

भारतीय मानक ब्यूरो

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भारतीय मानक प्रारूप

लोहे और इस्पात के तप्त निमज्जी जस्तीकरण की प्रक्रिया,
डिजाइन, परीक्षण और अनुप्रयोग के लिए रीति संहिता

भाग 1: खेप प्रक्रिया

(IS 2629 का दूसरा पुनरीक्षण)

(IS 2629, IS 4759 और IS 6159 का एकीकरण)

Draft Indian Standard

**Code of Practice for Process, Design, Testing and
Application of Hot Dip Galvanizing of Iron and Steel**

Part 1 : Batch Process

(Second Revision of IS 2629)

(Amalgamation of IS 2629, IS 4759 and IS 6159)

ICS 25.220.40

Corrosion Protection and Finishes
Sectional Committee, MTD 24

Last date for receipt of comments is
22/11/2024

FOREWORD

(Formal foreword clause will be added later)

This standard was first published in 1966 and subsequently revised in 1985. First revision was brought out to include the process requirements of continuous galvanizing process typical photographs of various defects in galvanized coatings on iron and steel.

Hot-dip galvanizing is an age-old, proven, and established process of applying zinc coating to iron or steel surface for protection against corrosion. The zinc coating firstly protects the base metal by acting as a barrier between the metal and the atmosphere and secondly affords sacrificial protection through its anodic capability, even when moderately sized areas of the base metal surface are exposed.

When an oxide and dirt-free article is immersed in a galvanizing bath, the metal surface reacts with molten zinc to form a surface layer consisting of pure zinc & intermediate layers of zinc-iron alloy considered to

be harder than the base steel. As the article is withdrawn from the bath, it picks up pure zinc which solidifies on cooling and forms the outer layer consisting of pure zinc. The intermediate zinc-iron alloy layers provide a strong bond between the ferrous base material along with zinc and resists corrosion and abrasion.

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, chemical composition of the article and the specific environment to which the article is exposed to.

It is essential that the design of any article required to be galvanized should consider not only the function of the article and its method of manufacture, but also the limitations imposed by the finish. The requirement of general design affording optimal protection of zinc coating is detailed in this revised & updated specification.

The galvanizing process can be grouped together under three categories, namely (a) wet process, (b) dry process, and (c) a combination of dry and wet process by batch galvanizing.

A summary of design requirement, environmental factors & defects, along with the typical photographs for illustration, commonly met with in the hot-dip galvanizing practice, their causes and remedial measures are given in Annex A. In this annex, the information given in the last column aids inspectors & users in interpreting the appearance and tests of the article to help them in arriving at a correct decision for accepting or rejecting the finished material. This standard is also crucial for industries involved in construction, transportation, infrastructure, and manufacturing where iron and steel structures are exposed to environmental conditions that can attribute to corrosion. By following the guidelines provided, organizations can design, specify, and maintain the durability, performance and coating quality of iron and steel structures.

Former title of the Indian Standard IS 2629 was 'Recommended Practice for Hot-Dip Galvanizing of Iron and Steel' which is revised to 'Code of Practice for Process, Design, Testing and Application of Hot Dip Galvanizing of Iron and Steel Part 1 : Batch Process'.

While reviewing the standard the committee felt to revise this standard keeping in view the latest development in the field of hot-dip galvanizing of iron and steel. This revision amalgamates below mentioned Indian Standards:

IS 2629 : 1985 Recommended practice for hot-dip galvanizing of iron and steel

IS 4759 : 1996 Hot - Dip zinc coatings on structural steel and other allied products - Specification

IS 6159 : 1998 Recommended practice for design and fabrication of iron and steel products prior to galvanizing and metal spraying

This standard is comprehensively revised for hot dip galvanizing by batch process only. Requirements of hot dip structural steel and other allied products which were part of IS 4759 : 1996 have been covered in this revision. Recommended practice for design and fabrication of iron and steel products prior to metal spraying which was part of IS 6159 : 1998 has been covered in IS 5905 (Part 1).

Working conditions and safety measures that must be observed in galvanizing plants are provided in Annex B.

While preparing the standard, necessary assistance has been derived from ISO 14713-1 : 2017 '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', ISO 14713-2 : 2019 'Hot dip galvanizing; guidelines & recommendations for protection against corrosion of iron and steel in structures'

and ISO 1461 : 2022 ‘Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods’ , issued by the International Organization for Standardization.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022. ‘Rules for rounding off numerical values (*second revision*)’. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

Draft Indian Standard

**Code of Practice for Process, Design, Testing and Application of
Hot Dip Galvanizing of Iron and Steel**

Part 1 : Batch Process

(Second Revision of IS 2629)

(Amalgamation of IS 2629, IS 4759 and IS 6159)

1 SCOPE

This standard recommends important guidelines for general hot-dip galvanizing of iron and steel which are hot dip galvanized by batch process. The revised standard specifies the general properties of coatings, specifications, process, design requirements, guidance on exposure condition of galvanized steel and test methods for coatings applied by dipping fabricated iron and steel articles (including certain castings) in molten zinc (containing 98.5% zinc and not more than 1.5 % of other metals and elements). It does not apply to the following:

- a) Articles hot dip galvanized by continuous process. (to be covered in part 2)
- b) Hot dip galvanized products like nut, bolts and fasteners (done by centrifuge process) for which specific standards exist and which might include additional requirements or requirements that are different from those of this Standard.

