INTERNATIONAL STANDARD

ISO 9223

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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.

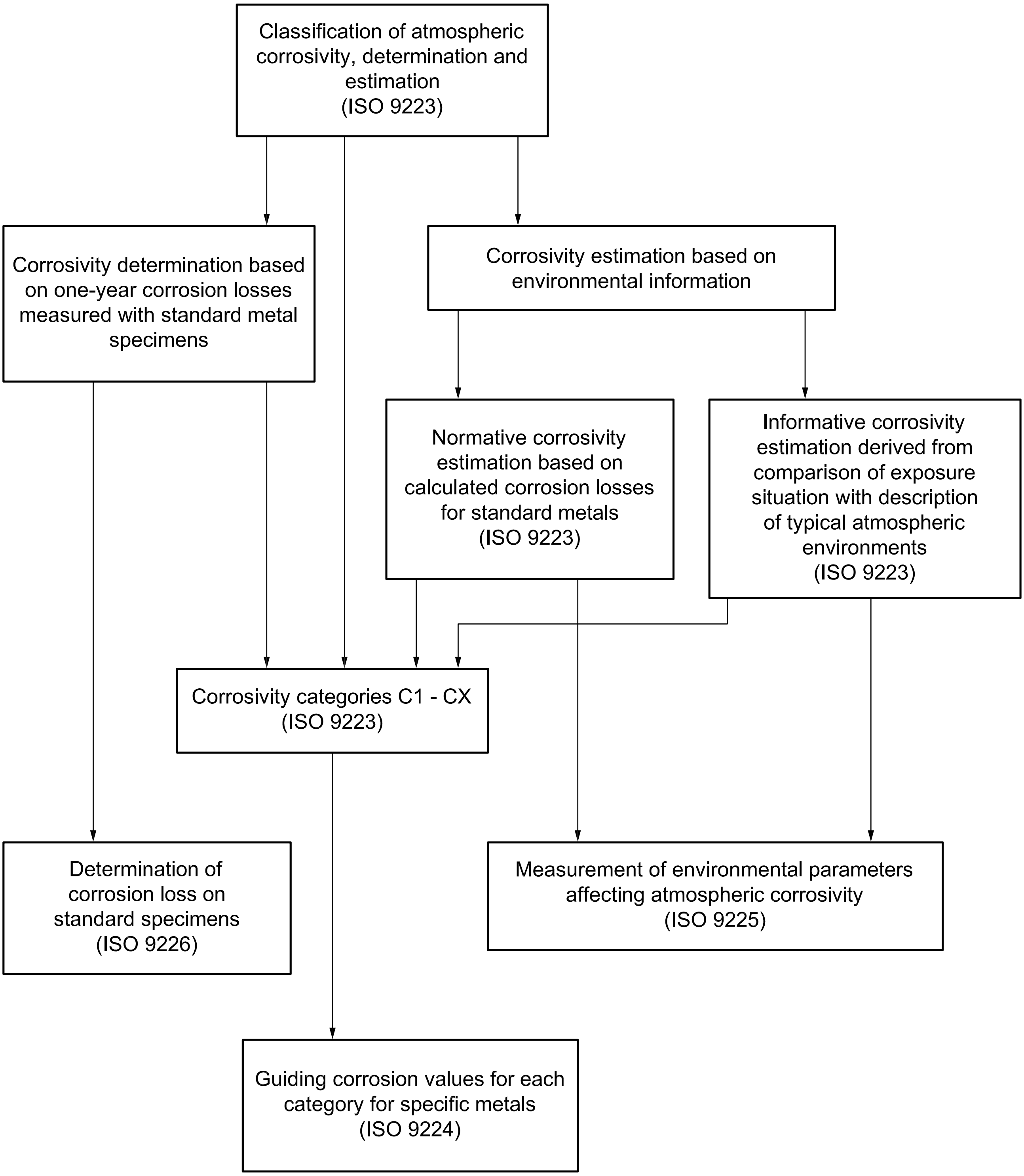

Figure 1 — Classification of atmospheric corrosivity

INTERNATIONAL STANDARD **ISO 9223:2012(E)**

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:

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

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

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

Use Equation (2) for zinc:

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

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

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

Use Equation (3) for copper:

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

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

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

Use Equation (4) for aluminium:

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

$f_\text{Al} = 0{,}009 \cdot (T - 10)$ 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)].

For details of the environmental parameters, see Table 3, which also gives the measured intervals of the parameters. If P_d is replaced with 0,8P_c in the dose-response functions, as explained in the table footnote to Table 3, P_c shall also be an annual average.

