
**Protection against corrosion of iron and
steel in structures — Zinc and aluminium
coatings — Guidelines**

*Protection contre la corrosion du fer et de l'acier dans les constructions —
Revêtements de zinc et d'aluminium — Lignes directrices*



Foreword

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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 International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 14713 was prepared by the European Committee for Standardization (CEN) in collaboration with ISO Technical Committee TC 107, *Metallic and other coatings*, Subcommittee SC 4, *Hot-dip coatings (galvanized, etc.)*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this standard, read "...this European Standard..." to mean "...this International Standard...".

Annexes A to C of this International Standard are for information only.

Annex ZA provides a list of corresponding International and European Standards for which equivalents are not given in the text.

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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of an identical text or by endorsement, at the latest by August 1999, and conflicting national standards shall be withdrawn at the latest by August 1999.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.

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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 °C and +60 °C

3.2

elevated temperatures

temperatures between +60 °C and +150 °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, 'I', '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

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.

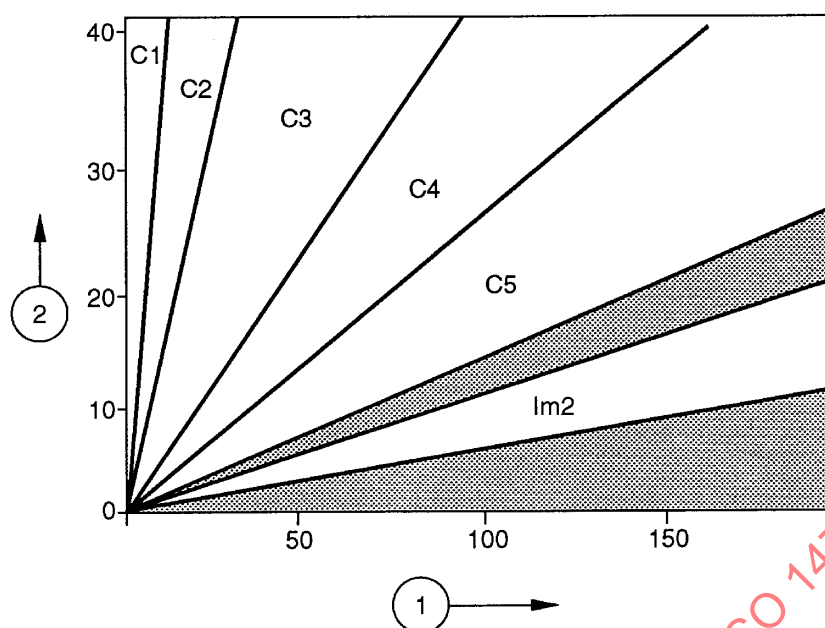
For more aggressive and wet environments, two coats of paint are used to minimize through-pores.

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.			

Table 2 — Recommendations for protective coating systems for specific environments

a) Corrosivity category C2 (zinc corrosion rate typically < 0,7 µm/year or < 5 g/m ² /year for long exposures). Lives for corrosivity category C1 will typically be 5 to 10 times longer			
Typical life to first maintenance years	General description and suitability	Mean coating thickness on each surface µm (minimum)	Notes (at end of table 2)
Very long (≥ 20)	Hot dip galvanized conforming to ISO 1461	25 to 85 ^a	1, 2, 3, 4
	Tube hot dip galvanized (e.g. conforming to EN 10240)	25 to 55 ^a	1, 2, 3, 4
	Sealed or unsealed sprayed aluminium conforming to ISO 2063	100	4, 5, 6
	Sealed aluminium conforming to ISO 2063	50	4, 5, 6
	Sealed or unsealed sprayed zinc conforming to ISO 2063	50	1, 4, 5, 8
	Hot dip galvanized sheet Z275 (see EN 10142 or EN 10147 or ISO 4998)	20	1
	Zinc electroplated steel (general)	20	1
Long (10 to < 20)	As above		
Medium (5 to < 10)	As above		
Short (< 5)	As above		
a Depending on the 'coating quality' specified for the tube (e.g. see EN 10240) or thickness of the steel in a product (see ISO 1461).			

Table 2 (continued)

b) Corrosivity category C3 (indoor) (high humidity, some air pollution, frequent condensation) (zinc corrosion rate typically 0,7 µm/year to 2 µm/year or 5 g/m ² /year to 15 g/m ² /year for long exposures)			
Typical life to first maintenance years	General description and suitability	Mean coating thickness on each surface µm (minimum)	Notes (at end of table 2)
Very long (≥ 20)	Hot dip galvanized conforming to ISO 1461	45 to 85 ^a	1, 2, 3, 4
	Tube hot dip galvanized (e.g. conforming to EN 10240)	45 to 55 ^a	1, 2, 3, 4
	Sealed or unsealed sprayed aluminium conforming to ISO 2063	100	4, 5, 6
	Sealed or unsealed zinc conforming to ISO 2063	100	1, 4, 5, 6
Long (10 to < 20)	As above or: Tube hot dip galvanized (e.g. conforming to EN 10240)	25	1, 2, 3, 4
	Hot dip galvanized conforming to ISO 1461	25	1, 2, 3, 4
Medium (5 to < 10)	As above or: Hot dip galvanized sheet Z275 (see EN 10142 or EN 10147 or ISO 4998)	20	1
	Zinc electroplated steel (general)	20	1
Short (< 5)	As above		

^a See footnote to table 2a).

Table 2 (continued)

c) Corrosivity category C3 (outdoor) (zinc corrosion rate typically 0,7 µm/year to 2 µm/year; 5 g/m ² /year to 15 g/m ² /year for long exposures)			
Typical life to first maintenance years	General description and suitability	Mean coating thickness on each surface µm (min)	Notes (at end of table 2)
Very long (≥ 20)	Hot dip galvanized conforming to ISO 1461 (all thicknesses of steel)	45 to 85 ^a	1, 2, 3, 4
	Sealed sprayed aluminium conforming to ISO 2063	100	4, 5, 6
	Sealed or unsealed sprayed zinc conforming to ISO 2063	100	1, 4, 5, 6
	Tube hot dip galvanized (e.g. conforming to EN 10240)	45 to 55 ^a	1, 2, 3, 4
Long (10 to < 20)	As above or: Tube hot dip galvanized (e.g. conforming to EN 10240)	25	1, 2, 3, 4, 9
	Hot dip galvanized conforming to ISO 1461	25	1, 2, 3, 4, 9
Medium (5 to < 10)	As above or: Hot dip galvanized sheet Z275 (see EN 10142 or EN 10147 or ISO 4998); cold formed zinc-coated sheet	20	1, 9
	Zinc electroplated steel (general)	20	1, 9
Short (< 5)	As above		

Table 2 (continued)

d) Corrosivity category C4 (zinc corrosion rate typically 2 µm/year to 4 µm/year; 15 g/m ² /year to 30 g/m ² /year for long exposures)			
Typical life to first maintenance years	General description and suitability	Mean coating thickness on each surface µm (minimum)	Notes (at end of table 2)
Very long (≥ 20)	Hot dip galvanized conforming to ISO 1461 (steel ≥ 6 mm thick)	85	1, 2, 3, 4
	Sealed sprayed aluminium conforming to ISO 2063	100	4, 5, 6
	Sealed or unsealed sprayed zinc conforming to ISO 2063	100	1, 4, 5, 6
Long (10 to < 20)	As above or: Hot dip galvanized conforming to ISO 1461 (steel < 6 mm thick)	45 to 70 ^a	1, 2, 3, 4
	Tube hot dip galvanized conforming to EN 10240	45 to 55 ^a	1, 2, 3, 4
Medium (5 to < 10)	As above or: Hot dip galvanized sheet Z275 (see EN 10142 or EN 10147 or ISO 4998)	20	1, 9
	Zinc electroplated steel (general)	25	1, 9
	Tube hot dip galvanized (e.g. conforming to EN 10240)	25	1, 2, 3, 4, 9
	Hot dip galvanized conforming to ISO 1461 ^b	25	1, 2, 3, 4, 9
Short (< 5)	As above		
^a Depending on the 'coating quality' specified for the tube (e.g. see EN 10240) or thickness of the steel in a product (see ISO 1461) more than one minimum mean is specified.			
^b Threads < 6 mm diameter on components.			

