
Corrosion tests in artificial atmospheres — Salt spray tests

*Essais de corrosion en atmosphères artificielles — Essais aux
brouillards salins*

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ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

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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).

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*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 262, *Metallic and other inorganic coatings, including for corrosion protection and corrosion testing of metals and alloys*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This fifth edition cancels and replaces the fourth edition (ISO 9227:2017), which has been technically revised.

The main changes are as follows:

- the arrangement of test specimens has been added;
- the arrangement of collecting devices has been changed; examples of arrangement of collecting devices have been added as [Annex E](#);
- DC04, DC05 and UNS G10080 have been added for steel reference specimens as an alternative of CR4-grade steel, and interlaboratory comparison for reference specimens has been added as [Annex E](#);
- the diluted acetic acid for preparing the test solution of AASS and CASS has been added;
- the allowed limit of copper concentration when the cabinet once used for CASS is re-used for NSS or AASS has been specified.

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

There is seldom a direct relation between resistance to the action of salt spray and resistance to corrosion in other media, because several factors influencing the progress of corrosion, such as the formation of protective films, vary greatly with the conditions encountered. Therefore, the test results should not be regarded as a direct guide to the corrosion resistance of the tested metallic materials in all environments where these materials can be used. Also, the performance of different materials during the test should not be taken as a direct guide to the corrosion resistance of these materials in service.

Nevertheless, the method described gives a means of checking that the comparative quality of a metallic material, with or without corrosion protection, is maintained.

Different metallic substrates (metals) cannot be tested in direct comparison in accordance to their corrosion resistances in salt spray tests. Comparative testing is only applicable for the same kind of substrate.

Salt spray tests are generally suitable as corrosion protection tests for rapid analysis for discontinuities, pores and damage in organic and inorganic coatings. In addition, for quality control purposes, comparison can be made between specimens coated with the same coating. As comparative tests, however, salt spray tests are only suitable if the coatings are sufficiently similar in nature.

When interpreting test results (e.g. minimum time until appearance defects or protection defects) for product quality control or acceptance specifications, it is important to recognize that the salt spray test can have a low level of reproducibility, especially with production parts tested in different laboratories.

It is often not possible to use results gained from salt spray testing as a comparative guide to the long-term behaviour of different coating systems, since the corrosion stress during these tests differs significantly from the corrosion stresses encountered in practice.

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Corrosion tests in artificial atmospheres — Salt spray tests

1 Scope

This document specifies the apparatus, the reagents and the procedure to be used in conducting the neutral salt spray (NSS), acetic acid salt spray (AASS) and copper-accelerated acetic acid salt spray (CASS) tests for assessment of the corrosion resistance of metallic materials, with or without permanent or temporary corrosion protection.

It also describes the method employed to evaluate the corrosivity of the test cabinet environment.

It does not specify the dimensions or types of test specimens, the exposure period to be used for a particular product, or the interpretation of results. Such details are provided in the appropriate product specifications.

The salt spray tests are particularly useful for detecting discontinuities, such as pores and other defects, in certain metallic, organic, anodic oxide and conversion coatings.

The NSS test is particularly applicable to:

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

The AASS test is especially useful for testing decorative coatings of copper + nickel + chromium, or nickel + chromium. It has also been found suitable for testing anodic and organic coatings on aluminium.

The CASS test is useful for testing decorative coatings of copper + nickel + chromium, or nickel + chromium. It has also been found suitable for testing anodic and organic coatings on aluminium.

The salt spray methods are all suitable for checking that the quality of a metallic material, with or without corrosion protection, is maintained. They are not intended to be used for comparative testing as a means of ranking different materials relative to each other with respect to corrosion resistance or as means of predicting long-term corrosion resistance of the tested material.

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 3574, *Cold-reduced carbon steel sheet of commercial and drawing qualities*

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

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

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

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 terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 reference specimen

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

Note 1 to entry: The reference material is the material with known test performance.

