INTERNATIONAL STANDARD

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Corrosion of metals and alloys — Corrosivity of atmospheres — Classification

Corrosion des métaux et alliages — Corrosivité des atmosphères — Classification

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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.

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.

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

Annex A forms an integral part of this International Standard. Annex B is for information only.

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Introduction

Metals, alloys and metallic coatings may suffer atmospheric corrosion when their surfaces are wetted. The nature and rate of the attack will depend 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.

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

There are two ways of determining the corrosivity category of a given location according to this International Standard (see figure 0.1).

The corrosivity categories are defined by the corrosion effects on standard specimens as specified in ISO 9226. The corrosivity categories may be assessed in terms of the most significant atmospheric factors influencing the corrosion of metals and alloys i.e. time of wetness and pollution level.

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.

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.

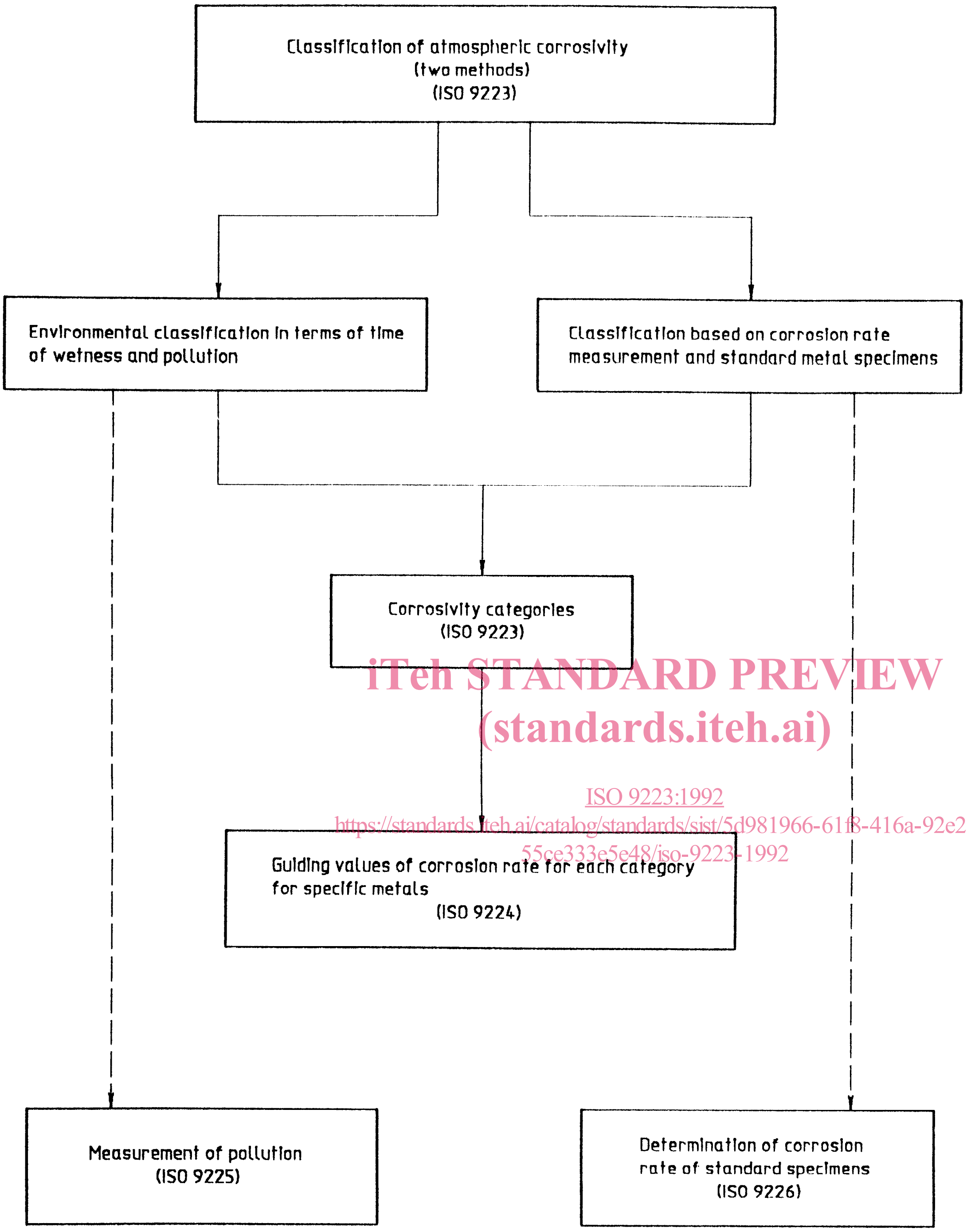

Figure 0.1 — Classification of atmospheric corrosivity

Corrosion of metals and alloys — Corrosivity of atmospheres — Classification

1 Scope

1.1 This International Standard specifies the key factors in the atmospheric corrosion of metals and alloys. These are the time of wetness (τ), pollution by sulfur dioxide (SO_2) (P) and air-borne salinity (S). Corrosivity categories (C), which are defined on the basis of these three factors, are used for the classification of atmospheres.

1.2 The classification given in this International Standard can be used directly to evaluate the corrosivity of atmospheres for metals and alloys under known conditions of time of wetness, pollution by sulfur dioxide (SO_2) and/or airborne salinity.

This International Standard does not characterize the corrosivity of specific service atmospheres, e.g. atmospheres in the chemical or metallurgical industries. The pollution and time of wetness characterization of these environments cannot be generalized.

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