Table 2 (continued)

e) Corrosivity category C5, very high (least corrosive half of category) (zinc corrosion rate typically 4 µm/year to 6 µm/year; 30 g/m ² /year to 40 g/m ² /year for long exposures)			
Typical life to first maintenance years	General description and suitability	Mean coating thickness on each surface µm (minimum)	Notes (at end of table 2)
Very long (≥ 20)	Hot dip galvanized (thick coatings — not always available, see note 2 at end of table 2)	115	1, 2, 3, 4, 10, 11
	Unsealed sprayed aluminium conforming to ISO 2063	150	4, 6
	Unsealed sprayed zinc conforming to ISO 2063	150	1, 4, 6
	Sealed sprayed aluminium conforming to ISO 2063	150	4, 5, 6
	Sealed sprayed zinc conforming to ISO 2063	150	4, 5, 6
Long (10 to < 20)	As above or: Hot dip galvanized conforming to ISO 1461 (steel ≥ 6 mm thick)	85	1, 2, 3, 4
	Sealed sprayed aluminium conforming to ISO 2063	100	4, 5, 6
	Sealed sprayed zinc conforming to ISO 2063	100	4, 5, 6
Medium (5 to < 10)	As above or: Hot dip galvanized conforming to ISO 1461 (steel < 6 mm thick)	45 to 70 ^a	1, 2, 3, 4
	Unsealed sprayed zinc or aluminium conforming to ISO 2063	100	1, 4, 6
	Tube hot dip galvanized (e.g. conforming to EN 10240)	45 to 55 ^a	1, 2, 3, 4
Short (< 5)	As above or: Hot dip galvanized conforming to ISO 1461 ^c	25	1, 2, 3, 4, 9
	Tube hot dip galvanized (e.g. conforming to EN 10240)	25	1, 2, 3, 4, 9
	Hot dip galvanized sheet Z275 (see EN 10142 or EN 10147 or ISO 4998)	20	1, 9
	Zinc electroplated steel (general)	20	1, 9
^a Depending on the 'coating quality' specified for the tube (e.g. see EN 10240) or thickness of the steel in a product (see ISO 1461) more than one minimum mean is specified.			
^b Threads < 6 mm diameter on components.			

Table 2 (continued)

f) Corrosivity category C5, very high (most corrosive part of category) (zinc corrosion rate typically 6 µm/year to 8 µm/year; 40 g/m ² /year to 60 g/m ² /year for long exposures)			
Typical life to first maintenance years	General description and suitability	Mean coating thickness on each surface µm (minimum)	Notes (at end of table 2)
Very long (≥ 20)	Hot dip galvanized	150 to 200 ^c	1, 2, 3, 4, 10, 11
	Unsealed sprayed aluminium conforming to ISO 2063	250	4, 6
	Unsealed sprayed zinc conforming to ISO 2063	250	1, 4, 6
	Sealed sprayed aluminium conforming to ISO 2063	150	4, 5, 6
	Sealed sprayed zinc conforming to ISO 2063	150	4, 5, 6
Long (10 to < 20)	As above or: Hot dip galvanized (thick coating - not always available, see note 2 at end of table 2)	115	1, 2, 3, 4, 10, 11
	Unsealed sprayed aluminium conforming to ISO 2063	150	4, 6
	Unsealed sprayed zinc conforming to ISO 2063	150	1, 4, 6
	Sealed sprayed aluminium conforming to ISO 2063	100	4, 5, 6
	Sealed sprayed zinc conforming to ISO 2063	100	4, 5
Medium (5 to < 10)	As above or: Hot dip galvanized conforming to ISO 1461 (steel ≥ 3 mm thick)	70 to 85	1, 2, 3, 4
Short (< 5)	As above or: Hot dip galvanized to ISO 1461 (steel < 3 mm thick or centrifuged ^b)	25 to 55 ^a	1, 2, 3, 4, 9
	Tube hot dip galvanized (e.g. conforming to EN 10240)	25 to 55 ^a	1, 2, 3, 4, 9
	Hot dip galvanized sheet Z275 (see EN 10142 or EN 10147 or ISO 4998);	20	9
^a Depending on the 'coating quality' specified for the tube (e.g. see EN 10240) or thickness of the steel in a product (see ISO 1461) more than one minimum mean is specified. ^b Threads < 6 mm diameter on components. ^c For these conditions and life to first maintenance > 20 years a very thick galvanized coating is required, e.g. 150 µm to 200 µm. Such coatings should not be specified until the matter has been discussed with a hot dip galvanizer and sample products have been satisfactorily hot dip galvanized. See ISO 1461 and note 2 at end of table 2 for general guidance.			

Table 2 (continued)

g) Corrosivity category Im2: Temperate sea water ^{d,e} : zinc corrosion rate typically 10 µm/year to 20 µm/year; 70 g/m ² /year to 150 g/m ² /year			
Typical life to first maintenance years	General description and suitability	Mean coating thickness on each surface µm (minimum)	Notes (at end of table 2)
Very long (≥ 20)	Sealed sprayed aluminium conforming to ISO 2063	150	4, 5, 6
	Sealed sprayed zinc conforming to ISO 2063	250	4, 5, 6
Long (10 to < 20)	As above or: Hot dip galvanized (see footnote c under table 2f))	150 to 200	1, 2, 3, 4, 11
	Sealed sprayed zinc conforming to ISO 2063	150	4, 5, 6
Medium (5 to < 10)	As above or: Hot dip galvanized (thick coating — see note 2 at end of table 2)	115	1, 2, 3, 4
Short (< 5)	As above or: Hot dip galvanized conforming to ISO 1461 (steel ≥ 3 mm)	70 to 85	1, 2, 3, 4
^d Hot dip galvanized tube, sheet and fittings normally have additional protection when used in sea water. ^e Brackish water may be more or less corrosive than sea water and no general estimates of durability can be given.			

Table 2 (continued)

NOTE 1 Life to first maintenance of protective coating systems: The list of systems given in table 2, classified by environment and typical time to first maintenance, indicate the options open to the specifier. The recommended treatments listed for longer lives will always protect for shorter periods and are often also economical for these shorter periods.

Table 2 can be applied to any zinc coating to determine life to first maintenance. The corrosion rate applicable to each part of the table is given in the heading. It is impossible to achieve an exactly uniform thickness of any type of coating. Where the term 'mean coating thickness - minimum value' is used in the heading to the third column of table 2 and elsewhere it indicates a minimum; in practice, the overall mean is likely to be substantially in excess of this minimum: this is important as the zinc and aluminium coatings are able to provide protection to adjacent areas which may lose their coating prematurely. It should be noted that thickness requirements in EN 10240 are minimum local thickness requirements. Furthermore the thickness quoted for coatings in these tables may not match specified coating thicknesses in some standards.

In table 2, guidance is given for coatings as applied to structural and cold-forming grades of hot dip galvanized sheet and cold-rolled sections, on zinc electroplated sheet and on coatings thermally sprayed with zinc or aluminium or hot dip galvanized after manufacture. Hot dip galvanized fabricated and semi-fabricated products made from thin material and fasteners and other centrifuged work usually have intermediate thicknesses of coating (see also relevant product standards). As the life of all zinc coatings is approximately proportional to the thickness or mass of zinc coating present, the relative performance of such intermediate thicknesses can readily be assessed. The life to first maintenance of metallic zinc coatings in typical atmospheres and sea water is shown in figure 1. Life in the atmosphere increases with decrease in sulfur dioxide pollution, if other factors remain constant.

Throughout the table, the commonly available hot dip galvanized sheet Z275 has been identified. Life to first maintenance values for thicker sheet coatings, e.g. the Z450 grade, are proportionally higher. Thinner coating grades give proportionally lower life to first maintenance values.

Zinc/aluminium alloy coatings (with 5% to 55% aluminium) usually last longer than pure zinc; pending wider use, they are not included in this table. There is widespread technical literature available on these classes of materials.

