



SLOVENSKI STANDARD
SIST EN ISO 14713:1999

01-oktober-1999

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Protection against corrosion of iron and steel in structures - Zinc and aluminium coatings
- Guidelines (ISO 14713:1999)

Schutz von Eisen- und Stahlkonstruktionen vor Korrosion - Zink- und
Aluminiumüberzüge - Leitfäden (ISO 14713:1999)

Protection contre la corrosion du fer et de l'acier dans les constructions - Revêtements
de zinc et d'aluminium - Lignes directrices (ISO 14713:1999)

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ICS:

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EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN ISO 14713

March 1999

ICS 25.220.40; 91.080.10

English version

Protection against corrosion of iron and steel in structures - Zinc
and aluminium coatings - Guidelines (ISO 14713:1999)

Protection contre la corrosion du fer et de l'acier dans les
constructions - Revêtements de zinc et d'aluminium - Lignes
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This European Standard was approved by CEN on 20 November 1998.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

The text of EN ISO 14713:1999 has been prepared by Technical Committee CEN/TC 262 "Metallic and other inorganic coatings", the secretariat of which is held by BSI, in collaboration with Technical Committee ISO/TC 107 "Metallic and other inorganic coatings".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by August 1999, and conflicting national standards shall be withdrawn at the latest by August 1999.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

This European Standard constitutes guidelines containing general recommendations on the corrosion protection of iron and steel structures, including connections, by zinc or aluminium coatings. Particular reference is made to hot dip coating and thermal spraying on hot-rolled steel or cold-formed steel but these recommendations also apply to other zinc coatings (electroplating, mechanical coating, sherardizing, etc.). Initial protection is covered in relation to:

- a) available standard processes;
- b) design considerations; and
- c) environments of use.

These guidelines also consider the influence of the initial choice of aluminium or zinc coating in relation to the subsequent application of paint or powder coatings.

These guidelines provide general recommendations and do not deal with the maintenance of corrosion protection in service for steel with zinc or aluminium coatings: maintenance of corrosion protection will be covered in a separate document (see ISO 12944-5).

Requirements specific to each type of metallic coating form the subject of specific standards. Requirements for metallic coatings which are applied in the factory to certain products and which constitute an integral part of those products (e.g. nails, fasteners, ductile iron pipes) are given in the corresponding product standards.

2 Normative reference(s)

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

ISO 1461:1999, *Hot dip galvanized coatings on fabricated iron and steel articles — Specification.*

ISO 2063, *Metallic and other inorganic coatings — Thermal spraying — Zinc, aluminium and their alloys.*

ISO 2064, *Metallic and other inorganic coatings — Definitions and conventions concerning the measurement of thickness.*

ISO 2081, *Metallic coatings — Electroplated coatings of zinc on iron or steel.*

ISO 4998, *Continuous hot-dip zinc-coated carbon steel sheet of structural quality.*

ISO 9223, *Corrosion of metals and alloys — Corrosivity of atmospheres — Classification.*

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

EN 10142, *Specification for continuously hot dip zinc coated low carbon steel sheet and strip for cold forming — Technical delivery conditions.*

EN 10147, *Specification for continuously hot-dip zinc coated structural steel sheet and strip — Technical delivery conditions.*

EN 10240, *Internal and/or external protective coatings for steel tubes — Specification for hot dip galvanized coatings applied in automatic plants.*

3 Term(s) and definition(s)

For the purposes of this standard, the following definitions apply, together with those given in ISO 1461, ISO 2063 and ISO 2064.

3.1 atmospheric corrosion
corrosion caused by exposure to the atmosphere at temperatures between $-55\text{ }^{\circ}\text{C}$ and $+60\text{ }^{\circ}\text{C}$

3.2 elevated temperatures
temperatures between $+60\text{ }^{\circ}\text{C}$ and $+150\text{ }^{\circ}\text{C}$

3.3 exceptional exposure
special cases; exposure that substantially intensifies the corrosion exposure and/or places increased demands on the corrosion protection system

3.4 life to first maintenance
the time interval that can elapse after initial coating before coating deterioration reaches the point that maintenance is necessary to restore protection of the basis metal.