Table 3 — Parameters used in the derivation of dose-response functions, including symbol, description, interval and unit

Symbol	Description	Interval	Unit
T	Temperature	−17,1 to 28,7	°C
RH	Relative humidity	34 to 93	%
P_d	SO_2 deposition	0,7 to 150,4	mg/(m^2·d)
S_d	Cl^- deposition	0,4 to 760,5	mg/(m^2·d)

The sulfur dioxide (SO_2) values determined by the deposition method, P_d, and volumetric method, P_c, are equivalent for the purposes of this International Standard. The relationship between measurements using both methods may be approximately expressed as $P_d = 0,8\ P_c$ [P_d in mg/(m^2·d), P_c in µg/m^3].

NOTE All parameters are expressed as annual averages.

Care shall be taken when extrapolating the equations outside the intervals of environmental parameters for their calculations (e.g. in coastal environments).

8.3 Informative corrosivity estimation based on description of exposure conditions

The corrosivity of an atmospheric environment increases with the effect of the temperature-humidity complex (covering also time of wetness) and the levels of other corrosive agents.

Typical atmospheric types of pollution and levels are introduced in Annex B.

Exposure conditions (category of location) of material, component or structure influence the impact of environment.

A qualitative description of typical environments related to the atmospheric corrosivity categories for the purposes of informative corrosivity estimation is given in Annex C.

Annex A
(informative)

Sources of uncertainty associated with the determination and estimation of atmospheric corrosivity

A.1 General

The corrosivity of atmospheric environments shall be classified either through determination of the corrosivity category based on the exposure of specimens or by estimation based on environmental parameters and the use of a dose-response function. The use of these two different denominations for the assessment of a corrosivity category implies that two different levels of uncertainty can be expected for the determination (low uncertainty) and estimation (high uncertainty) procedures. This annex serves to establish those two levels of uncertainty.

The basis for the details given in this annex is a separate statistical analysis performed in connection with the derivation of the dose-response functions for the estimation procedure.

A.2 Distribution of errors

Log-normal distributions, i.e. normal distributions of logarithmic values, are observed for the corrosion rates. If the uncertainty is expressed by a standard deviation of logarithmic values, s, then

$$\Delta\ln(r_{\mathrm{corr}}) = \pm s \qquad (A.1)$$

This means that the uncertainty interval in general is asymmetric and can be expressed as $r_{\mathrm{corr}}\cdot e^{\pm s}$. However, if s is small, the interval becomes approximately symmetric. This can be illustrated by the following two examples. If $s = 0{,}7$, then $e^{s} = 2$ and $e^{-s} = 1/2$, which corresponds to an interval from −50 % to +100 %. On the other hand, if $s = 0{,}01$, then $e^{s} = 1{,}01$ and $e^{-s} = 0{,}99$, which corresponds to an interval from −1 % to +1 % or ±1 %.

A.3 Levels of uncertainty

Table A.1 gives the estimated levels of uncertainty. The large difference between the two procedures is clear from the table and this is what motivates the two different denominations of the assessment. A.4 gives a description of possible sources of error and an explanation of those errors is included in the values given in Table A.1.

Table A.1 — Estimated levels of uncertainty for assessment of the corrosivity category based on determination (exposure of specimens) and estimation (dose-response function)

Metal	Level of uncertainty	
	Determination	Estimation
Carbon steel	±2 %	−33 % to +50 %
Zinc	±5 %	−33 % to +50 %
Copper	±2 %	−33 % to +50 %
Aluminium	±5 %	−50 % to +100 %

A.4 Sources of uncertainty

Regarding the determination of corrosivity categories based on exposure of specimens, it should first be clarified that the levels given in Table A.1 are expressed for an average value calculated from three individual values and not for an individual corrosion value.

The uncertainty levels given in Table A.1, both for determination and estimation, are based on the exposure of materials at many different test sites, but only for one exposure period. Thus, the values should have a general validity, but the variation in corrosion attack that can occur from year to year, depending on natural variations in climate, is not included in the values in Table A.1.

Regarding the estimation of corrosivity categories based on the dose-response functions, the total uncertainty consists of two parts, uncertainty in the dose-response functions and uncertainty in the measurements of environmental parameters. Of these, the uncertainty in the dose-response functions is dominant. Also, the values in Table A.1 are based on an average uncertainty over the range of parameters used in the function. As for all regression functions, this uncertainty is lowest in the middle range, corresponding to corrosivity category C3, and higher at the lower and upper ranges, corresponding to corrosivity categories C1 and C5. Uncertainty for category CX is the highest and it is not covered by this calculation.

