INTERNATIONAL STANDARD

ISO 14713-2

Second edition
2019-10

Zinc coatings — Guidelines and recommendations for the protection against corrosion of iron and steel in structures —

Part 2: Hot dip galvanizing

Revêtements de zinc — Lignes directrices et recommandations pour la protection contre la corrosion du fer et de l'acier dans les constructions —

Partie 2: Galvanisation à chaud

Reference number
ISO 14713-2:2019(E)

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Published in Switzerland

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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

This document was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*, Subcommittee SC 4, *Hot dip coatings (galvanized, etc.)*.

This second edition cancels and replaces the first edition (ISO 14713-2:2009), which has been technically revised. The main changes compared with the previous edition are as follows:

— minor technical changes have been made and two new notes have been added to Table 1;

— improvements have been made to the clarity of recommendations throughout Clause 6;

— extensive revisions have been made to the figures in Annex A;

— Tables A.1, A.2 and A.3 have been added in Annex A.

A list of all parts in the ISO 14713 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The protection afforded by the hot dip galvanized coating to the article will depend upon the method of application of the coating, the design of the article and the specific environment to which the article is exposed. The hot dip galvanized article can be further protected by the application of additional coatings (outside the scope of this document), such as organic coatings (paints or powder coatings). When applied to hot dip galvanized articles, this combination of coatings is often known as a "duplex system".

Specific product-related requirements, for which specific standards could exist (e.g. for hot dip galvanized coatings on tubes or fasteners), take precedence over these general recommendations.

Zinc coatings — Guidelines and recommendations for the protection against corrosion of iron and steel in structures —

Part 2: Hot dip galvanizing

1 Scope

This document gives guidelines and recommendations for the general principles of design appropriate to articles to be hot dip galvanized after fabrication (e.g. in accordance with ISO 1461) for the corrosion protection of, for example, articles that have been manufactured in accordance with EN 1090-2.

This document does not apply to hot dip galvanized coatings applied to continuous wire or sheet (e.g. to EN 10346).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 8044, *Corrosion of metals and alloys — Basic terms and definitions*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8044 and the following apply.

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

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

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

3.1
hot dip galvanizing
formation of a coating of zinc and/or zinc-iron alloys on iron and steel products by dipping prepared steel or cast irons in the zinc melt

3.2
hot dip galvanized coating
coating obtained by *hot dip galvanizing* (3.1)

Note 1 to entry: The term "hot dip galvanized coating" is subsequently referred to as the "coating".

3.3
duplex system
hot dip galvanized coating (3.2) with an additional paint or powder coating

4 Design for hot dip galvanizing

4.1 General

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

Some internal stresses in the articles to be galvanized will be relieved during the hot dip galvanizing process and this can cause deformation or damage to the coated article. These internal stresses arise from the finishing operations at the fabrication stage, such as cold forming, welding, oxy-cutting or drilling, and from the residual stresses inherited from the rolling mill.

The purchaser should seek the advice of the galvanizer before designing or making a product that is subsequently to be hot dip galvanized, as it can be necessary to adapt the construction of the article for the hot dip galvanizing process.

4.2 Surface preparation

The design and the materials used should permit good surface preparation. This is essential for the production of a high-quality coating (see 6.4).

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

4.3 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. Preferably, articles should be designed to enable coating in a single dipping operation. 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. Partial immersion (and then dipping for a second time to complete the coating) is less common than the single, complete immersion operation.

All work is secured during immersion in the baths. Arrangements for lifting and handling should be made before articles are delivered to the galvanizer. When necessary, the customer should consult the galvanizer and advise of any limitations (e.g. on the use of existing holes). Lifting lugs are often incorporated to assist general handling.

Articles may be held in racks or jigs. Some contact marks can 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 the circulation of air, pretreatment liquids and zinc to all surfaces of the article. 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 can adhere poorly, can look unattractive and is wasteful.

Suitable articles, e.g. heat exchangers and gas cylinders, can, if required, be hot dip galvanized on the outside only. 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.

Hot dip galvanizing of hollow sections ensures protection of both internal and external surfaces. Small amounts of trapped zinc ash can be unavoidable within hollow sections and, for certain shapes and designs, cannot be removed.

4.4 Design features

Preferred design features for articles to be hot dip galvanized are shown in Annex A.

WARNING — It is essential that sealed compartments be avoided or be vented, otherwise there is a serious risk of explosion that could cause serious injury to operators. This aspect of design shall be given careful consideration and is essential in order to maintain satisfactory standards of health and safety for operators.

In addition to provision for venting and draining of tubular fabrications, holes also allow a coating to be formed on the inside surfaces and therefore ensure better protection for the article. Occasionally, at sufficiently high levels of residual stress in the article, stress relief can occur at the hot dip galvanizing temperature. This is one of the main causes of unexpected distortion or cracking of the steel article. Symmetrical sections are preferred and, 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 can be desirable before hot dip galvanizing.

The purchaser should discuss with the galvanizer the requirements for coating and assembly of fabricated articles before galvanizing. Compact sub-assemblies (which occupy minimum bath space) are the most economical to galvanize. Welding is preferable before hot dip galvanizing, to ensure a continuous hot dip galvanized coating over the weld.

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, combined with bolting after galvanizing, improves long-term corrosion resistance.

Holes that 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 could 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 corners.

Internal venting of hollow sections should be avoided. If internal venting is unavoidable, it should be agreed in advance with the galvanizer [see also ISO 1461:2009, A.2, e)] and the customer should ensure that:

a) the holes are of maximum possible size;

b) provision for internal venting is adequately documented (e.g. by photography) before assembly.