NOTE 2 Thickness of hot dip galvanizing on products: ISO 1461 specifies the standard hot dip galvanized coating at the equivalent of 85 µm minimum for steel 6 mm thick or more. Thinner steel, automatically hot dip galvanized tubes and centrifugal work (usually threaded work and fittings) have thinner coatings, but usually greater than 45 µm. Where it is desired to use coatings of different thicknesses to those stated, their lives can be ascertained by calculation; the life of a zinc coating is (to a first approximation) proportional to its thickness. For tubes, EN 10240 includes an option for the purchaser to specify a thicker coating requirement which will give an extended service life. Hot dip galvanized coatings thicker than 85 µm are not specified in ISO 1461 but the general provisions of that standard apply and, together with specific thickness figures, may form a specification capable of third party verification. It is essential to know the composition of the steel to be used and the galvanizer should be consulted before specifying as these thicker coatings may not be available for all types of steel. Where the steel is suitable, thick coatings may be specified; the following figures are given as a guideline.

Product and thickness, <i>t</i> mm	Local coating thickness µm (minimum)	Average coating thickness µm (minimum)
Steel $t \geq 6$	100	115
Steel $3 < t < 6$	85	95
Steel $1 < t \leq 3$	60	70
Small centrifuged articles	Not recommended	Not recommended

Thicker coatings than those listed above (e.g. 150 µm to 200 µm) require even more care in selection of steels. With all thick coatings it may be necessary to check the thickness obtainable by hot dip galvanizing a sample product. The composition of iron and steel also affects the rate of reaction of steels with zinc. In general, if the silicon plus 2½ times the phosphorus content is less than 0,1%, coherent light grey coatings are likely to form. Good, coherent coatings of controlled-thickness can, however, be obtained on most types of steel.

NOTE 3 Build-up or repair of zinc coatings: Inadequate thickness, e.g. on small components, may be made up by applying zinc-dust paints to give the total thickness of zinc needed for the life requirements. Discontinuities and damaged areas may be made good by spraying with zinc, special zinc-alloy solder-sticks or zinc-rich paint (see ISO 1461). The specifier should ensure that the repaired area is compatible with any subsequent coatings that may be applied.

NOTE 4 Maintenance intervals for metal coatings which are to be painted (see 7.5): When bare hot dip galvanized surfaces or sealed sprayed metal surfaces are maintained by the use of paint, the future maintenance intervals will be those of the metal-plus-paint system which often is less than that for the bare metal coating but longer than for a similar paint system applied directly to the steel. Unsealed sprayed metal coatings should preferably be adequate, without maintenance in service, to protect the structure for its required life because maintenance operations for unsealed coatings are usually more elaborate than for sealed coatings. The systems recommended in table 2 in the 'very long' life category will, in general, meet the life requirements when maintenance takes place after 20 years. Where there is scope for maintenance of very long life coatings before the 20 year period has elapsed, it may be advantageous to undertake such maintenance, especially if the structure is required to last indefinitely. In the most unfavourable combination of circumstances in any one category, it may be necessary to blast-clean and recoat the steel.

Table 2 (concluded)

NOTE 5 Sealed thermally sprayed coatings: The appearance and life of sprayed metal coatings is improved by sealing. Vinyl or epoxy co-polymer sealers are widely used. There is no need for a measurable overlay of sealer but sealers should be applied until absorption is complete. Sealing is particularly desirable with aluminium coatings and when it is desired to retain the sprayed coating when the surface is eventually maintained; such maintenance then needs only the renewal of the sealer. Painting of sprayed metal coatings is seldom the preferred treatment except when colour, an inert barrier or additional abrasion resistance is required.

NOTE 6 Contact of metal coatings with concrete: The alkalinity of concrete makes it unsuitable for direct contact with aluminium or aluminium coatings and an inert barrier layer should be present. In the atmosphere, an interface of either aluminium or zinc with concrete, soil, etc, benefits from application of an inert layer which in suitable cases can be formed in situ by controlled reaction of zinc with the concrete as this ensures a good and consistent bond strength.

NOTE 7 Anti-fouling paints: Special formulations of paints are available to prevent formation of marine deposits on structures. Most anti-fouling paints need to be re-applied every year or every two years. Zinc and aluminium should not normally be overcoated with copper or mercury compounds.

NOTE 8 Thin thermally sprayed coatings: ISO 2063 permits 50 µm unsealed zinc coatings indoors and 50 µm painted zinc coatings both indoors and in urban environments and hence they have been included here. Consultation with the thermal sprayer is recommended when specifying such thin coatings as in practice many thermal sprayers recommend higher minima.

NOTE 9 In the more aggressive atmospheres, coatings of zinc under about 30 µm should be painted initially.

NOTE 10 In the more aggressive atmospheres, maintenance is recommended at 10 years or even earlier if the optimum long life cycle is to be achieved.

NOTE 11 Very long lives can also be achieved by zinc or aluminium coatings plus paint (see 7.5). Metal coatings plus paint or powder coatings applied initially are an alternative to increasing the thickness of the metal coating. Such coatings can usually be specified for maintenance after 10 years to 15 years.

Annex A (informative)

Design for hot dip galvanizing of products

A.1 General

It is essential that the design of any article required to be finished should take into account not only the function of the article and its method of manufacture but also the limitations imposed by the finish. Figures A.1 to A.11 illustrate some of the important design features, some of which are specific to hot dip galvanizing.

A.2 Surface preparation

The design and the materials used should permit good surface preparation. This is essential for the production of a high quality coating. It is essential that surface contaminants, including those that cannot be removed by pickling, e.g. oil, fat, paint, welding slags and spatter and similar impurities such as anti-spatter compounds, be completely removed. It is essential that lacquers, wax, paint, oil and grease-based markings be avoided. Surfaces should be free from defects to ensure a coating of good appearance and serviceability.

Graphite exposed at the surface of iron castings interferes with wetting by molten metal and those castings that have been annealed may have silica particles in the surface layers which have to be removed in order to obtain a good quality hot dipped coating. Grit blasting is recommended both before and after annealing.

A.3 Procedures related to design considerations

The hot dip bath and associated plant should be of adequate capacity to process the articles to be hot dip coated with zinc. Articles that are too large for the available baths may be partially immersed and then reversed for length or depth so that a complete coating is obtained.

All work has to be secured during immersion in the baths. Bolt holes are often available. Lifting lugs (see figure A.9) are often incorporated to assist general handling. Articles may be held in racks or jigs; some contact marks may be visible after hot dip galvanizing in such cases. The dipping operation involves vertical movement out of the bath, but the parts being withdrawn may be inclined at an angle. The processing sequence requires circulation of air, pretreatment liquids and zinc to all surfaces of the workpiece. Air pockets prevent local surface preparation and give uncoated surfaces; liquids in enclosed air vaporize at the hot dip galvanizing temperature of about 450 °C and the force generated can cause buckling or explosions; excess zinc may adhere poorly, may look unattractive and is wasteful.

Suitable articles, e.g. heat exchangers and gas cylinders, may be hot dip galvanized on the outside only (see figure A.11). This involves special techniques and equipment (e.g. to push the article into the bath against the buoyancy of the molten zinc) and a specialist galvanizer should be consulted in advance.

A.4 Design features

Preferred design features for articles to be hot dip galvanized are shown in figures A.1 to A.11.

WARNING It is essential that sealed compartments are avoided or are vented, otherwise there is a serious risk of explosion.

The provision of holes for venting and draining tubular fabrications (see figures A.5 and A.10) also allows a coating to be formed on the inside surfaces and therefore ensures better protection for the article. Occasionally, at sufficiently high levels of residual stress in the component, stress relief may occur at the hot dip galvanizing temperature. This is one of the main causes of unexpected distortion or cracking of the steel component. Symmetrical sections are preferred; as far as possible, large variations in thickness or cross section, e.g. thin sheet welded to thick angles, should be avoided; welding and fabrication techniques should be chosen to minimize the introduction of unbalanced stresses; differential thermal expansion should be minimized during welding and processing. Heat treatment may be desirable before hot dip galvanizing processing. Discussions with the galvanizer on the order of assembly of fabricated components may be helpful. Compact sub-assemblies (which occupy minimum bath space) are most economical to galvanize. Welding is preferable before hot dip galvanizing to ensure a continuous hot dip galvanized coating over the weld. Further information regarding stresses in the basis metal is given in ISO 1461:1999, C.1.5.