4 Materials

4.1 Iron and steel substrates

Steel can be hot-rolled or cold-formed. Hot rolling is used to produce the familiar angle, 'T', 'H' and other structural sections. Some smaller structural sections, e.g. lattice trusses and cladding rails, and also cladding panels, are cold-formed.

Steel is basically an alloy of iron and carbon with other elements added depending on the required performance and processing method. The metallurgical and chemical nature of the steel is irrelevant to protection by thermally sprayed coatings. In hot dip galvanizing, the reactivity of the steel is modified by its chemical composition, particularly by the silicon plus phosphorus contents (see ISO 1461:1999, annex C).

Cast and wrought irons are of various metallurgical and chemical compositions. This is irrelevant to protection by thermally sprayed coatings but special comment is needed regarding the cast-irons most suitable for hot dip galvanizing as follows.

- Grey iron castings: grey iron has a carbon content of greater than 2%, the majority of which is graphite in flake form.
- Spheroidal graphite (SG) castings: similar to grey iron in many aspects of composition but with carbon present primarily as graphite in spheroidal form initiated by additions of magnesium or cerium.
- Malleable iron castings: blackheart, whiteheart and pearlitic. Toughness and workability are derived from annealing processes and no primary graphite is permissible.

Conventional hydrochloric acid pickling does not remove mould-sand deposits, graphite or temper carbon from the surface of cast-iron. Grit-blasting is necessary to remove these contaminants. Surface cleaning of complex shapes can be undertaken by specialist galvanizing companies using hydrofluoric acid.

Care needs to be exercised in the design of cast-iron sections. Small castings of simple shape and solid cross-section do not present problems for galvanizing provided that the material and surface condition are suitable. Larger castings should have a

balanced design with uniform section thicknesses to avoid distortion and cracking due to thermal stress. Large fillet radii and pattern numbers should be used and sharp corners and deep recesses avoided.

The rough surface finish which castings tend to possess may result in thicker galvanized coatings than on rolled components.

4.2 Non-ferrous metals as coatings

Metal coating is an effective method of retarding or preventing corrosion of ferrous materials. Zinc and aluminium, or their alloys with each other and with iron, are the most commonly used, usually as hot dip or thermally sprayed metallic coatings, because they protect iron and steel both by barrier action and by galvanic action.

Corrosion of zinc, aluminium and their alloys is affected by the time for which they are exposed to wetness and contamination of the surface, but the corrosion rates are much slower than for steel and often decrease with time; the relative importance of different contaminants also changes.

These non-ferrous coatings may be left unmaintained if the total corrosion of the coating and the underlying iron or steel is insufficient to affect the performance of the structure in its designed period of use. If a longer life in total is required, maintenance of the coating should be by painting either initially or at least while some original coating remains.

5 Selection of zinc or aluminium coating system

The zinc or aluminium coating system to be used should be selected taking the following items into account:

- a) the general environment in which it is to be applied (see clause 6 and table 1);
- b) local variations in the environment, including anticipated future changes and any special conditions;
- c) the required life to first maintenance of the metal coating system (see table 2 under the applicable environment);
- d) the need for ancillary components;
- e) the need for painting, either initially or when the metal coating is approaching the end of its life to first maintenance to achieve minimal maintenance cost;
- f) the availability and cost;
- g) if the life to first maintenance of the system is less than that required for the structure, its ease of maintenance.

The operational sequence for applying the selected system should be determined in consultation with the steel fabricator and the metal coating system applicator.

NOTE 1 Additional information may be given in product specifications.

NOTE 2 Zinc-aluminium systems, both for hot dip coating (notably sheet and wire) and for thermal spraying are available in some countries and for some articles but they are not universally available and — in common with other alloy coatings — are not listed in table 2.