4.5 Tolerances

The thickness of the coating is determined mainly by the nature and thickness of the steel. On mating surfaces and at holes, extra tolerance should be provided to allow for the thickness of the coating metal. For coatings on flat surfaces, an allowance of at least 1 mm has been found satisfactory. See ISO 1461 for definitions of significant surfaces and acceptance criteria for the coating. For threaded work, for example, for hot dip galvanized and centrifuged nuts and bolts, current practices differ according to the country. See 7.1.

5 Design for storage and transport

Hot dip galvanized articles should be stacked securely so that the articles can be handled, stored and transported safely.

Where there is a specific need to minimize the development of wet-storage staining (primarily basic zinc oxide and zinc hydroxide, formed on the surface of the galvanized coating during storage of articles in humid conditions), this should be communicated by the purchaser to the galvanizer at the time of ordering and any relevant control measures should be agreed upon.

Such measures can include, for example, storage of articles such that free movement of air across the surfaces of the article is allowed, the use of spacers to minimize contact areas on the work, chemical post-treatment or avoidance of close nesting of work (where the design allows this). Shrink wrapping can lead to water retention within the articles and subsequent wet-storage staining.

In accordance with ISO 1461, the presence of wet-storage staining is not a cause for rejection, provided the coating thickness remains above the specified minimum requirements at the time of acceptance inspection.

6 Effect of article condition on quality of hot dip galvanizing

6.1 General

Most steels can be hot dip galvanized in accordance with ISO 1461. This includes unalloyed carbon steels (see, e.g., EN 10025-2), fine-grained steels (see, e.g., EN 10025-3 and EN 10025-4), quenched and tempered steels, hollow sections that are hot finished (see, e.g., EN 10210-1), hollow sections that are cold finished (see, e.g., EN 10219-1), reinforcement steels (see, e.g., EN 10080 and EN 10348-2), fastener grade steels [see, e.g., ISO 898 (all parts)], grey cast iron (see, e.g., EN 1561) and malleable cast iron (see, e.g., EN 1562). Where other ferrous metals are to be galvanized, adequate information or samples should be provided by the purchaser for the galvanizer to decide whether these steels can be satisfactorily galvanized. Sulfur-containing free-cutting steels are normally unsuitable. Stainless steels are unsuitable.

6.2 Material composition

Certain elements, in particular silicon (Si) and phosphorus (P), in the steel surface can affect hot dip galvanizing by prolonging the reaction between iron and molten zinc. Therefore, certain steel compositions can achieve more consistent coatings with regard to appearance, thickness and smoothness. The prior history of the steel (e.g. whether hot rolled or cold rolled) can also affect its reaction with molten zinc. Where aesthetics are important or where particular coating thickness or surface smoothness criteria exist, specialist advice on steel selection should be sought prior to fabrication of the article or hot dip galvanizing.

Table 1 gives simplified guidance on steel compositions that are associated with certain typical coating characteristics when galvanizing is carried out at temperatures of 440 °C to 460 °C.

Table 1 — Coating characteristics related to steel composition

Category	Typical levels of reactive elements % (mass fraction)	Additional information	Typical coating characteristics
A	≤ 0,03 % Si <u>and</u> < 0,02 % P	See NOTE 1 and NOTE 4	Coating has a shiny appearance with a finer texture. Coating structure includes outer zinc layer.
B	≥ 0,14 % Si to ≤ 0,25 % Si	Other elements can also affect steel reactivity. In particular, phosphorus levels greater than 0,035 % will give increased reactivity.	Coating can have shiny or matt appearance. Coating structure can include outer zinc layer or iron-zinc alloy can extend through to the coating surface depending on steel composition.
C	> 0,03 % Si to < 0,14 % Si	Excessively thick coatings can be formed.	Coating has a darker appearance with a coarser texture. Iron/zinc alloys dominate coating structure and often extend to the coating surface, with reduced resistance to handling damage.
D	> 0,25 % Si	Coating thickness increases with increasing silicon content.	

NOTE 1 Steels with compositions satisfying the formula Si ≤ 0,03 % and Si + 2,5P ≤ 0,09 % are also expected to exhibit these characteristics. For cold rolled steels, these characteristics are expected to be observed when the steel composition satisfies the formula Si + 2,5P ≤ 0,04 %.

NOTE 2 The presence of alloying elements (e.g. nickel or aluminium) in the zinc melt can have a significant effect on the coating characteristics indicated in this table. This table does not provide relevant guidance for high-temperature galvanizing (i.e. immersion in molten zinc at 530 °C to 560 °C).

NOTE 3 The steel compositions indicated in this table will vary under the influence of other factors (e.g. hot rolling) and the boundaries of each range will vary accordingly.

NOTE 4 Steels with compositions < 0,01 % silicon that also have aluminium contents > 0,035 % can exhibit lower reactivity that could result in a lower than expected coating thickness. These steels can exhibit reduced levels of coating cohesion.

NOTE 5 The design of the article to be galvanized can also influence coating characteristics.

6.3 Castings

Castings should be as free as possible from surface porosity and shrinkage holes and should be cleaned by grit blasting, electrolytic pickling or by other methods especially suitable for castings. 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 that castings tend to possess can result in thicker galvanized coatings than on rolled articles.

NOTE Castings can take several forms:

— 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: black-heart, white-heart and pearlitic. The toughness and workability are derived from annealing processes and no primary graphite is permissible.

