INTERNATIONAL STANDARD

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

Corrosion des métaux et alliages — Corrosivité des atmosphères — Classification, détermination et estimation

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 9223 was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys*.

This second edition cancels and replaces the first edition (ISO 9223:1992), which has been technically revised.

Introduction

Metals, alloys and metallic coatings can suffer atmospheric corrosion when their surfaces are wetted. The nature and rate of the attack depends upon the properties of surface-formed electrolytes, particularly with regard to the level and type of gaseous and particulate pollutants in the atmosphere and to the duration of their action on the metallic surface.

The character of the corrosion attack and the corrosion rate are consequences of the corrosion system, which comprises the metallic materials, the atmospheric environment, technical parameters and operation conditions.

The corrosivity category is a technical characteristic which provides a basis for the selection of materials and protective measures in atmospheric environments subject to the demands of the specific application, particularly with regard to service life.

Data on the corrosivity of the atmosphere are essential for the development and specification of optimized corrosion protection for manufactured products.

The corrosivity categories are defined by the first-year corrosion effects on standard specimens as specified in ISO 9226. The corrosivity categories can be assessed in terms of the most significant atmospheric factors influencing the corrosion of metals and alloys.

The measurement of relevant environmental parameters is specified in ISO 9225.

The ways of determining and estimating the corrosivity category of a given location according to this International Standard and the relationships among them are presented in Figure 1. It is necessary to distinguish between corrosivity determination and corrosivity estimation. It is also necessary to distinguish between corrosivity estimation based on application of a dose-response function and that based on comparison with the description of typical atmospheric environments.

This International Standard does not take into consideration the design and mode of operation of the product, which can influence its corrosion resistance, since these effects are highly specific and cannot be generalized. Steps in the choice of optimized corrosion protection measures in atmospheric environments are defined in ISO 11303.

