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

Corrosion des métaux et alliages — Essais accélérés comprenant des expositions cycliques à des conditions de brouillard salin, de séchage et d'humidité

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Contents

	Page
Foreword.....	iv
Introduction.....	v
1 Scope.....	1
2 Normative references.....	1
3 Terms and definitions.....	2
4 Test solution.....	2
4.1 General.....	2
4.2 Preparation of the sodium chloride solution.....	2
4.3 pH adjustment.....	2
5 Apparatus.....	3
5.1 Component protection.....	3
5.2 Exposure equipment.....	3
6 Test specimens.....	4
7 Arrangement of the test specimens.....	4
8 Operating conditions.....	5
9 Continuity of tests.....	6
10 Duration of tests.....	6
11 Treatment of test specimens after testing.....	6
11.1 General.....	6
11.2 Non-organic coated test specimens: metallic and/or inorganic coated.....	6
11.3 Organic coated test specimens.....	6
11.3.1 Scribed organic coated test specimens.....	6
11.3.2 Organic coated but not scribed test specimens.....	7
12 Evaluation of results.....	7
13 Test report.....	7
Annex A (informative) Typical apparatus for cyclic salt mist, dry and wet corrosion tests.....	9
Annex B (informative) Method for evaluation of the corrosivity of the apparatus.....	11
Annex C (normative) Preparation of test specimens with organic coatings for testing.....	13
Annex D (normative) Required supplementary information for testing test specimens with organic coatings.....	14
Bibliography.....	15

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).

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).

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.

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 14993:2001), which has been technically revised. The main technical changes are as follows:

- the document has been harmonized with ISO 9227;
- the terms and definitions clause has been added;
- the allowed range of mass loss of steel reference specimen has been changed.

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.

Introduction

Corrosion of metallic materials with or without corrosion protection is influenced by many environmental factors, the importance of which may vary depending on the type of metallic material and 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 the most important factors that enhance the corrosion of metallic materials.

The accelerated corrosion test method described in this document is designed to simulate and enhance the environmental influence on a metallic material of exposure to an outdoor climate, where exposure to salt-contaminated conditions occurs and may promote corrosion.

The test method involves cyclic exposure of test specimens to a mist of salt solution, to drying conditions and to periods of high humidity. However, the method is mainly intended for comparative testing and 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 within which it may be used. Nevertheless, the method provides valuable information on the performance of materials exposed to salt-contaminated environments similar to those used in the test.

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WARNING — This document may involve hazardous materials, operations and equipment. It does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this document to establish appropriate safety and health practices.

1 Scope

This document specifies the apparatus and test procedure to be used in conducting accelerated corrosion tests for the comparative evaluation of metallic materials with or without permanent corrosion protection or temporary corrosion protection in salt-contaminated outdoor environments. The test involves cyclic exposure of the specimens to neutral salt mist, “dry” and “wet” conditions. The type of test specimen and the exposure period are not specified.

The particular advantages of this test over common accelerated tests such as the neutral salt spray (NSS) test lie in its ability to better reproduce the corrosion that occurs in outdoor salt-contaminated environments.

This document is applicable to

- metals and their alloys,
- metallic coatings (anodic and cathodic),
- conversion coatings,
- anodic oxide coatings, and
- organic coatings on metallic materials.

NOTE Methods of test for coatings to determine their resistance, in the presence of scribe marks through to the substrate, to various cyclic corrosion conditions which include the condensation of water on the test specimens during periods of humidity are given in ISO 11997-1.

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 1514, *Paints and varnishes — Standard panels for testing*

ISO 2808, *Paints and varnishes — Determination of film thickness*

ISO 4623-2:2016, *Paints and varnishes — Determination of resistance to filiform corrosion — Part 2: Aluminium substrates*

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8044 and the following 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/>

3.1 reference material

material with known test performance

3.2 reference specimen

portion of the *reference material* (3.1) that is to be exposed with the intention to check the reproducibility and repeatability of the test results for the test cabinet in use

3.3 test specimen

specific portion of the samples upon which the testing is to be performed

3.4 substitute specimen

specimen made of inert materials (such as plastic or glass) used for the substitute of a *test specimen* (3.3)

4 Test solution

4.1 General

Instructions for the preparation and use of a neutral sodium chloride solution are given in 4.2 and 4.3.