6.4 Surface condition

The surface of the basis metal should be clean before dipping into the molten zinc. Degreasing and pickling in acid are the recommended methods of cleaning the surface. Excessive pickling should be avoided. Surface contamination that cannot be removed by pickling, e.g. carbon films (such as rolling oil residues), oil, grease, paint, some weld anti-spatter sprays, welding slag, labels, glues, marking materials, fabrication oils and similar impurities, should be removed prior to pickling as this can otherwise lead to uncoated areas after galvanizing. Weld anti-spatter sprays that are not removed during degreasing and pickling should be avoided. Silicone-free sprays are preferred. The excessive use of welding spray should be avoided. Burnt-on suds-type cutting fluids and burnt-on weld anti-spatter sprays should be removed. The purchaser is responsible for removing such contamination, unless alternative arrangements have been agreed between the galvanizer and the purchaser.

NOTE Some steel surface conditions arising from their prior processing, e.g. rolling, are not always visible prior to galvanizing and can have an adverse effect on coating quality. Steels with laps or folds can lead to raised areas or ridges in the coating.

6.5 Influence of steel surface roughness on the hot dip galvanized coating thickness

The roughness of the steel surface has an influence on the thickness and structure of the coating. The effect of surface unevenness, e.g. scratches or striations, of the steel surface generally remains visible after galvanizing. A rough steel surface, as obtained by grit blasting, coarse grinding, etc., prior to pickling, gives a thicker coating than a surface that is obtained by pickling alone.

6.6 Influence of thermal cutting processes and welding

6.6.1 Thermal cutting

Flame-cutting, laser-cutting and plasma-cutting changes the steel composition and structure in the zone on and around the cut surface, so that the minimum coating thickness can be more difficult to obtain and the coating so formed can exhibit a decreased cohesion/adhesion to the steel substrate. In order to obtain these coating thicknesses more reliably and to ensure adequate cohesion/adhesion of the coating, flame-cut, laser-cut and plasma-cut surfaces should be ground off by the fabricator and sharp edges should be removed.

6.6.2 Welding

Significant differences between the composition (in particular, the silicon content) of the weld metal and the parent metal can lead to a different coating appearance and thickness at the weld seams. The use of low-silicon welding rods minimizes these effects.

6.6.3 Free edges

Flame cutting can cause localized hardness variations, which can act as stress raisers. A light surface grinding of the edges of the flame-cut areas can remove this effect and minimize the risk of crack initiation during galvanizing. It can also be possible to use flame-softening in these areas.

Re-entrant corners, punched cuts and notches should be carried out in accordance with EN 1090-2:2018, 6.7. It is recommended that such cuts are made using mechanical methods. Special considerations are necessary in the k-areas of universal beams, where copes are cut.

NOTE For hot rolled steel sections, the k-area is the area of the radius where the flange and the web intersect.

6.7 Effect of internal stresses in the steel article

6.7.1 General

The hot-dip galvanizing process involves dipping clean, pretreated, fabricated steel articles in a bath of molten zinc/zinc alloy at a temperature of about 450 °C and withdrawing them when the metallurgical reaction developing the coating is complete. Relief of large or imbalanced stresses in the article during the dipping process can occur. The galvanizer cannot be responsible for any associated deformation of the steelwork during galvanizing (as the specific state of stress in the article at the time of dipping is not in his or her control) unless the distortion has occurred through inappropriate handling (e.g. mechanical damage or incorrect suspension of the article).

6.7.2 Distortion cracking

In rare occurrences, when the internal residual stress in a fabrication overcomes the tensile strength of the steel used to form the article, distortion cracking can occur. Good design for galvanizing will normally avoid these problems.

During the heating and cooling cycle, the article experiences stresses, caused by the differential thermal expansion of elements within the article, interact with the pre-existing stresses in the article. The magnitude of the resultant stress field in the article cannot readily be predicted. During the heating and cooling cycle, imbalanced stresses can contribute to a degree of distortion. Good design for galvanizing and good fabrication practice will minimize any potential for distortion to occur. Where experience shows that specific steels, pretreatments, thermal and mechanical treatments, pickling and hot dip galvanizing procedures have been satisfactory, this information serves as an indication that an embrittlement problem is not to be expected for the same combination of steels, pretreatments, thermal and mechanical treatments and galvanizing procedures.

Hardened and/or high-tensile steels (steels with yield strengths above 650 MPa) can contain internal stresses of such a magnitude that pickling and hot dip galvanizing can increase the risk of cracking of the steel in the hot dip galvanizing bath. Despite the normally low potential for problems of this nature, there could be some critical geometrical configurations of heavy structures for which these effects can be reduced by stress relieving before pickling and hot dip galvanizing. Specialist advice should be sought when hot dip galvanizing such steels.

6.7.3 Hydrogen embrittlement

Structural steels are not normally embrittled by the absorption of hydrogen during pickling. The use of pickling inhibitors reduces hydrogen generation and hydrogen absorption. Remaining hydrogen (if any) does not, in general, affect structural steels. With structural steels, absorbed hydrogen is normally discharged during hot dip galvanizing. For fasteners that are to be hot dip galvanized, see ISO 898-1 and ISO 10684.

6.7.4 Strain age embrittlement

To reduce the risk of embrittlement, local cold deformation should be kept as low as possible at the design stage and at the fabrication stage. Where this latter condition cannot be fulfilled, a heat treatment for stress relieving can be applied to the deformed area before pickling and hot dip galvanizing and/or a steel that is not susceptible to strain age-hardening can be selected.