Articles should be designed so as to assist the access and drainage of molten metal and so that air locks are avoided. A smooth profile, avoiding unnecessary edges and corners, assists hot dip galvanizing; this, and bolting after galvanizing, improves long-term corrosion resistance.

Holes which are necessary in structures for the hot dip galvanizing process are preferably made before assembly and by cutting or grinding-off corners of sections; this facilitates the absence of 'pockets' in which excess molten zinc can solidify. When already assembled, burning may be the optimum method of producing holes as the space available for drilling may not allow the hole to be close enough to the edge or corner.

A.5 Clearances

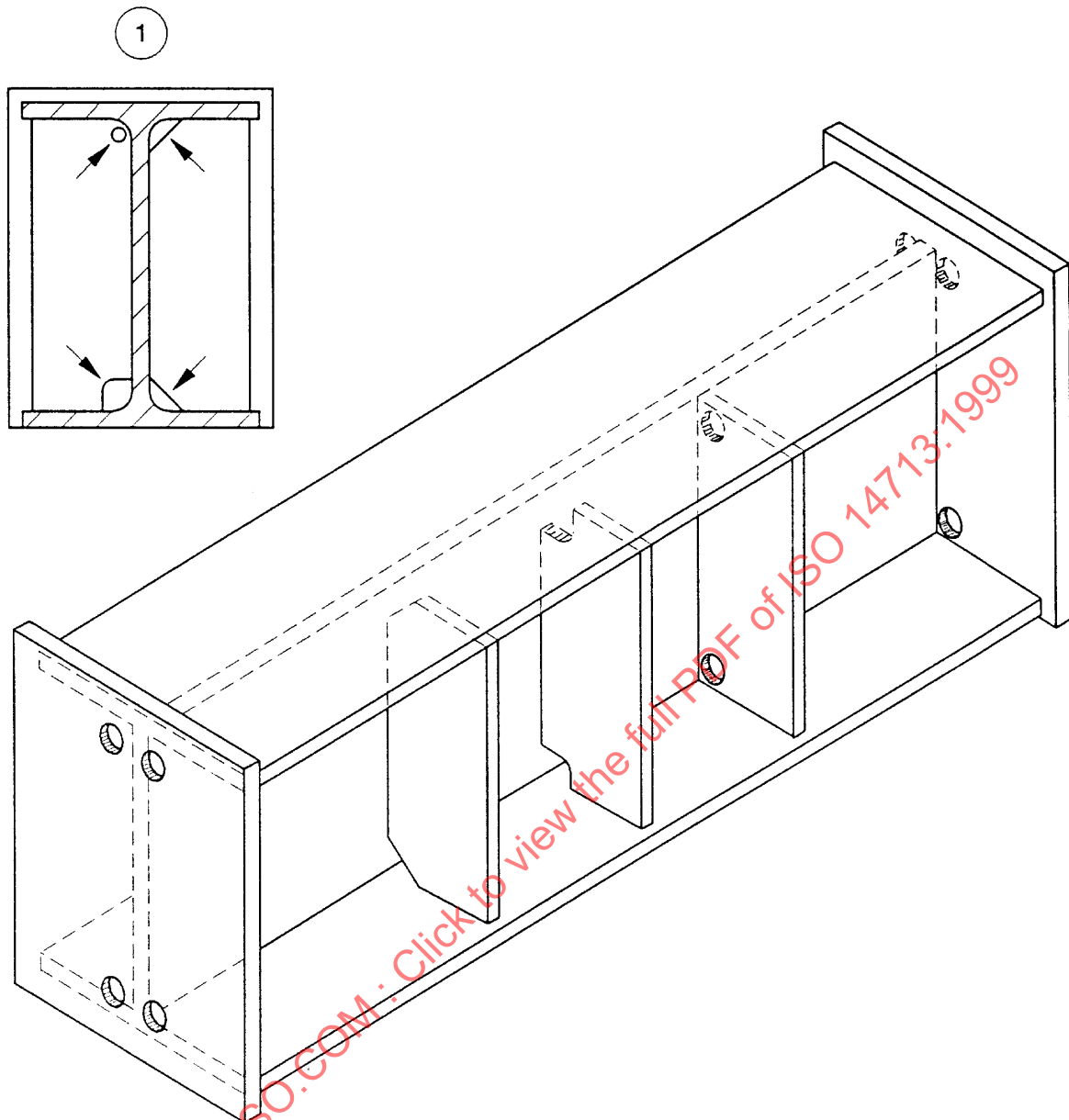
The thickness of the hot dip coating is determined mainly by the nature and thickness of the steel. On mating surfaces and at holes, extra clearance should be provided to allow for the thickness of the coating metal. Typically, for hot dip galvanized coatings on flat surfaces, an allowance of 1 mm has been found satisfactory.

For threaded work, the situation is more complicated. For example, for hot dip galvanized and centrifuged nuts and bolts, current practices differ in different countries. Either:

- a) the bolts are threaded to the tolerances laid down in the appropriate specification without allowance being made for hot dip galvanizing; the nuts are then tapped up to 0,4 mm oversize after hot dip galvanizing; or
- b) the bolts are undersized (e.g. Swedish Standards SS 3192 to SS 3194) so that standard threads on hot dip galvanized nuts can be used in all cases.

A.6 Design for storage and transport

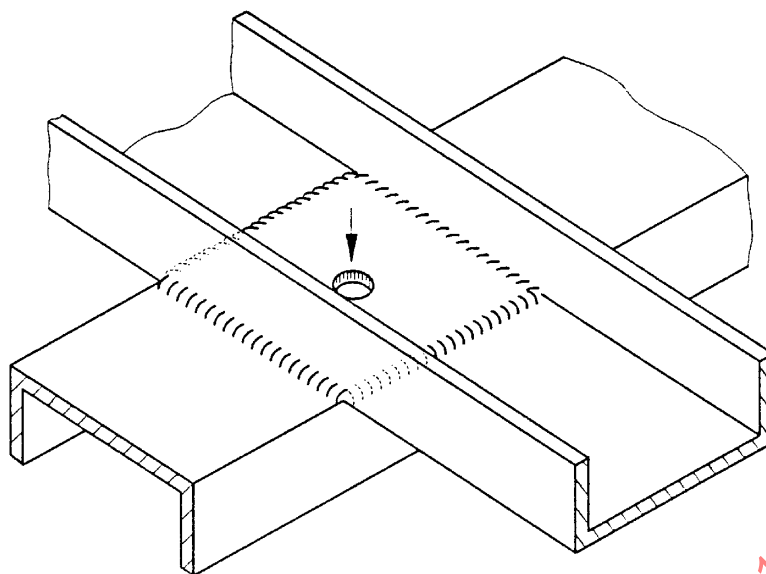
Hot dip galvanized iron and steel should always be stacked so that air can circulate freely over all surfaces. Where large flat surfaces occur, e.g. box sections, spacers should be used (unless projections can be incorporated in the design) to reduce wet storage stain if stored or if transported outdoors. Articles should not be designed for nesting or close packing where condensation and/or capillary action can attract water between contacting surfaces (see also ISO 1461).



