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# Corrosion of metals and alloys — — Stress corrosion testing — —

# Part 12: Requirements for atmospheric stress corrosion cracking testing



*Corrosion des métaux et alliages — Essais de corrosion sous contrainte —*

*Partie 12: Exigences relatives aux essais de fissuration par corrosion sous contrainte atmosphérique*



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## Foreword

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

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www.iso.org/members.html.

# Corrosion of metals and alloys — Stress corrosion testing —

# Part 12: Requirements for atmospheric stress corrosion cracking testing

## 1 Scope

This document specifies the general requirements for designing and conducting tests to assess the susceptibility of metals and alloys to stress corrosion cracking under atmospheric exposure conditions.

The testing methodology includes exposure to natural environments and environments in artificially accelerated laboratory tests.

Applications include aluminium and its alloys in aerospace and construction; stainless steels in construction, pressure vessels, and nuclear waste containment; high strength low alloy steels in automotive, construction, and in lifting chains.

## 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 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

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



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

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

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

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

ISO 7539-6, *Corrosion of metals and alloys — Stress corrosion testing — Part 6: Preparation and use of precracked specimens for tests under constant load or constant displacement*

ISO 7539-8, *Corrosion of metals and alloys — Stress corrosion testing — Part 8: Preparation and use of specimens to evaluate weldments*

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

~~ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*~~

~~ASTM F21, *Standard test method for hydrophobic films by the atomizer test*~~

ISO 8565:2011, *Metals and alloys — Atmospheric corrosion testing — General requirements*

ISO 9225, *Corrosion of metals and alloys — Corrosivity of atmospheres — Measurement of environmental parameters affecting corrosivity of atmospheres*

ASTM F21, *Standard test method for hydrophobic films by the atomizer test*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7539--1, ISO 7539--6, ISO 7539--8, 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/obphttps://www.iso.org/obp

— ——IEC Electropedia: available at https://www.electropedia.org/https://www.electropedia.org/

**3.1**
**atmospheric stress corrosion cracking**
environmentally induced cracking due to the exposure of metals and alloys under nominally static stress to the atmosphere, usually accompanied with deposition of salts and pollutants



## 4 Principle

Atmospheric corrosion depends on the quantity of water in the film formed on the metal surface, which varies as the metal surface wets and dries, and the nature and extent of deposition of particles, aerosols, and gaseous pollutants and contaminants. The corrosivity of the environment changes during the wetting and drying cycle. On initial wetting, the corrosivity increases as the accumulated pollutants on the surface dissolve. As the surface wets further, the solution dilutes and becomes less corrosive. A subsequent decrease in the relative humidity causes the surface water content to decrease. The corrosivity of the solution then increases because of concentration of salts. Oxygen diffusion to the reacting surface is also enhanced during the initial wetting and the later drying process as the diffusion layer thickness is smaller under these conditions. Correspondingly, the susceptibility of the metal to localised corrosion and stress corrosion cracking is enhanced during the transition from wet-to-dry and vice versa.

The primary challenge in atmospheric stress corrosion cracking testing is how best to account for the time variation of the environment (i.e. temperature, humidity, gaseous pollutants etc.), which can change on a very irregular basis, superimposed on daily and seasonal cycles. Furthermore, there can be features of the local environment such that the chemistry of the species forming on the surface maycan be complex and not characterised by broad classifications such as marine, and industrial, and so on..

Testing in a representative natural environment would appear the most appropriate way of accounting for realistic exposure conditions, whether outdoors or in some form of construction. However, adopting such an approach can be constrained by the required long-term nature of exposure, to allow for the progressive build-up of deposits and to ensure statistical validity of the data. Information on temperature and wetting and drying cycles maycan also be incomplete, and there are challenges for in situ crack growth monitoring.

Laboratory testing offers the opportunity for accelerated testing in artificial atmospheres, commonly by application of salt deposits from the outset that can be more aggressive, and by selecting temperature and humidity conditions that can be more conducive to stress corrosion cracking. The challenge arises in using laboratory data for predicting behaviour under practical exposure conditions.



 

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Existing standards for atmospheric corrosion do not include stress corrosion cracking testing, and stress corrosion cracking testing standards do not adequately account for atmospheric exposure testing. This document aims to appropriately specify best practice in combining both features.

## 5 Test specimen preparation

**5.1** The stress-strain response of the alloy shall be determined prior to any stress corrosion cracking test and the proof stress, ultimate tensile stress and elongation to fracture shall be quantified in accordance with ISO 6892-1.