Annex B
(informative)

Characterization of the atmosphere in relation to its corrosivity

It is necessary for the classification approach for informative corrosivity estimation to be simple and user-friendly as regards the choice of parameters to be considered. For the purposes of this International Standard, the key factors of the atmosphere for corrosion of metals and alloys are the temperature-humidity complex, and sulfur dioxide and chloride pollution levels.

For unsheltered positions, the corrosion impact is mentioned in terms of dry and wet deposition. Wet deposition includes transport by means of precipitation and dry deposition denotes transport by any other process.

In sheltered positions, only dry deposition occurs. The cumulative effect of pollutants, including particulates, should be considered. Specific problems of atmospheric corrosivity of low aggressive indoor atmospheres are characterized in ISO 11844-1, ISO 11844-2 and ISO 11844-3.

The wetting of surfaces is caused by many factors, for example dew, rainfall, melting snow and a high humidity level. The length of time during which the relative humidity is greater than 80 % at a temperature greater than 0 °C is used to estimate the calculated time of wetness, τ, of corroding surfaces. The time of wetness is underestimated by the time that the temperature exceeds 0 °C and 80 % RH in frigid zones (freezing point depression).

Information on calculated time of wetness is helpful for informative atmospheric corrosivity estimation.

Table B.1 presents time of wetness characteristics for different exposure conditions.

The most important factor within a particular temperature-humidity complex is the pollution level caused by sulfur dioxide or airborne salinity. The pollution level shall be measured in accordance with the specifications of ISO 9225.

Other kinds of pollution can also exert an effect [oxides of nitrogen (NO_x), nitric acid (HNO_3) and industrial dust in populated and industrial zones] or the specific operational and technological pollution of microclimates [chlorine (Cl_2), hydrogen sulfide (H_2S), organic acids and de-icing agents]. These types of pollution have not been used as classification criteria.

According to this International Standard, the other kinds of pollution should be considered as accompanying ones [e.g. oxides of nitrogen (NO_x) in urban atmospheres] or specific operational ones (e.g. vapours of acids in operational microclimates). Concentrations of the most important pollutants in different atmospheric environments are listed in Table B.2.

The decreasing sulfur dioxide levels in many parts of the world and the elevated levels of nitrogen oxides caused by increasing traffic, together with ozone and particulates, has created a new multipollutant environmental situation. In other parts of the world, in relation to rapid development of industry, the corrosion effect of SO_2 pollution is intensified and still dominating.

Atmospheric pollution considered for corrosivity classification in the frame of this International Standard is divided into two groups: pollution by sulfur dioxide (SO_2) and by airborne salinity. These two types of pollution are representative for rural, urban, industrial and marine atmospheres. The grouping of pollution by sulfur dioxide (SO_2) for standard outdoor atmospheres is given in Table B.3.

Grouping of salinity in levels characteristic of types of atmospheres is given in Table B.4. It is necessary to consider the high importance of chloride accumulation on surfaces not washed by rain, especially in humid sites.

The time of wetness is underestimated by the time that the temperature exceeds 0 °C and 80 % RH in frigid zones (freezing point depression).

Table B.1 — Time of wetness in different exposure conditions

Time of wetness h/a	Level	Example of occurrence
$\tau \leq 10$	τ_1	Internal microclimates with climatic control
$10 < \tau \leq 250$	τ_2	Internal microclimates without climatic control except for internal non-air conditioned spaces in damp climates
$250 < \tau \leq 2\,500$	τ_3	Outdoor atmospheres in dry, cold climates and some zones of temperate climates; properly ventilated sheds in temperate climates
$2\,500 < \tau \leq 5\,500$	τ_4	Outdoor atmospheres in all climates (except for dry and cold climates); ventilated sheds in humid conditions; unventilated sheds in temperate climates
$5\,500 < \tau$	τ_5	Some zones of damp climates; unventilated sheds in humid conditions

NOTE 1 The time of wetness of a given locality depends on the temperature-humidity complex of the open-air atmosphere and the category of the location and is expressed in hours per year (h/a).

NOTE 2 Sheltered surfaces in marine atmospheres, where chlorides are deposited, can experience substantially increased times of wetness, due to the presence of hygroscopic salts.

NOTE 3 In indoor atmospheres without climatic control, sources of water vapour cause higher times of wetness.

