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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.

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 12944-2 was prepared by Technical Committee ISO/TC 35, *Paints and varnishes,* Subcommittee SC 14, *Corrosion protection of steel structures by protective paint systems.*

ISO 12944 consists of the following parts, under the general title *Paints and varnishes — Corrosion protection of steel structures by protective paint systems*:

— *Part 1: General introduction*

— *Part 2: Classification of environments*

— *Part 3: Design considerations*

— *Part 4: Types of surface and surface preparation*

— *Part 5: Protective paint systems*

— *Part 6: Laboratory performance test methods*

— *Part 7: Execution and supervision of paint work*

— *Part 8: Development of specifications for new work and maintenance*

Annexes A and B of this part of ISO 12944 are for information only.

Introduction

Unprotected steel in the atmosphere, in water and in soil is subject to corrosion that may lead to damage. Therefore, to avoid corrosion damage, steel structures are normally protected to withstand the corrosion stresses during the service life required of the structure.

There are different ways of protecting steel structures from corrosion. ISO 12944 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, it is necessary for owners of such structures, planners, consultants, companies carrying out corrosion protection work, inspectors of protective coatings and manufacturers of coating materials to have at their disposal state-of-the-art information in concise form on corrosion protection by paint systems. Such information has to be as complete as possible, unambiguous and easily understandable to avoid difficulties and misunderstandings between the parties concerned with the practical implementation of protection work.

This International Standard — ISO 12944 — 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 is familiar with other relevant International Standards, in particular those dealing with surface preparation, as well as relevant national regulations.

Although ISO 12944 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 this standard may result in serious financial consequences.

ISO 12944-1 defines the overall scope of all parts 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 for a given project.

This part of ISO 12944 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 presented. Different environments for immersed and buried structures are also described. All these environments are relevant to the choice of protective paint systems.

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

Part 2:
Classification of environments

1 Scope

1.1 This part of ISO 12944 deals with the classification of the principal environments to which steel structures are exposed, and the corrosivity of these environments. It

— 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;

— gives information on some special corrosion stresses that may 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.

1.2 This part of ISO 12944 does not deal with the classification of those environments that consist of special atmospheres (for example those in and around chemical and metallurgical plants).

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 12944. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 12944 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 9223:1992, *Corrosion of metals and alloys — Corrosivity of atmospheres — Classification.*

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

ISO 12944-1:1998, *Paints and varnishes — Corrosion protection of steel structures by protective paint systems — Part 1: General introduction.*

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

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[1] To be published.

3 Definitions

For the purposes of this part of ISO 12944, the following definitions apply in addition to those given in ISO 12944-1.

NOTE — Some of the definitions have been taken from ISO 8044:1989, *Corrosion of metals and alloys — Vocabulary,* as indicated.

3.1 corrosivity: Ability of an environment to cause corrosion in a given corrosion system. [ISO 8044]

3.2 corrosion stresses: The environmental factors which promote corrosion.

3.3 corrosion system: System consisting of one or more metals and all parts of the environment which influence corrosion. [ISO 8044]

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

3.5 atmosphere: A mixture of gases, and normally also aerosols and particles, that surrounds a given object.

3.6 atmospheric corrosion: Corrosion with the Earth's atmosphere at ambient temperature as the corrosive environment. [ISO 8044]

3.7 type of atmosphere: Characterization of the atmosphere on the basis of the corrosive agents present and their concentration.

NOTE — The main corrosive agents are gases (especially sulfur dioxide) and salts (especially chlorides and/or sulfates).

3.7.1 rural atmosphere: The atmosphere prevailing in rural areas and small towns, without significant contamination by corrosive agents such as sulfur dioxide and/or chlorides.

3.7.2 urban atmosphere: The contaminated atmosphere prevailing in densely populated areas without significant industry. It has moderate concentrations of pollutants such as sulfur dioxide and/or chlorides.

3.7.3 industrial atmosphere: The atmosphere contaminated by corrosive pollutants from local and regional industry (mainly sulfur dioxide).

3.7.4 marine atmosphere: The atmosphere over and near the sea.

NOTE — A marine atmosphere will extend a certain distance inland, depending on topography and prevailing wind direction. It is heavily polluted with sea-salt aerosols (mainly chlorides).

3.8 local environment: The atmospheric conditions prevailing around a constituent element of a structure.

NOTE — These conditions determine the corrosivity category and include both meteorological and pollution parameters.

3.9 micro-environment: The environment at the interface between a constituent element of a structure and its surroundings. The micro-environment is one of the decisive factors in the assessment of corrosion stresses.

3.10 time of wetness: The period during which a metal surface is covered by a film of electrolyte that is capable of causing atmospheric corrosion. 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 same time, the temperature is above 0 °C.

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 may be so thin that it is invisible to the naked eye.

The corrosion rate is increased by the following factors:

- an increase in 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 may 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

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.

4.2.1 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.

4.2.2 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 may 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) may 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 part of ISO 12944.

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 as well as the use of the structure may 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 For the purposes of ISO 12944, atmospheric environments are classified into six atmospheric-corrosivity categories:

C1	very low
C2	low
C3	medium
C4	high
C5-I	very high (industrial)
C5-M	very high (marine)

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 may 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 table 1. The examples listed are informative and may 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 in a temperate climate** (informative only)	
	Low-carbon steel		**Zinc**		**Exterior**	**Interior**
	Mass loss g/m^2	**Thickness loss** µm	**Mass loss** g/m^2	**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 may 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-I very high (industrial)	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Industrial areas with high humidity and aggressive atmosphere.	Buildings or areas with almost permanent condensation and with high pollution.
C5-M very high (marine)	> 650 to 1 500	> 80 to 200	> 30 to 60	> 4,2 to 8,4	Coastal and offshore areas with high salinity.	Buildings or areas with almost permanent condensation and with high pollution.

NOTES

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

2 In coastal areas in hot, humid zones, the mass or thickness losses can exceed the limits of category C5-M. Special precautions must therefore be taken when selecting protective paint systems for structures in such areas.

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 International Standard, various environments can be described. In table 2, three different environments are given together with their designations. See 4.2 for more detail.

NOTE — In many such situations, cathodic protection is involved and this should be borne in mind.

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	Harbour areas with structures like sluice gates, locks, jetties; offshore structures
Im3	Soil	Buried tanks, steel piles, steel pipes

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 — Calculated time of wetness and selected characteristics of various types of climate
(taken from ISO 9223:1992)

Type of climate	Mean value of the annual extreme values			Calculated time of wetness at RH > 80% and temperature > 0 °C
	Low temperature °C	High temperature °C	Highest temperature with RH > 95 % °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, equable	+ 13	+ 35	+ 33	

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 may 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 clause B.2). Such stresses may 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 (for example 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 may 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 must 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

Special stresses, for the purposes of ISO 12944, 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.2.1 Chemical stresses

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

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