1 section through the main beam showing the three types of cut-out needed to facilitate metal flow during hot dip galvanizing

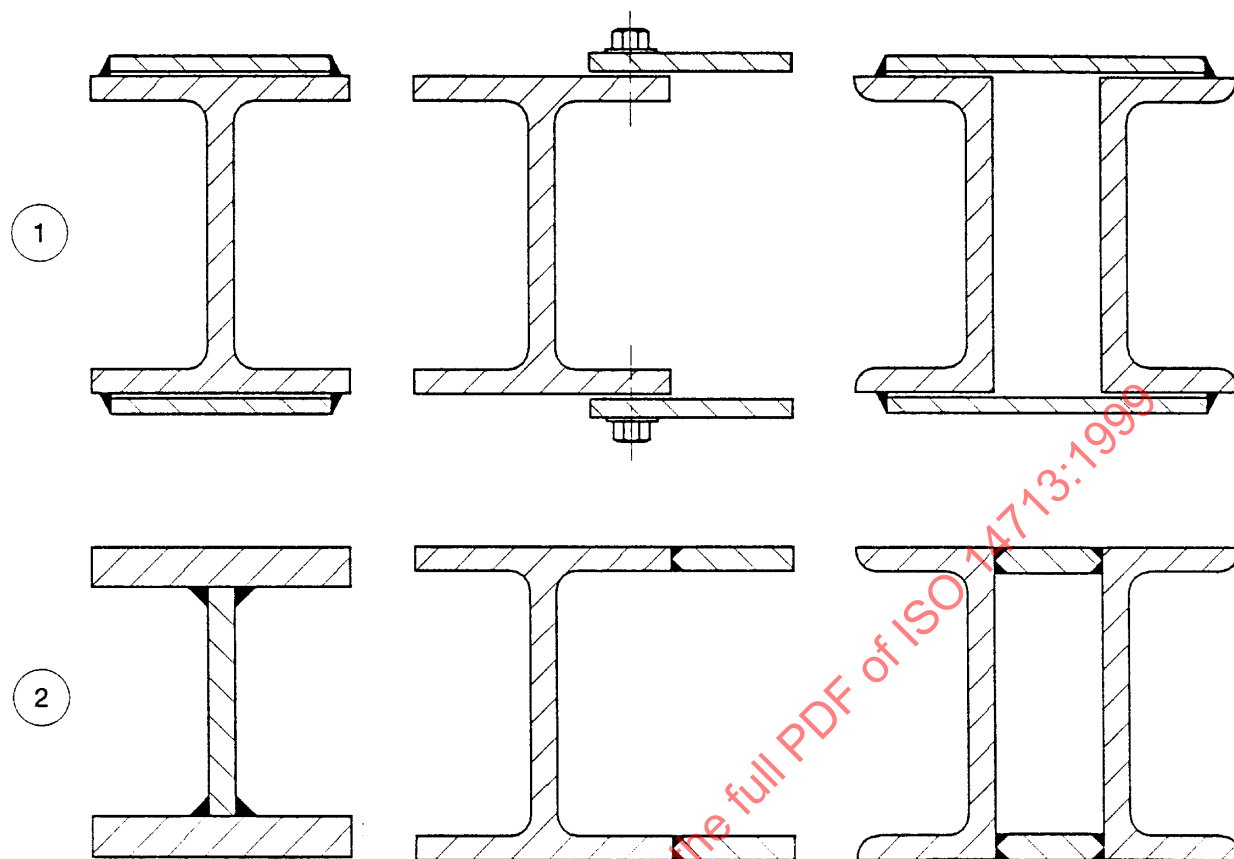
NOTE External stiffeners, welded gussets and webs on columns and beams and gussets in channel sections should have their corners cropped. The gaps created should be as large as possible without compromising structural strength. If welding is required around the edge created, a radiused cut is desirable to facilitate continuity of the weld around the cut end to the other side. Circular holes are less effective; if used, they should be as close to corners and edges as practicable. Where more convenient, the cropped corners or holes may be in the main beam. In large box sections (see also figure A.9), internal stiffeners should have the centre cut away in addition to cropping corners; cropping alone is sufficient with small box sections. Angle bracings should, if possible, be stopped short of the main beam flange. Where base plates are present, extra venting is needed. All these features are a) to prevent entrapment of air during processing and hence allow access of pickle acids and molten zinc to all surfaces of the work; b) to facilitate drainage during withdrawal from acid and rinse tanks and from the galvanizing bath. The precise position of holes and gaps may vary with the dipping technique and a galvanizer should be consulted at the design stage.

Figure A.1 — Beams, gussets and webs



NOTE For surfaces in contact, a hole should be drilled as indicated, especially with thin steel. Hole sizes take into account the area of overlap. More than one hole may be needed depending on the shape of the overlap; entrapment of liquid should be avoided (see figure A.3). This precaution is necessary in order to avoid explosions in the hot dip galvanizing operation. It is not necessary to drill through both pieces in contact but to do so assists free flow of liquid.

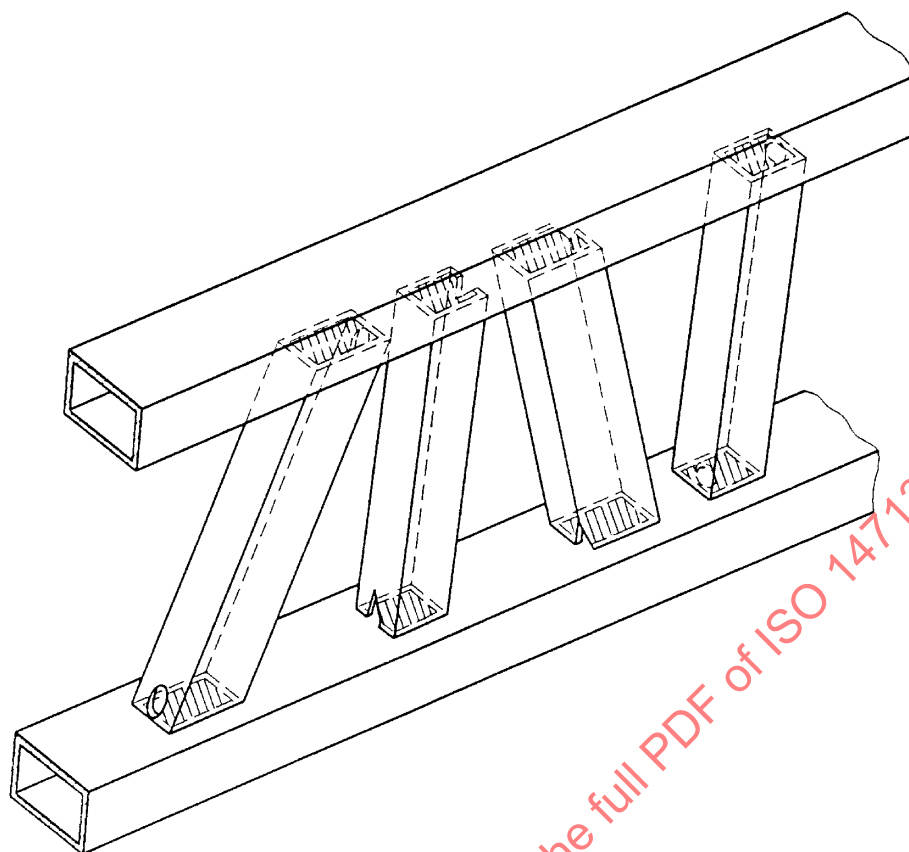
Figure A.2 — Welding flat surfaces together



