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Corrosion of metals and alloys — Corrosion tests in artificial atmospheres — Guidelines for selection of accelerated corrosion test for product qualification

Corrosion des métaux et alliages — Essais de corrosion en atmosphères artificielles — Lignes directrices pour un échantillon d'essais de corrosion accéléré pour la qualification du produit

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Foreword

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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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 156, *Corrosion of metals and alloys.*

Introduction

This document is a guideline for selection of suitable accelerated corrosion tests and is a survey of different internationally standardized test methods.

For that reason, this document is not suitable to be standardized but the document is greatly needed by the industry and test institutes.

The document has for that reason been prepared as a Technical Report.

In corrosion testing there has been a development from qualitative to more quantitative methods and the prerequisites for corrosion testing in product qualification are changing. Modern technologies for control and regulation of climatic test parameters are adopted in test equipment so that the reproducibility of tests increases. To make possible a better translation of laboratory test results into in-service performance, quantitative methods for characterization of corrosivity have been introduced during recent years. To evaluate the effect of corrosion attack on product functional performance, quantitative methods are adopted for assessing changes in the functional properties, as well as in the associated chemical changes resulting from corrosion of the materials of the component.

Field-site exposure testing was and still is the traditional way to verify the corrosion resistance of new materials and products, especially for testing new surface treatment systems or coatings for corrosion protection. Field test sites can be selected at places of high corrosivity as in marine or industrial areas. The field test sites therefore often represent worst cases of environments and as such the tests at those sites can be considered as accelerated tests. The degree of acceleration is, however, mostly moderate and it generally takes a long time to get an answer whether a tested material or product should be considered qualified with respect to its corrosion resistance.

For qualification of new materials and products with respect to corrosion resistance, therefore, accelerated corrosion tests generally need to be adopted during product design work. The higher the degree of acceleration of a corrosion test the more favourable the accelerated corrosion test will be in keeping the required testing time short. On the other hand, the higher the acceleration of the corrosion process needs to be during testing the harder it is to simulate properly the naturally occurring corrosion processes. This points at the main problem in designing meaningful accelerated corrosion tests for product qualification.

Large efforts have been made to develop accelerated corrosion tests for the purpose of product qualification. As a result of this work, a broad spectrum of methods now exists of which some are also available as International Standards. However, some of those tests are intended only for checking the comparative quality of a metallic material with or without corrosion protection, while others may even be useful for predicting or estimating the long-term performance of a product with metallic materials when exposed to corrosive stress representing in-service conditions.

To identify the most relevant method for one specific application requires knowledge that usually goes beyond what you can get from a single standard. This guideline therefore presents a framework for comparing existing accelerated corrosion tests so that the various aspects in the choice of best method and procedure can properly be taken into account.

Corrosion of metals and alloys — Corrosion tests in artificial atmospheres — Guidelines for selection of accelerated corrosion test for product qualification

1 Scope

This Technical Report is applicable for the selection of suitable accelerated atmospheric corrosion tests for qualification of products with metallic materials without or with permanent corrosion protection or temporary corrosion protection. The characteristics of a number of standardized accelerated corrosion tests are also given to serve as a guide in the preparation of test specifications.

In this Technical Report the following aspects are taken into account:

— Categories of accelerated atmospheric corrosion tests

— Recommended fields of application for the different kinds of tests and their suitability

— Corrosivity of tests and relative corrosion rates of standard metals

— Requirements for test equipment, criteria for reproducibility and correlation with in-service performance

— Recommended procedures for product qualification

The main purpose of this Technical Report is to present a framework for comparing the different accelerated corrosion test methods, which presently are available as International Standards. The suitability of a test method varies with the requirements set by the intended application of the product.