Annex A summarizes the technical content of this International Standard in an easily read form.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 8044:1989, *Corrosion of metals and alloys — Vocabulary*.

ISO 9224:1992, *Corrosion of metals and alloys — Corrosivity of atmospheres — Guiding values for the corrosivity categories*.

ISO 9225:1992, *Corrosion of metals and alloys — Corrosivity of atmospheres — Measurement of pollution*.

ISO 9226:1992, *Corrosion of metals and alloys — Corrosivity of atmospheres — Determination of corrosion rate of standard specimens for the evaluation of corrosivity*.

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 corrosivity[1] of the atmosphere: The ability of the atmosphere to cause corrosion in a given corrosion system (e.g. atmospheric corrosion of a given metal or alloy).

3.2 time of wetness: The period during which a metallic surface is covered by adsorptive and/or liquid films of electrolyte that are capable of causing atmospheric corrosion.

3.2.1 calculated time of wetness: The time of wetness estimated from the temperature-humidity complex (see 5.2).

3.2.2 experimental time of wetness: The time of wetness indicated directly by various measuring systems (see 5.3).

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[1] See ISO 8044:1989, subclause 2.18.

3.3 pollution category: A 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.

3.4 type of atmosphere: Characterization of the atmosphere on the basis of appropriate classification criteria other than corrosivity (industrial, marine, etc.) or of complementary operational factors (chemical, etc.).

3.5 temperature-humidity complex: The combined effect of temperature and relative humidity on the corrosivity of the atmosphere.

3.6 category of location: Conventionally defined typical exposure conditions of a component or structure, e.g. in the open air, under shelter, in a closed space etc.

4 Symbols and abbreviations

τ	Time of wetness
P	Pollution category with sulfur compounds based on sulfur dioxide (SO_2) levels
S	Pollution category based on airborne salinity contamination
C	Atmospheric corrosivity category
θ	Air temperature
h/a	Hours per year
r_{corr}	Corrosion rate for the first year of atmospheric exposure
r_{av}	Average corrosion rate for the first 10 years of atmospheric exposure
r_{lin}	Steady state corrosion rate derived from long term atmospheric exposure

5 Characterization of the atmosphere in relation to its corrosivity

5.1 For the purposes of this International Standard, the key corrosion factors of the atmosphere for metals and alloys are time of wetness, and sulfur dioxide (SO_2) and chloride pollution levels.