4.2 Preparation of the sodium chloride solution

Dissolve a sufficient mass of sodium chloride in distilled or deionized water with a conductivity no higher than 20 $\mu\text{S}/\text{cm}$ at $25\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$ to produce a concentration of $50\text{ g/l} \pm 5\text{ g/l}$. The sodium chloride concentration of the sprayed solution collected shall be $50\text{ g/l} \pm 5\text{ g/l}$. The specific gravity range for a $50\text{ g/l} \pm 5\text{ g/l}$ solution is 1,029 to 1,036 at $25\text{ }^{\circ}\text{C}$.

The sodium chloride shall not contain a mass fraction of the heavy metals of copper (Cu), nickel (Ni) and lead (Pb) in total more than 0,005 %. It shall not contain a mass fraction of sodium iodide more than 0,1 % and a mass fraction of total impurities more than 0,5 %, calculated for dry salt.

NOTE Sodium chloride with anti-caking agents can act as corrosion inhibitors or accelerators. A useful sodium chloride salt grade is a grade named Ph. Eur/USP or JIS, ACS.

4.3 pH adjustment

Adjust the pH of the salt solution so that the pH of the sprayed solution collected within the test cabinet is 6,5 to 7,2 at $25\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$. Check the pH using electrometric measurement. Measurements of pH shall be done using electrode suitable for measuring in weakly buffered sodium chloride solutions in deionized water. Make any necessary corrections by adding hydrochloric acid, sodium hydroxide or sodium bicarbonate solution of analytical grade.

NOTE Possible changes in pH can result from loss of carbon dioxide from the solution when it is sprayed. Such changes can be avoided by reducing the carbon dioxide content of the solution by, for example, heating it to a temperature greater than $35\text{ }^{\circ}\text{C}$ before it is placed in the apparatus, or by making the solution from freshly boiled water.

5 Apparatus

5.1 Component protection

All components in contact with the salt mist spray or the test solution shall be made of, or lined with, materials which are resistant to corrosion by the test solution and which do not influence the corrosivity of the sprayed test solution.

The supports for the test specimen shall be constructed such that different substrate types do not influence each other. It shall also be constructed so that the supports themselves do not influence the test specimens.

5.2 Exposure equipment

5.2.1 Test cabinet, that meets the conditions of homogeneity and distribution of the spray. Due to the limited capacity of test cabinets smaller than 0,4 m³, the effect of the loading of the test cabinet on the distribution of the spray and temperature shall be carefully considered. The solution shall not be sprayed directly onto test specimens but rather spread throughout the test cabinet so that it falls naturally down on them. The upper parts of the test cabinet shall be designed so that drops of sprayed solution formed on its surface do not fall on the specimens being tested.

The size and shape of the test cabinet shall be such that during periods of exposure to salt mist spray, the collection rate of solution in the test cabinet is within the limits specified in [8.2](#).

NOTE A schematic diagram of one possible design of test cabinet and associated apparatus for salt mist cyclic corrosion testing is shown in [Annex A](#).

5.2.2 Humidity and temperature control system, that maintains the test cabinet and its contents at the specified temperature and humidity (see [8.1](#)). The temperature shall be measured at a position at least 100 mm from walls and radiant heat sources.

5.2.3 Spraying device, for spraying the salt solution during periods of exposure to salt mist spray comprising a supply of air at controlled pressure, a reservoir containing the solution to be sprayed and one or more atomizers.

The compressed air supplied to the atomizers shall be passed through a filter to remove all traces of oil or solid matter and shall be at an overpressure of 70 kPa to 170 kPa. The pressure is typically 98 kPa ± 10 kPa but can vary depending on the type of test cabinet and atomizer used.

5.2.4 Air saturator, consisting of a saturation tower containing hot water at a temperature higher than that of the test cabinet. In order to prevent evaporation of water from the sprayed droplets, the air shall be humidified before entering the atomizer, by passage through this tower.