Table B.2 — Outdoor concentration of some of the most important pollutants in different types of environments

Pollutant	Concentration/deposition (yearly average value)	Source
SO_2	rural: 2 – 15 (µg/m^3) urban: 5 – 100 (µg/m^3) industrial: 50 – 400 (µg/m^3)	The main sources for SO_2 are the use of coal and oil and emissions from industrial plants.
NO_2	rural: 2 – 25 (µg/m^3) urban: 20 – 150 (µg/m^3)	Traffic is the main source for NO_2 emissions.
HNO_3	rural: 0,1 – 0,7 (µg/m^3) urban/industrial: 0,5 – 4 (µg/m^3)	HNO_3 is correlated with NO_2. High concentrations of NO_2, organic compounds and UV light increase the concentration.
O_3	20 – 90 (µg/m^3)	O_3 is formed in the atmosphere by an interactions among sunlight, oxygen and pollutants. The concentrations are higher in polluted rural atmospheres and lower in high-traffic urban areas.
H_2S	normally: 1 – 5 (µg/m^3) industrial and animal shelter: 20 – 250 (µg/m^3)	There are some natural sources, for instance swamps and volcanic activities. The pulp and paper industry and farming give the highest concentrations.
Cl_2	normally: 0,1 (µg/m^3) some industry plants: up to 20 (µg/m^3)	The main source is emissions from the pulp and paper industry.
Cl^-	0,1 – 200 (µg/m^3) depending on geographic situation – in marine atmospheres 300 – 1 500 (µg/m^3)	The main sources are the ocean and de-icing of roads.

Table B.2 (*continued*)

Pollutant	Concentration/deposition (yearly average value)	Source
NH_3	normally low concentrations: < 20 (µg/m^3) close to source: up to 3 000 (µg/m^3)	Fertilization in the agricultural area source and emissions from industry and food production can give the highest average values.
Particles-PM$_{10}$	rural: 10 – 25 (µg/m^3) urban/industrial: 30 – 70 (µg/m^3)	Rural: largely inert components Urban: high-concentration traffic areas, corrosive components Industrial: emissions from production can give high concentrations.
Particles (dust deposits)	rural 450 – 1 500 [mg/(m^2·a)] urban/industrial: 1 000 – 6 000 [mg/(m^2·a)]	Rural: largely inert components Urban and industrial: corrosion active components (SO_4^{2-}, NO_3^-, Cl^-)
Soot	rural: < 5 [mg/(m^2·a)] urban and industrial: up to 75 [mg/(m^2·a)]	Coal and wood burning is a major source. Diesel soot from cars is another source.

NOTE This table introduces general limits of concentrations or deposition of pollutants. The real (actual) intervals are different in the particular parts of the world, depending on the level of industrialization and the application of measures for the abatement of pollution (legal measures, end-of-pipe technologies, etc.).

Table B.3 — Grouping of pollution by sulfur-containing substances represented by SO_2

Deposition rate of SO_2 mg/(m^2·d)	Concentration of SO_2 µg/m^3	Level
$P_d \leq 4$	$P_c \leq 5$	P_0 Rural atmosphere
$4 < P_d \leq 24$	$5 < P_c \leq 30$	P_1 Urban atmosphere
$24 < P_d \leq 80$	$30 < P_c \leq 90$	P_2 Industrial atmosphere
$80 < P_d \leq 200$	$90 < P_c \leq 250$	P_3 Highly polluted industrial atmosphere

NOTE 1 Methods of determination of sulfur dioxide (SO_2) are specified in ISO 9225.

NOTE 2 The sulfur dioxide (SO_2) values determined by the deposition, P_d, and volumetric, P_c, methods are equivalent for the purposes of this International Standard. The relationship between measurements using both methods can be approximately expressed as: $P_d = 0{,}8\ P_c$. This conversional factor is based on the deposition rate measurements on alkaline surfaces.

NOTE 3 For the purposes of this International Standard, the sulfur dioxide (SO_2) deposition rate and concentration are calculated from continuous measurements during at least one year and are expressed as the annual average. The results of short-term measurements can differ considerably from long-term values. Such results are only used for guidance.

NOTE 4 The ranges given cover common levels in individual types of atmospheres. Extreme values are listed in Table B.2.

Table B.4 — Grouping of pollution by airborne salinity represented by chloride

Deposition rate of chloride mg/(m^2·d)	**Level**
$S_d \leq 3$	S_0
$3 < S_d \leq 60$	S_1
$60 < S_d \leq 300$	S_2
$300 < S_d \leq 1\,500$	S_3

NOTE 1 The airborne salinity level according to this International Standard is based on the wet candle method specified in ISO 9225.

