
**Composites and metal assemblies —
Galvanic corrosion tests of carbon
fibre reinforced plastics (CFRPs)
related bonded or fastened
structures in artificial atmospheres
— Salt spray tests**

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*Assemblages composites et métal — Essais de corrosion galvanique des
structures en plastiques renforcés de fibres de carbone (CFRP) jointes
ou fixées en atmosphères artificielles — Essais au brouillard salin*

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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).

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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 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*.

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

This document specifies the testing method for galvanic corrosion of composites and metal assemblies subject to salt spray environment using a bonded or fastened specimen.

The potential benefits to CFRP-metal users of implementing a galvanic corrosion test based on this document are:

- a) addressing corrosion risks relating CFRPs of drastically nobler galvanic potential than metals to form a global cell between CFRP and metal – new risks drastically exceeding the scope of ISO 9227 for a local cell of isolated metal – utilizing the resources of ISO 9227;
- b) expanding CFRP applications to the fields of corrosive environments that still require the combinations with metallic components;
- c) the detection or the prevention of galvanic current insulation loss, such as ion migration and time-related degradation in sealant film, injected calking layer and glass fibre reinforced plastics (GFRPs) layer;
- d) demonstrating the conformity to specified conditions for type certification requirements in the engineering such as aircraft developments;
- e) evaluating the corrosion related procedures for maintenance, repair and overhaul (MRO) in the engineering operations such of CFRP aircrafts.

It is not the intent of this document to imply the need for:

- omitting relevant field tests for CFRP related engineering;
- generally specifying the dimensions of test specimen to represent CFRPs related bonded or fastened structures;
- superimposing test results for specific applications of the parameters that exceed the range of this document;
- comparative testing as a means of ranking different protections with respect to corrosion resistance.

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Composites and metal assemblies — Galvanic corrosion tests of carbon fibre reinforced plastics (CFRPs) related bonded or fastened structures 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 galvanic corrosion resistance of joints and bonded structures between carbon fibre reinforced plastics (CFRPs) and metallic materials, with or without permanent or temporary insulation for the galvanic current.

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 6361-2, *Wrought aluminium and aluminium alloys — Sheets, strips and plates — Part 2: Mechanical properties*

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

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 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 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 ceramic or glass) used for the substitute of a test specimen

Note 1 to entry: Examples of inert materials are ceramic or glass.

3.5
control specimen

specimen made of CFRP, which is identical to the CFRPs of test specimen, used to check the reproducibility, repeatability and deviation or drift by solution absorption of the test results

3.6
neutral salt spray test
NSS

test method in which a 5 % sodium chloride solution is atomized under a controlled environment

Note 1 to entry: It particularly applies to:

- CFRPs and metals or their alloys in fastened or bonded form;
- sacrificial protections (anodic and cathodic);
- organic coatings on pinned or riveted joints of CFRPs and metals.

3.7
acetic acid salt spray test
AASS

test method in which a 5 % sodium chloride solution with the addition of glacial acetic acid is atomized under a controlled environment

Note 1 to entry: It is especially useful for testing CFRPs with lightning strike protection layer (LSP) of Cu or Al mesh or foil in acid-rain or exhaust gas environment.

3.8
copper-accelerated acetic acid salt spray test
CASS

test method in which a 5 % sodium chloride solution with the addition of copper chloride and glacial acetic acid is atomized under a controlled environment

Note 1 to entry: It is useful for modelling an aged structure of CFRPs with LSPs and Al alloys in fastened or bonded form in acid-rain or exhaust gas environment.

3.9
scribed specimen

specimen with organic or inorganic coating, which is intentionally line-damaged with scriber needle

3.10
purity of salt

mass fraction of sodium chloride excluding contaminant

4 Test solutions

4.1 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 $25\text{ }^\circ\text{C} \pm 2\text{ }^\circ\text{C}$ to produce a concentration of $50\text{ g/l} \pm 5\text{ g/l}$. The conductivity shall be measured just before the preparation, as dissolution of carbon dioxide in atmospheric environment

can drift the value. The sodium chloride concentration of the sprayed solution collected shall be $50 \text{ g/l} \pm 5 \text{ g/l}$. The specific gravity range of a $50 \text{ g/l} \pm 5 \text{ g/l}$ solution is from 1,029 to 1,036 at $25 \text{ }^\circ\text{C}$.

The sodium chloride shall contain less than 0,001 % mass fraction of copper and less than 0,001 % mass fraction of nickel, as determined by atomic absorption spectrophotometry or another analytical method of similar sensitivity. It shall not contain more than 0,1 % of a mass fraction of sodium iodide, or more than 0,5 % of a mass fraction of total impurities calculated for dry salt. Industrial salt is not recommended due to possible deviation of the impurities.

4.2 pH adjustment

4.2.1 pH of the salt solution

If necessary, control the pH of distilled or deionized water to 7,0 by the aeration of nitrogen gas - dissolution of carbon dioxide can drift the pH - in the preparation of the sodium chloride solution. Adjust the pH of the salt solution to the desired value on the basis of the pH of the sprayed solution collected.

