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Paints and varnishes — Corrosion protection of steel structures by protective paint systems —

Part 2: Classification of environments

Peintures et vernis — Anticorrosion des structures en acier par systèmes de peinture —

Partie 2: Classification des environnements

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 35, *Paints and varnishes*, Subcommittee SC 14, *Protective paint systems for steel structures*.

This second edition cancels and replaces the first edition (ISO 12944-2:1998), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the normative references have been updated;

— 4.2.1 "General" has been added;

— the units in Table 1 have been corrected;

— the bibliography has been updated;

— the text has been editorially revised.

A list of all parts in the ISO 12944 series can be found on the ISO website.

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Introduction

Unprotected steel in the atmosphere, in water and in soil is subjected to corrosion that can lead to damage. Therefore, to avoid corrosion damage, steel structures are normally protected to withstand the corrosion stresses to which they will be subjected during the service life required of the structure.

There are different ways of protecting steel structures from corrosion. ISO 12944 (all parts) deals with protection by paint systems and covers, in the various parts, all features that are important in achieving adequate corrosion protection. Additional or other measures are possible but require particular agreement between the interested parties.

In order to ensure effective corrosion protection of steel structures, owners of such structures, planners, consultants, companies carrying out corrosion protection work, inspectors of protective coatings and manufacturers of coating materials need to have at their disposal state-of-the-art information in concise form on corrosion protection by paint systems. It is vital that such information is as complete as possible, unambiguous and easily understandable to avoid difficulties and misunderstandings between the parties concerned with the practical implementation of protection work.

ISO 12944 (all parts) is intended to give this information in the form of a series of instructions. It is written for those who have some technical knowledge. It is also assumed that the user of ISO 12944 (all parts) is familiar with other relevant International Standards, in particular those dealing with surface preparation.

Although ISO 12944 (all parts) does not deal with financial and contractual questions, attention is drawn to the fact that, because of the considerable implications of inadequate corrosion protection, non-compliance with requirements and recommendations given in ISO 12944 (all parts) can result in serious financial consequences.

ISO 12944-1 defines the overall scope of ISO 12944. It gives some basic terms and definitions and a general introduction to the other parts of ISO 12944. Furthermore, it includes a general statement on health, safety and environmental protection, and guidelines for using ISO 12944 (all parts) for a given project.

This document describes the environmental impact on steel structures. It covers structures exposed to the atmosphere as well as those immersed in water or buried in soil. For different atmospheric environments, a classification system based on corrosivity categories is also presented. Different environments for immersed and buried structures are also described. All these environments are relevant to the choice of protective paint systems.

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Paints and varnishes — Corrosion protection of steel structures by protective paint systems —

Part 2: Classification of environments

1 Scope

This document deals with the classification of the principal environments to which steel structures are exposed, and the corrosivity of these environments. This document

— defines atmospheric-corrosivity categories, based on mass loss (or thickness loss) by standard specimens, and describes typical natural atmospheric environments to which steel structures are exposed, giving advice on the estimation of the corrosivity,

— describes different categories of environment for structures immersed in water or buried in soil, and

— gives information on some special corrosion stresses that can cause a significant increase in corrosion rate or place higher demands on the performance of the protective paint system.

The corrosion stresses associated with a particular environment or corrosivity category represent one essential parameter governing the selection of protective paint systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 12944-1, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 1: General introduction*

ISO 12944-3, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 3: Design considerations*

ISO 12944-4, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 4: Types of surface and surface preparation*

ISO 12944-5, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 5: Protective paint systems*

ISO 12944-6, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 6: Laboratory performance test methods*

ISO 12944-7, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 7: Execution and supervision of paint work*

ISO 12944-8, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 8: Development of specifications for new work and maintenance*

ISO 12944-9, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 9: Protective paint systems and laboratory performance test methods for offshore and related structures*

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12944-1, ISO 12944-3, ISO 12944-4, ISO 12944-5, ISO 12944-6, ISO 12944-7, ISO 12944-8, ISO 12944-9 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
corrosivity
ability of an environment to cause corrosion of a metal in a given corrosion system

[SOURCE: ISO 8044:2015, 2.14]

3.2
climate
weather prevailing at a given location or in a given area, as established statistically by meteorological parameters recorded over a prolonged period

3.3
atmosphere
mixture of gases, and normally also aerosols and particles, that surrounds a given object

3.4
atmospheric corrosion
corrosion with the earth's *atmosphere* (3.3) at ambient temperature as the corrosive environment

[SOURCE: ISO 8044:2015, 3.4]

3.5
type of atmosphere
characterization of the *atmosphere* (3.3) on the basis of the corrosive agents present and their concentration

Note 1 to entry: The main corrosive agents are gases (especially sulfur dioxide) and salts (especially chlorides and/or sulfates).

