INTERNATIONAL STANDARD

# ISO 11844-1

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# Corrosion of metals and alloys — Classification of low corrosivity of indoor atmospheres —

## Part 1: Determination and estimation of indoor corrosivity

*Corrosion des métaux et alliages — Classification de la corrosivité faible des atmosphères d'intérieur —*

*Partie 1: Détermination et estimation de la corrosivité des atmosphères d'intérieur*



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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 11844-1 was prepared by Technical Committee ISO/TC 156, *Corrosion of metals and alloys*.

ISO 11844 consists of the following parts, under the general title *Corrosion of metals and alloys — Classification of low corrosivity of indoor atmospheres*:

— *Part 1: Determination and estimation of indoor corrosivity*

— *Part 2: Determination of corrosion attack in indoor atmospheres*

— *Part 3: Measurement of environmental parameters affecting indoor corrosivity*

## Introduction

Metals, alloys and metallic coatings are subject to atmospheric corrosion under the impact of air humidity, especially when gaseous and solid substances of atmospheric pollution co-impact. Corrosivity data are of fundamental importance for derivation of suitable corrosion protection, or for evaluation of serviceability of metal elements of a product.

ISO 9223 classifies the atmospheric environment into 5 corrosivity categories.

Low-corrosivity indoor atmospheres are indoor atmospheres with C 1 (very low) or C 2 (low) corrosivity categories according to ISO 9223.

The classification in ISO 9223 is too broad for some purposes in low-corrosivity indoor atmospheres, e.g. places where electronic devices, sophisticated technical products, or works of art and historical objects are stored.

For such purposes, it is necessary to subdivide the corrosivity categories C 1 (very low) and C 2 (low) into indoor corrosivity categories in this part of ISO 11844.

The evaluation of low-corrosivity indoor atmospheres can be accomplished by direct determination of corrosion attack of selected metals (see ISO 11844-2) or by measurement of environmental parameters (see ISO 11844-3) which may cause corrosion on metals and alloys.

This part of ISO 11844 describes general procedures for derivation and estimation of indoor corrosivity categories.

A general approach to classification of corrosivity in indoor atmospheres is given in the scheme shown in Figure 1.