4.2.2 Neutral salt spray test (NSS)

Adjust the pH of the salt solution (see 4.1) so that the pH of the sprayed solution collected within the test cabinet (5.2) is 6,5 to 7,2 at $25 \text{ }^\circ\text{C} \pm 2 \text{ }^\circ\text{C}$. Check the pH using electrometric measurement or in routine checks, with a short-range pH paper, which can be read in increments or 0,2 pH units or less. If pH electrodes are used, they shall be suitable for measuring pH in weakly buffered sodium chloride solutions in de-ionized water. Make any necessary corrections by adding hydrochloric acid, sodium hydroxide or sodium bicarbonate solution of analytical grade.

4.2.3 Acetic acid salt spray test (AASS)

Add a sufficient amount of glacial acetic acid to the salt solution (see 4.1) to ensure that the pH of samples of sprayed solution collected in the test cabinet (see 5.2) is between 3,1 and 3,3. 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 at $25 \text{ }^\circ\text{C} \pm 2 \text{ }^\circ\text{C}$. If pH electrodes are used, they shall be suitable for measuring pH in weakly buffered sodium chloride solutions in de-ionized water. Make any necessary corrections by adding glacial acetic acid or sodium hydroxide of analytical grade.

4.2.4 Copper-accelerated acetic acid salt spray test (CASS)

Dissolve a sufficient mass of copper (II) chloride dihydrate ($\text{CuCl}_2 \cdot 2\text{H}_2\text{O}$) in the salt solution (see 4.1) 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].

Adjust the pH using the procedures described in 4.2.3.

4.3 Filtration

Test solutions prepared using the procedures described in 4.1 and 4.2.1 in laboratory environment are suitable for the spraying applications. However, if necessary, filter the solution before placing it in the reservoir of the apparatus, to remove any solid matter or contaminant which might affect the apertures of the spraying device. Any incident relating to the solid matter shall be reported as described in 13.2 r).

5 Apparatus

5.1 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 solution.

If necessary, electric insulation shall be devised for the apparatus to prevent the influence from inside or outside of the apparatus.

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 Spray cabinet. The cabinet for galvanic corrosion test 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 m³, the effect of the loading of the cabinet on the distribution of the spray and temperature should be carefully considered. The sprayed solution shall be fell down naturally on the test specimens, and the upper parts of the cabinet shall be designed so that drops of spayed solution formed on its surface do not fall on the test specimens being tested (see [Annex A](#)).

If a cabinet for galvanic corrosion test 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.

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 [Table 3](#), measured as specified in [9.3](#).

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 drawing water prior to discharging it to the drainage system.

5.3 Heater and temperature control. An appropriate system for galvanic corrosion test maintains the cabinet and its contents at the specified temperature (see [Table 3](#)). The temperature shall be measured at least 100 mm from the walls.

5.4 Spraying device. The device for spraying the test 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 filtered to remove all traces of contaminants such as oil or solid matter, and the atomizing pressure shall be at an overpressure of 70 kPa to 170 kPa. The pressure should be 98 kPa ± 10 kPa.

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 [4.1](#). The humidified air shall also be heated such that when mixed with the salt solution, 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 nozzle. 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 [9.3](#)). A common used humidifier is the saturation tower, where temperature and pressure are controllable. [Table 1](#) gives guidance values on temperature and pressure combinations for the saturation tower.

Table 1 — Guiding values of galvanic corrosion test for the solution temperature 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	
	Neutral salt spray (NSS) and acetic acid salt spray (AASS)	Copper-accelerated acetic acid salt spray (CASS)
70	45	61
84	46	63
98	48	64
112	49	66
126	50	67
140	52	69

The atomizers shall be made of inert material such as ceramic and glass. Baffles 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 supply salt solution to the nozzle shall be kept stable to ensure a continuous and uniform fall out as described in 9.3. 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 nozzle such that a continuous spray is achieved.

Distilled or deionized water with a conductivity not higher than 20 µS/cm at 25 °C ± 2 °C shall be used for humidifier.

5.5 Collecting devices. Suitable collecting devices for galvanic corrosion test shall be available in such number that the homogeneity of the cabinet can be checked, at least two, consisting of funnels made of chemically inert material, with the stems inserted into graduated cylinders or other similar containers. Suitable funnels 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, one close to an inlet of spray and one remote from an inlet. They shall be placed so that only mist, and not liquid falling from specimens or from parts or the cabinet, is collected.

6 Method for evaluating cabinet corrosivity

6.1 General

To check the reproducibility and repeatability of the galvanic corrosion test results for one piece of apparatus, or for similar items of apparatus in different laboratories, it is necessary to verify the apparatus at regular intervals as described in 6.2 to 6.4.

To determine the corrosivity of the tests, reference-metal specimens made of steel or aluminium shall be used.

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

6.2 Reference specimens

To verify the apparatus, use four or six reference specimens of 1 mm ± 0,2 mm thickness and 150 mm × 70 mm, of CR4-grade steel in accordance with ISO 3574, or aerospace grade A1050 pure aluminium in accordance with ISO 6361-2, with an essentially faultless surface and a matt finish