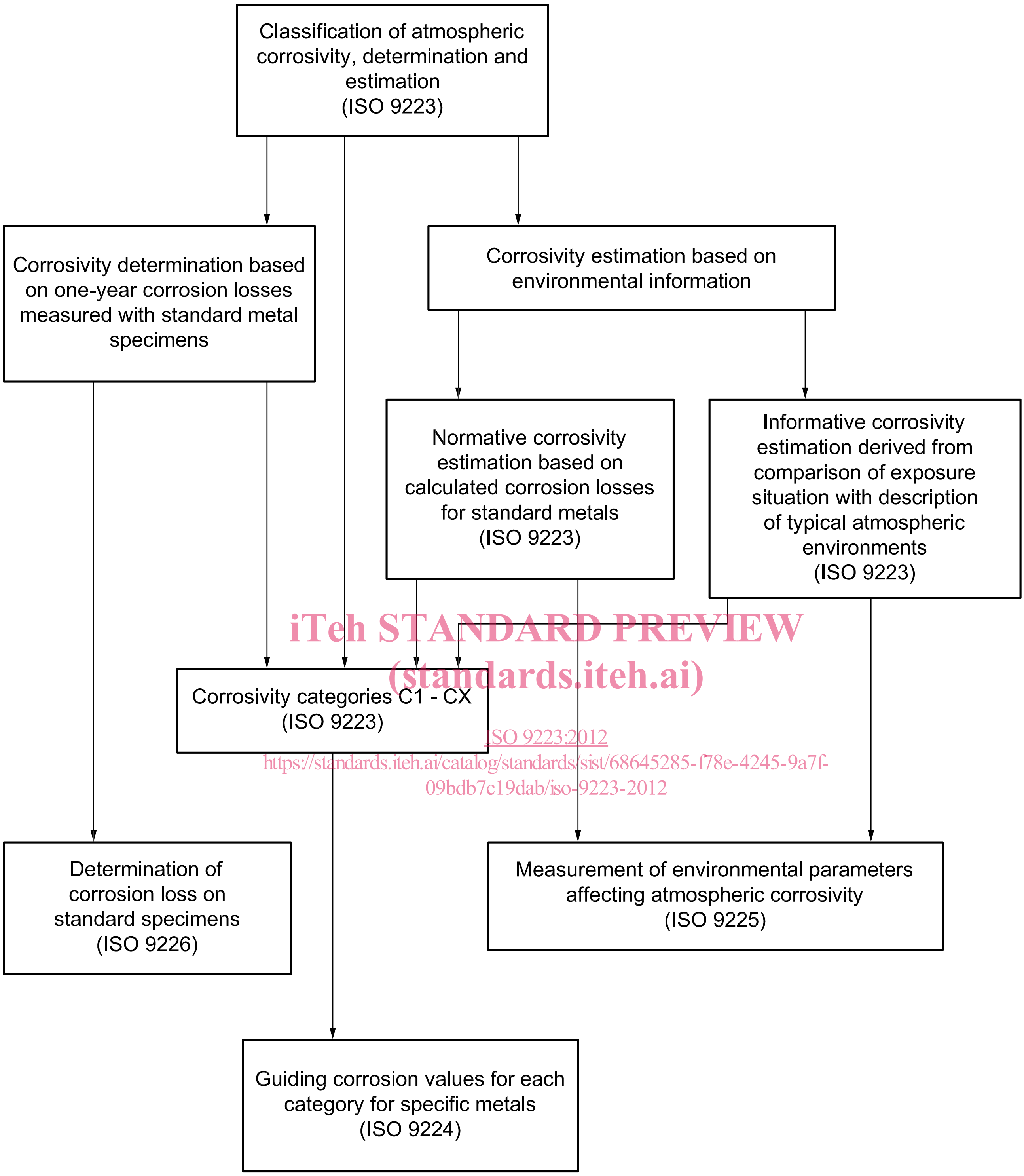

Figure 1 — Classification of atmospheric corrosivity

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

1 Scope

This International Standard establishes a classification system for the corrosivity of atmospheric environments. It

- defines corrosivity categories for the atmospheric environments by the first-year corrosion rate of standard specimens,
- gives dose-response functions for normative estimation of the corrosivity category based on the calculated first-year corrosion loss of standard metals, and
- makes possible an informative estimation of the corrosivity category based on knowledge of the local environmental situation.

This International Standard specifies the key factors in the atmospheric corrosion of metals and alloys. These are the temperature-humidity complex, pollution by sulfur dioxide and airborne salinity.

Temperature is also considered an important factor for corrosion in areas outside the temperate macroclimatic zone. The temperature-humidity complex can be evaluated in terms of time of wetness. Corrosion effects of other pollutants (ozone, nitrogen oxides, particulates) can influence the corrosivity and the evaluated one-year corrosion loss, but these factors are not considered decisive in the assessment of corrosivity according to this International Standard.

This International Standard does not characterize the corrosivity of specific service atmospheres, e.g. atmospheres in chemical or metallurgical industries.

The classified corrosivity categories and introduced pollution levels can be directly used for technical and economical analyses of corrosion damage and for a rational choice of corrosion protection measures.

2 Normative references

The following referenced documents are indispensable for the application 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 8044, *Corrosion of metals and alloys — Basic terms and definitions*

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

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

ISO 11844-2, *Corrosion of metals and alloys — Classification of low corrosivity of indoor atmospheres — Part 2: Determination of corrosion attack in indoor atmospheres*

ISO 11844-3, *Corrosion of metals and alloys — Classification of low corrosivity of indoor atmospheres — Part 3: Measurement of environmental parameters affecting indoor corrosivity*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8044 and the following apply.

3.1
corrosivity of atmosphere
ability of the atmosphere to cause corrosion in a given corrosion system

3.2
category of corrosivity of atmosphere
standardized rating of corrosivity of atmosphere in relation to the one-year corrosion effect

3.3
type of atmosphere
characterization of the atmosphere on the basis of appropriate classification criteria other than corrosivity or of complementary operation factors

EXAMPLE Rural, urban, industrial, marine, chemical, etc.

3.4
temperature-humidity complex
combined effect of temperature and relative humidity on the corrosivity of the atmosphere

3.5
time of wetness
period when a metallic surface is covered by adsorptive and/or liquid films of electrolyte to be capable of causing atmospheric corrosion

3.6
pollution level
numbered rank based on quantitative measurements of specific chemically active substances, corrosive gases or suspended particles in the air (both natural and the result of human activity) that are different from the normal components of the air

3.7
category of location
conventionally defined typical exposure conditions of a component or structure

EXAMPLE Exposure in the open air, under shelter, in a closed space, etc.

3.8
dose-response function
relationship derived from results of field tests for calculation of corrosion loss from average values of environmental parameters

4 Symbols and abbreviated terms

4.1 Symbols

r_{corr} Corrosion rate for the first year of atmospheric exposure

T Air temperature

P_d SO_2 deposition rate

P_c SO_2 concentration

S_d Cl^- deposition rate

τ Time of wetness

4.2 Abbreviated terms

C Atmospheric corrosivity category

RH Relative humidity

5 Category of corrosivity of the atmosphere

The corrosivity of the atmosphere is divided into six categories (see Table 1).