5.2 The wetting of surfaces is caused by many factors, for example, dew, rainfall, melting snow and a high humidity level. The length of time when the relative humidity is greater than 80 % at a temperature (θ) greater than 0 °C is used to estimate the calculated time of wetness (τ) of corroding surfaces (see note 1).

5.3 The experimental time of wetness can be determined directly by various measuring systems (see note 2).

5.4 The most important factor within a particular category of time of wetness is the pollution level caused by sulphur dioxide or airborne salinity.

5.5 The pollution level shall be measured in accordance with the specifications of ISO 9225.

5.6 Other kinds of pollution can also exert an effect [oxides of nitrogen, (NO_x) and industrial dust in populated and industrial zones] or the specific operational and technological pollution of microclimates [chloride, (Cl_2), hygrogen sulfide, (H_2S), organic acids and de-iceing 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 [for example: oxides of nitrogen (NO_x) in urban atmospheres] or specific operational ones (for example: vapours of acids in operational microclimates).

NOTES

1 The time of wetness calculated by this method does not necessarily correspond with the actual time of exposure to wetness, because wetness is influenced by: the type of metal, the shape, mass and orientation of the object, the quantity of corrosion product, the nature of pollutants on the surface and other factors. These considerations may increase or decrease the actual time of wetness. However, this criterion is usually sufficiently accurate for the characterization of atmospheres. The relevance of the time of wetness decreases with the degree of sheltering.

2 The indicated time may depend upon the type of instrument and the sensor used. The times of wetness indicated by various systems are not directly comparable and are convertible only within a limited extent of temperature-humidity characteristics.

6 Classification of time of wetness

6.1 The time of wetness (according to 5.2 and 5.3) depends upon the macroclimatic zone and the category of the location.

6.2 The classification of time of wetness for atmospheres is given in table 1. The classified values are based on the long term characteristics of macroclimatic zones for typical conditions of the location categories.

6.3 The calculated times of wetness and selected climatological characteristics of the macroclimatic zones of the Earth are shown in annex B as general guidelines.

6.4 For times of wetness τ_1, almost no condensation is expected. For τ_2, the probability of liquid forming on the metallic surface is low. Times τ_3 to τ_5 include periods of condensation and precipitation.

Table 1 — Classification of time of wetness

Category	Time of wetness		Example of occurrence
	h/a	%	
τ_1	$\tau \leqslant 10$	$\tau \leqslant 0{,}1$	Internal microclimates with climatic control
τ_2	$10 < \tau \leqslant 250$	$0{,}1 < \tau \leqslant 3$	Internal microclimates without climatic control except for internal non-air-conditioned spaces in damp climates
τ_3	$250 < \tau \leqslant 2\,500$	$3 < \tau \leqslant 30$	Outdoor atmospheres in dry, cold climates and part of temperate climates; properly ventilated sheds in temperate climates
τ_4	$2\,500 < \tau \leqslant 5\,500$	$30 < \tau \leqslant 60$	Outdoor atmospheres in all climates (except for the dry and cold climates); ventilated sheds in humid conditions; unventilated sheds in temperate climates
τ_5	$5\,500 < \tau$	$60 < \tau$	Part of damp climates; unventilated sheds in humid conditions

NOTES

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 or as part of exposure time (in percentage).

2 The values of time of wetness in percentage are rounded and informative only.

3 The occurrence column does not include all the possibilities due to the degree of sheltering.

4 Sheltered surfaces in marine atmospheres where chlorides are deposited may experience substantially increased times of wetness, due to the presence of hygroscopic salts and should be classified in the category τ_5.

5 In indoor atmospheres without climatic control, the time of wetness categories τ_3 to τ_5 can occur when sources of water vapour are present.

6 For the times of wetness τ_1 and τ_2, the probability of corrosion is higher for dusty surfaces.

7 Classification of pollution categories

7.1 Atmospheric pollution is divided into two categories: pollution by sulfur dioxide (SO_2) and by airborne salinity. These two types of pollution are representative for rural, urban, industrial and marine atmospheres.