- 1 avoid
2 prefer

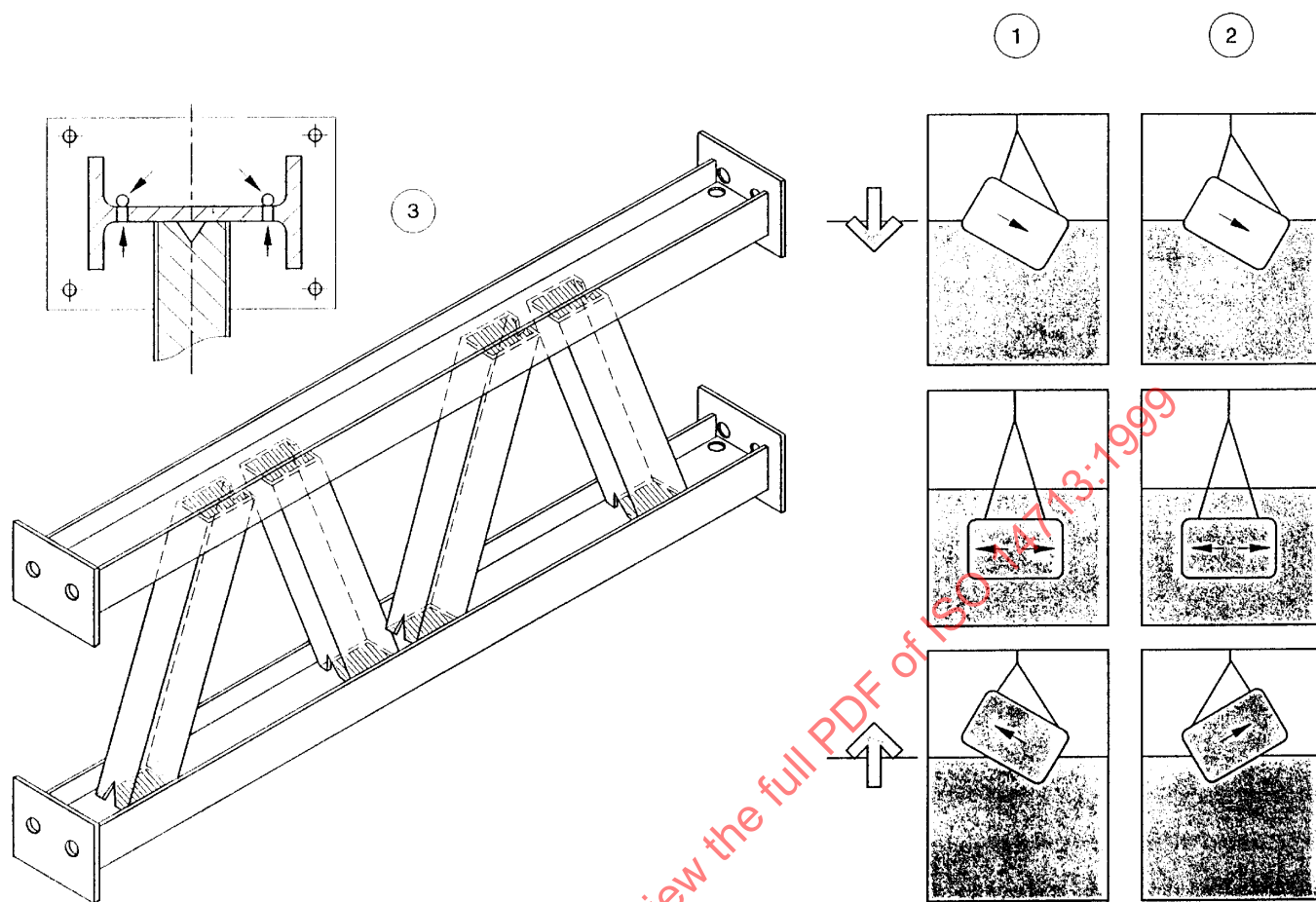
NOTE Narrow gaps between parts, and especially surfaces in flat contact with each other, will allow liquid to penetrate but will not allow a hot dip galvanized coating to form between them. Welded joints should be continuous if they are not enclosing an otherwise unvented surface. Bolted joints are preferably made after hot dip galvanizing. All components can be hot dip galvanized. Hot dip galvanizing of suitable standard rolled products before assembly by bolting facilitates both processing and construction and allows for easy disassembly later; it is also the most practical method and the least costly.

Figure A.3 — Narrow gaps



NOTE Provision should be made for venting and draining (preferably visible externally for reasons of inspection and safety). Cross sections or chord members with ends sealed, e.g. by plates, should be provided with drilled holes or V-notches diagonally opposite each other at top and bottom, as close as possible to the sealed end. The holes should be as large as possible; a typical minimum for small fabrications is 10 mm diameter; holes in larger fabrications should be about 25% of the diameter of the member. (See also figure A.5.)

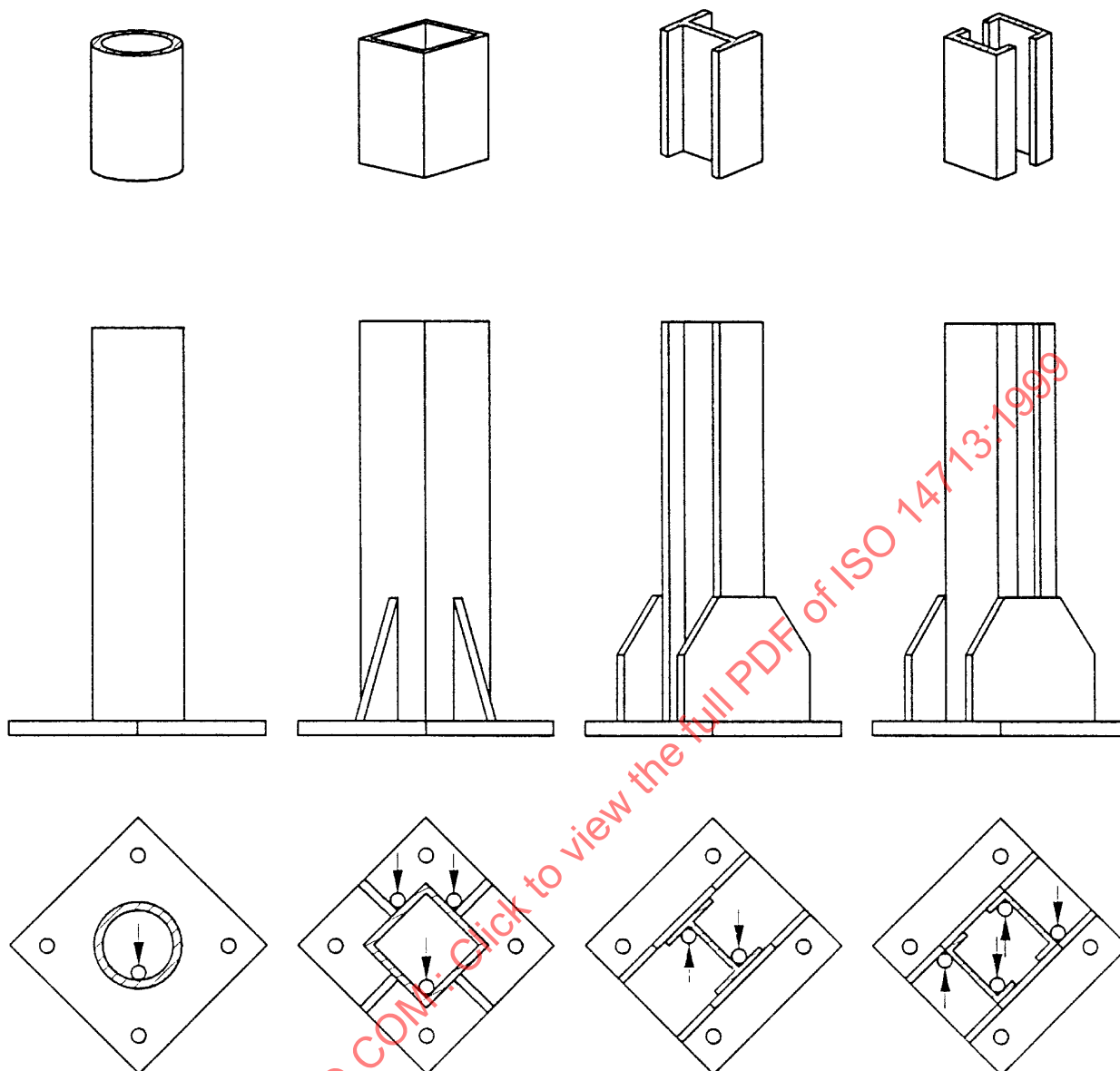
Figure A.4 — Structural hollow sections



- 1 example of orientation during immersion (most commonly used)
- 2 example of orientation during immersion (alternative)
- 3 indicative venting

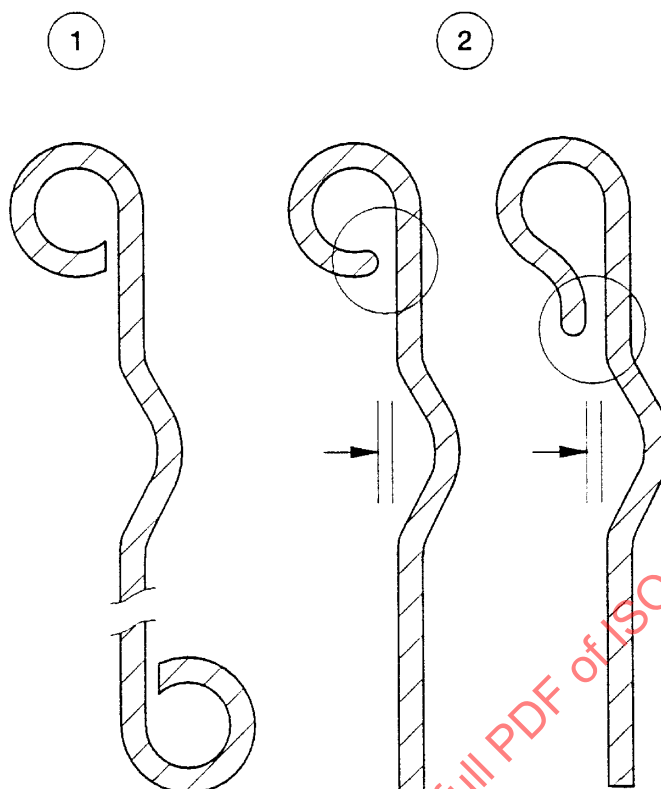
NOTE The zinc should drain freely; preferred practice is to immerse at an angle and, after immersion, to withdraw at the opposite angle. The position of the vents should be related to the alignment during withdrawal.