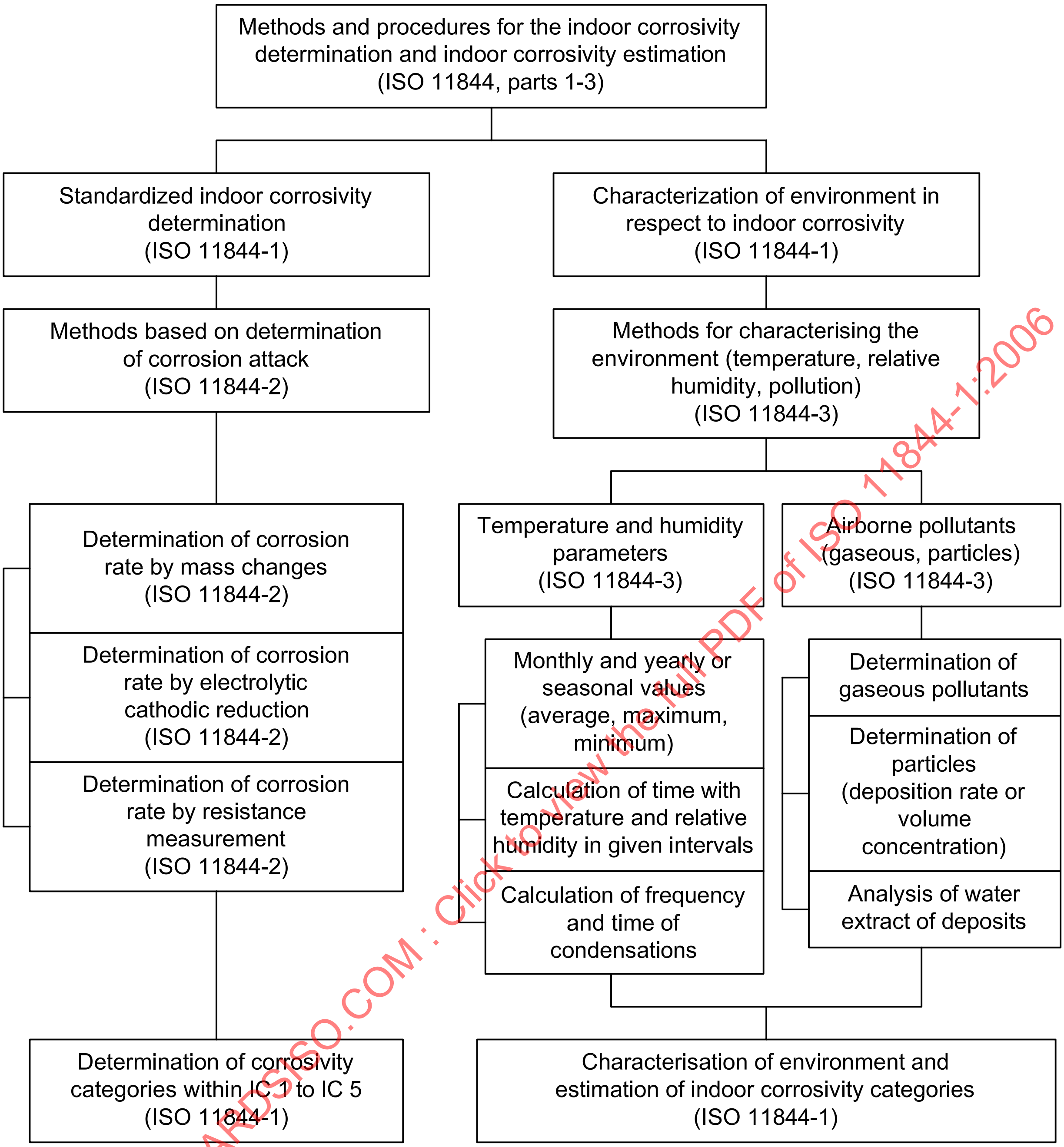


**Figure 1 — Scheme for classification of low corrosivity in indoor atmospheres**

# Corrosion of metals and alloys — Classification of low corrosivity of indoor atmospheres —

## Part 1: Determination and estimation of indoor corrosivity



## 1 Scope

This part of ISO 11844 deals with the classification of low corrosivity of indoor atmospheres.

The aim of this part of ISO 11844 is

— to characterise indoor atmospheric environments of low corrosivity that can affect metals and metallic coatings during storage, transport, installation or operational use,

— to set a consistent way of indoor corrosivity classification, and

— to prescribe procedures for derivation and estimation of indoor corrosivity categories.

This part of ISO 11844 specifies technical metals, whose corrosion attack after a defined exposure period is used for determination of corrosivity categories of indoor atmospheres of low corrosivity.

This part of ISO 11844 defines corrosivity categories of indoor atmospheres according to corrosion attack on standard specimens.

This part of ISO 11844 indicates important parameters of indoor atmospheres that can serve as a basis for an estimation of indoor corrosivity.

Selection of a method for determination of corrosion attack, description of standard specimens, its exposure conditions and evaluation are the subject of ISO 11844-2. Measurement of environmental parameters affecting indoor corrosivity is the subject of ISO 11844-3.

## 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 9223:1992, *Corrosion of metals and alloys — Corrosivity of atmosphere — Classification*

ISO 11844-2:2005, *Corrosion of metals and alloys — Classification of low corrosivity of indoor atmospheres — Part 2: Determination of corrosion attack in indoor atmospheres*

 

ISO 11844-3:—[1]), *Corrosion of metals and alloys — Classification of low corrosivity of indoor atmospheres — Part 3: Measurement of environmental parameters affecting indoor corrosivity*

IEC 60654-4:1987, *Operating conditions for industrial-process measurement and control equipment. Part 4: Corrosive and erosive influences*

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

**3.1**
**corrosivity of atmospheres**
ability of the atmosphere to cause corrosion in a given corrosion system (e.g. atmospheric corrosion of a given metal or alloy)

[ISO 9223:1992, definition 3.1]

**3.2**
**temperature-humidity complex**
combined effect of temperature and relative humidity on the corrosivity of the atmosphere

[ISO 9223:1992, definition 3.5]

**3.3**
**time of wetness**
period during which a metallic surface is covered by adsorptive and/or liquid films of electrolyte that are capable of causing atmospheric corrosion

[ISO 9223:1992, definition 3.2]

**3.3.1**
**calculated time of wetness**
time of wetness estimated from the temperature-humidity complex

[ISO 9223:1992, definition 3.2.1]

**3.3.2**
**experimental time of wetness**
time of wetness indicated directly by various measuring systems

[ISO 9223:1992, definition 3.2.2]

**3.4**
**atmospheric pollution**
specific corrosion-active substances, gases or suspended particles in the air (both natural and the result of human activity)



## 4 Symbols and abbreviations

IC corrosivity categories of indoor atmospheres.