3.6
local environment
atmospheric conditions prevailing around a constituent element of a structure

Note 1 to entry: These conditions determine the *corrosivity* (3.1) category and include both meteorological and pollution parameters.

3.7
micro-environment
environment at the interface between a constituent element of a structure and its surroundings

Note 1 to entry: The micro-environment is one of the decisive factors in the assessment of corrosion stresses.

3.8
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

Note 1 to entry: Guidance values for time of wetness can be calculated from temperature and relative humidity by summing the hours during which the relative humidity is above 80 % and, at the same time, the temperature is above 0 °C.

[SOURCE: ISO 9223:2012, 3.5, modified — Note 1 to entry has been added.]

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4 Corrosion stresses due to the atmosphere, water and soil

4.1 Atmospheric corrosion

Atmospheric corrosion is a process that takes place in a film of moisture on the metal surface. The moisture film can be so thin that it is invisible to the naked eye.

The corrosion rate is increased by the following factors:

— an increase in the relative humidity;

— the occurrence of condensation (when the surface temperature is at or below the dew point);

— an increase in the amount of pollution in the atmosphere (the corrosive pollutants can react with the steel and can form deposits on the surface).

Experience has shown that significant corrosion is likely to take place if the relative humidity is above 80 % and the temperature above 0 °C. However, if pollutants and/or hygroscopic salts are present, corrosion occurs at much lower humidity levels.

The atmospheric humidity and air temperature in a particular region of the world will depend on the climate prevailing in that part of the world. A brief description of the most important climates is given in Annex A.

The location of the constituent element of a structure also influences corrosion. Where structures are exposed to the open air, climatic parameters such as rain and sunshine and pollutants in the form of gases or aerosols affect corrosion. Under cover, the climatic influences are reduced. Indoors, the effect of atmospheric pollutants is reduced, although a locally high corrosion rate caused by poor ventilation, high humidity or condensation is possible.

For the estimation of the corrosion stresses, an appreciation of the local environment and the micro-environment is essential. Examples of decisive micro-environments are the underside of a bridge (particularly over water), the roof of an indoor swimming pool, and the sunny and shady sides of a building.

4.2 Corrosion in water and soil

4.2.1 General

Special care shall be taken when considering structures that are partly immersed in water or partly buried in soil. Corrosion under such conditions is often restricted to a small part of the structure where the corrosion rate can be high. Exposure tests for estimating the corrosivity of water or soil environments are not recommended. However, different immersion/burial conditions can be described.

4.2.2 Structures immersed in water

The type of water — fresh, brackish or salt — has a significant influence on the corrosion of steel. Corrosivity is also influenced by the oxygen content of the water, the type and quantity of dissolved substances and the water temperature. Animal or vegetable growth can accelerate corrosion.

Three different zones for immersion in water can be defined:

— the underwater zone is the area which is permanently exposed to water;

— the intermediate (fluctuating level) zone is the area in which the water level changes due to natural or artificial effects, thus giving rise to increased corrosion due to the combined impact of water and the atmosphere;

— the splash zone is the area wetted by wave and spray action which can give rise to exceptionally high corrosion stresses, especially with sea water.

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4.2.3 Structures buried in soil

Corrosion in soil is dependent on the mineral content of the soil and the nature of these minerals, and on the organic matter present, the water content and the oxygen content. The corrosivity of soil is strongly influenced by the degree of aeration. The oxygen content will vary and corrosion cells can be formed. Where major steel structures such as pipelines, tunnels, tank installations, etc., pass through different types of soil, soils with differing oxygen contents, soils with differing ground water levels, etc., increased local corrosion (pitting) can occur due to formation of corrosion cells.

For further details, see EN 12501-1.

Different types of soil and differences in soil parameters are not considered as classification criteria in this document.

4.3 Special cases

For the selection of a protective paint system, special stresses to which a structure is subjected and special situations in which a structure is located shall also be taken into account. Both the design and the use of the structure can lead to corrosion stresses not taken into consideration in the classification system given in Clause 5. Examples of such special cases are given in Annex B.

5 Classification of environments

5.1 Atmospheric-corrosivity categories

5.1.1 According to ISO 9223, atmospheric environments are classified into six atmospheric-corrosivity categories:

— C1 very low corrosivity

— C2 low corrosivity

— C3 medium corrosivity

— C4 high corrosivity

— C5 very high corrosivity

— CX extreme corrosivity

NOTE CX covers different extreme environments. One specific extreme environment is the offshore environment covered by ISO 12944-9. Other extreme environments are not covered in the other parts of ISO 12944.