6 Corrosion in different environments

6.1 Corrosion in the atmosphere

Table 1 gives basic groups of environments (related to ISO 9223). Where the relative humidity is below 60%, the corrosion rate of iron and steel is negligible and it may not require metal coating, e.g. inside many buildings. Metal coating with or without painting may however be required for appearance or for reasons of hygiene, e.g. in a food factory. When the relative humidity is higher than 60% or where exposed to wet or immersed conditions or prolonged condensation then, like most metals, iron and steel is subject to more serious corrosion. Contaminants deposited on the surface, notably chlorides and sulfates, accelerate attack. Substances that deposit on the surface of the iron and steel increase corrosion if they absorb moisture or go into solution on the surface of the iron and steel. The temperature also influences the corrosion rate of unprotected iron and steel and temperature fluctuations have a stronger effect than the average temperature value.

The macro environment is best defined by scientific measurements (e.g. relative humidity, temperature, sulfate and chloride deposition rates) but such data are often not available. The qualitative descriptions in table 1 and figure 1 have, therefore, been developed in relation to the latest UN and other global studies. The underlying tendency for corrosion in different countries or parts of countries is different, e.g. an 'industrial' atmosphere in Scandinavia or in Spain may be less corrosive than an 'industrial' atmosphere in the UK. The corrosion rate for zinc and zinc alloy coatings has decreased substantially in the past 30 years and is expected to continue to decrease in the atmosphere as a result of decrease in atmospheric pollution. Every effort should be made to choose the atmospheric environmental category on the basis of known performance or sulfate or chloride levels: the sulfur dioxide level is the most significant with zinc; in otherwise similar atmospheres, the rate of corrosion of zinc increases linearly with increase in sulfur dioxide.

The micro environment, i.e. the conditions prevailing around the structure, is also important because it allows a more precise assessment of the likely conditions than study of the basic climate alone. It is not always known at the planning stage of a project. Every effort should be made to identify it accurately, however, because it is an important factor in the total environment against which corrosion protection is required. An example of a micro climate is the underside of a bridge (particularly over water).

The corrosion of steelwork inside buildings is dependent upon the internal environment but in 'normal' atmospheres, e.g. dry and heated, is insignificant. Steelwork in the perimeter walls of buildings is influenced by the configuration within the perimeter wall, e.g. steelwork in clear separation from the outer leaf of a wall comprising two parts separated by an air space is at less risk of corrosion than steelwork in contact with or embedded in the outer leaf. Buildings containing industrial processes, chemical environments, wet or contaminated environments should be given special consideration. Steelwork which is partially sheltered, e.g. farm barns, aircraft hangars, should be considered as being subject to the exterior environment.

6.2 Corrosion in soil

Corrosion in soil is dependent on the mineral content, the nature of these minerals and on the organic components, water content and oxygen content (aerobic and anaerobic corrosion). Corrosion rates in disturbed soil conditions are usually higher than in undisturbed soil.

Lime-containing soils and sandy soils (providing that they are chloride-free) are in general least corrosive, whilst clay soils and clay marl soils are corrosive to a limited extent. In bog and peat soils, the corrosiveness depends on the total acid content.

Where major iron and steel structures such as pipelines, tunnels, tank installations, pass through different types of soil, increased corrosion (pitting) can occur at isolated points (anodic areas) by the formation of differential aeration cells. For some uses, e.g. earth reinforcement, a controlled backfill is used in conjunction with a metal coating.

Corrosion cells can also form at the soil/air and soil/ground water level interfaces, leading possibly to increased corrosion and these areas should be given special consideration. Conversely, the application of cathodic protection for structures in soil (or in water) can both modify the protective coating requirements and lengthen their life. Specialist advice should be sought for full guidance on all conditions involved.

The factors influencing corrosion in soil make it impracticable to include simple guidance in table 2.