3.2 test specimen

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

3.3 substitute specimen

inert materials (such as plastic or glass) used for the substitute of a *test specimen* (3.2)

4 Principle

WARNING — This document can involve hazardous materials, operations and equipment. This document 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 document to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

The NSS test is the test method in which a neutral approximate 5 % sodium chloride solution is atomized under a controlled environment.

The AASS test is the test method in which an approximate 5 % sodium chloride solution acidified by the addition of acetic acid is atomized under a controlled environment.

The CASS test is the test method in which an approximate 5 % sodium chloride solution acidified by the addition acetic acid and with the addition of copper(II) chloride is atomized under a controlled environment.

5 Test solutions

5.1 Preparation of the sodium chloride solution

Dissolve a sufficient mass of sodium chloride in distilled or deionized water with a conductivity not higher than 20 $\mu\text{S}/\text{cm}$ at 25 °C to produce a concentration in a range between 45 g/l and 55 g/l. The sodium chloride concentration of the sprayed solution collected shall be 50 g/l \pm 5 g/l. The specific gravity range for a 50 g/l \pm 5 g/l solution is 1,029 to 1,036 at 25 °C.

The sodium chloride shall not contain a mass fraction of the heavy metals 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 Anti-caking agents added to the sodium chloride can act as corrosion inhibitors or accelerators. A useful sodium chloride salt grade is a grade named Ph. Eur/USP or JIS, ACS.

5.2 Preparation of each test solution with pH adjustment

5.2.1 pH of the salt solution

Adjust the pH of the salt solution to the desired value on the basis of the pH of the sprayed solution collected.

5.2.2 Neutral salt spray test

Adjust the pH of the salt solution (see 5.1) so that the pH of the sprayed solution collected within the test cabinet (6.2 and 6.5) is 6,5 to 7,2 at $25\text{ °C} \pm 2\text{ °C}$. Check the pH using electrometric measurement. Measurements of pH shall be done using electrodes suitable for measuring in weakly buffered sodium chloride solutions in distilled or deionized water. Make any necessary corrections by adding hydrochloric acid, sodium hydroxide or sodium bicarbonate solution of analytical grade.

WARNING — Hydrochloric acid (CAS Registry Number[®]1) 7647-01-0) solution is toxic, corrosive, irritating and very toxic to aquatic life. Refer to the safety data sheet for details. Handling of hydrochloric acid solution shall be restricted to skilled personnel or conducted under their control. Care shall be taken in the disposal of this solution.

WARNING — Sodium hydroxide (CAS 1310-73-2) solution is toxic, corrosive and irritating. Refer to the safety data sheet for details. Handling of sodium hydroxide solution shall be restricted to skilled personnel or conducted under their control. Care shall be taken in the disposal of this solution.

NOTE Possible changes in pH can result from loss of carbon dioxide in 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 above 35 °C before it is placed in the apparatus, or by making the solution using freshly boiled water.

5.2.3 Acetic acid salt spray test

Add a sufficient amount of glacial acetic acid not less than 99,7 % of mass fraction or diluted acetic acid more than 10 % of mass fraction to the salt solution (see 5.1) to ensure that the pH of samples of sprayed solution collected in the test cabinet (6.2 and 6.5) is between 3,1 and 3,3 at $25\text{ °C} \pm 2\text{ °C}$. Take the added volume of acetic acid into account when making up the initial sodium chloride solution. If the pH of the solution initially prepared is 3,0 to 3,1, the pH of the sprayed solution is likely to be within the specified limits. Check the pH using electrometric measurement. Measurements of pH shall be done using electrodes suitable for measuring in weakly buffered sodium chloride solutions in distilled or deionized water. Make any necessary corrections by adding acetic acid, sodium hydroxide, or sodium bicarbonate of analytical grade.