Figure A.5 — Orientation during hot dip galvanizing



NOTE Vent holes at each end of the fabrication should be diagonally opposed. The preferred option should be determined in conjunction with the hot dip galvanizer.

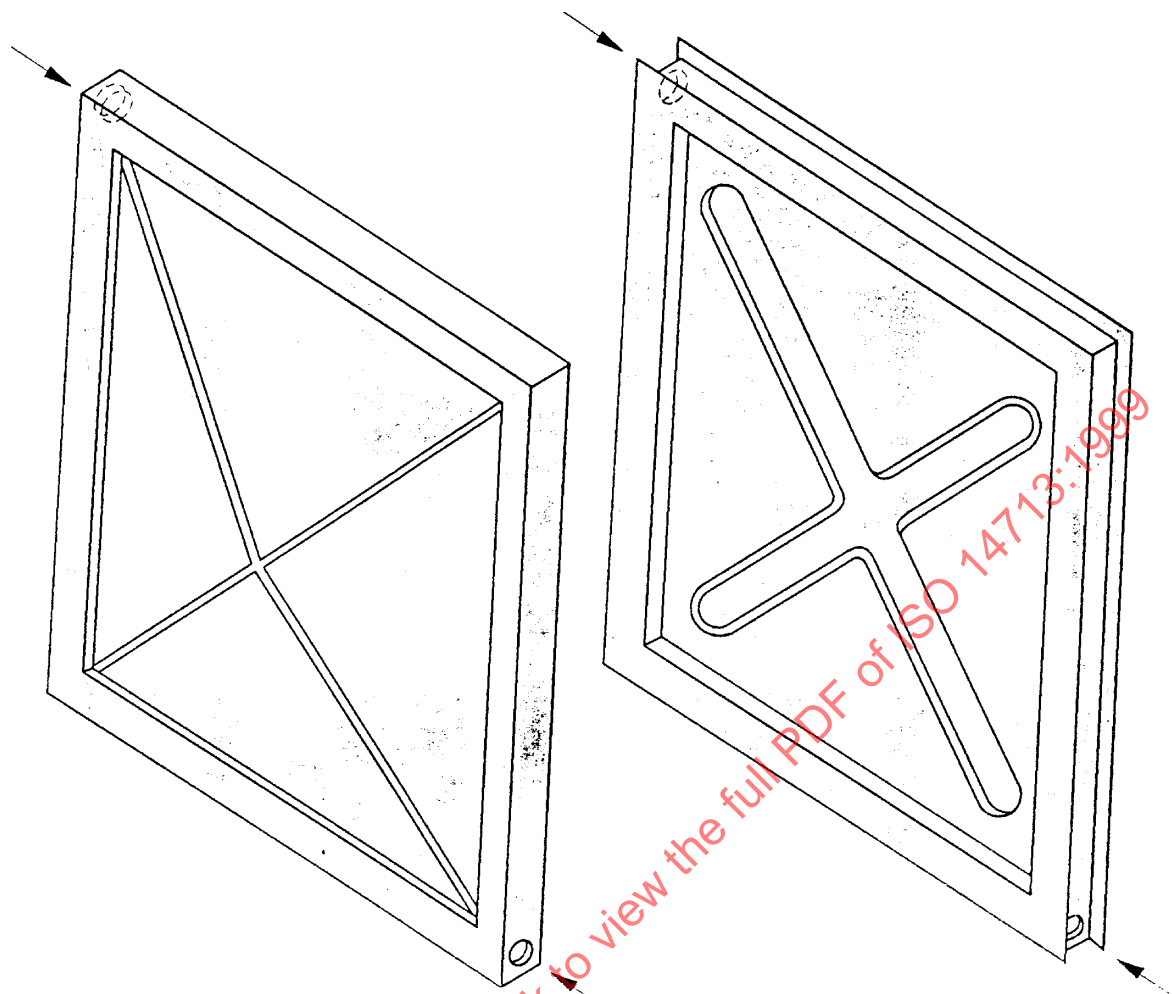
Figure A.6 — Alternative designs for venting sections fixed to base plates



- 1 avoid
2 prefer

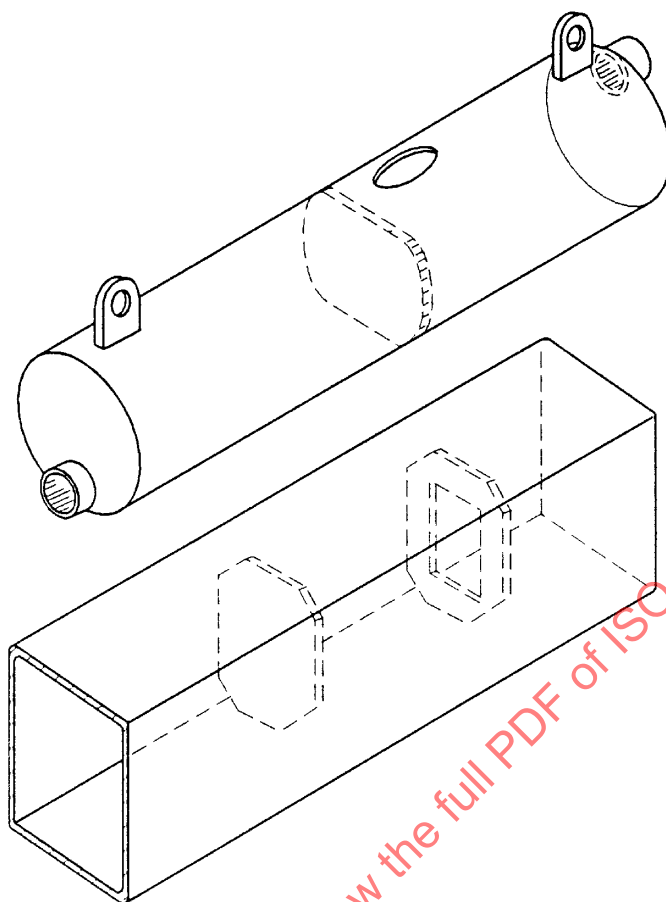
NOTE The design of the part and the method of support in the zinc bath should allow free flow of zinc from within the rolled edge at the time of withdrawal from the molten zinc. Rolled edges should be open and with an adequate gap between the edge of the rolled section and the parent plate and also should not be present at opposite orientations so that molten zinc is held by one of the 'cups'.