6.3 Corrosion in water

The type of water — soft or hard fresh water/brackish water/salt water — has a major influence on the corrosion of iron and steel in water and the selection of protective metal coatings. With zinc coatings, corrosion is affected primarily by the chemical composition of the water but temperature, pressure, flow rate, agitation and oxygen availability are all important. For example, zinc should not be used in hot non-scale-forming waters; heavy corrosion of zinc can also occur in condensate, especially between about 55 °C and 80 °C (e.g. in saunas). Otherwise, barrier protection can occur at all temperatures; below about 60 °C, zinc can also provide cathodic protection. The duration of life of zinc surfaces in cold scale-forming waters is usually higher than in non-scale-forming waters (Ryznar's or Langelier's index should be used to calculate whether the water is scale-forming). Choice of aluminium or zinc is often on the basis of pH value: aluminium for pH <5 or 6; zinc for pH >5 or 6 (depending on other factors). Since the composition of non-saline waters can vary greatly, previous experience or expert advice should be sought. For hot water, specialist advice should always be sought (see also for example DIN 50930-3:1991). Coatings used for all structures (including pipes, fittings, tanks and tank covers) in contact with potable water should be non-toxic and should not impart any taste or odour, colour or turbidity to the water, nor foster microbial attack. With tanks, if additional protection to hot dip galvanizing is necessary, sufficient coats of high-build bitumen paint should be applied.

Zones of fluctuating water level (i.e., the area in which the water level changes as a result of natural fluctuations — e.g., tidal movements, or artificial alteration of the water level in lock chambers or reservoirs) or splash zones should be given special consideration as, in addition to water attack, there can also be atmospheric attack and abrasion.

The many factors affecting corrosion in fresh water make it impracticable to present simple tabular guidance in table 2. Some guidelines for seawater are in table 2g) but it is emphasized that for all water exposures specialist advice should be sought for full guidance on all conditions involved.

6.4 Exceptional exposure (special cases)

6.4.1 General

Because of the multiplicity of types of exceptional exposure/special cases, only a few samples are discussed in 6.4.2 to 6.4.4 and table 2 does not cover such effects.

6.4.2 Chemical attack

Corrosion is increased locally by pollution from industrial processes, notably by acids in the case of zinc coatings and by alkalis in the case of aluminium coatings.

Many organic solvents have little effect on non-ferrous metals but specific advice should be sought for each chemical.

6.4.3 Abrasion

Natural mechanical exposure can occur in waters by shifting of boulders, abrasion by sand, wave splashing, etc. Particles entrained by the wind (for example sand) can also cause increased attack.

The non-ferrous metal coatings have much higher abrasion resistance (a factor of 10 or more) than most conventional paint coatings. The zinc-iron alloys are particularly hard.

Areas walked on or driven on or which rub together can be subject to severe abrasion. Areas under coarse gravel are subjected to severe erosion by impact and abrasion. The good bond between metal coatings and steel (particularly in hot dip galvanizing and sherardizing where there is an alloying reaction) helps to limit such effects.

6.4.4 Exposure to elevated and high temperature

All the metal coatings described are usually suitable for elevated temperatures. Separate advice has to be sought regarding any organic materials/coatings.

Temperatures above 200 °C are not considered in this International/European Standard. Temperatures between +200 °C and +500 °C occur only under special conditions of construction and operation, e.g. in steel chimneys, flue gas ducts, gas take-off mains in coking plants. Specialist advice should be sought for the coating of surfaces so exposed.

7 Design of protective systems

7.1 General principles

Design of structures and plant should influence the choice of protective system. It may be appropriate and economic to modify the design to suit the preferred protective system.

Points a) to i) should be considered.

- a) Safe and easy access for maintenance should be provided.
- b) Pockets and recesses in which water and dirt can collect should be avoided; a design with smooth contours facilitates application of a protective coating and helps to improve corrosion resistance. Corrosive chemicals should be directed away from structural components, e.g. drainage tubes should be used to control de-icing salts.
- c) Areas which are inaccessible after erection should be given a coating system designed to last the required life of the structure.
- d) If bimetallic corrosion is possible, additional protective measures should be considered (see PD 6484, British Standards Institution, for example).
- e) Where the coated iron and steel is likely to be in contact with other building materials, special consideration should be given to the contact area; e.g. the use of paint, tapes or plastic foils should be considered.
- f) Hot dip galvanizing, sherardizing, mechanical coating or electroplating can be provided only in works; thermal spraying and zinc flake coating can be applied in works or on site. When paint is to be applied to a metal coating the application is more readily controlled in works but, where there is a likelihood of substantial damage occurring during transportation and erection, specifiers may prefer to apply the final paint coat on site.

Where the total system is applied off-site, the specification has to cover the need for care at all stages to prevent damage to the finished iron and steel and set out repair procedures to the coating once the steelwork is erected.