**5.2** The test specimen shall be manufactured as specified in the appropriate test standard: ISO 7539-2, ISO 7539-3, ISO 7539-4, ISO 7539-5, ISO 7539-6 or ISO 7539-8. Other specimen geometries can be considered depending on material dimensions, crack orientation, or the application of coatings [1].

NOTE In most applications, the long-term nature of testing usually necessitates the use of self-contained loading and specimen assemblies.

**5.3** A range of possible specimen configurations including self-loaded 2-, 3-, or 4-point bend, C-ring, or tensile test specimens may be adopted. U-bend specimens are commonly used because of their simplicity and cheapness, and notched fracture mechanics specimens such as double cantilever beam are also adopted.

NOTE For testing under controlled salt deposition conditions in a laboratory, flat test specimens stressed in 2-, 3-, or 4-point bend or in tension can be preferable to optimise uniformity of salt deposition and to minimise gravity-induced flow of corrosion products.

**5.4** The surface shall be prepared to a well-defined finish (e.g. ground, polished, electropolished) and the average surface roughness, *Ra*, measured.

**5.5** For some alloys, a machined and ground finish can result in significant changes in near-surface microstructure and hardness, and introduce residual stress and physical defects. Characterisation of the near-surface microstructure should be undertaken. Measurement of near-surface residual stress should also be performed unless test specimens are loaded significantly beyond yield (e.g. U-bend), since relaxation would ensue in that case.

**5.6** The surface shall be degreased with a suitable degreasing agent and the efficacy of this process demonstrated using an atomizer test method, as specified in ASTM F21.

## 6 Application of stress

**6.1** The stress should be applied in accordance with the particular test standard adopted.

**6.2** Fixed displacement testing can result in stress relaxation due to short-term and long-term creep, which also varies with temperature, to crack development, and/or material loss. When the goal is to load the specimen to a specified stress, such as in a self-loaded tensile test specimen using a proof ring or similar device, compensation for short-term relaxation can be made by re-loading the specimen to the desired stress and checking the extent of stress relaxation. Typically, the reduction in stress should be less than 1 % of the set value over a 12 h period at ambient condition. For such test specimens, the stress shall be determined upon test conclusion to evaluate the extent of stress relaxation over the whole exposure period.



 

## 7 Natural exposure testing

**7.1** The atmospheric corrosion test site should be appropriate for the intended application of the test material and should provide facilities for both:

a) ~~a)~~ open-air exposure, i.e. direct exposure to all atmospheric conditions and atmospheric contaminants;~~ and~~

b) ~~b)~~ sheltered exposure, i.e. exposure with protection from rainfall and solar radiation, either under a cover or in a partly closed space, such as shutter sheds, where the test specimens are also protected by shuttered side walls.

**7.2** Comprehensive details of the shelter and the manner of exposing specimens shall be given.

NOTE Shelters eliminate washing of corrosion products by rainfall and can also impact on the surface temperature by limiting the rise of surface temperature associated with direct sunlight or by constraining a decrease for external cooler/windy conditions.

**7.3** The results obtained under different designs of shelters shall be considered distinct.

**7.4** Natural exposure testing of stress corrosion specimens should be based on the principles set out for corrosion testing in ISO 8565~~:2011~~, with the test specimens mounted on frames of metallic or wooden construction in such a way that the rack material shall exert no influence on the corrosion of the test specimen.



**7.5** The method of attaching specimens to the test frame shall prevent neighbouring specimens from touching, sheltering or influencing one another. There should be complete electrical insulation between the specimens and the test frame. If this is not possible, there shall be no electrolyte pathway from the specimen gauge area and metallic test frame components. Fixing elements may be made from inert and durable materials. Alternatively, bolts or screws, fitted with electrically insulating sleeves and washers, may be used. The area of contact between the test specimens and their holders shall be as small as possible and should be protected from the test environment.

**7.6** The test frames shall be designed to control specimen orientation relative to the pollutant and contaminant source.

The specific orientation of the specimen depends on specimen type but should be optimised to maximise uniformity of deposit distribution and wetness on the most stressed region of the specimen.

**7.7** The design of the frame shall be such that test specimens are not affected by water which runs off the test frame or other specimens, or by splash water from the ground. The minimum height shall be chosen to prevent both splashing by rainwater and burial in snow-drifts and should be not less than 0,5 m from ground level.

**7.8** The following environmental data for the characterization of the atmosphere shall be obtained as specified in ISO 8565:2011, Annex A; specifically:

— ~~—~~air temperature, in degrees Celsius;

— ~~—~~relative atmospheric humidity (RH), as a percentage;

— ~~—~~amount of precipitation, in millimetres per day;



 

 