Cold-work embrittlement is a basic metallurgical phenomenon affecting any steel grade. According to the extent of cold-work deformation, the strength of steel is increased whereas the toughness and ductility are simultaneously decreased. Limits on bend radii given in the relevant steel standards, e.g. EN 10025-2, should be followed. The risks inherent to cold-work embrittlement can be reduced by selecting a steel grade with higher toughness properties. See EN 1993-1-10 for further information.

NOTE 1 Susceptibility to strain-age hardening and the consequent risk of embrittlement is principally caused by the nitrogen content of the steel, which, in turn, is largely dependent on the steel-making process. As a general guide, the problem does not occur in modern steel-making practices. Aluminium-killed steels, or steels containing sufficient alternative nitrogen-binding elements (such as V, Nb and Ti), are the least susceptible to strain-age hardening.

NOTE 2 Heat-treated or cold-worked steels can be tempered by the heat in a hot dip galvanizing bath and lose some of any increased strength obtained by heat treatment or cold working.

6.7.5 Liquid metal assisted cracking or liquid metal embrittlement

Liquid metal assisted cracking (LMAC), or liquid metal embrittlement (LME), occurs when a combination of steel characteristics, fabrication detailing and galvanizing processing variables create conditions for brittle cracking of a steel article during galvanizing. Such a combination of factors rarely occurs in practice. Guidance exists that encourages control of the design (e.g. location of stress concentrations) and detailing of the article (e.g. steel quality, levels of residual stress, quality of welding, position and finishing of drilled or punched holes and flame-cut surfaces), and the galvanizing conditions (e.g. pretreatment conditions, dipping speed, zinc melt composition) for fabrications that could be susceptible to LMAC.

6.8 Large objects or thick steels

Longer handling times are needed in the galvanizing bath for large articles and this, as well as the metallurgical properties of thick steels due to normal manufacturing methods, can cause thick coatings to form. Longer cooling periods can also lead to variations in surface appearance. Combinations of significantly different section thicknesses in large articles will produce different coating thicknesses.

6.9 Hot dip galvanizing practice

Very small amounts of alloying elements may be added to the galvanizing bath as part of the processing technique of galvanizers, notably to reduce the adverse effects of silicon and phosphorus or to modify the surface appearance of the galvanized coating. Such possible additions (while conforming to the requirements of ISO 1461) do not affect the long-term corrosion resistance of the galvanized coating.

Where there is a special requirement, levels of additions or impurities in the bath or in the coating may be specified by the purchaser. For example, where boilers (i.e. tanks and cylinders) are hot dip galvanized and specified for use with hot dip galvanized tubes in potable water systems, the purchaser may require that their coating conforms to the same compositional requirements as for tubes in EN 10240.

For cases related to a critical material and/or to critical conditions of design and fabrication, the galvanizing parameters should be optimized to reduce the risk of distortion or damage. The galvanizer should record the process parameters at all stages of the galvanizing process. Tests can be performed on a small initial lot to assess the suitability of the galvanizing procedure.

7 Effect of hot dip galvanizing process on the article

7.1 Dimensional tolerances on mating threads

There are two different ways to make allowances. Either:

a) the bolts are threaded according to the tolerances laid down in the appropriate specification before galvanizing without allowance being made for hot dip galvanizing and the nuts are then tapped after galvanizing, or

b) the bolts are undersized before galvanizing so that standard threads on hot dip galvanized nuts can be used in all cases.

ISO 10684 also provides requirements for galvanized fasteners.

There are no coating requirements for internal threads that are threaded or re-threaded after hot dip galvanizing. The coating on external threads galvanically protects the internal threads when assembled. The coated threads should have adequate strength to meet the design requirement.

7.2 Effect of process heat

Materials that will be adversely affected by the heat of the hot dip galvanizing bath should not be hot dip galvanized.

Heat-treated or cold-worked steels may be tempered by the heat in the hot dip galvanizing bath and lose some of any increased strength obtained by heat treatment or cold working.

8 After-treatments

Normally, articles should not be stacked together while hot or wet. Small articles dipped in bulk in baskets or on jigs should be centrifuged immediately after withdrawal from the zinc to remove any surplus zinc. To retard the possible formation of wet-storage stain on the surface, articles can be given a suitable surface treatment after hot dip galvanizing.

If the articles are to be painted or powder coated after galvanizing, the purchaser should inform the galvanizer before the article is galvanized.

For the application of duplex systems involving the use of paints, the requirements for surface treatment, painting system, coating thickness, application technologies, etc. should be defined by agreement between the customer and purchaser. More information is given in ISO 12944-5. For the application of duplex systems involving the use of powder coatings, recommendations for powders, pretreatments, applications and system performance can be found in EN 13438 and EN 15773.

Annex A
(informative)

Preferred designs of articles for hot dip galvanizing

External stiffeners, end plates and webs on columns and beams and gussets in channel sections should have their corners cropped as shown in Figure A.1. 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 the corners and edges as practicable.