During periods of exposure to the salt mist, the appropriate temperature depends on the pressure used and on the type of atomizer nozzle and shall be adjusted so that the rate of collection of spray in the test cabinet and the concentration of the collected spray are kept to within the specified limits (see [8.2](#)). The level of water shall be maintained automatically to ensure adequate humidification.

The atomizers shall be made of inert material, e.g. glass or plastic materials. Baffles may be used to prevent direct impact of spray on the test specimens and the use of adjustable baffles is helpful in obtaining constant distribution of spray within the test cabinet. The level of the salt solution in the supply tank shall be maintained automatically to ensure constant spray delivery throughout the test.

5.2.5 Collecting devices, at least two, consisting of clean funnels with a collecting area of approximately 80 cm² made of glass or other chemically inert material, with the stems inserted into graduated cylinders or other similar containers. The purpose of the collecting devices is to confirm that the collection rate is within specified limits (see [8.2](#)). They shall be placed in the zone of the test cabinet where the test

specimens are placed, one close to the spray inlet and one remote from an inlet and in such a way that only spray, and not the liquid falling from specimens or from parts of the test cabinet, is collected.

5.2.6 Air dryer, comprising a heating device and fan to supply dried air of the specified humidity during “dry” periods (see [Table 1](#)).

5.2.7 Exhaust system, by which air is exhausted from the test cabinet. It shall not be influenced by the back pressure of the atmosphere when the air is released at a point outside the building.

6 Test specimens

6.1 The number and type of test specimens, their shape and their dimensions, shall be selected in accordance with the specification for the material or product being tested. When not specified, these parameters shall be mutually agreed between the interested parties. Unless otherwise specified or agreed, test specimens with an organic coating to be tested shall be made from burnished steel conforming with ISO 1514, and of approximate dimensions 150 mm × 100 mm × 1 mm. [Annex C](#) describes how test specimens with organic coatings shall be prepared for testing. [Annex D](#) gives supplementary information that shall be supplied, as appropriate, for testing test specimens with organic coatings.

6.2 The test specimens shall be thoroughly cleaned before testing, if not otherwise specified. The cleaning method employed shall depend on the nature of the material, its surface and the contaminants and shall not include the use of any abrasives or solvents which may attack the surface of the specimens.

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

6.3 If the test specimens are cut from a larger coated sample, 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, which remains stable under the conditions of the test, such as paint, wax or adhesive tape.

7 Arrangement of the test specimens

7.1 The test specimens shall be placed in the test cabinet so that they are not in the direct path of spray from the atomizer.

7.2 If the test cabinet is not full of test specimens, it is recommended to fill it with inert flat substitute specimens of the same size as a reference specimen, in order to ensure uniformity of the spray. The material used shall be plastics, glass, or other inert insulating materials, which would not influence corrosion of the test specimens being tested.

7.3 The angle at which the surfaces of the test specimens are exposed in the test cabinet is very important. The specimen shall, in principle, be flat and placed in the test cabinet facing upwards at an angle as close as possible to 20° to the vertical. This angle shall, in all cases, be within limits 15° to 25°. In the case of irregular surfaces, e.g. entire components, these limits shall be adhered to as closely as possible.

7.4 The test specimens shall be arranged so that they do not come into contact with the test cabinet and so that the surfaces to be tested are exposed to free circulation of spray. The specimens may be placed at different levels within the test cabinet, as long as the solution does not drip from specimens or their supports at one level onto other specimens placed below. However, for a new examination, or for tests with a total duration exceeding 96 h, location permutation of specimens is permitted. In this case, the number and frequency of the permutations are left to the operator and shall be indicated in the test report.

7.5 The supports for the test specimens shall be made of inert non-metallic material, such as glass, plastic or suitably coated wood. If it is necessary to suspend specimens, the material used shall not be metallic but shall be synthetic fibre, cotton thread or another inert insulating material.