$r_{corr}$ corrosion rate derived from mass-loss measurement after an exposure of one year.

$r_{mi}$ rate of mass increase after an exposure of one year.

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1) To be published.

# 5 Classification of corrosivity

## 5.1 General

The corrosivity of indoor atmospheres can be classified either by determination of the corrosion attack on standard specimens of selected standard metals as given in Clause 6 or, where this is not possible, by estimation of corrosivity based on the knowledge of humidity, temperature and pollution conditions as described in Clause 7 and informative Annexes B, C and D.

Estimation of corrosivity as described in 7.2. and Annexes C and D may lead to wrong conclusions. Therefore, the determination of corrosivity by measurement of the corrosion attack on standard specimens is strongly recommended.

## 5.2 Categories of indoor corrosivity

For the purpose of this part of ISO 11844, indoor atmospheres are classified into 5 corrosivity categories denoted IC 1 to IC 5. The classification is given in Table 1.

**Table 1 — Corrosivity categories of indoor atmospheres**

| Indoor corrosivity category | |
|---|---|
| IC 1 | Very low indoor corrosivity |
| IC 2 | Low indoor corrosivity |
| IC 3 | Medium indoor corrosivity |
| IC 4 | High indoor corrosivity |
| IC 5 | Very high indoor corrosivity |

# 6 Determination of indoor atmospheric corrosivity

The determination of corrosivity of indoor atmospheres is based on measurements of corrosion attack on standard specimens of four reference metals after an exposure for one year in accordance with ISO 11844-2. From the mass loss or mass increase, the indoor corrosivity category for each metal is determined from Table 2.

Metals complement each other in the classification of indoor corrosivity for a given environment.

# 7 Characterization of indoor atmospheres with respect to indoor corrosivity

## 7.1 General

Environmental characteristics are informative and allow assessment of specific corrosion effects with regard to individual metals and metallic coatings.

Methods for characterization and measurement of environmental parameters in indoor atmospheres are given in ISO 11844-3.

This method of corrosivity estimation is, in many cases, oversimplified and may give misleading results.

An estimation of corrosivity is based on

— climatic influences (outdoor situation including pollution),

— indoor microclimate influences, and

— indoor gaseous and particle pollution.

The corrosivity of an indoor atmosphere increases with higher humidity and depends on the type and level of pollution.

Frequency of variation of relative humidity (RH) and temperature ($T$) in intervals, and frequency and time of condensation, are important characteristics.

Indoor atmospheres are polluted by the components from external and internal sources. Typical pollutants are $SO_2$, $NO_2$, $O_3$, $H_2S$, $Cl_2$, $NH_3$, HCl, $HNO_3$, $Cl^-$, $NH_4^+$, organic acids, aldehydes and particles (see informative Annex B).

Corrosion for many of the metals is significantly influenced by the synergistic effects of different pollutants.

Metals and metallic coatings have their own specific corrosion behaviour in indoor atmospheres (see informative Annex C).

## 7.2 Estimation of indoor corrosivity

**7.2.1** Characterization of the environment summarised in a guideline (Annex D), forms a basis for indoor corrosivity estimation. Description of typical environments related to the estimation of indoor corrosivity categories is presented in Table D.3.

**7.2.2** Important factors of indoor corrosion are defined as the highest levels of measured environmental parameters and as a description of other and specific environmental influences affecting indoor corrosion of metals.