7.2 The classification of pollution by sulfur dioxide (SO_2) for standard outdoor atmospheres is given in table 2.

Table 2 — Classification of pollution by sulphur-containing substances represented by (SO_2)

Deposition rate of SO_2 $mg/(m^2 \cdot d)$	Concentration of SO_2 $\mu g/m^3$	Category
$P_d \leqslant 10$	$P_c \leqslant 12$	P_0
$10 < P_d \leqslant 35$	$12 < P_c \leqslant 40$	P_1
$35 < P_d \leqslant 80$	$40 < P_c \leqslant 90$	P_2
$80 < P_d \leqslant 200$	$90 < P_c \leqslant 250$	P_3

NOTES

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

2 The sulfur dioxide (SO_2) values determined by the deposition (P_d) and volumetric (P_c) methods are equivalent for the purpose of classification. The relationship between measurements using both methods could be approximately expressed as: $P_d = 0,8\ P_c$.

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 result of short term measurements may differ considerably from long term averages. Such results are only used for guidance.

4 Any concentration of sulfur dioxide (SO_2) within category P_0 is considered to be the background concentration and is insignificant from the point of view of corrosive attack.

5 Pollution by sulfur dioxide (SO_2) within category P_3 is considered extreme and is typical of operational microclimates beyond the scope of this International Standard.

6 In shed-type atmospheres and, especially, in indoor atmospheres, the concentration of the pollutants is reduced in inverse proportion to the degree of sheltering.

Table 3 — Classification of pollution by airborne salinity represented by chloride

Deposite rate of chloride mg/(m^2·d)	Category
$S \leqslant 3$	S_0
$3 < S \leqslant 60$	S_1
$60 < S \leqslant 300$	S_2
$300 < S \leqslant 1\ 500$	S_3

NOTES

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

2 The results obtained by the application of various methods for the determination of the salt content in the atmosphere are not always directly comparable and convertible.

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

4 Any chloride deposition rate within category S_0 is taken as the background concentration and is insignificant from the point of view of corrosive attack.

5 Extreme pollution by chloride, which is typical of marine splash and spray, is beyond the scope of this International Standard.

6 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.

7.3 The classification of pollution by chlorides (Cl$^-$) refers to outdoor atmospheres which are polluted by airborne salinity in marine environments. The classification is given in table 3.

8 Categories of corrosivity of the atmosphere

The corrosivity of the atmosphere is divided into five categories (see table 4).

Table 4 — Categories of corrosivity of the atmosphere

Category	Corrosivity
C 1	Very low
C 2	Low
C 3	Medium
C 4	High
C 5	Very ligh

9 Classification of corrosivity based on corrosion rate measurements of standard specimens

Numerical values of the first year corrosion rates for standard metals (carbon steel, zinc, copper, aluminium) are given in table 5 for each of the corrosivity categories. The values cannot be extrapolated for the prediction of long-term corrosion behaviour. Guiding corrosion values and addtional information are given in ISO 9224.

Table 5 — Corrosion rates (r_{corr}) for the first year of exposure for the different corrosivity categories