Where it is more convenient, the cropped corners or holes may be in the main beam. In large box sections, internal stiffeners should have the centre cut away in addition to cropping the 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. These features:

a) prevent entrapment of air during processing and hence allow access of pickle acids and molten zinc to all surfaces of the work;

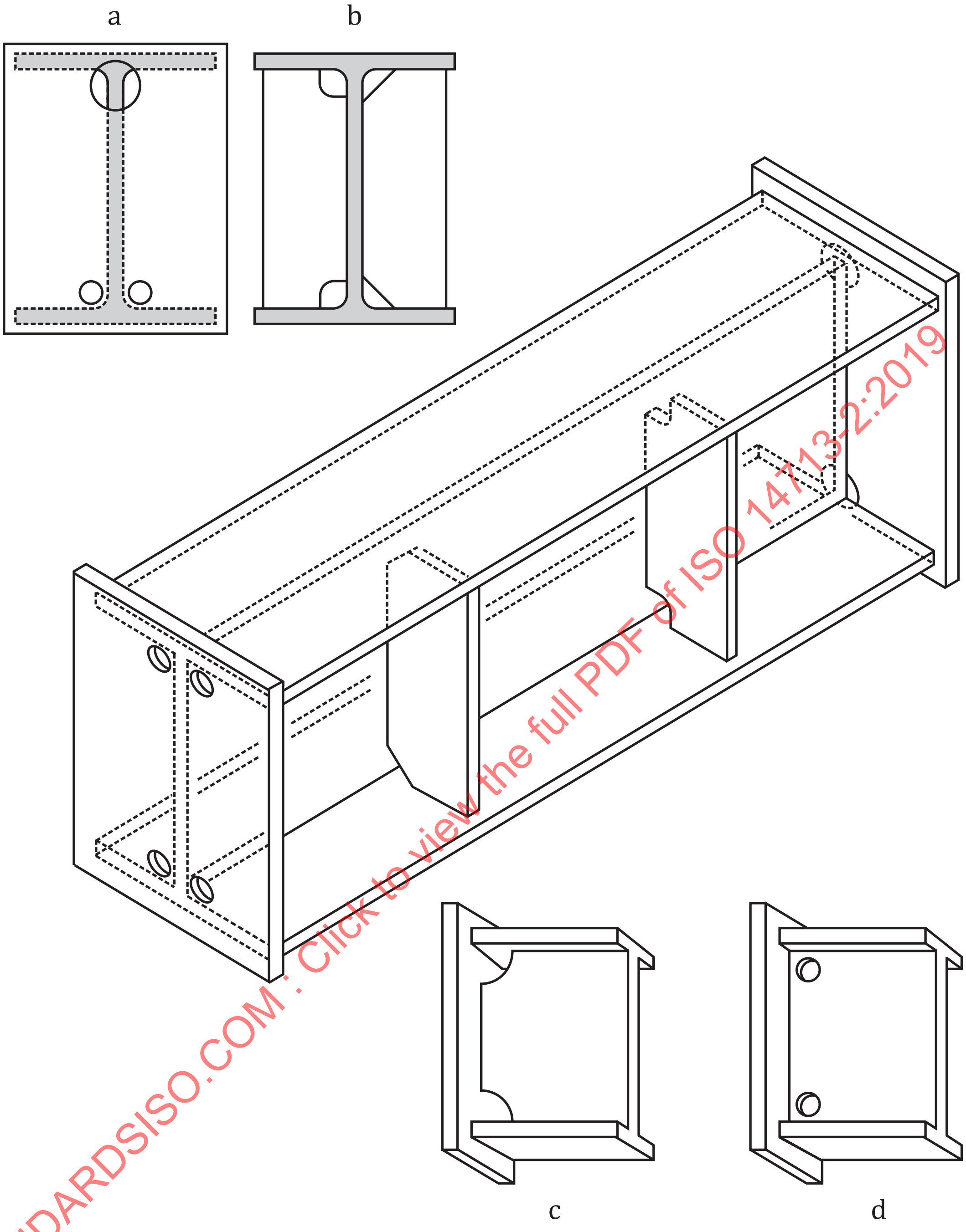
b) facilitate drainage during withdrawal from acid and rinsing tanks and from the galvanizing bath.

The precise position of holes and gaps can vary with the dipping technique (e.g. orientation) and a galvanizer should be consulted at the design stage.

Where optimum venting (in accordance with this document) for galvanizing cannot be incorporated into the design (e.g. where the introduction of holes into base plates already welded to beams is prohibited), satisfactory, safe and efficient alternative venting arrangements should be agreed between the customer and the galvanizer.

The potential effects of alternative venting arrangements on the quality of the coated article should be taken into account (e.g. surface finish, potential for distortion or potential for steel cracking).

The drilling of holes in k-areas should be avoided. If transverse stiffeners, plates, etc. have been welded to the beam across the web and venting is necessary, this should be done in the stiffener or plate and not in the k-area of the beam. See also 6.6.3.



Key

a examples of holes in end plates

b examples of crops and cut-outs in stiffeners

c cut-outs in fabricated beams

d holes in web of beams

Figure A.1 — Examples of cut-outs and holes needed to facilitate zinc flow during hot dip galvanizing showing options for venting and draining

For surfaces in contact, holes should be drilled as shown in Figure A.2. Hole sizes take into account the area of overlap. More than one hole could be needed, depending on the shape of the overlap; entrapment of liquid should be avoided (see Figure A.3 and Table A.1). This precaution is necessary in order to avoid explosions in the hot dip galvanizing operation and to protect operators. It is not always necessary to drill through both pieces in contact, but to do so assists the free flow of liquid. The holes should be drilled as close to the corners as possible. Agreement between the designer and the galvanizer is required to coordinate the position of holes and points of lifting for galvanizing.