**7.2.3** The determination of indoor corrosivity categories is illustrated in Tables 2 and 3.



**Table 2 — Classification of corrosivity of indoor atmospheres based on corrosion rate measurements by mass loss determination of standard specimens**

| Corrosivity category | | Corrosion rate ($r_{corr}$) mg/(m²·a) | | | |
|---|---|---|---|---|---|
| | | **Carbon steel** | **Zinc** | **Copper** | **Silver** |
| IC 1 | Very low indoor | $r_{corr} \leqslant 70$ | $r_{corr} \leqslant 50$ | $r_{corr} \leqslant 50$ | $r_{corr} \leqslant 170$ |
| IC 2 | Low indoor | $70 < r_{corr} \leqslant 1\,000$ | $50 < r_{corr} \leqslant 250$ | $50 < r_{corr} \leqslant 200$ | $170 < r_{corr} \leqslant 670$ |
| IC 3 | Medium indoor | $1\,000 < r_{corr} \leqslant 10\,000$ | $250 < r_{corr} \leqslant 700$ | $200 < r_{corr} \leqslant 900$ | $670 < r_{corr} \leqslant 3\,000$ |
| IC 4 | High indoor | $10\,000 < r_{corr} \leqslant 70\,000$ | $700 < r_{corr} \leqslant 2\,500$ | $900 < r_{corr} \leqslant 2\,000$ | $3\,000 < r_{corr} \leqslant 6\,700$ |
| IC 5 | Very high indoor | $70\,000 < r_{corr} \leqslant 200\,000$ | $2\,500 < r_{corr} \leqslant 5\,000$ | $2\,000 < r_{corr} \leqslant 5\,000$ | $6\,700 < r_{corr} \leqslant 16\,700$ |

**Table 3 — Classification of corrosivity of indoor atmospheres based on rate of mass increase measured with standard specimens**

| Corrosivity category | | Rate of mass increase ($r_{mi}$) mg/(m²·a) | | | |
|---|---|---|---|---|---|
| | | **Carbon steel** | **Zinc** | **Copper** | **Silver** |
| IC 1 | Very low indoor | $r_{mi} \leqslant 70$ | $r_{mi} \leqslant 50$ | $r_{mi} \leqslant 25$ | $r_{mi} \leqslant 25$ |
| IC 2 | Low indoor | $70 < r_{mi} \leqslant 700$ | $50 < r_{mi} \leqslant 250$ | $25 < r_{mi} \leqslant 100$ | $25 < r_{mi} \leqslant 100$ |
| IC 3 | Medium indoor | $700 < r_{mi} \leqslant 7\,000$ | $250 < r_{mi} \leqslant 700$ | $100 < r_{mi} \leqslant 450$ | $100 < r_{mi} \leqslant 450$ |
| IC 4 | High indoor | $7\,000 < r_{mi} \leqslant 50\,000$ | $700 < r_{mi} \leqslant 2\,500$ | $450 < r_{mi} \leqslant 1\,000$ | $450 < r_{mi} \leqslant 1\,000$ |
| IC 5 | Very high indoor | $50\,000 < r_{mi} \leqslant 150\,000$ | $2\,500 < r_{mi} \leqslant 5\,000$ | $1\,000 < r_{mi} \leqslant 2\,500$ | $1\,000 < r_{mi} \leqslant 2\,500$ |

NOTE 1 The specification of standard specimens of carbon steel, zinc, copper and silver, and the procedures for evaluation of the mass change is given in ISO 11844-2.

NOTE 2 Corrosion rate measurements by mass loss determination of standard specimens (Table 2) is preferably used for higher indoor corrosivity categories. Also, in atmospheres where a high deposition of particles is expected, the mass loss determination is preferred.

NOTE 3 An approximate relation between the corrosivity categories in this part of ISO 11844, and severity levels in ANSI/ISA –S71.04-1985, is given in Annex A (informative).

NOTE 4 The upper limit of corrosivity category IC 3 corresponds roughly to the upper limit of corrosivity category C 1 according to ISO 9223.

NOTE 5 The upper limit of corrosivity category IC 5 corresponds roughly to the upper limit of corrosivity category C 2 according to ISO 9223.

# Annex A
(informative)

## Relation between ISO, IEC and ISA classification systems

ISO 9223:1992, IEC 60654-4:1987, Appendix B and ANSI/ISA S71.04-1985 all include corrosion rate determination for classifying environmental conditions.

ISO 9223:1992 gives corrosivity categories based on corrosion of carbon steel, zinc, copper and aluminium, expressed as mass loss after one year of exposure.