Corrosivity category	Corrosion rates (r_{corr}) of metals				
	Units	Carbon steel	Zinc	Copper	Aluminium
C 1	$g/(m^2 \cdot a)$	$r_{corr} \leqslant 10$	$r_{corr} \leqslant 0,7$	$r_{corr} \leqslant 0,9$	Negligible
	µm/a	$r_{corr} \leqslant 1,3$	$r_{corr} \leqslant 0,1$	$r_{corr} \leqslant 0,1$	—
C 2	$g/(m^2 \cdot a)$	$10 < r_{corr} \leqslant 200$	$0,7 < r_{corr} \leqslant 5$	$0,9 < r_{corr} \leqslant 5$	$r_{corr} \leqslant 0,6$
	µm/a	$1,3 < r_{corr} \leqslant 25$	$0,1 < r_{corr} \leqslant 0,7$	$0,1 < r_{corr} \leqslant 0,6$	—
C 3	$g/(m^2 \cdot a)$	$200 < r_{corr} \leqslant 400$	$5 < r_{corr} \leqslant 15$	$5 < r_{corr} \leqslant 12$	$0,6 < r_{corr} \leqslant 2$
	µm/a	$25 < r_{corr} \leqslant 50$	$0,7 < r_{corr} \leqslant 2,1$	$0,6 < r_{corr} \leqslant 1,3$	—
C 4	$g/(m^2 \cdot a)$	$400 < r_{corr} \leqslant 650$	$15 < r_{corr} \leqslant 30$	$12 < r_{corr} \leqslant 25$	$2 < r_{corr} \leqslant 5$
	µm/a	$50 < r_{corr} \leqslant 80$	$2,1 < r_{corr} \leqslant 4,2$	$1,3 < r_{corr} \leqslant 2,8$	—
C 5	$g/(m^2 \cdot a)$	$650 < r_{corr} \leqslant 1\,500$	$30 < r_{corr} \leqslant 60$	$25 < r_{corr} \leqslant 50$	$5 < r_{corr} \leqslant 10$
	µm/a	$80 < r_{corr} \leqslant 200$	$4,2 < r_{corr} \leqslant 8,4$	$2,8 < r_{corr} \leqslant 5,6$	—

NOTES

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

2 The corrosion rates expressed in grams per square metre year $[g/(m^2 \cdot a)]$ have been recalculated in micrometres per year (µm/a) and rounded.

3 The materials are characterized in ISO 9226.

4 Aluminium experiences localized corrosion but the corrosion rates shown in the table were calculated as uniform corrosion. Maximum pit depth is a better indicator of potential damage, but this characteristic cannot be evaluated after the first year of exposure.

5 Corrosion rates exceeding the upper limits in category C 5 represent environments beyond the scope of this International Standard.

10 Classification of corrosivity based on environmental data

10.1 The pollution categories and time of wetness categories are used for the determination of the corrosivity category for individual metals.

10.2 Corrosivity categories corresponding to the classified time of wetness and pollution categories are given in table 6.

10.3 In the case of the time of wetness category τ_1, the corrosivity category is always 1, except in highly polluted indoor atmospheres.

Table 6 — Estimated corrosivity categories of the atmosphere

Unalloyed carbon steel															
	τ_1			τ_2			τ_3			τ_4			τ_5		
	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3
P_0-P_1	1	1	1 or 2	1	2	3 or 4	2 or 3	3 or 4	4	3	4	5	3 or 4	5	5
P_2	1	1	1 or 2	1 or 2	2 or 3	3 or 4	3 or 4	3 or 4	4 or 5	4	4	5	4 or 5	5	5
P_3	1 or 2	1 or 2	2	2	3	4	4	4 or 5	5	5	5	5	5	5	5
Zinc and copper															
	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3
P_0-P_1	1	1	1	1	1 or 2	3	3	3	3 or 4	3	4	5	3 or 4	5	5
P_2	1	1	1 or 2	1 or 2	2	3	3	3 or 4	4	3 or 4	4	5	4 or 5	5	5
P_3	1	1 or 2	2	2	3	3 or 4	3	3 or 4	4	4 or 5	5	5	5	5	5
Aluminium															
	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3
P_0-P_1	1	2	2	1	2 or 3	4	3	3 or 4	4	3	3 or 4	5	4	5	5
P_2	1	2	2 or 3	1 or 2	3 or 4	4	3	4	4 or 5	3 or 4	4	5	4 or 5	5	5
P_3	1	2 or 3	3	3 or 4	4	4	3 or 4	4 or 5	5	4 or 5	5	5	5	5	5

NOTE — Corrosivity is expressed as the numerical part of the corrosivity category code (for example: 1 instead of C 1).