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

**Part 2:
Hot dip galvanizing**

iTeh STANDARD PREVIEW

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

ISO 14713-2:2009
Partie 2: Galvanisation à chaud

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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 document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 14713-2 was prepared by Technical Committee ISO/TC 107, *Metallic and other inorganic coatings*, Subcommittee SC 4, *Hot dip coatings (galvanized, etc.)*.

This first edition, together with ISO 14713-1 and ISO 14713-3, cancels and replaces ISO 14713:1999, which has been technically revised

ISO 14713 consists of the following parts, under the general title *Zinc coatings — Guidelines and recommendations for the protection against corrosion of iron and steel in structures*:

- *Part 1: General principles of design and corrosion resistance*
- *Part 2: Hot dip galvanizing*
- *Part 3: Sherardizing*

The principal changes to this part of ISO 14713 compared to ISO 14713:1999 are the following.

- This part of ISO 14713 only provides design guidance for hot dip galvanizing of articles.
- The normative references (Clause 2) have been updated to take into account the very latest standards available to readers.
- Additional guidance on the effect of the iron/steel surface composition has been provided (6.1.1, Table 1).
- Additional information has been provided on the effect of thermal cutting processes (6.4) and the influence of internal stresses in the basis steel during hot dip galvanizing (6.5).

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

Part 2: Hot dip galvanizing

1 Scope

This part of ISO 14713 provides guidelines and recommendations regarding the general principles of design which are appropriate for articles to be hot dip galvanized for corrosion protection.

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 application of additional coatings (outside the scope of this part of ISO 14713), 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”.

The guidelines and recommendations in this part of ISO 14713 do not deal with the maintenance of corrosion protection in service for steel with hot dip galvanized coatings. Guidance on this subject can be found in ISO 12944-5.

Specific product-related requirements (e.g. for hot dip galvanized coatings on tubes or fasteners, etc.) will take precedence over these general recommendations.

2 Normative references

The following referenced documents are indispensable for the application 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 1461, *Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods*

ISO 4964, *Steel — Hardness conversions*

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

ISO 10684, *Fasteners — Hot dip galvanized coatings*

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

EN 10210-1, *Hot finished structural hollow sections of non-alloy and fine grain steels — Part 1: Technical delivery requirements*

EN 10219-1, *Cold formed welded structural hollow sections of non-alloy and fine grain steels — Part 1: Technical delivery requirements*

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

EN 10346, *Continuously hot-dip coated steel flat products — Technical delivery conditions*

3 Terms and definitions

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

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

NOTE The term “hot dip galvanized coating” is subsequently referred to as the “coating”.

4 Design for hot dip galvanizing

4.1 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. 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 may cause deformation or damage of 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 hot dip galvanizer before designing or making a product that is subsequently to be hot dip galvanized, as it may be necessary to adapt the construction of the article for the hot dip galvanizing process.

The purchaser should be aware of the two distinct types of hot dip galvanizing and take these distinctions into account when designing articles:

- a) hot dip galvanizing after fabrication – where, after suitable pretreatment, fabricated iron or steel articles are dipped in a bath containing a zinc melt (see ISO 1461);
- b) continuous galvanizing – where, after suitable pretreatment, sheet materials are continuously fed through a zinc melt and the hot dip galvanized sheet materials are then used to fabricate an article (see EN 10346).

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 6.2). 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.

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 has to be secured during immersion in the baths. Bolt holes are often available. Lifting lugs 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 work piece. 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. 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.

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 may cause serious injury to operators. This aspect of design should be given careful consideration and is essential in order to maintain satisfactory standards of health and safety for operators.

The provision of holes for venting and draining tubular fabrications 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 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 and differential thermal expansion should be minimized during welding and processing. Heat treatment may be desirable before hot dip galvanizing. The purchaser should discuss with the galvanizer the requirements for coating and assembly of fabricated components. 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.

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 corners.

4.5 Tolerances

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 tolerance should be provided to allow for the thickness of the coating metal. For hot dip galvanized 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, the situation is more complicated. For example, for hot dip galvanized and centrifuged nuts and bolts, current practices differ according to the country.

Either

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

or

b) the bolts are undersized (see e.g. Swedish Standard SS 3194) so that standard threads on hot dip galvanized nuts can be used in all cases.

ISO 10684 also provides some guidance.

5 Design for storage and transport

Hot dip galvanized work should be stacked securely so that the work 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 work 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 might include, for example: storage of work such that free movement of air across the surfaces of the work is allowed, the use of spacers to minimize contact areas on the work, or avoidance of close nesting of work (where the design allows this).