IEC 60654-4:1987, Appendix B classifies the reactivity of the environment, measuring corrosion film thickness on copper after 30 days of exposure.

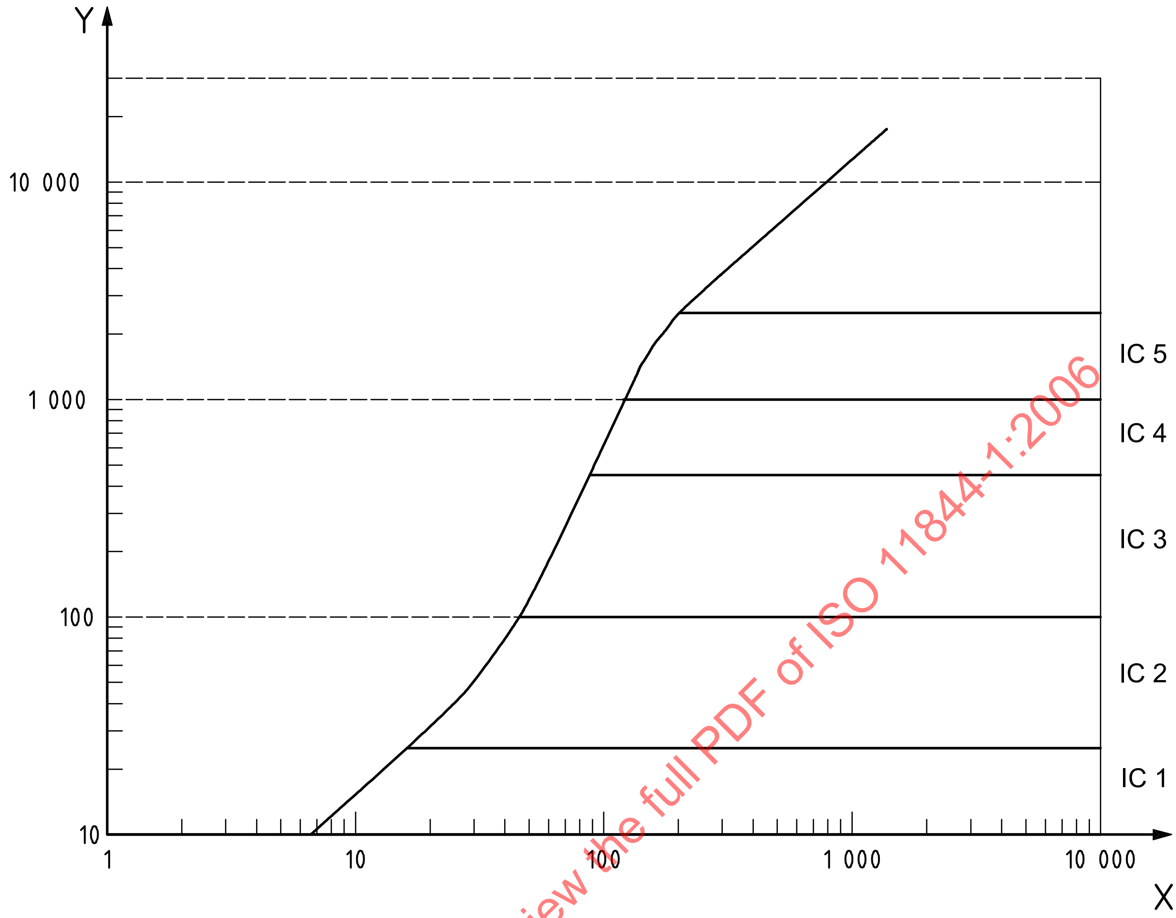
ANSI/ISA S71.04-1985 gives severity levels, based on copper corrosion measured as corrosion film thickness after 30 days of exposure.

In order to compare these classification systems, corrosion figures for copper are selected, copper being the only metal common to all standards. Furthermore, all corrosion rates have to be transformed to the same unit. Corrosion figures given in the standards are first expressed as mass increase. Secondly, for the IEC and ISA standards, mass increase after 30 days of exposure is transformed to one year. The correlation between 30 days and one year of exposure is graphically presented in Figure A.1. The graphical representation is based on expressions given in the IEC and ISA standards.