8 Operating conditions

8.1 The test conditions are summarized in [Table 1](#).

Table 1 — Test conditions

1	Salt mist conditions 1) Temperature 2) Salt solution	35 °C ± 1 °C pH 6,5 to 7,2, salt concentration 50 g/l ± 5 g/l as described in Clause 4
2	“Dry” conditions (The air is purged under dry conditions.) 1) Temperature 2) Relative humidity	60 °C ± 1 °C < 30 %
3	“Wet” conditions (Condensation on the test specimens shall not occur under wet conditions.) 1) Temperature 2) Relative humidity	50 °C ± 1 °C > 95 %
4	Period and content of a single exposure cycle	Total period 8 h, as follows: Salt mist spray 2 h “Dry” conditions 4 h “Wet” conditions 2 h (These times include the time for reaching the specified temperature for each condition.)
5	Time to reach the specified condition (i.e. period taken for temperature and humidity to reach the specified values once the test condition has begun)	Mist to “Dry” < 30 min “Dry” to “Wet” < 15 min “Wet” to Mist < 30 min (Mist conditions are attained almost instantaneously once this condition begins.)
6	Angle at which test specimens are supported	20° ± 5° to the vertical

NOTE The ± tolerances given are the allowable operational fluctuations, which are defined as the positive and negative deviations from the setting of the sensor at the operational control set point during equilibrium conditions. This does not mean that the set value may vary by plus/minus the amount indicated from the given value.

8.2 The test shall not be started until it has been confirmed, with the test cabinet filled to a similar extent as during the test, that, when the apparatus is operated in the salt mist condition, the collection rate of solution measured over a period of 24 h of continuous spraying is within the range 1 ml/h to 2 ml/h for a horizontal collecting area of 80 cm² and that other conditions are as specified. In particular, the solution collected in each of the collecting devices shall have a sodium chloride concentration of 50 g/l ± 5 g/l and a pH value in the range 6,5 to 7,2.

8.3 A test solution that has been sprayed shall not be re-used.

8.4 During the salt mist conditions of the test, the change from the set pressure shall be within ± 0,002 5 MPa.

8.5 To check the reproducibility of the test results, the corrosivity of the apparatus shall be verified at regular intervals. A suitable method for the evaluation of the corrosivity of the apparatus by use of reference specimens is described in [Annex B](#).

8.6 During operation, the solution tank shall be covered by a lid to prevent dust or other contaminants from influencing the solution and to prevent the concentration of sodium chloride and the pH from fluctuating.

9 Continuity of tests

Tests shall preferably be continued without interruption throughout the test duration. When it is necessary to interrupt the operation for the removal of specimens for inspection, the period of interruption should be minimized. In case of interruption for a longer period, its cause, duration and treatment used shall be stated to the test report.

10 Duration of tests

The period of test shall be as designated by the specification covering the material or product being tested. When not specified, the period shall be agreed by the interested parties.

Recommended periods of exposure are 30 cycles (240 h), 45 cycles (360 h), 60 cycles (480 h), 90 cycles (720 h), 180 cycles (1 440 h).

11 Treatment of test specimens after testing

11.1 General

How to treat test specimens after testing should be included in the test specification or material specification given by the customer. It shall be agreed with the test parties before starting the test.

11.2 Non-organic coated test specimens: metallic and/or inorganic coated

At the end of the test period, remove the test specimens from the test cabinet and allow them to dry for 0,5 h to 1 h before rinsing, in order to reduce the risk of removing corrosion products. Before they are examined, carefully remove the residues of spray solution from their surfaces. A suitable method is to rinse the test specimens gently in clean running tap water, at a temperature not exceeding 40 °C, and then to dry them immediately in a stream of air, at an overpressure not exceeding 200 kPa and at a distance of approximately 300 mm.

NOTE ISO 8407 can be used for treatment of the specimen after the test.

11.3 Organic coated test specimens

11.3.1 Scribed organic coated test specimens

Clean the surface of the organic coated test specimens under running tap water directly after removing the test specimens out of the test cabinet. A soft sponge may be used to remove dirt and salt rests out of the scribed area but not to remove evaluable corrosion phenomena. Remove the delaminated area around the scribe by one of the following methods.

- a) Using a knife. Carefully remove the loose coating using a knife blade held at an angle, positioning the blade at the interface between the coating and the substrate and forcing the coating away from the substrate.
- b) Using an adhesive tape.

NOTE Removing the organic coating (paint coating) depends on the kind of coating (paint) and its behaviour in wet conditions. If agreed by the interested parties, let the test specimens dry in room atmosphere for 24 h and then treat them as described under a) and b).