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 9223, *Corrosion of metals and alloys — Corrosivity of atmospheres — Classification, determination and estimation*

ISO 9224:2012, *Corrosion of metals and alloys — Corrosivity of atmospheres — Guiding values for the corrosivity categories*

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

ISO 9226, *Corrosion of metals and alloys — Corrosivity of atmospheres — Determination of corrosion rate of standard specimens for the evaluation of corrosivity*

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

ISO 10062, *Corrosion tests in artificial atmosphere at very low concentrations of polluting gas(es)*

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

ISO 11474, *Corrosion of metals and alloys — Corrosion tests in artificial atmosphere — Accelerated outdoor test by intermittent spraying of a salt solution (Scab test)*

ISO 11844-1, *Corrosion of metals and alloys — Classification of low corrosivity of indoor atmospheres — Part 1: Determination and estimation of indoor corrosivity*

ISO 11997-1, *Paints and varnishes — Determination of resistance to cyclic corrosion conditions — Part 1: Wet (salt fog)/dry/humidity*

ISO 11997-2, *Paints and varnishes — Determination of resistance to cyclic corrosion conditions — Part 2: Wet (salt fog)/dry/humidity/UV light*

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

ISO 16151, *Corrosion of metals and alloys — Accelerated cyclic tests with exposure to acidified salt spray, "dry" and "wet" conditions*

ISO 16701, *Corrosion of metals and alloys — Corrosion in artificial atmosphere — Accelerated corrosion test involving exposure under controlled conditions of humidity cycling and intermittent spraying of a salt solution*

ISO 20340, *Paints and varnishes — Performance requirements for protective paint systems for offshore and related structures*

ISO 21207, *Corrosion tests in artificial atmospheres — Accelerated corrosion tests involving alternate exposure to corrosion-promoting gases, neutral salt-spray and drying*

IEC 60068-2-11, *Environmental testing - Part 2: Tests. Test Ka: Salt mist*

IEC 60068-2-30, *Environmental testing - Part 2-30: Tests - Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60068-2-52, *Environmental testing - Part 2: Tests - Test Kb: Salt mist, cyclic (sodium, chloride solution)*

IEC 60068-2-60, *Environmental testing - Part 2: Tests - Test Ke: Flowing mixed gas corrosion test*

IEC 60068-2-78, *Environmental testing - Part 2-78: Tests - Test Cab: Damp heat, steady state*

3 Categories and characteristics of accelerated corrosion tests

The oldest and most wildly used method for laboratory accelerated corrosion testing is maybe the continuous neutral salt spray test (category A in Table 1). The continuous salt spray test is particularly useful for detecting discontinuities such as pores and other defects in certain metallic, anodic oxide and conversion coatings as well as in organic coatings. However, although used extensively for the purposes of qualification testing, results from continuous salt spray testing seldom correlate well with in-service performance.

Table 1 — Categories of accelerated atmospheric corrosion tests

Category of test		Examples of standards
A	Continuous salt spray tests	ISO 9227; IEC 60068-2-11
B	Tests with alternating immersion of test objects in a salt solution followed by drying or intermittent salt spraying and drying	ISO 11130;
C	Tests with cyclic variation of humidity (dry/wet) and including also steps of salt spraying	ISO 11474, ISO 14993; ISO 11997-1; ISO 11997-2; ISO 16151; ISO 16701, ISO 20340, IEC 60068-2-52
D	Tests with continuous exposure to atmospheres with low concentrations of corrosion promoting gases and at moderately high humidity	ISO 10062; IEC 60068-2-60
E	Tests with continuous exposure to atmospheres with higher concentrations of corrosion promoting gases and at higher humidity including also steps of drying and short period of salt spraying	ISO 21207
F	High humidity tests	IEC 60068-2-78, IEC 60068-2-30, NT ELEC 025 (with condensation) See reference [1] in the Bibliography

One way to increase this ability is to introduce a step of drying after salt spray exposure (category B in Table 1). Even better, however is to combine salt spray exposure with humidity cycling between a high humidity level and a low humidity level (category C in Table 1) and, thus, introducing both wetting and drying in the corrosion test cycle.

Results from such tests turn out to correlate reasonably well with in-service performance at normal outdoor conditions. A number of cyclic accelerated corrosion tests based on this principle have been developed and standardized. The complexity of such tests, however, varies and so the requirements for test equipment. To get better control of the factors determining the rate of corrosion and relevance to in-service corrosion performance advanced systems have come into use.

Certain air pollutants as sulphur dioxide SO_2, nitrogen dioxide NO_2, hydrogen sulphide H_2S, and chlorine Cl_2 present in air as trace substances promote corrosion of metals under high humidity conditions and need to be taken into consideration in the evaluation of corrosion resistance of products that are especially sensitive to corrosion failures such as electronic devices. High humidity exposure tests in the presence of such air pollutants are therefore frequently used in the qualification of electronic products with respect to corrosion resistance (category D in Table 1).