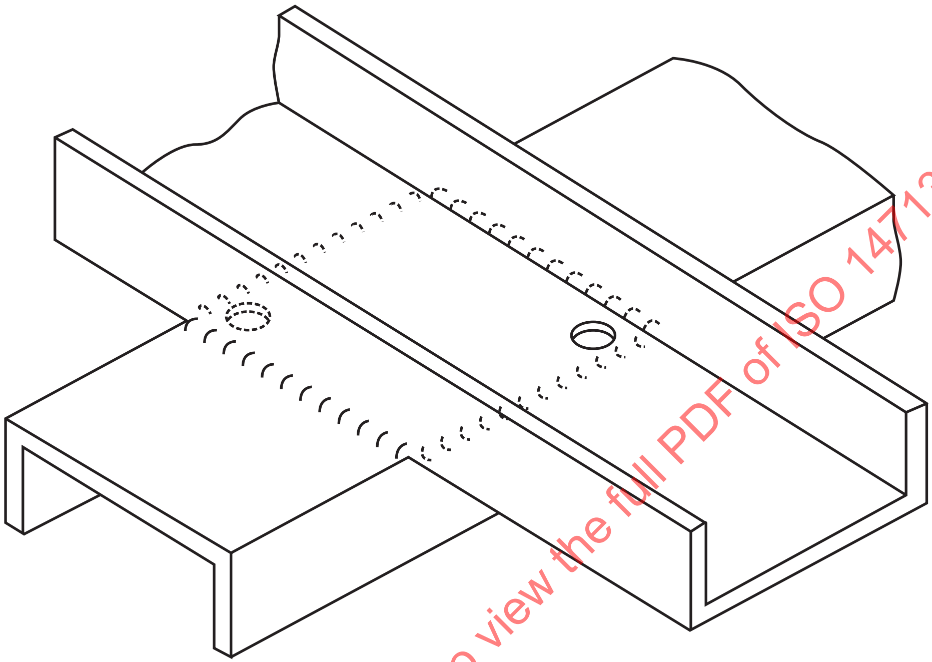


Figure A.2 — Welding flat surfaces together

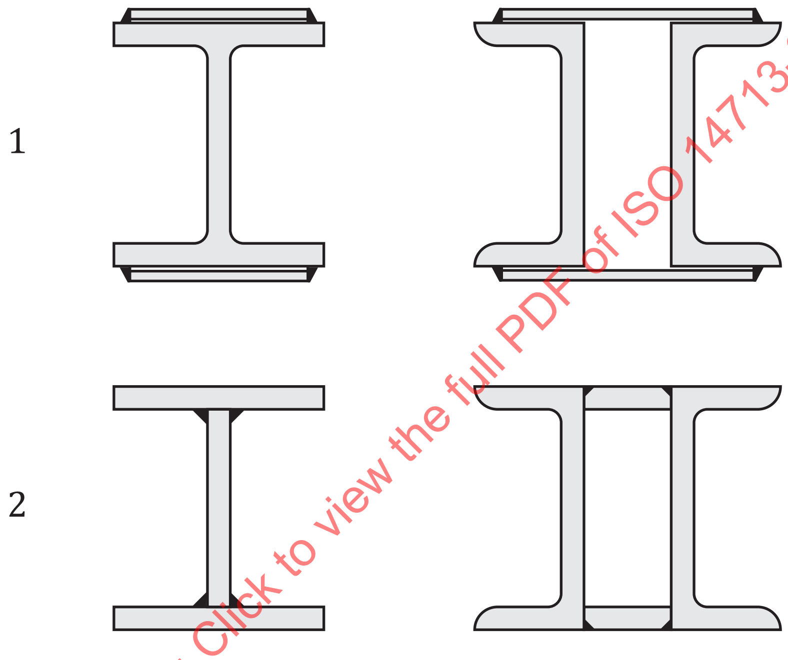
Table A.1 — Recommendations for minimum actions at areas of overlap

Area of overlap	Recommended action
Up to 100 cm^2	Circumferential tight weld. The material used should be dry for the welding process and overlapping parts should be smooth and assembled without gaps.
100 cm^2 to 1 000 cm^2	In diagonally opposite positions, either: 2 × ≥ 12 mm holes at corners or 2 × ≥ 25 mm intermittence of welds at corners.
1 000 cm^2 to 2 500 cm^2	Either: 4 × ≥ 12 mm holes at corners or 4 × ≥ 25 mm intermittence of welds at corners.
≥ 2 500 cm^2	In diagonally opposite positions, either: ≥ 12 mm holes at corners and circumferentially at least every 300 mm from the corners or ≥ 25 mm intermittence of weld at corners and circumferentially at least every 300 mm from the corners.

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. These liquids can leak out after galvanizing and can affect the appearance of the coating.

Such effects can be avoided by proper design. Welded joints should be continuous if they do not enclose an otherwise unvented surface as shown in Figure A.3. Bolted joints are preferably made after hot dip galvanizing.

All articles 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.



Key

1 avoid

2 prefer

Figure A.3 — Narrow gaps

Provision should be made for venting and draining (visible externally for reasons of inspection and safety) as shown in Figure A.4. Cross-sections or chord members with ends sealed, e.g. by plates, should be provided with drilled holes, circular cut-outs or V-notches diagonally opposite each other at the top and bottom, as close as possible to the sealed end. Additional holes in the chords shown in Figure A.4 will aid flow of molten zinc and improve process efficiency and quality.

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).

Internal venting should be avoided (see 4.4).