11.3.2 Organic coated but not scribed test specimens

Coated but not scribed test specimens shall be cleaned under running tap water so that corrosion products and/or corrosion phenomena which have to be evaluated are not influenced by cleaning.

12 Evaluation of results

Many different criteria for the evaluation of the test results may be applied to meet particular requirements, for example:

- a) appearance after the test;
- b) appearance after removing superficial corrosion products;
- c) number and distribution of corrosion defects, i.e. pits, cracks, blisters, rusting or creep from scribes in the case of organic coatings be assessed by methods described in ISO 8993 or ISO 10289 and, for organic coatings, in ISO 4628-1, ISO 4628-2, ISO 4628-3, ISO 4628-4, ISO 4628-5 and ISO 4628-8 (see [Annex D](#));
- d) the time elapsed before the appearance of the first signs of corrosion;
- e) changes in mass (in accordance with ISO 8407);
- f) alteration revealed by micrographic examination;
- g) changes in mechanical properties.

NOTE It is good engineering practice to define the appropriate criteria in the specification for a coating or a product to be tested.

13 Test report

The test report shall contain the following information:

- a) reference to this document, i.e. ISO 14993:2018;
- b) type and purity of salt and water used;
- c) description of the test equipment;
- d) description of the material or product tested;
- e) dimensions and shape of the test specimen, and the nature and area of the surface tested;
- f) preparation of the test specimen, including any cleaning treatment applied before testing and any protection given to edges or other special areas;
- g) known characteristics of any coating, with an indication of the surface, if required;
- h) number of test specimens subjected to the test representing each material or product;
- i) angle at which the tested surfaces were inclined;
- j) temperature and relative humidity in each of the salt mist, “dry” and “wet” conditions during testing;
- k) the time taken to undergo the transitions from mist to “dry”, “dry” to “wet”, and “wet” to salt mist conditions during the test;

- l) mist collection rate, salt concentration and pH of the solution collected during the pre-test;
- m) the corrosivity of test determined as, for example, described in [Annex B](#);
- n) the frequency and duration of any interruptions;
- o) the number of cycles or the duration of the test;
- p) the frequency and number of the test specimen location permutation, if required;
- q) the method used to clean the test specimen after testing and any loss resulting from the cleaning operation and the method used for calibrating this mass loss;
- r) test results (see [Clause 12](#));
- s) if necessary, photographic records and/or descriptions of the appearance of tested specimens;
- t) any deviation from test procedure;
- u) any unusual features observed;
- v) the date of the test.

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Annex A (informative)

