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Corrosion of metals and alloys — Accelerated cyclic corrosion tests with exposure to synthetic ocean water salt-deposition process — “Dry” and “wet” conditions at constant absolute humidity

Corrosion des métaux et alliages — Essais de corrosion cyclique accélérée avec exposition à l’eau de mer synthétique par procédé de dépôt de sel — Conditions “sèches” et conditions “humides” à taux d’humidité absolue constant

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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 16539 was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys*.

Introduction

Corrosion of metallic materials, with or without corrosion protection, is influenced by many environmental factors, the importance of which can vary with the type of metallic materials and with the type of environment. It is impossible, therefore, to design accelerated laboratory corrosion tests in such a way that all environmental factors influencing resistance to corrosion are taken into account. Laboratory tests are, therefore, designed to simulate the effects of most important factors, which enhance the corrosion of metallic materials.

The accelerated corrosion tests described in this International Standard are designed to simulate and enhance the environmental influence on a metallic material of exposure to outdoor climates, where exposure to salt-contaminated conditions occurs and can promote corrosion. It has been prepared by reference to technical papers and reports (see the Bibliography).

The particular advantages of two tests described in this International Standard over conventional accelerated tests, such as the neutral salt spray test (NSS) as specified in ISO 9227 and the wet (salt fog)/dry/humidity test as specified in ISO 14993, lies in their better ability to reproduce the corrosion that occurs in atmospheric environments which contain much sea salt.

Accelerated corrosion tests to simulate atmospheric corrosion in such environments are intended/expected to include the following requirements.

a) Constant absolute humidity: It is generally observed that temperature and relative humidity change under a constant absolute humidity in outdoor environments. The water absorption of deposited salts is an important factor affecting atmospheric corrosion behaviour. The same relationship, constant absolute humidity, as an actual environment is intended/expected to exist for temperature and relative humidity during dry/wet cycles.

b) Control of the amount of salt deposition: The amount of the salt deposition on test specimens is intended/expected to be changed according to the corrosivity of the atmosphere in which the tested metallic material can be used. A salt-containing test solution is intended/expected to be diluted or the spraying time is intended/expected to be adjusted to provide the same yearly average amount of the salt deposition as an actual environment.

Therefore, the tests described in this International Standard involve the salt deposition and cyclic dry/wet conditions under a constant absolute humidity.

The results obtained do not permit far-reaching conclusions on the corrosion resistance of the tested metallic material under the whole range of environmental conditions in which it can be used. Nevertheless, the tests provide valuable information on the relative performance of materials exposed to salt-contaminated environments similar to those used in the tests.

The International Organization for Standardization (ISO) draws attention to the fact that it is claimed that compliance with this International Standard can involve the use of a patent concerning the tests given in Clause 8, Table 3, and Figure 2.

ISO takes no position concerning the evidence, validity, and scope of this patent right.

The holder of this patent right has ensured the ISO that he/she is willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with ISO. Information can be obtained from:

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Corrosion of metals and alloys — Accelerated cyclic corrosion tests with exposure to synthetic ocean water salt-deposition process — “Dry” and “wet” conditions at constant absolute humidity

1 Scope

This International Standard specifies two accelerated corrosion test procedures, Methods A and B, for the evaluation of corrosion behaviour of surface-treated metals and their alloys with and without paint on them in atmospheric environments. It also specifies the apparatus used. The two tests involve salt deposition and dry/wet conditions at a constant absolute humidity.

Method A applies to:

metals and their alloys (including corrosion-resistance alloys)

Method B applies to:

metals and their alloys

metals and their alloys with coatings [including metallic coatings (anodic or cathodic), organic coatings, and conversion coatings]

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4628-1, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 1: General introduction and designation system*

ISO 4628-2, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 2: Assessment of degree of blistering*

ISO 4628-3, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 3: Assessment of degree of rusting*

ISO 4628-4, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 4: Assessment of degree of cracking*

ISO 4628-5, *Paints and varnishes — Evaluation of degradation of coatings — Designation of quantity and size of defects, and of intensity of uniform changes in appearance — Part 5: Assessment of degree of flaking*

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

ISO 8993, *Anodizing of aluminium and its alloys — Rating system for the evaluation of pitting corrosion — Chart method*

ISO 9227, *Corrosion tests in artificial atmospheres — Salt spray tests*

ISO 10289, *Methods for corrosion testing of metallic and other inorganic coatings on metallic substrates — Rating of test specimens and manufactured articles subjected to corrosion tests*