NOTE 2 The results obtained by applying various methods (i.e. dry plate method) for the determination of the salt content in the atmosphere are not always directly comparable and convertible. Derived conversion factors are given in ISO 9225.

NOTE 3 For the purposes of this International Standard, the chloride deposition rate is expressed as the annual average. The results of short-term measurements are very variable and depend very strongly upon weather effects.

NOTE 4 Extreme pollution by chloride, which is typical of strong marine splash and spray, is outside of the scope of this International Standard.

NOTE 5 The airborne salinity is strongly dependent on the variables influencing the transport inland of sea-salt, such as wind direction, wind velocity, local topography, distance of the exposure site from the sea, etc.

Annex C
(informative)

Description of typical atmospheric environments related to the estimation of corrosivity categories

Table C.1 — Description of typical atmospheric environments related to the estimation of corrosivity categories

Corrosivity category[a]	Corrosivity	Typical environments — Examples[b]	
		Indoor	**Outdoor**
C1	Very low	Heated spaces with low relative humidity and insignificant pollution, e.g. offices, schools, museums	Dry or cold zone, atmospheric environment with very low pollution and time of wetness, e.g. certain deserts, Central Arctic/Antarctica
C2	Low	Unheated spaces with varying temperature and relative humidity. Low frequency of condensation and low pollution, e.g. storage, sport halls	Temperate zone, atmospheric environment with low pollution (SO$_2$ $<$ 5 µg/m^3), e.g. rural areas, small towns Dry or cold zone, atmospheric environment with short time of wetness, e.g. deserts, subarctic areas
C3	Medium	Spaces with moderate frequency of condensation and moderate pollution from production process, e.g. food-processing plants, laundries, breweries, dairies	Temperate zone, atmospheric environment with medium pollution (SO$_2$: 5 µg/m^3 to 30 µg/m^3) or some effect of chlorides, e.g. urban areas, coastal areas with low deposition of chlorides Subtropical and tropical zone, atmosphere with low pollution
C4	High	Spaces with high frequency of condensation and high pollution from production process, e.g. industrial processing plants, swimming pools	Temperate zone, atmospheric environment with high pollution (SO$_2$: 30 µg/m^3 to 90 µg/m^3) or substantial effect of chlorides, e.g. polluted urban areas, industrial areas, coastal areas without spray of salt water or, exposure to strong effect of de-icing salts Subtropical and tropical zone, atmosphere with medium pollution
C5	Very high	Spaces with very high frequency of condensation and/or with high pollution from production process, e.g. mines, caverns for industrial purposes, unventilated sheds in subtropical and tropical zones	Temperate and subtropical zone, atmospheric environment with very high pollution (SO$_2$: 90 µg/m^3 to 250 µg/m^3) and/or significant effect of chlorides, e.g. industrial areas, coastal areas, sheltered positions on coastline

Table C.1 (*continued*)

Corrosivity category[a]	Corrosivity	Typical environments — Examples[b]	
		Indoor	**Outdoor**
CX	Extreme	Spaces with almost permanent condensation or extensive periods of exposure to extreme humidity effects and/or with high pollution from production process, e.g. unventilated sheds in humid tropical zones with penetration of outdoor pollution including airborne chlorides and corrosion-stimulating particulate matter	Subtropical and tropical zone (very high time of wetness), atmospheric environment with very high SO_2 pollution (higher than $250\ \mu g/m^3$) including accompanying and production factors and/or strong effect of chlorides, e.g. extreme industrial areas, coastal and offshore areas, occasional contact with salt spray

NOTE 1 Deposition of chlorides in coastal areas is strongly dependent on the variables influencing the transport inland of sea salt, such as wind direction, wind velocity, local topography, wind sheltering islands outside the coast, distance of the site from the sea, etc.

NOTE 2 Extreme effect by chlorides, which is typical of marine splash or heavy salt spray, is outside of the scope of this International Standard.

NOTE 3 Corrosivity classification of specific service atmospheres, e.g. in chemical industries, is outside of the scope of this International Standard.

NOTE 4 Surfaces that are sheltered and not rain-washed in marine atmospheric environments where chlorides are deposited and cumulated can experience a higher corrosivity category due to the presence of hygroscopic salts.

NOTE 5 A detailed description of types of indoor environments within corrosivity categories C1 and C2 is given in ISO 11844-1. Indoor corrosivity categories IC1 to IC5 are defined and classified.

[a] In environments with expected “CX category”, it is recommended that the atmospheric corrosivity classification from one-year corrosion losses be determined.

[b] The concentration of sulfur dioxide (SO_2) should be determined during at least one year and is expressed as the annual average.

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