Table 1 — Categories of corrosivity of the atmosphere

Category	Corrosivity
C1	Very low
C2	Low
C3	Medium
C4	High
C5	Very high
CX	Extreme

6 Classification of corrosivity of the atmosphere

The corrosivity of atmospheric environments shall be classified either by determination of the corrosivity in accordance with Clause 7 or, where this is not possible, by estimation of the corrosivity in accordance with Clause 8. Both methods of the corrosivity evaluation represent a generalized approach and are characterized by some uncertainties and limitations.

A corrosivity category determined from the first-year corrosion loss reflects the specific environmental situation of the year of exposure.

A corrosivity category estimated from the dose-response function reflects the statistical uncertainty of the given function.

A corrosivity category estimated using the informative procedure based on the comparison of the local environmental conditions with the description of typical atmospheric environments can lead to misinterpretations. This approach is to be used if experimental data are not available.

Annex A defines uncertainties related to the determination and normative estimation of atmospheric corrosivity categories.

Detailed classification of low corrosivity of indoor atmospheres covering the corrosivity categories C1 and C2 in terms of this International Standard is specified in ISO 11844-1, ISO 11844-2 and ISO 11844-3.

7 Corrosivity determination based on corrosion rate measurement of standard specimens

Numerical values of the first-year corrosion rates for standard metals (carbon steel, zinc, copper, aluminium) are given in Table 2 for each corrosivity category. One-year exposure tests should start in the spring or autumn. In climates with marked seasonal differences, a starting time in the most aggressive period is recommended. The first-year corrosion rates cannot be simply extrapolated for the prediction of long-term corrosion behaviour. Specific calculation models, guiding corrosion values and additional information on long-term corrosion behaviour, are given in ISO 9224.

Table 2 — Corrosion rates, r_{corr}, for the first year of exposure for the different corrosivity categories

Corrosivity category	Corrosion rates of metals r_{corr}				
	Unit	**Carbon steel**	**Zinc**	**Copper**	**Aluminium**
C1	g/(m^2·a)	$r_{corr} \leq 10$	$r_{corr} \leq 0{,}7$	$r_{corr} \leq 0{,}9$	negligible
	µm/a	$r_{corr} \leq 1{,}3$	$r_{corr} \leq 0{,}1$	$r_{corr} \leq 0{,}1$	—
C2	g/(m^2·a)	$10 < r_{corr} \leq 200$	$0{,}7 < r_{corr} \leq 5$	$0{,}9 < r_{corr} \leq 5$	$r_{corr} \leq 0{,}6$
	µm/a	$1{,}3 < r_{corr} \leq 25$	$0{,}1 < r_{corr} \leq 0{,}7$	$0{,}1 < r_{corr} \leq 0{,}6$	—
C3	g/(m^2·a)	$200 < r_{corr} \leq 400$	$5 < r_{corr} \leq 15$	$5 < r_{corr} \leq 12$	$0{,}6 < r_{corr} \leq 2$
	µm/a	$25 < r_{corr} \leq 50$	$0{,}7 < r_{corr} \leq 2{,}1$	$0{,}6 < r_{corr} \leq 1{,}3$	—
C4	g(m^2·a)	$400 < r_{corr} \leq 650$	$15 < r_{corr} \leq 30$	$12 < r_{corr} \leq 25$	$2 < r_{corr} \leq 5$
	µm/a	$50 < r_{corr} \leq 80$	$2{,}1 < r_{corr} \leq 4{,}2$	$1{,}3 < r_{corr} \leq 2{,}8$	—
C5	g/(m^2·a)	$650 < r_{corr} \leq 1\,500$	$30 < r_{corr} \leq 60$	$25 < r_{corr} \leq 50$	$5 < r_{corr} \leq 10$
	µm/a	$80 < r_{corr} \leq 200$	$4{,}2 < r_{corr} \leq 8{,}4$	$2{,}8 < r_{corr} \leq 5{,}6$	—
CX	g/(m^2·a)	$1\,500 < r_{corr} \leq 5\,500$	$60 < r_{corr} \leq 180$	$50 < r_{corr} \leq 90$	$r_{corr} > 10$
	µm/a	$200 < r_{corr} \leq 700$	$8{,}4 < r_{corr} \leq 25$	$5{,}6 < r_{corr} \leq 10$	—

NOTE 1 The classification criterion is based on the methods of determination of corrosion rates of standard specimens for the evaluation of corrosivity (see ISO 9226).