Typical apparatus for cyclic salt mist, dry and wet corrosion tests

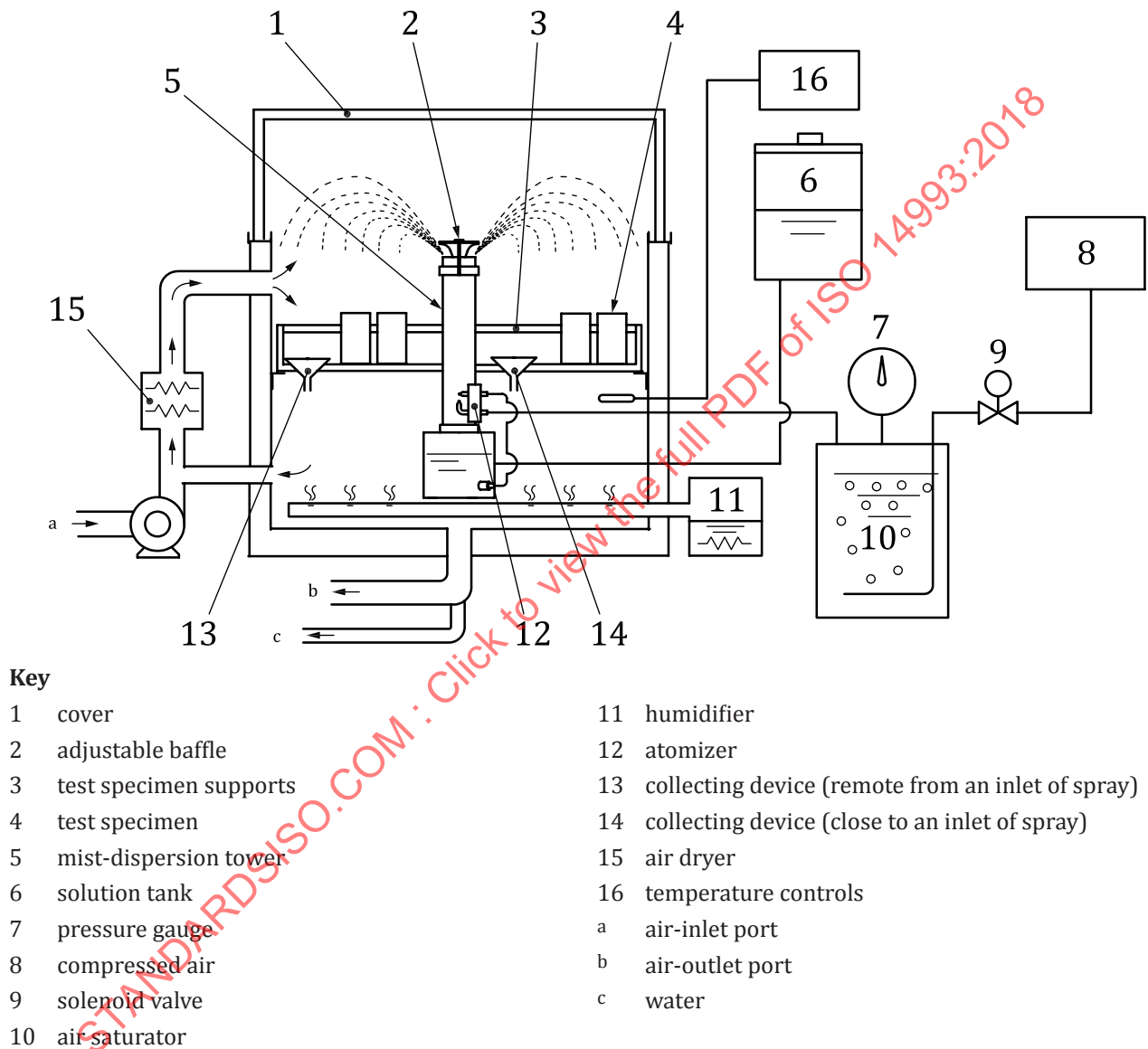
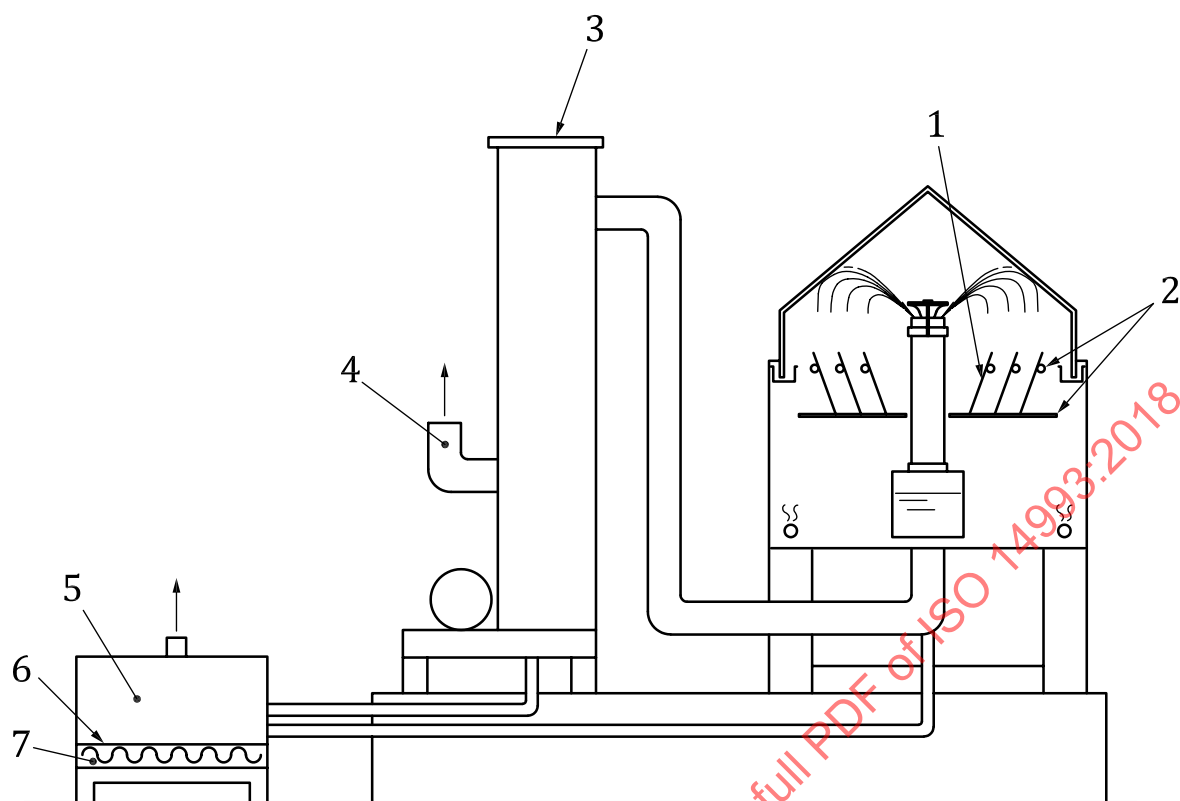