- g) Hot dip galvanizing (in accordance with ISO 1461) or thermal spraying (in accordance with ISO 2063) should take place after bending and other forms of fabrication.
- h) Methods of marking parts prior to coating.
- i) Precautions required to minimize the likelihood of deformation during processing or subsequently.

7.2 Practical design

Design practice for hot dip coating differs from that for thermal spray coatings. Annex A provides guidance on design for hot dip coatings and annex B for thermally sprayed coatings. These supplement the general principles of good design for steel structures.

Design should be discussed with the hot dip galvanizer at an early stage in order that stresses introduced during fabrication may be balanced where possible. Some stresses in the basis metal will be relieved during the hot dip galvanizing process and this could cause deformation of the coated article.

Design for electroplating with zinc follows the general design principles for electroplating and these are not given here. Design for sherardizing and for mechanical coating is best discussed with specialist applicators; in general these processes are most suitable for small parts which can be tumbled in a barrel but specialist plants may be available for other shapes.

7.3 Tubes and hollow sections

7.3.1 General

If dry and hermetically sealed, the internal surfaces of tubes and hollow sections will not need protection. Where hollow sections are fully exposed to the weather and are not hermetically sealed, consideration should be given to the need for both internal and external protection, avoidance of internal deposits and for the drainage of any water which enters.

7.3.2 Hot dip galvanized protection

Hot dip galvanizing gives equal thickness internally and externally. When tubes and hollow sections are hot dip galvanized after assembly into structures, drainage/venting holes should be provided for processing purposes (see annex A).

7.3.3 Thermal spray protection

It may not be possible to provide thermal spray protection on some internal surfaces because there is inadequate access for the spray gun. If, consequently, a less protective scheme is used on the internal surfaces of partially sealed structures, other methods (e.g. dessicants) should be considered to increase protective coating life.

7.4 Connections

7.4.1 Fastenings to be used with thermal spray or hot dip coatings

The protective treatment of bolts, nuts and other parts of the structural connections should be given careful consideration. Ideally, their protective treatment should be of a standard at least equal to that specified for the general surfaces. Specific requirements are given in the appropriate product standards and in a series of standards for coatings on fasteners which are in the course of preparation/publication.

Hot dip galvanized (see for example ISO 1461) which covers specified minimum coating thicknesses up to 55 μm), sherardized (European Standard (work item 00262097) is at committee draft stage) or other coatings on steel fasteners should be considered. Alternatively, stainless steel fasteners can be used; they should be painted after assembly if necessary for aesthetic purposes or to prevent bimetallic corrosion when immersed in chloride solutions. In such cases, the stainless steel should be given an appropriate pretreatment.

The mating surfaces of connections made with high strength friction grip bolts should be given special treatment. It is not necessary to remove thermally sprayed or hot dip coatings from such areas to obtain an adequate coefficient of friction; however, consideration has to be given to any long-term slip or creep avoidance requirements and to any necessary adjustments to the assembly dimensions.

7.4.2 Welding considerations related to coatings

Welding techniques influence whether weld areas are

- a) protected after surface preparation and before welding; or
- b) left bare until the welding is complete.

It is preferable to weld prior to hot dip galvanizing or thermal spraying. After welding, the surface should be prepared to the standard specified for preparing the steelwork overall before applying the protective coating process. Welding should be balanced (i.e. equal amounts each side of the main axis) to avoid introducing unbalanced stresses in a structure. Welding residues have to be removed before coating. The normal pretreatments for thermal spraying are usually sufficient for this purpose but extra pretreatment may be needed for hot dip galvanizing; in particular, weld slag should be removed separately. Some forms of welding leave alkaline deposits behind. These have to be removed by blast-cleaning followed by washing with clean water before applying thermally-sprayed coatings. (This does not apply to hot dip galvanizing where the pretreatment process removes alkaline deposits.)

It is desirable that fabrication takes place without the use of a blast primer as this has to be removed before hot dipping or thermal spraying.

Where welding takes place after hot dip galvanizing or thermal spraying, it is preferable before welding to remove the coating locally in the area of the weld to ensure the highest quality weld. After welding, protection should be appropriately restored locally by thermal spraying, 'solder sticks' and/or zinc dust paints.