Corrosion effects may appear at air volume fractions of pollutants less than of 10^{-6}. The conduct of air pollutant corrosion tests, therefore, requires very special kind of test equipment. Moreover mixtures of polluting gases are often used to simulate synergistic effects.

To assess corrosion resistance of certain products, tests combining intermittent salt spraying with exposure to corrosion promoting gases have also been introduced (category E in Table 1). Additional synergistic effects may be tested by such methods. The tests are also recommended for qualification of products designed for use in relative corrosive environments.

Sometimes tests involving exposure of test specimens to high humidity and to condensing water are considered as corrosion tests (category F in Table 1). Such test may produce corrosion effects on metallic parts of products if surface contaminants in the form of salts are present. Condensation tests are also used for the testing of organic coatings because they may induce damage caused by swelling and out-leakage of additives. For testing of electronic devices high humidity tests are used for control of air-tightness and in-leakage of water in the equipment. A special case of that is testing the corrosion protection capability of a semi permeable enclosure with electric device by initiating rapid cooling of the enclosure. This will cause the pumping of damp air into the enclosure and there result in condensation of water vapour if the cooling effect is sufficiently high.

4 Recommended fields of application for different kinds of tests and their suitability

During recent years methods for quantitative assessment and classification of atmospheric corrosivity have been developed and some of those exist also as International Standards. Atmospheric corrosivity for a specific location may either be estimated from meteorological data as described in ISO 9223 or assessed by measuring the corrosion rate of standard metal specimens at this location as described in ISO 9226.

The suitability of the different categories of corrosion tests for product qualification is given in Table 2 for four different fields of applications and at varying corrosivity of an intended in-service environment in those applications.

The corrosivity categories C1 = very low corrosivity, C2 = low corrosivity, C3 = medium corrosivity, C4 = high corrosivity, C5 = very high corrosivity and CX = extreme corrosivity given in Table 2 are defined quantitatively in the standard ISO 9223. The severity classes G1 = mild, G2 = moderate, G3 = harsh, and GX = severe appearing in Table 2 also are quantitatively defined in ISA S71.04 (Reference[2] in the Bibliography). Corrosivity classification for low corrosive atmospheres is also described in ISO 11844-1, which includes a comparison of ISO and ISA corrosivity categories.

For expressing the suitability of a specific category of corrosion test the following classes are used:

P = Preferred kind of method,

U = Useful for comparative testing of similar products, and

N = Not useful unless for quality control of the same product.

Table 2 — Suitability of corrosion test methods for different fields of application

Field of application		Suitability of different categories of corrosion tests					
Description	**Corrosivity**	**A** (constant salt spray)	**B** (alternate immersion)	**C** (humidity cycling with salt spraying)	**D** (air pollutant exposure)	**E** (air pollutant exposure, drying and salt spray)	**F** (condensation)
Marine constructions	Top site (C4-C5)	N	U	P	-	P2)	-
	Splash (C5)	N	U	-	-	-	-
	Sub-sea 1)	-	-	-	-	-	-
Automotive	Chassis (C4-C5)	N	U	P	-	P2)	-
	Engine compartment (C2-C4)	N	U	P	-	P2)	-
	Passenger compartment (C1)	-	-	-	P2)	-	P
Building constructions	Open (C3-C5)	N	U	P	-	P2)	-
	Sheltered (C2-C4)	N	U	P	-	P2)	-
	Indoor (C1-C2)	-	-	-	P2)	-	P
Electric devices	Severe(GX)	U3)	U3)	U3)	-	P	P4)
	Harsh (G3)	U3)	U3)	U3)	-	P	P4)
	Mild to Moderate (G1-G2)	-	-	-	P		P

P = Preferred kind of method

U = Useful for comparative testing of similar products

N = Not useful unless for quality control of the same product

1) The total immersion test should be used.

2) Is the preferred kind of method for electric devices but is also of more general applicability.

3) For the testing of tightness.

4) Preferred kind of method when the effect of inner salt contaminants dominates.

General statements on the suitability of the different categories of tests for assessing the corrosion resistance of specific metallic materials are given in Table 3 by making use of the same classes of suitability as used in Table 2.