Figure A.1 — Typical apparatus for cyclic corrosion tests (front view)



Key

- 1 test specimen
- 2 test specimen support
- 3 exhaust air treatment unit
- 4 air-outlet port
- 5 drain-treatment unit
- 6 salt tray
- 7 heating elements

Figure A.2 — Typical apparatus for cyclic corrosion tests (side view)

Annex B (informative)

Method for evaluation of the corrosivity of the apparatus

B.1 Reference test specimens

To verify the corrosivity of the apparatus, at least four reference specimens made of steel should be used.

The reference specimen should be made of CR 4 grade steel according to ISO 3574, with a surface free from pores, slight marks and scribes, and with a mat finish (arithmetical mean deviation of the profile $Ra = 0,8 \mu\text{m} \pm 0,3 \mu\text{m}$). The reference specimen made of steel should have a dimension of $1,0 \text{ mm} \pm 0,2 \text{ mm}$ thickness and $150 \text{ mm} \times 70 \text{ mm}$. Cut these reference specimens from cold-rolled plates or strips.

As a complement to the reference specimens made of steel, at least four reference specimens of zinc with an impurity level of less than 0,1 %, in mass fraction, may be used. The reference specimens made of zinc should have dimensions of $50 \text{ mm} \times 100 \text{ mm} \times 1 \text{ mm}$.

Clean the reference specimens carefully, immediately prior to testing. Cleaning should eliminate all those traces (dirt, oil or other foreign matter) that can influence the test results.

Thoroughly clean the reference specimens with an appropriate organic solvent (such as a hydrocarbon with a boiling point between 60°C and 120°C) using a clean soft brush or soft cloth, non-woven lint free cloth, that does not leave any remains or an ultrasonic cleaning device. Carry out the cleaning in a vessel full of solvent. After cleaning, rinse the reference specimens with fresh solvent and then dry them.

Determine the mass of the reference specimens to $\pm 1 \text{ mg}$. Protect one face of the reference specimens with a removable coating, for example an adhesive plastic film. The edges of the reference specimens may be protected by the adhesive tape as well.

B.2 Arrangement of the reference specimens

Four reference specimens should be positioned in four quadrants (if six specimens are available, place them in six different positions including four quadrants) in the zone of the test cabinet where the test specimens are placed, with the unprotected face upwards, and at an angle of $20^\circ \pm 5^\circ$ to the vertical.

The supports for the reference specimens should be made of, or coated with, inert material, such as plastic. The lower edge of the reference specimens should be in level with the top of the salt spray collector.

The apparatus should be verified during the testing of test specimens. If this is the case, great care should be taken that the specimens do not affect each other. Otherwise, the test cabinet should be filled with substitute specimens to maintain the homogeneity of the test cabinet. The verification procedure should be performed using the same settings as for the test runs.

B.3 Duration of test

The test duration should be 48 h (6 exposure cycles).