NOTE 2 The corrosion rates, expressed in grams per square metre per year [g/(m^2·a)], are recalculated in micrometres per year (µm/a) and rounded.

NOTE 3 The standard metallic materials are characterized in ISO 9226.

NOTE 4 Aluminium experiences uniform and localized corrosion. The corrosion rates shown in this table are calculated as uniform corrosion. Maximum pit depth or number of pits can be a better indicator of potential damage. It depends on the final application. Uniform corrosion and localized corrosion cannot be evaluated after the first year of exposure due to passivation effects and decreasing corrosion rates.

NOTE 5 Corrosion rates exceeding the upper limits in category C5 are considered extreme. Corrosivity category CX refers to specific marine and marine/industrial environments (see Annex C).

8 Corrosivity estimation based on environmental information

8.1 Corrosivity estimation — General

If it is not possible to determine the corrosivity categories by the exposure of standard specimens, an estimation of corrosivity may be based on corrosion loss calculated from environmental data or on information on environmental conditions and exposure situation.

8.2 Normative corrosivity estimation based on calculated first-year corrosion losses

Dose-response functions for four standard metals are given, describing the corrosion attack after the first year of exposure in open air as a function of SO_2 dry deposition, chloride dry deposition, temperature and relative humidity. Functions are based on results of worldwide corrosion field exposures and cover climatic earth conditions and pollution situation within the scope of this International Standard. Some limitations and uncertainties are characterized in Annex A.

Dose-response functions for calculation of the first-year corrosion loss of structural metals:

Use Equation (1) for carbon steel:

$$r_{\text{corr}} = 1{,}77 \cdot P_{\text{d}}^{0{,}52} \cdot \exp(0{,}020 \cdot \text{RH} + f_{\text{St}}) + 0{,}102 \cdot S_{\text{d}}^{0{,}62} \cdot \exp(0{,}033 \cdot \text{RH} + 0{,}040 \cdot T) \quad (1)$$

$f_{\text{St}} = 0{,}150 \cdot (T - 10)$ when $T \leq 10$ °C; otherwise $-0{,}054 \cdot (T - 10)$

$N = 128$, $R^2 = 0{,}85$

Use Equation (2) for zinc:

$$r_{\text{corr}} = 0{,}012\,9 \cdot P_{\text{d}}^{0{,}44} \cdot \exp(0{,}046 \cdot \text{RH} + f_{\text{Zn}}) + 0{,}017\,5 \cdot S_{\text{d}}^{0{,}57} \cdot \exp(0{,}008 \cdot \text{RH} + 0{,}085 \cdot T) \quad (2)$$

$f_{\text{Zn}} = 0{,}038 \cdot (T - 10)$ when $T \leq 10$ °C; otherwise, $-0{,}071 \cdot (T - 10)$

$N = 114$, $R^2 = 0{,}78$

Use Equation (3) for copper:

$$r_{\text{corr}} = 0{,}005\,3 \cdot P_{\text{d}}^{0{,}26} \cdot \exp(0{,}059 \cdot \text{RH} + f_{\text{Cu}}) + 0{,}010\,25 \cdot S_{\text{d}}^{0{,}27} \cdot \exp(0{,}036 \cdot \text{RH} + 0{,}049 \cdot T) \quad (3)$$

$f_{\text{Cu}} = 0{,}126 \cdot (T - 10)$ when $T \leq 10$ °C; otherwise, $-0{,}080 \cdot (T - 10)$

$N = 121$, $R^2 = 0{,}88$

Use Equation (4) for aluminium:

$$r_{\text{corr}} = 0{,}004\,2 \cdot P_{\text{d}}^{0{,}73} \cdot \exp(0{,}025 \cdot \text{RH} + f_{\text{Al}}) + 0{,}001\,8 \cdot S_{\text{d}}^{0{,}60} \cdot \exp(0{,}020 \cdot \text{RH} + 0{,}094 \cdot T) \quad (4)$$

$f_{\text{Al}} = 0{,}009 \cdot (T - 10)$ when $T \leq 10$ °C; otherwise $-0{,}043 \cdot (T - 10)$

$N = 113$, $R^2 = 0{,}65$

where

r_{corr} is first-year corrosion rate of metal, expressed in micrometres per year (µm/a);

T is the annual average temperature, expressed in degrees Celsius (°C);

RH is the annual average relative humidity, expressed as a percentage (%);

P_{d} is the annual average SO_2 deposition, expressed in milligrams per square metre per day [mg/(m^2·d)];

S_{d} is the annual average Cl^- deposition, expressed in milligrams per square metre per day [mg/(m^2·d)].