5.1.2 To determine corrosivity categories, the exposure of standard specimens is strongly recommended. Table 1 defines the corrosivity categories in terms of the mass or thickness loss of such standard specimens made of low-carbon steel and/or zinc after the first year of exposure. For details of standard specimens and the treatment of the specimens prior to and after exposure, see ISO 9226. Extrapolation of the mass or thickness losses to one year from shorter exposure times, or back-extrapolation from longer times, will not give reliable results and is therefore not permitted. The mass or thickness losses obtained for steel and zinc specimens can sometimes give different categories. In such cases, the higher corrosivity category shall be taken.

If it is not possible to expose standard specimens in the actual environment of interest, the corrosivity category may be estimated by simply considering the examples of typical environments given in

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Table 1. The examples listed are informative and might occasionally be misleading. Only the actual measurement of mass or thickness loss will give the correct classification.

NOTE Corrosivity categories can also be estimated by considering the combined effect of the following environmental factors: yearly time of wetness, yearly mean concentration of sulfur dioxide and yearly mean deposition of chloride (see ISO 9223).

Table 1 — Atmospheric-corrosivity categories and examples of typical environments

Corrosivity category	Mass loss per unit surface/thickness loss (after first year of exposure)				Examples of typical environments (informative only)	
	Low-carbon steel		Zinc		Exterior	Interior
	Mass loss g/m²	Thickness loss µm	Mass loss g/m²	Thickness loss µm		
C1 very low	≤ 10	≤ 1,3	≤ 0,7	≤ 0,1	—	Heated buildings with clean atmospheres, e.g. offices, shops, schools, hotels
C2 low	> 10 to 200	> 1,3 to 25	> 0,7 to 5	> 0,1 to 0,7	Atmospheres with low level of pollution: mostly rural areas	Unheated buildings where condensation can occur, e.g. depots, sports halls
C3 medium	> 200 to 400	> 25 to 50	> 5 to 15	> 0,7 to 2,1	Urban and industrial atmospheres, moderate sulfur dioxide pollution; coastal areas with low salinity	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies
C4 high	> 400 to 650	> 50 to 80	> 15 to 30	> 2,1 to 4,2	Industrial areas and coastal areas with moderate salinity	Chemical plants, swimming pools, coastal ship and boatyards
C5 very high	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Industrial areas with high humidity and aggressive atmosphere and coastal areas with high salinity	Buildings or areas with almost permanent condensation and with high pollution
CX extreme	> 1 500 to 5 500	> 200 to 700	> 60 to 180	> 8,4 to 25	Offshore areas with high salinity and industrial areas with extreme humidity and aggressive atmosphere and subtropical and tropical atmospheres	Industrial areas with extreme humidity and aggressive atmosphere

NOTE The loss values used for the corrosivity categories are identical to those given in ISO 9223.

5.2 Categories for water and soil

For structures immersed in water or buried in soil, corrosion is normally local in nature and corrosivity categories are difficult to define. However, for the purpose of this document, various environments can be described. In Table 2, four different environments are given together with their designations. See 4.2 for more details.

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Table 2 — Categories for water and soil

Category	Environment	Examples of environments and structures
Im1	Fresh water	River installations, hydro-electric power plants
Im2	Sea or brackish water	Immersed structures without cathodic protection (e.g. harbour areas with structures like sluice gates, locks or jetties)
Im3	Soil	Buried tanks, steel piles, steel pipes
Im4	Sea or brackish water	Immersed structures with cathodic protection (e.g. offshore structures)
NOTE For corrosivity category Im1 and Im3, cathodic protection can be used with a paint system tested accordingly		

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Annex A
(informative)

Climatic conditions

Usually, only general conclusions as to the likely corrosion behaviour can be drawn from the type of climate. In a cold climate or a dry climate, the corrosion rate will be lower than in a temperate climate; it will be greatest in a hot, humid climate and in a marine climate, although considerable local differences can occur.

The main concern is the length of time a structure is exposed to high humidities, also described as time of wetness. Table A.1 provides information on calculated time of wetness and selected characteristics of various types of climate.

Table A.1 — Calculated time of wetness and selected characteristics of various types of climate

Type of climate	Mean value of the annual extreme values			Calculated time of wetness at relative humidity > 80 % and temperature > 0 °C
	Low temperature	High temperature	Highest temperature with relative humidity > 95%	
	°C	°C	°C	h/year
Extremely cold	−65	+32	+20	0 to 100
Cold	−50	+32	+20	150 to 2 500
Cold temperate	−33	+34	+23	2 500 to 4 200
Warm temperate	−20	+35	+25	
Warm dry	−20	+40	+27	10 to 1 600
Mild warm dry	−5	+40	+27	
Extremely warm dry	+3	+55	+28	
Warm damp	+5	+40	+31	4 200 to 6 000
Warm damp, constant	+13	+35	+33	

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Annex B
(informative)

Special cases

B.1 Special situations

B.1.1 Corrosion inside buildings

Corrosion stresses on steel structures located inside buildings sheltered from the outside environment are generally insignificant.