After welding of coated steels, the surface should be prepared to the standard specified for preparing the steelwork overall before applying paint or fusion-bonded powder coatings.

Assemblies comprising different metals needing different pretreatments should be discussed with the processor.

7.4.3 Brazing or soldering

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Soft soldered assemblies cannot be hot dip galvanized and brazing should be avoided if possible — many types of brazing are unsuitable for hot dip galvanizing. The galvanizer should be consulted if brazing is being considered.

Since corrosive fluxes may be used in these processes, removal of flux residues after the coating process is essential to avoid corrosion of the coated parts; the design of these parts should facilitate this.

7.5 Zinc or aluminium coatings with an overcoating

ISO 12944-5 gives information on zinc or aluminium coatings with an overcoating. For less aggressive environments (or for shorter lives than indicated) a single coat of paint, over pretreatments if specified, is sufficient.

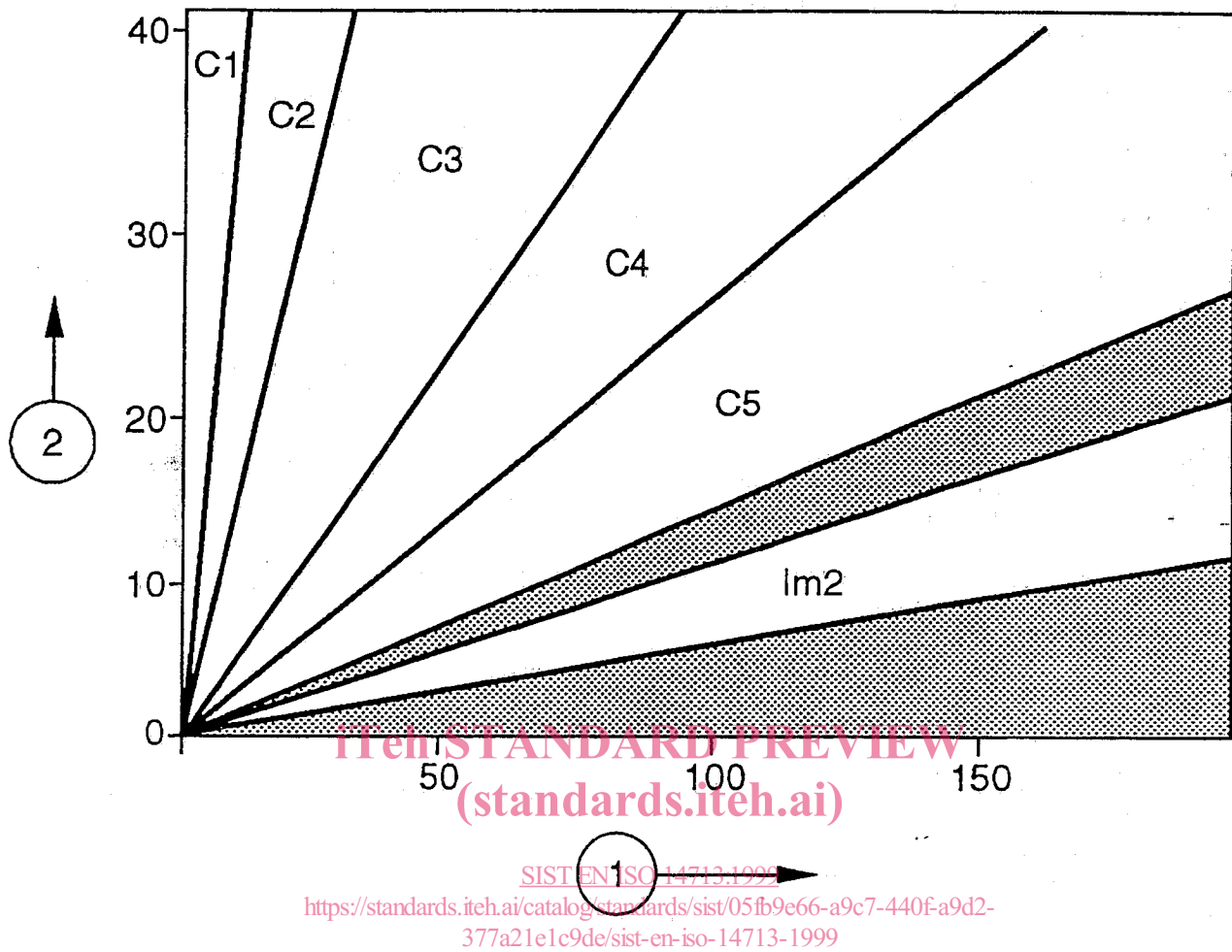
For more aggressive and wet environments, two coats of paint are used to minimize through-pores.