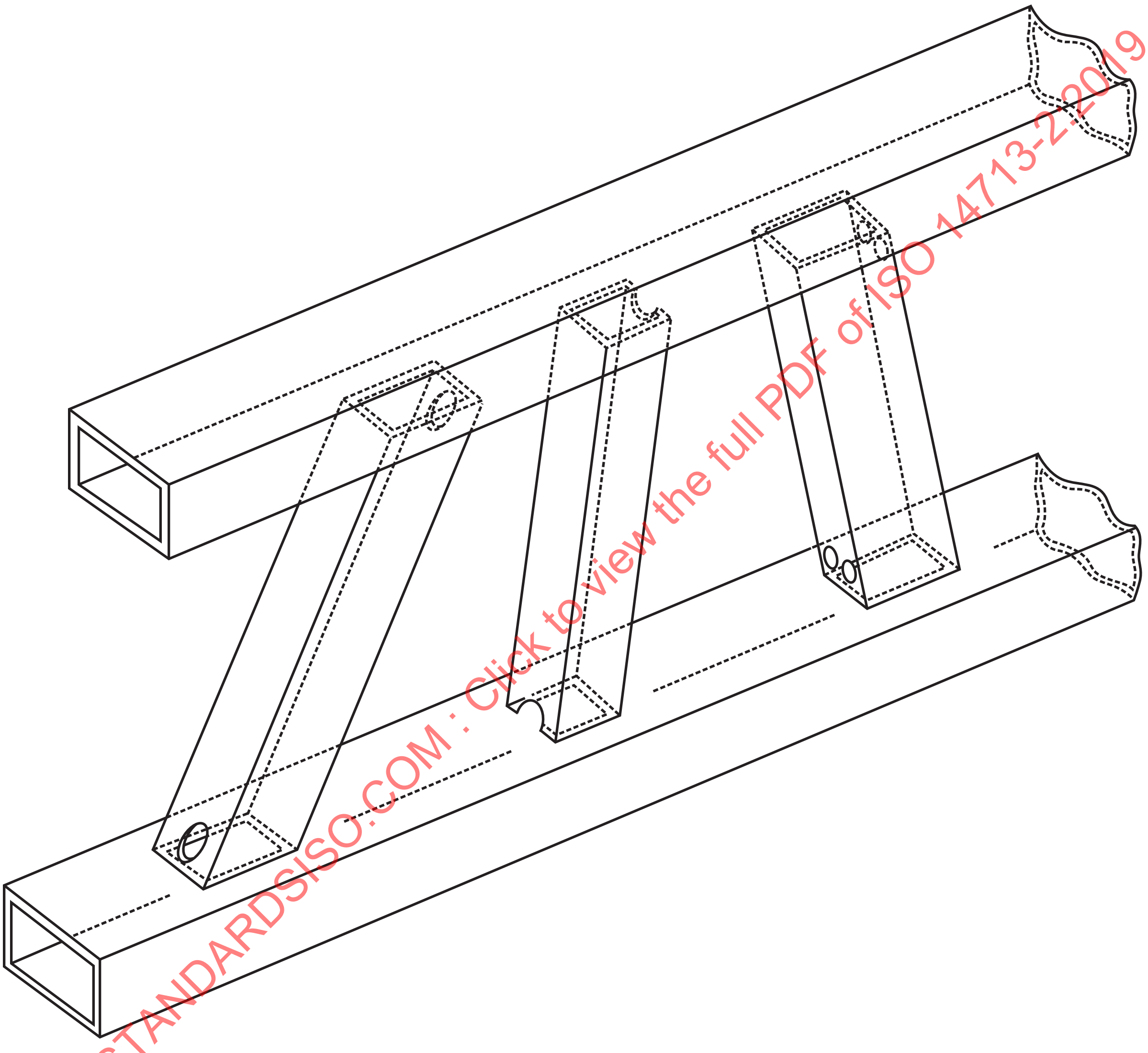
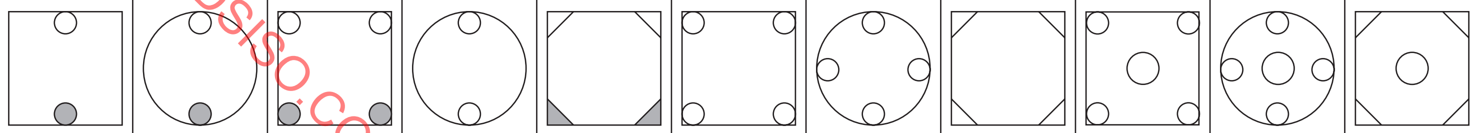


Figure A.4 — Structural hollow sections

Recommended sizes for venting/draining holes in hollow sections are given in Table A.2. Instead of straight crops, circular crops can also be used. The use of circular crops is advantageous because they have greater cross-sectional area. Depending on the type of construction, diagonally opposite holes are preferable, as explained in Figure A.5.

For very long hollow sections (e.g. longer than 6 m), the principles given in Table A.2 are valid but the size of the holes should be larger or additional holes are required.

Table A.2 — Recommended size and location of vent and drain holes for hollow sections

Section cross-sectional shape and dimensions (mm)			Number and location of holes or crops at each end of the hollow section										
			1 hole	1 hole	2 holes	2 holes	2 crops at corners	4 holes	4 holes	4 crops at corners	4 holes of 15 mm + 1 central hole	4 holes of 15 mm + 1 central hole	4 crops at corners of 25 mm + 1 central hole
													