WARNING — Glacial acetic acid (CAS 64-19-7) is a flammable liquid, toxic, corrosive and irritating. Refer to the safety data sheet for details. Handling of glacial acetic acid shall be restricted to skilled personnel or conducted under their control. Care shall be taken in the disposal of this solution.

1) CAS Registry Number[®] is a trademark of CAS corporation. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of the product named. Equivalent products may be used if they can be shown to lead to the same results.

5.2.4 Copper-accelerated acetic acid salt spray test

Dissolve a sufficient mass of copper(II) chloride dihydrate ($\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$) not less than 99,0 % of mass fraction in the salt solution (5.1) to produce a concentration of $0,26 \text{ g/l} \pm 0,02 \text{ g/l}$ [equivalent to $(0,205 \pm 0,015) \text{ g}$ of CuCl_2 per litre].

WARNING — Copper(II) chloride dihydrate (CAS 10125-13-0) is toxic, corrosive, irritating and very toxic to aquatic life. Refer to the safety data sheet for details. Handling of copper(II) chloride dihydrate shall be restricted to skilled personnel or conducted under their control. Care shall be taken in the disposal of this solution.

Adjust the pH using the procedures described in 5.2.3.

5.3 Filtration

If necessary, filter the solution before placing it in the reservoir of the apparatus, to remove any solid matter which can block the apertures of the spraying device.

6 Apparatus

6.1 Component protection

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

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.

6.2 Spray cabinet

The cabinet shall be such that the conditions of homogeneity and distribution of the spray are met. Due to the limited capacity of cabinets smaller than $0,4 \text{ m}^3$, the effect of the loading of the 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 cabinet so that it falls naturally down to them. The upper parts of the cabinet shall be designed so that drops of sprayed solution formed on its surface do not fall on the test specimens.

The size and shape of the cabinet shall be such that the collection rate of solution in the cabinet is within the limits specified in 10.3.

Preference shall be given to apparatus that has a means for properly dealing with fog after the test, prior to releasing it from the building for environmental conservation, and for diluting salt solution prior to discharging it to the drainage system.

NOTE A schematic diagram of one possible design of spray cabinet is shown in Annex A (see Figures A.1 and A.2).

6.3 Heater and temperature control

The test cabinet shall be maintained at the specified temperature (see 10.1) in the zone where the test specimens are placed by the appropriate system.

6.4 Spraying device

The device for spraying the salt solution comprises a supply of clean air, of controlled pressure and humidity, a reservoir to contain the solution to be sprayed, and one or more atomizers.

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

In order to prevent the evaporation of water from the sprayed droplets (aerosol), the air shall be humidified before entering the atomizer by passing through a suitable humidifier. The humidified air shall be saturated such that the concentration of the fallout solution falls within the specifications of 5.1. The humidified air shall also be heated such that when mixed with the salt solution and after the adiabatic expansion at the atomizer, there is no significant disturbance of the temperature in the cabinet. The appropriate temperature depends on the pressure used and on the type of atomizer. Temperature, pressure or humidification, or a combination thereof, shall be adjusted so that the rate of collection of the spray in the cabinet and the concentration of the collected spray are kept within the specified limits (see 10.3). A commonly used humidifier is the saturation tower where temperature and pressure are controllable. Table 1 gives guiding values on temperature and pressure combinations for the saturation tower.

Table 1 — Guiding values for the temperature of the hot water in the saturation tower

Atomizing overpressure kPa	Guiding values for the temperature, in °C, of the hot water in the saturation tower when performing the different salt spray test	
	NSS and AASS	CASS
70	45	61
84	46	63
98	48	64
112	49	66
126	50	67
140	52	69
160	53	70
170	54	71

The atomizers shall be made of inert material. Baffles made of inert material may be used to prevent direct impact of the spray on the test specimens, and the use of adjustable baffles is helpful in obtaining uniform distribution of the spray within the cabinet. For this purpose, a dispersion tower equipped with an atomizer may also be helpful.