ISO 11130, *Corrosion of metals and alloys — Alternate immersion test in salt solution*

ISO 14993, *Corrosion of metals and alloys — Accelerated testing involving cyclic exposure to salt mist, "dry" and "wet" conditions*

ISO 17872, *Paints and varnishes — Guidelines for the introduction of scribe marks through coatings on metallic panels for corrosion testing*

3 Test solution

3.1 Preparation of the mixed salt solution

The mass of reagents shown in Table 1 shall be dissolved in distilled water or deionized water, with a conductivity of not higher than 20 µS /cm at 25 °C ± 2 °C, to produce a mixed salt solution with a concentration of 36,0 g/l ± 3,6 g/l.

The composition of the mixed salt solution is the same as typical synthetic ocean water shown in ISO 11130:2010, A.3 (test solution for simulating the corrosive effects of ocean water).

Table 1 — Reagents and their concentrations of a mixed salt solution

Reagents	Concentration (g/l)
NaCl	24,53
$MgCl_2$	5,20
Na_2SO_4	4,09
$CaCl_2$	1,16
KCl	0,695
$NaHCO_3$	0,201
KBr	0,101
H_3BO_3	0,027
$SrCl_2$	0,025
NaF	0,003
WARNING – Handling of $SrCl_2$ and NaF can be hazardous and shall be restricted to use by skilled chemists or conducted under their control.	

3.2 pH adjustment

To adjust the pH of the solution, 5,0 g ± 0,5 g of NaOH shall be dissolved in water and diluted to total volume of 1 L to make 0,125 mol/l NaOH solution. It shall be added to the mixed salt solution to adjust the pH to 8,2 ± 0,1 at 25 °C ± 2 °C.

3.3 Preparation of the test solution

The test solution shall be used as the mixed salt solution or shall be diluted by 1:10 and 1:100 to the mixed salt solution with a concentration of 36,0 g/l ± 3,6 g/l, 3,60 g/l ± 0,36 g/l, and 0,360 g/l ± 0,036 g/l. When not specified, the concentration shall be agreed by the interested parties.

4 Apparatus

4.1 Component protection

All components in contact with the test solution shall be made of, or lined with, materials resistant to corrosion by the test solution and which do not influence the corrosivity of the atomized test solution. The apparatus shall include the components described in the following.

4.2 Exposure cabinet

It is essential that temperature and humidity in exposure cabinet are controlled constantly.

4.3 Salt deposition device

The atomizer shall be made of corrosion resistant materials, e.g. glass, plastic, or titanium. The atomized test solution shall be deposited homogeneously on specimens. The amount of deposited test solution shall be controlled. The diameter of the atomized test solution should be equal to or less than 100 µm.

The amount of deposited test solution can be controlled in the following manners:

a) by controlling the test period with a continuous atomization;

b) by controlling the amount of test solution, the atomized pressure, and the moving speed of the atomizer.

The compressed air supplied to the atomizer shall be passed through a filter to remove all trace of oil or solid matter.

4.4 Temperature and humidity control device

The device shall be capable of detecting and controlling the temperature and humidity around specimens. In the transition period of temperature and humidity, the device shall be capable of controlling the dry bulb temperature linear to target value and test period. The device shall be capable of controlling the humidity by keeping the absolute humidity constant to dry bulb temperature at least in every minute.

4.5 Rinse treatment of specimens

After the temperature and humidity cycle, the rinse treatment is conducted before re-depositing the test solution. Firstly, the test specimens are washed with drinking water, and then with deionized water. Water drops are then removed carefully with clean air in order not to take off corrosion products from the surface of the test specimens.

4.6 Types of apparatus

The following are three types of apparatus that satisfy the requirements specified in 4.1 to 4.5.

a) Two-cabinet type (automatic procedures)

Specimens move between salt deposition cabinet and exposure cabinet. The atomizer moves front to back and side to side, making it possible to change the amount of salt deposition on each specimen. Then, the specimens are moved to the exposure cabinet and wet/dry cycles and rinse treatment are conducted automatically (see Annex A).

b) One-cabinet type (automatic procedures)

Specimens are settled in one cabinet. The atomizer is set, and wet/dry cycles and rinse treatment are conducted automatically (see Annex B).

c) One-cabinet type (manual procedures)

After salt deposition (4.3) by hand, the test specimens shall be settled in the cabinet for wet/dry cycles. Then, the test specimens shall be taken out from the cabinet and rinse treatment conducted. After the salt deposition, the test specimens shall be settled up in the cabinet as quickly as possible (see Annex C).