If the interior of the building is only partly sheltered from the outside environment, the corrosion stresses can be assumed to be the same as those associated with the type of atmosphere surrounding the building.

The effect of corrosion stresses due to the climate inside the building can be considerably intensified by the use to which the building is put, and these stresses should be dealt with as special stresses (see B.2). Such stresses can occur in indoor swimming pools with chlorinated water, livestock buildings and other special-purpose buildings.

Cooler areas on structures can be subject to higher corrosion stresses as a result of seasonal formation of condensation.

In cases where surfaces are wetted by electrolytes, even if such wetting is only temporary (e.g. in the case of saturated building materials), particularly stringent corrosion requirements are necessary.

B.1.2 Corrosion in box members and hollow components

Hollow components that are hermetically sealed and thus inaccessible are not subjected to any internal corrosion, whereas tightly sealed casings which are opened occasionally are subject to small corrosion stresses.

The design of sealed hollow components and box members should ensure their airtightness (e.g. no discontinuous welds, tightly bolted joints). Otherwise, depending on the outside temperature, moisture from precipitation or condensation can be drawn in and retained. If this is likely to happen, the internal surfaces have to be protected. Note that condensation is often observed even in boxes which have been designed with tightly sealed casings.

Corrosion is to be expected inside box members and hollow components that are not closed on all sides, and appropriate measures taken. For more information on design, see ISO 12944-3.

B.2 Special stresses

B.2.1 General

Special stresses, for the purposes of ISO 12944 (all parts), are stresses which cause a significant increase in corrosion and/or which make higher demands on the performance of protective paint systems. Owing to the diversity of such stresses, only a selected number of examples can be presented here.

B.2.2 Chemical stresses

Corrosion is aggravated locally by pollutants deriving from the operation of a plant (e.g. acids, alkalis or salts, organic solvents, aggressive gases and dust particles).

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Such stresses occur in the vicinity of e.g. coking works, pickling shops, electroplating plants, dye mills, wood-pulp works, tanneries and oil refineries.

B.2.3 Mechanical stresses

B.2.3.1 In the atmosphere

Abrasive stresses (erosion) can occur due to particles (e.g. sand) being entrained by the wind.

Surfaces which are subject to abrasion are considered to be exposed to moderate or severe mechanical stresses.

B.2.3.2 In water

In water, mechanical stresses can be produced by boulder movement, the abrasive action of sand, wave action, etc.

Mechanical stresses can be divided into three classes:

a) weak: no, or very slight and intermittent, mechanical stresses, for example due to light debris or small quantities of sand entrained in slow-moving water;

b) moderate: moderate mechanical stresses, due, for example, to

   — solid debris, sand, gravel, shingle or ice entrained in moderate quantities in moderately fast-flowing water,

   — a strong current without entrained matter flowing past vertical surfaces,

   — moderate growth (animal or vegetable), and

   — moderate wave action,

c) severe: high mechanical stresses due, for example, to

   — solid debris, sand, gravel, shingle or ice entrained in large quantities by fast-flowing water over horizontal or inclined surfaces, and

   — dense growth (animal or vegetable), particularly if, for operational reasons, it is removed mechanically from time to time.

B.2.4 Stresses due to condensation

If the temperature at the surface of a structure remains below the dew point for several days, the condensation produced will represent a particularly high corrosion stress, especially if such condensation can be expected to recur at regular intervals (e.g. in water works, on cooling-water pipes).

B.2.5 Stresses due to medium or high temperatures

In this document, medium temperatures are those between +60 °C and +150 °C, and high temperatures are those between +150 °C and +400 °C. Temperatures of this magnitude only occur under special conditions during construction or operation (e.g. medium temperatures occur during the laying of asphalt on roads, and high temperatures occur in chimneys made of sheet steel, flue gas ducts, or gas off-take mains in coking works).

B.2.6 Increased corrosion due to combinations of stresses

Corrosion can develop more quickly on surfaces exposed simultaneously to mechanical and chemical stresses. This applies particularly to steel structures near roads on which grit and salt have been spread.

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Passing vehicles will splash salty water and throw up grit on to parts of such structures. The surface is then exposed to corrosion stresses from the salt and at the same time to mechanical stresses due to the impact of grit.

Other parts of the structure will be wetted by salt spray. This affects, for example, the underside of flyovers above roads that have been salted. The spray zone is generally assumed to extend to a distance of 15 m from the road concerned.

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[1] ISO 8044:2015, *Corrosion of metals and alloys — Basic terms and definitions*

[2] ISO 9223, *Corrosion of metals and alloys — Corrosivity of atmospheres — Classification, determination and estimation*

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

[4] EN 12501-1, *Protection of metallic materials against corrosion — Corrosion likelihood in soil — Part 1: General*

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