Figure A.7 — Rolled edges



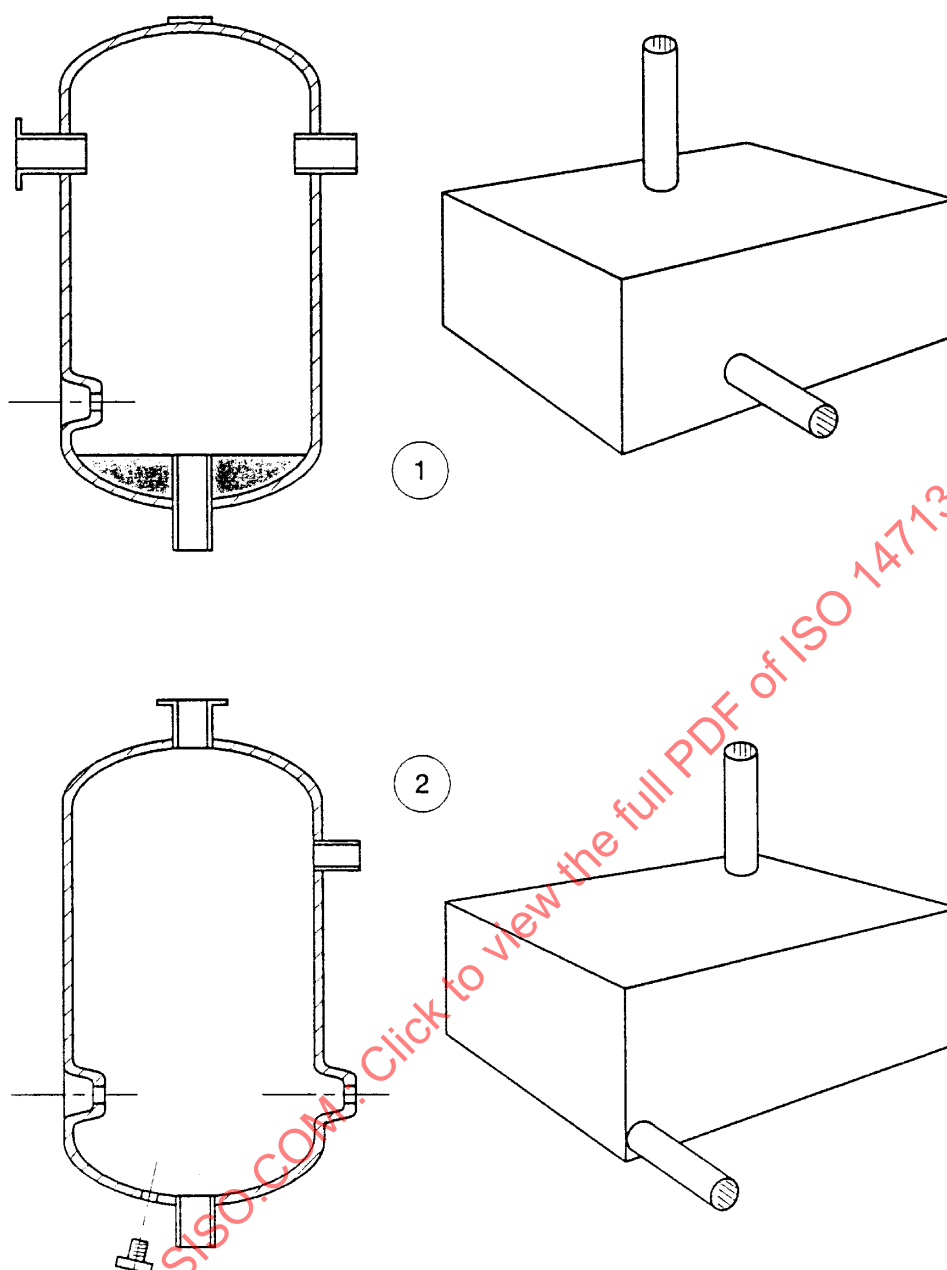
NOTE Large open tanks should be braced to minimize distortion. Where angles are used around the rim of the tank, openings should be provided in the corners. Flat panels are liable to distort. Where possible, braces, e.g. dished or ribbed panels, should be used.

Figure A.8 — Galvanizing of flat plates



NOTE Vents should be diametrically opposite and at least 50 mm in diameter. Internal baffles should be cropped top and bottom and the cropped areas should be visible through an inspection hole. Large vessels require an appropriate size manway in addition to the vent shown on the figure — a galvanizer can advise on size. Lifting lugs should be incorporated and should be adequate for the excess mass of molten zinc within the cylinder on withdrawal.

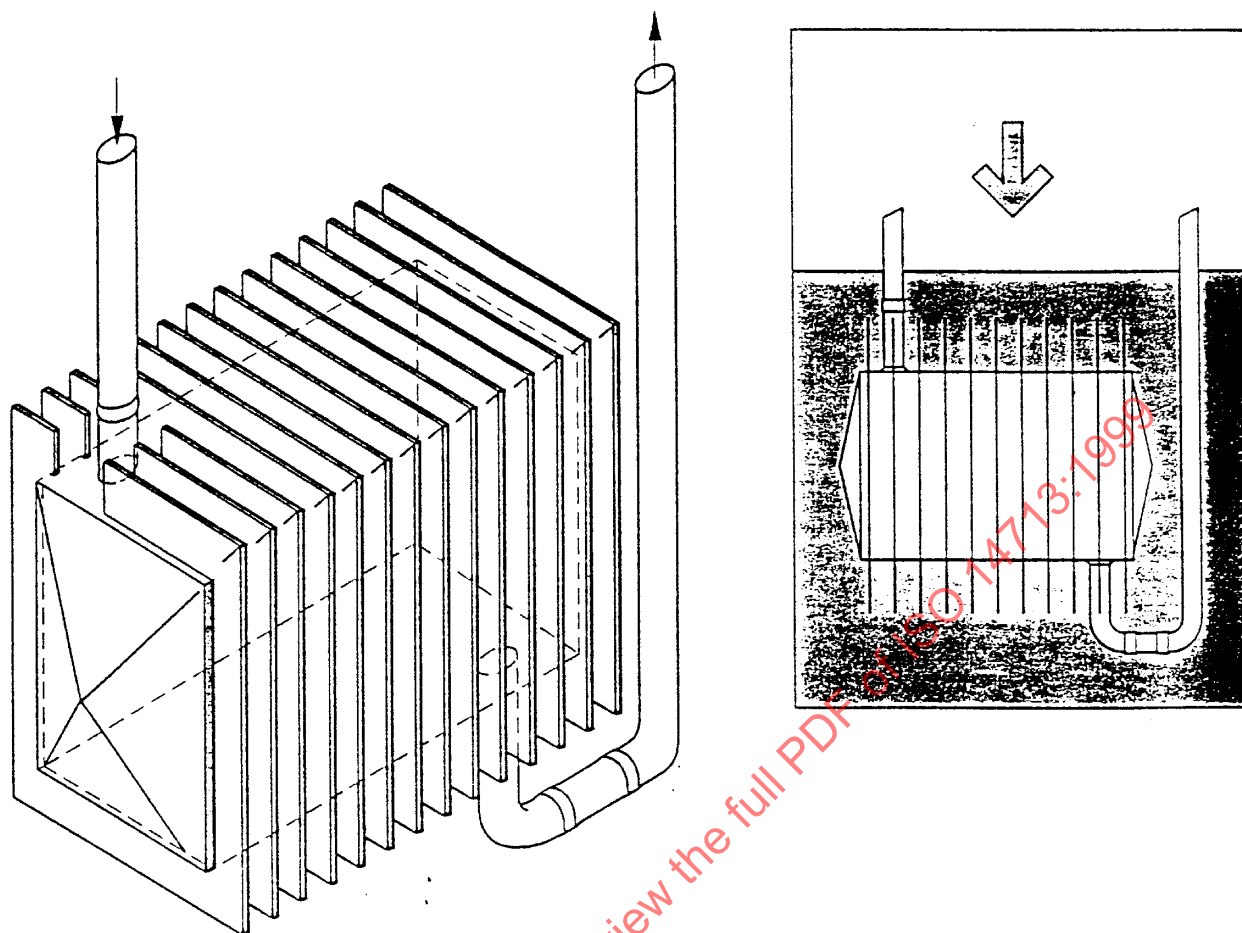
Figure A.9 — Cylinders



1 avoid
2 prefer

NOTE When internal bosses are used, a drain-hole should be included in the fabrication; this may be plugged after hot dip galvanizing if required.

Figure A.10 — Enclosed cavities



NOTE Where only the outside of an assembly is required to be hot dip galvanized (e.g. a container or a heat exchanger), it is necessary to a) seal openings that will be below the surface of the molten zinc; b) add extension pieces to suitable openings to allow the hot (and expanded) air from all parts of the assembly to escape; c) provide equipment to force the assembly under the molten zinc (without downward pressure, it would float only partially immersed).

Figure A.11 — External hot dip galvanizing only