5 Test specimens

5.1 The number and type of test specimens shall be selected according to the specification for the material or product being tested. When not so specified, these details shall be mutually agreed between the interested parties.

5.2 The test specimens shall be carefully cleaned prior to testing so as to remove those traces (dirt, oil, or other foreign matter), which could influence the result. The cleaning method employed shall depend on the nature of the materials and the contaminants, but shall not include the use of any abrasives or solvents which can attack the surface of the specimens.

5.3 For the metals or alloy without organic coatings and inorganic coating materials, the specimens shall be thoroughly cleaned with an appropriate organic solvent using a clean soft brush or an ultrasonic cleaning device. The cleaning shall be carried out in a vessel full of solvent. After cleaning, the specimens shall be rinsed with fresh solvent, then dried.

5.4 Unless otherwise specified, specimens intentionally coated with protective organic films should not be cleaned prior to the test. If cleaning is necessary, specimens shall be wiped with gauze impregnated with ethanol, taking care not to damage the surface of the specimens.

Care shall be taken that specimens are not contaminated after cleaning by careless handling.

5.5 If the test specimens are cut from a larger coated article, cutting shall be carried out in such a way that the coating is not damaged in the area adjacent to the cut. Unless otherwise specified, the cut edges shall be adequately protected by coating them with a suitable material, stable under the conditions of the test, such as paint, wax, or adhesive tape.

6 Salt deposition measurement method

The test solution shall be applied to make salt deposition on the surface of the specimen. The average amount of salt deposition shall be measured by the mass change of the specimen before and after salt-deposition process to the nearest 1 mg. These measurements shall be carried out as quickly as possible in order to prevent the specimen from drying.

7 Arrangement of the test specimens

After the salt deposition on the test specimens, the test specimens shall be placed in the cabinet. The test specimens shall be arranged so that they do not come into contact with the cabinet.

The specimen should be placed horizontally.

The specimens may be placed at different levels within the cabinet, as long as the droplet of the moisture does not drip from specimens or their supports at one level onto specimens placed below them.

8 Operating conditions and procedure

Operating conditions shall be in accordance with those given in Table 2 for Method A, and Table 3 for Method B. Operation procedure shall be in accordance with those given in Figure 1 for Method A, and Figure 2 for Method B.

A test solution that has used salt deposition shall not be re-used.

During the test, pressure in the cabinet shall maintain the atmospheric pressure.

Table 2 — Test conditions in Method A

Procedure	**Conditions**	
a) Salt deposition 1) Temperature 2) Test solution 3) Frequency 4) Salt deposition	1) Room temperature 2) Described in Clause 3 3) After every cycle 4) The amount of deposited test solution on a specimen shall be 250 g/m^2 ± 50 g/m^2. The concentration of the solution should be equal to or greater than 1/1 000 of synthetic ocean water.	
b) “Dry” condition	**Temperature**	**Relative humidity**
1) A	(49 ± 1) °C	(32 ± 5) %
2) B	(54 ± 1) °C	(25 ± 5) %
3) C	(55 ± 1) °C	(24 ± 5) %
4) D	(54 ± 1) °C	(25 ± 5) %
5) E	(49 ± 1) °C	(32 ± 5) %
c) “Wet” condition	(30 ± 1) °C	(90 ± 5) %
d) Rinse treatment	Clean drinking water Not exceeding 40 °C	
e) Length and composition of a single exposure cycle **(A single exposure cycle is 24 h.)**	“Wet” 6 h 36 min “Dry” 10 h 48 min “Wet” 6 h 36 min	
f) Time to reach the specified condition within a single exposure cycle	“Wet” to “Dry (A)” 2 h 22 min “Dry (A)” to “Dry (B)” 1 h 40 min “Dry (B)” to “Dry (C)” 1 h 22 min “Dry (C)” to “Dry (D)” 1 h 22 min “Dry (D)” to “Dry (E)” 1 h 40 min “Dry (E)” to “Wet” 2 h 22 min	

NOTE 1 Temperature and humidity shall be changed linearly at specified time intervals [see f) in this table]. Consecutive dry conditions A to E give the same absolute humidity, dew point 30°C.

NOTE 2 The tolerances (±) given for temperature and relative humidity are the allowable fluctuations of the parameter concerned about the given value under equilibrium conditions. This does not mean that the value can vary by plus/minus the amount indicated from the given value.