.3.3 Temperature (maximum, minimum, average).

7.3.4 Gas purge, e.g. aeration/deaeration (describe conditions or technique).

7.3.5 Agitation (describe conditions or technique).

7.3.6 Type of apparatus used for test.

7.3.7 Duration of each test.

7.3.8 Chemical composition of the material and appropriate designation, e.g. BS, DIN, UNS, etc., where applicable.

7.3.9 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, etc.).

7.3.10 Form of material (sheet, wire, tube, solid bars or similar).

7.3.11 Position of the specimens in the test piece (with sketch if necessary).

7.3.12 Dimensions (exact size, shape and area) and mass of specimens.

7.3.13 Condition of the surface of the material (with or without rolling skin, thickness of rolling skin, pickled, ground, polished or other pretreatment).

7.3.14 Mechanical properties of the material.

7.3.15 Structure of the material, including any chemical or mechanical pretreatment.

7.3.16 Protective layers and coatings (type, composition and thickness).

7.3.17 Treatment used to prepare specimens for test.

7.3.18 Number of specimens of each material tested and whether specimens were tested separately or which specimens were tested in the same container.

7.3.19 Method used to clean specimens after exposure and the extent of any error expected by this treatment.

7.3.20 Initial and final masses and actual reduction in mass and change of thickness for each specimen.

7.3.21 Methods of evaluation of corrosion damage if other than general, such as crevice corrosion, pit depth and distribution, and results of microscopic examination or mechanical tests.

7.3.22 Corrosion rates for each specimen. Recommended units are mm/yr or μm/yr for thickness loss and $mg/dm^2/d$ for mass loss.

7.4 Minor occurrences or deviations from the proposed test programme often can have significant effects and should be reported if known.

7.5 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)

Bibliography

[1] ISO 7539-1:1987, *Corrosion of metals and alloys — Stress corrosion testing — Part 1: General guidance on testing procedures.*

[2] ISO 7539-2:1989, *Corrosion of metals and alloys — Stress corrosion testing — Part 2: Preparation and use of bent-beam specimens.*

[3] ISO 7539-3:1989, *Corrosion of metals and alloys — Stress corrosion testing — Part 3: Preparation and use of U-bend specimens.*

[4] ISO 7539-4:1989, *Corrosion of metals and alloys — Stress corrosion testing — Part 4: Preparation and use of uniaxially loaded tension specimens.*

[5] ISO 7539-5:1989, *Corrosion of metals and alloys — Stress corrosion testing — Part 5: Preparation and use of C-ring specimens.*

[6] ISO 7539-6:1989, *Corrosion of metals and alloys — Stress corrosion testing — Part 6: Preparation and use of pre-cracked specimens.*

[7] ISO 7539-7:1989, *Corrosion of metals and alloys — Stress corrosion testing — Part 7: Slow strain rate testing.*

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