Please note that extrapolation in time is not very reliable and cannot be done at all for low corrosion rates.





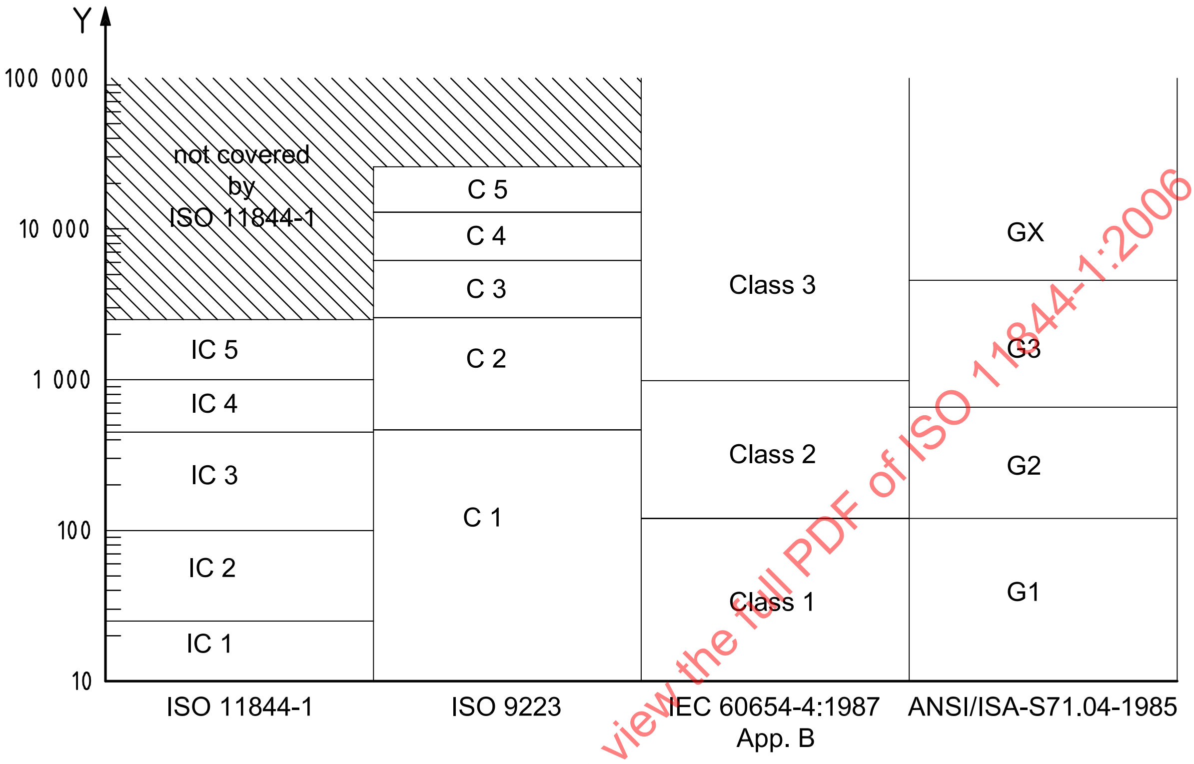

**Key**

X Mass increase after 30 days of exposure ($mg/m^2$)

Y Mass increase after 1 year of exposure ($mg/m^2$)

**Figure A.1 — Copper mass increase, transformation between 30 days and one year of exposure**

In Figure A.2, the classification systems of the different standards are compared. The comparison is based on copper corrosion rate, assuming that CuO, $Cu_4SO_4(OH)_6$ and $Cu_2S$ are the predominant corrosion products. Corrosion rate figures given in the standards are all transformed to copper mass increase after one year of exposure




**Key**

Y Mass increase after 1 year of exposure (mg/m$^2$)