The life of a coated structure is longer than the life of a coating system as some steel can be lost by corrosion before a structure becomes unserviceable. If it is necessary to prolong the life of the coating still further, maintenance has to take place before any rusting occurs and preferably while at least 20 µm to 30 µm of metallic coating remains. This gives a maintained metal plus overcoating system a longer total life than a simple paint coating.

If maintenance is delayed until the coating has been consumed and rusting has started, the iron and steel have to be maintained in the same way as rusted painted steel.

The total life of a metal plus overcoating system is usually significantly greater than the sum of the lives of the metal coating (given in table 2) and a suitable paint or fusion-bonded powder coating used separately. There is a synergistic effect, i.e. the presence of metal coatings reduces under-rusting of the paint film; the paint preserves the metal coating from early corrosion. Where it is desired to retain a reasonably intact layer of paint as a basis for maintenance, the initially applied paint system should have extra thickness.

Maintenance usually takes place when the metal coating loses its appearance or becomes degraded. Metal coatings usually take longer to degrade than paint. Hence a metal coating may be recommended for 20 years or more to first maintenance whereas the same coating when covered by paint is, for reasons of appearance of the paint, recommended for only 10 years to first maintenance. It should also be noted that an area of degraded paint can retain moisture and hence hasten the corrosion of metal, particularly on a surface not washed by rain.



1 coating thickness, in micrometres

2 coating life to first maintenance, in years

NOTE 1 Each environment is shown as a band; the lines show typical upper and lower coating lives for that environment.

NOTE 2 The specific effects of microenvironments are not included.

Figure 1 — Typical lives to first maintenance of zinc coatings in different categories of environment based on typical corrosion rates

Table 1 — Environmental categories, corrosion risk and corrosion rate

Code	Corrosivity category	Corrosion risk	Corrosion rate Average thickness loss for zinc ^{a,b,c} µm/year
C1	Interior: dry	Very low	≤0,1
C2	Interior: occasional condensation Exterior: exposed rural inland	Low	0,1 to 0,7
C3	Interior: high humidity, some air pollution Exterior: urban inland or mild coastal	Medium	0,7 to 2
C4	Interior: swimming pools, chemical plants etc Exterior: industrial inland or urban coastal	High	2 to 4
C5	Exterior: industrial with high humidity or high salinity coastal	Very high	4 to 8
Im2	Sea water in temperate regions	Very high	10 to 20 ^d

^a The thickness loss values are identical to those given in ISO 9223, except that for rates of 2 µm (per year) or more the figures are rounded to whole numbers.

^b The corrosion rates of zinc which are applicable in table 2 are given in the headings to each section of the table. To a first approximation, the corrosion of all metallic zinc surfaces is at the same rate in a particular environment. Iron and steel will normally corrode 10 to 40 times faster than zinc, the higher ratios usually being in high chloride environments. Aluminium coatings do not have a linear corrosion rate with time. The relationship is to data on flat sheet given in ISO 9223.

^c Change in atmospheric environments with time. A substantial reduction in pollution, especially sulfur dioxide, has occurred world-wide in the past 30 years. This means that present corrosion rates (the table is based on 1990 to 1995 data) for each environmental category are much lower than historic rates; even lower rates can be expected in the future if pollution continues to fall.

^d Temperate sea water is less corrosive to zinc than tropical salt water, which is usually at a higher temperature. This table is designed for use in European temperate sea water. Specialist advice should be sought for tropical conditions.