Round	**Square**	**Rectangular**	**Diameter of hole** (mm)				**Size of crop** (mm)	**Diameter of hole** (mm)		**Size of crop** (mm)	**Diameter of central hole** (mm)		
15	**15**	**—**	10	10	—	—	—	—	—	—	—	—	—
20	**20**	**30 × 15**	10	10	—	—	—	—	—	—	—	—	—
30	**30**	**40 × 20**	12	12	10	10	—	—	—	—	—	—	—
40	**40**	**50 × 30**	14	14	12	12	10	—	—	—	—	—	—
50	**50**	**60 × 40**	16	16	12	12	13	10	10	—	—	—	—
60	**60**	**80 × 40**	20	20	12	12	15	10	10	12	—	—	—
80	**80**	**100 × 60**	25	20	16	16	20	12	12	15	—	—	—
100	**100**	**120 × 80**	30	25	20	20	25	14	15	20	—	—	—
120	**120**	**160 × 80**	35	30	25	25	30	20	20	25	—	—	—
160	**160**	**200 × 120**	45	40	35	30	40	25	20	30	35	—	—
200	**200**	**260 × 140**	60	50	40	35	50	30	25	35	50	40	—
300	**300**	**350 × 250**	—	—	60	55	75	45	40	55	80	70	75
400	**400**	**450 × 250**	—	—	80	75	100	60	50	75	110	100	110
500	**500**	**600 × 300**	—	—	100	90	125	75	65	90	140	125	135
600	**600**	**700 × 400**	—	—	120	110	150	85	75	110	170	150	165

NOTE 1 The shaded holes or crops indicate the hole or crop in the opposite end of the hollow section.

NOTE 2 The size of crop given in this table refers to the length of the adjacent side (not the diagonal length).

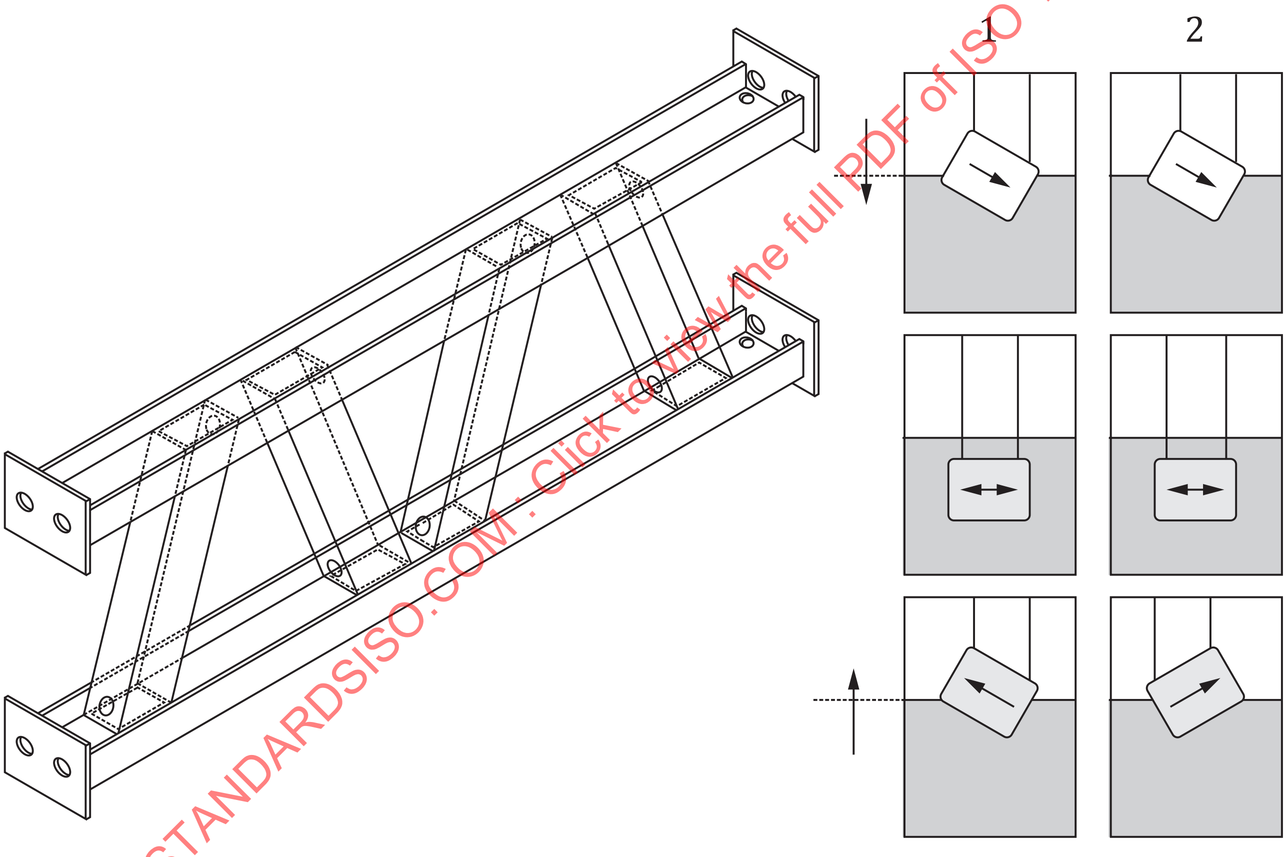
NOTE 3 Table entries that are not applicable are designated by "—".

For welded box sections, the use of crops is preferable but, if holes are used, the recommended distance from the edge of the weld given in Table A.3 should be applied.

Table A.3 — Recommended minimum edge distance of vent and drain holes for welded box sections

Type/size of weld (a = weld throat thickness)		**Edge distance** (mm)
Fillet	**Groove (HY or HV)**	
a ≤ 7 mm	a ≤ 8 mm	10
7 mm < a ≤ 10 mm	8 mm < a ≤ 14 mm	15
10 mm < a ≤ 14 mm	14 mm < a ≤ 20 mm	20

The zinc should drain freely. The preferred practice is to immerse at an angle and, after immersion, to withdraw at the opposite angle as shown in Figure A.5. The position of the vents should be related to the alignment during withdrawal.



Key

1 example of orientation during immersion (most commonly used)

2 example of orientation during immersion (alternative)

Figure A.5 — Orientation during hot dip galvanizing and indicative venting