**Figure A.2 — Copper corrosivity classification according to ISO, IEC and ISA**



# Annex B
(informative)

## Outdoor and indoor concentrations of some of the most important pollutants in different types of environments

**Table B.1**

| Pollutant | Concentration (yearly average value) µg/m³<br>outdoor | | indoor |
|---|---|---|---|
| $SO_2$ | rural:<br>urban:<br>industrial: | 2 - 15<br>10 - 100<br>50 - 250 | non-process rooms:<br>(30 - 50) % lower than the outdoor level<br>process rooms:<br>up to 2 000 |
| $NO_2$ | rural:<br>urban: | 2 - 20<br>20 - 150 | only minor differences between outdoor and indoor concentrations of $NO_2$ unless close to the source |
| $O_3$ | | 20 - 80 | indoor concentrations are in most cases lower than outdoor (1 - 30) |
| $H_2S$ | normally:<br>industry and animal shelter: | 1 - 5<br>20 - 250 | no reduction indoors; indoor levels are sometimes higher than outdoor levels |
| $Cl_2$ | normally<br>very low concentrations:<br>at industry plants: | <br>0,1<br>up to 20 | indoor concentrations are in most cases low, in process rooms in the pulp and paper industry, observed concentration up to 50 |
| $Cl^-$ | depending on geographic situation | 0,1 - 200 | lower levels than in outdoor air, reduction depending on the ventilation and filter systems used |
| $NH_3$ | normally<br>low concentrations:<br>close to source: | <br>< 20<br>up to 3 000 | no reduction indoors |
| organic components (acids, aldehydes) | specific industrial pollution | | important component of indoor pollution, indoor concentrations are affected by human activity |
| particles (dust deposits) | rural:<br>urban and industrial: | largely inert components<br>corrosion-active components ($SO_4^{2-}$, $NO_3^-$, $Cl^-$, lime) | non-process rooms:<br>large reduction of outdoor concentration<br>process rooms:<br>specific aggressive components |
| soot | rural:<br>urban and industrial: | < 5<br>up to 75 | non-process rooms:<br>large reduction of outdoor concentration<br>process rooms:<br>up to 200 |



# Annex C
(informative)

## General characterisation of metal corrosion in indoor atmospheres

The basic corrosion factors in indoor atmospheres are temperature-humidity characteristics and pollution by gaseous and solid substances. The importance of humidity and temperature impact cannot be expressed simply and consistently by the time of wetness defined in ISO 9223.

Type of indoor atmosphere can significantly influence the level of each atmospheric parameter, as well as its distribution. Pollutant concentrations are generally lower in indoor environments, except for cases of internal sources of pollution.

The basic characteristics of indoor atmospheric environments, in relation to corrosion of metals and various ways of their exploitation, are represented by the following.

a) Temperature, humidity and their changes cannot be derived directly from outdoor conditions and depend on the purpose of use of the indoor space in unconditioned atmospheric environments.

b) Transfer of outdoor pollution depends on the way and degree of sheltering, or on controlled conditions in indoor atmospheric environments (filtration, conditioning).

c) Successive cumulation of particles and increasing conductivity of deposits water extracts can change corrosivity indoors for longer exposures.

d) It is difficult to determine a relatively limited selection of the decisive corrosion factors and levels of their importance in indoor atmospheric environments; one of the reasons being that metals show specific sensitivity to individual environmental factors.

Besides emissions formed outside objects, indoor environments are polluted by substances formed by

— release from building and construction materials and materials used for furnishing and equipment of interiors,

— human presence, which means products of metabolism including: formaldehyde, formic acid, acetic acid, butyric acid, acetone, ammonia, $CO_2$, $H_2S$, water vapour, microbes, etc., and

— human activity, which means products related to operation and production activities.

The corrosion behaviour of important technical metals is specified in Table C.1.