In accordance with ISO 1461, the development of wet-storage staining shall not be a cause for rejection, provided the coating thickness remains above the specified minimum requirements.

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6 Effect of article condition on quality of hot dip galvanizing

6.1 General

Most steels, including 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), fastener grade steels (see e.g. ISO 898), grey cast iron (see e.g. EN 1561) and malleable cast iron (see e.g. EN 1562), can be hot dip galvanized according to ISO 1461. 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.

6.1.1 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 445 °C to 460 °C.

Table 1 — Coating characteristics related to steel composition

Category	Typical levels of reactive elements	Additional information	Typical coating characteristics
A	$\leq 0,04$ % Si <u>and</u> $< 0,02$ % P	See Note 1	Coating has a shiny appearance with a finer texture. Coating structure includes outer zinc layer.
B	0,14 % Si to 0,25 % Si	Fe/Zn alloy may extend through to the coating surface. Coating thickness increases with increasing silicon content. Other elements may also affect steel reactivity. In particular, phosphorus levels greater than 0,035 % will give increased reactivity.	
C	$> 0,04$ % Si to $\leq 0,14$ % Si	Excessively thick coatings may 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 $Si + 2,5P \leq 0,09$ % 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 $Si + 2,5P \leq 0,04$ %.

NOTE 2 The presence of alloying elements (e.g. nickel) 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 and the boundaries of each range will vary accordingly.

6.1.2 Castings

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

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.

6.2 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, welding slag, labels, glues, marking materials, fabrication oils and similar impurities, should be removed prior to pickling; this allows for more effective and efficient use of pretreatment materials. The purchaser is responsible for removing such contamination, unless alternative arrangements have been agreed between the galvanizer and the purchaser.

6.3 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 of the basis metal generally remains visible after galvanizing. A rough steel surface as obtained by grit blasting, course grinding, etc., prior to pickling, gives a thicker coating than a surface that is obtained by pickling alone.

6.4 Influence of thermal cutting processes

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 may be more difficult to obtain and the coating so formed may 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.

6.5 Effect of internal stresses in the basis steel

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6.5.1 General

The hot-dip galvanizing process involves dipping clean, pretreated, fabricated steel articles in the 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 may 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 control) unless the distortion has occurred through inappropriate handling (e.g. mechanical damage or incorrect suspension of the article).

6.5.2 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 may occur. Good design for galvanizing will normally avoid these problems.

During the heating and cooling cycle, the work experiences stresses, caused by the differential thermal expansion of elements within the work, that interact with the pre-existing stresses in the fabrication. The magnitude of the resultant stress field in the work item cannot readily be predicted. During the heating and cooling cycle, imbalanced stresses may 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, the 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) may contain internal stresses of such a magnitude that pickling and hot dip galvanizing may 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 might be some critical geometrical configuration of heavy structures for which these effects might be reduced by stress relieving before pickling and hot dip galvanizing. Specialist advice should be sought when hot dip galvanizing such steels.

6.5.3 Hydrogen embrittlement

Structural steels are not normally embrittled by the absorption of hydrogen during pickling, and hydrogen remaining (if any) does not, in general, affect structural steels. With structural steels, absorbed hydrogen is discharged during hot dip galvanizing. If steels are harder than approximately 34 HRC, 340 HV or 325 HB (see ISO 4964), care is necessary to minimize hydrogen absorption during surface preparation. The welds and the heat affected zone (HAZ) of structural steels do not normally exceed a hardness value of 340 HV. Consequently, these zones are not normally embrittled by the absorption of hydrogen during pickling.

6.5.4 Strain age embrittlement

To reduce the risk of embrittlement, the 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 which 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. The risks inherent to cold-work embrittlement can be reduced by selecting a steel grade with higher toughness properties; considering the original impact energy and transition temperature of the non-deformed steel material, each percent of cold-work deformation should be balanced by a 3 °C decrease of the transition temperature.

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 practice. 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 the hot dip galvanizing bath and lose some of any increased strength obtained by heat treatment or cold working.

6.5.5 Liquid metal assisted cracking (LMAC) or liquid metal embrittlement (LME)

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 component (e.g. steel quality, levels of residual stress, quality of welding, and position and finishing of drilled or punched holes and flame-cut surfaces), and the galvanizing conditions (e.g. pretreatment conditions, dipping speed and zinc melt constitution) for fabrications that might be susceptible to LMAC.

NOTE Additional guidance on this issue is under consideration/development.

6.6 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, may cause thick coatings to form.

6.7 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; e.g. 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.