The salt solution supplied to the atomizer shall be kept stable to ensure a continuous and uniform fall out as described in 10.3. A stable level of spraying can be achieved by either controlling the level of salt solution in the reservoir or restricting the flow of salt solution to the atomizer such that a continuous spray is achieved.

Distilled or deionized water with a conductivity not higher than 20 μ S/cm at 25 °C shall be used for humidification of spray air.

6.5 Collecting devices

At least two collecting devices shall be used to check the homogeneity of the spraying of the cabinet. Suitable funnels shall be made of chemically inert material, with the stems inserted into graduated cylinders or other similar containers and have a diameter of 100 mm, which corresponds to a collecting area of approximately 80 cm². The collecting devices shall be placed in the zone of the cabinet where the test specimens are placed. They shall be placed so that only mist, and not liquid falling from specimens or from parts of the cabinet, is collected.

The collecting devices shall be placed as follows.

- a) During the test, two collecting devices should be placed at central points in the zone (see Annex E for an example).

- b) For calibration purposes, the collection rate of the cabinet shall be verified with at least six collecting devices, which are placed at the four corners and two central points of the zone (see [Annex E](#) for an example). This verification is done without test specimens in the cabinet, but preferably with substitute specimens (see also [10.2](#)). It is recommended to perform it after installation, a move, modifications, adjustments or repair of the cabinet, after detecting nonconformities of the spray collection rate during running tests [see a)], and after idle periods longer than four weeks.
- c) If the collecting devices cannot be placed at four corners and/or at the central two points in the zone, they may be placed at another point by agreement between the interested parties. The number of collecting devices placed may also be changed according to the size of the cabinet by the agreement between the interested parties. In those cases, it shall be stated in the test report.

NOTE During permanent operation, a reasonable time period of the verification of the collection rate of the cabinet is generally considered to be three months.

When nonconforming spray collection rates are found during verification [see b)], the cabinet shall be adjusted or the test specimens shall not be placed in the nonconforming area.

6.6 Re-use

If the cabinet has been used once for an AASS or CASS test, or has been used for any other purpose with a solution differing from that specified for the NSS test, it shall not be used for the NSS test until a thorough cleaning procedure has been completed and the pH of collected solution has been verified by the method in [5.2.2](#) and the corrosivity of the cabinet verified by the method in [Clause 7](#) to not be significantly affected by previous tests.

Additionally, it is recommended to check that the copper concentration in the collected solution is below the allowed limit of 2,5 mg/l (see [5.1](#)), better below 0,5 mg/l, when the cabinet was previously used for CASS, but should now be used for AASS or NSS.

NOTE It is very difficult to clean a cabinet sufficiently that was once used for AASS or CASS testing so that it can be used for an NSS test.

7 Method for evaluating cabinet corrosivity

7.1 General

To determine the corrosivity of the cabinet, reference specimens made of steel shall be used. It is necessary to verify the cabinet at regular intervals as described in [7.2](#) to [7.4](#).

NOTE 1 During permanent operation, a reasonable time period between two checks of the corrosivity of the cabinet is generally considered to be three months.

As a complement to the reference specimens made of steel, high-purity zinc reference specimens may also be exposed in the tests in order to determine the corrosivity against this metal as described in [Annex B](#).

NOTE 2 The corrosivity of the cabinet verified with steel or high-purity zinc reference specimens via their mass loss does not guarantee reproducible times to the occurrence of certain corrosion products on coated specimens from industrial production.

7.2 Reference specimens

To verify the apparatus, use at least four reference specimens of 1,0 mm ± 0,2 mm thickness and 150 mm × 70 mm of CR4-grade steel in accordance with ISO 3574 with an essentially faultless surface and a matt finish (arithmetical mean deviation of the profile Ra = 0,8 µm ± 0,3 µm). Cut these reference specimens from cold-rolled plates or strips. Alternatively to CR4-grade steel, the following steel grades