**Table C.1 — Corrosion behaviour of basic metal representatives in indoor environments**

| Metal | Corrosion behaviour |
|---|---|
| Steel | spontaneously forms oxides and other corrosion products with a limited protecting ability<br>very sensitive to relative humidity and to sulfurdioxide<br>the central transformations are the oxidation and reduction processes that link $Fe^{2+}$ and $Fe^{3+}$<br>indoors, at the relative humidity higher than about 50 % multilayers of water will be adsorbed; particularly at presence of particles corrosion process analogous to the outdoor corrosion process with lower corrosion rate will occur |
| Zinc | the indoor zinc corrosion rate is affected by relative humidity, the deposited particles or the zinc corrosion products appear to absorb sufficient moisture to stimulate chemical degradation process<br>sensitive to indoor organic compounds<br>synergistic effect of $SO_2$, $NO_2$ and $O_3$<br>indoor zinc tarnish often starts at points where dust particles have settled on the surface, indoor zinc surfaces have upon them adherent particles containing large concentrations of chloride and sulphate ions<br>the indoor corrosion rates can be constrained to negligible levels by maintaining moderate relative humidity |
| Copper | sensitive to relative humidity<br>sensitive to a broad range of pollutants<br>significant influence of $H_2S$, sulfur dioxide<br>little influence of $NO_2$, $Cl_2$ and $NH_3$<br>synergistic effect of $SO_2$, $NO_2$ and $O_3$<br>the most severe contaminant is hydrogen sulfide, especially in combination with chlorine<br>corrosion rate shows a general decrease with time (particularly for the less corrosive sites) |
| Silver | corrodes indoors at approximately equivalent rates to outdoors, the reason for this similarity is supposed to be independence of silver corrosion rate on relative humidity<br>the corrosion rate is governed by the reaction with $H_2S$, rather than by the acidity of the pollutants<br>corrosion rate is dependent on the reduced sulfur pollutant concentration<br>gaseous hydrogen peroxide, which is sometimes present, strongly accelerates corrosion<br>quite sensitive to molecular chlorine<br>insensitive to organic acids and has not been reported to be reactive towards most other common indoor organic molecules and radicals<br>corrosion rate decreases with time |
| Nickel | in mild environments, suffers very little from visible corrosion<br>corrosion is, to a large extent, determined by the sulfur dioxide content and relative humidity<br>the corrosion rate in complex polluted environments is strongly dependent on relative humidity<br>synergistic effect of $SO_2$, $NO_2$ and $O_3$ |
| Lead | quite reactive to common atmospheric gases, forming of insulating corrosion-product layers<br>indoor exposures produce lead carboxylates<br>relatively sensitive to air pollution by organic aldehydes and acids |



**Table C.1** (*continued*)

| Metal | Corrosion behaviour |
|---|---|
| Tin | quickly covered with an oxide film with good corrosion protection<br>chlorine and chloride-containing pollutants attack thin oxide films and increase the rate of corrosion, especially in combination with high levels of relative humidity |
| Aluminium | rapidly forms an insulating oxide layer<br>low rates of corrosion in most indoor environments<br>chloride ions stimulate localised attack on the surface<br>highest corrosion rate in environments characterised by high levels of chlorides in combination with high relative humidity |
| Gold | gold, as a very noble metal, does not corrode in normal indoor environments<br>corrosion behaviour of gold-plated surfaces is influenced by pollutants in a complex manner<br>if gold is used as thin coating, pore corrosion can occur even in a rather mild environment<br>pore corrosion, resulting from corrosion of a nickel undercoating, or of a copper substrate, is stimulated by high levels of relative humidity, chlorine, sulfur dioxide and hydrogen sulfide |
| Stainless steel | in mild environments without corrosion effect<br>deposits of particles with ionic components (chlorides) can stimulate localised attack on surfaces in environments with higher relative humidity |



# Annex D
(informative)

# Guideline for estimation of indoor corrosivity

## D.1 General description of type of indoor atmospheric environment

Estimation of indoor corrosivity is based on the knowledge of humidity, temperature and pollution characteristics of the given environment. The corrosion effect of these parameters is usually interdependent.

The general description of the indoor atmospheric environment concerning working conditions forms the first step in the procedure of the environmental characterization.

Methods for measurement of environmental parameters affecting indoor corrosivity are specified in ISO 11844-3.

Description of type of indoor atmospheric environment:

— production room, museum, church, laboratory, etc.;

— heated, unheated, conditioned;

— ventilated, without ventilation;

— seasonal variations;

— specific influences.



## D.2 Temperature

Important temperature characteristics are

— temperature average (monthly, seasonal, annual),

— minimum and maximum temperature (monthly, seasonal, annual), and

— character of temperature changes (fluent, abrupt, accidental).

The measurement period is preferably one year, or one month for each yearly season. Shorter periods should cover typical seasonal or operational situations.

## D.3 Relative humidity

Important relative humidity characteristics are

— humidity average (monthly, seasonal, annual),

— minimum and maximum humidity (monthly, seasonal, annual),

— time with relative humidity in a given interval, and

— level for average of relative humidity (see Table D.1).