2 REFERENCES

The following Indian Standards contain provisions, which through reference in this text, constitute provision of this standard. At the time of the publication, the editions indicated below were valid. All the standards are subject to revision, and parties to agreement based on this standard are encouraged to investigate the possibility of applying the most recent editions of these standards indicated below:

IS No.	Title
IS 209 : 2024	Zinc ingot – Specification (<i>fourth revision</i>)
IS 265 : 2021	Hydrochloric Acid – Specification (<i>fifth revision</i>)
IS 266 : 2024	Sulphuric acid – Specification (<i>third revision</i>)
IS 2633 : 1986	Method for testing uniformity of coating on zinc coated articles (<i>second revision</i>)
IS 6745 : 1972	Methods for determination of mass of zinc coating on zinc coated iron and steel articles (<i>seventh revision</i>)
IS 11759 : 1986	Code of practice for repair of damaged hot dip galvanized coatings
IS 14191 : 2024 / ISO 9223 : 2012	Corrosion of metals and alloys — Corrosivity of atmospheres — Classification, determination and estimation
IS 14321: 2024 / ISO 9224 : 2012	Corrosion of metals and alloys — Corrosivity of atmospheres — Guiding values for the corrosivity categories

IS 14297 : 2024 / Corrosion of metals and alloys — Corrosivity of atmospheres — Measurement of
ISO 9226 : 2012 environmental parameters affecting corrosivity of atmospheres

3 TERMINOLOGIES

To this standard, the following definitions shall 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 iron in a molten zinc bath.

3.2 Hot Dip Galvanized Coating

Coating obtained by hot dip galvanizing.

3.2.1 Reference Area

Area within which a specific number of single measurements are made.

3.2.2 Local Coating Thickness

Mean value of coating thickness obtained from the specific number of measurements within a reference area for a magnetic test.

3.2.3 Mean Coating Thickness

Average value of the local coating thicknesses.

3.2.4 Coating Mass

Total mass of zinc and/or zinc alloys per area of surface, expressed in g/m^2 .

3.2.5 Coating Thickness

Total thickness of zinc and/or zinc alloys, expressed in μm .

3.2.6 Local Coating Mass

Value of coating mass obtained from a single gravimetric test.

3.2.7 Mean Coating Mass

Average value of the coating masses determined either by using a control sample selected in accordance with Clause 5 using tests in accordance with IS 6745 or by conversion of the mean coating thickness.

Average value of the coating determined through the sum of required number of local coatings as indicated in Table 2.

3.2.8 Minimum Value of the Coating Thickness

Lowest mean obtained from the specified number of measurements in a magnetic test within a reference area.

3.3 Inspection Lot

Single order or single delivery load.

3.4 Acceptance Inspection

Inspection of an 'inspection-lot' at the hot dip galvanization works, unless otherwise specified.

3.5 Uncoated Area

Areas on the iron or steel articles that do not react with the molten zinc.

3.6 Molten Zinc

Molten mass containing primarily zinc in the bath.

3.7 Ash

A mixture of zinc oxide and varying quantities of metallic zinc. The former is formed as a result of oxidation of pure zinc on the bath surface and when the oxide is skimmed off, a certain amount of metallic zinc gets entrapped and removed along with it.

3.8 Dross

An intermetallic compound (FeZn_{13}), which is a complex mixture of zinc and iron, forms in the galvanizing bath as a result of the reaction of molten zinc with iron or iron salts and settles down at the bottom of the bath. Zinc content in dross will vary between 94 percent to 97 percent depending on the quantity of metallic zinc entrapped in dross during its removal from the pot.

3.9 Flux

A chemical compound applied in the form of an aqueous solution and dried on to the work in the dry process or spread as a molten blanket over the zinc bath in the wet process. The primary purpose of the flux is to help in keeping the surface of both work and molten zinc free from oxide at the time of reaction. In both the galvanizing processes fluxing helps maintaining the surface of work free from oxides.

3.10 Over-Pickling

The undue attack of the underlying ferrous surface by the pickling solution after the removal of scale.

3.11 Inhibitor

A substance added to pickling solution to prevent undue attack on clean metal without affecting the scale removing property of the pickling solution.

3.12 Wet Storage Stain

A white corrosion product, mainly containing zinc oxide / hydroxide and basic zinc carbonate, that accumulates on the galvanized surface exposed to water film or moist air in atmosphere. Locally also known as white rust.

3.13 Wetting Agent

A substance added to pickling and prefluxing solutions to facilitate wetting of the work surface.

3.14 Weld Seepage

Emission of previously retained pre-treatment solutions from narrow spaces between two closely contacting surfaces that have been subject to intermittent welding or from very small cavities (pinholes) in the welds of a galvanized article.

4 GENERAL REQUIREMENTS

4.1 General

This Standard sets out requirements for the contents of the molten zinc bath used to apply a galvanized coating to articles. The chemical composition and the surface condition (finish and roughness) of the base metal may affect the appearance, thickness, texture and physical/mechanical properties of the zinc coating.

4.2 Hot Dip Galvanizing Bath

The hot dip galvanizing bath shall primarily contain 98.5 percent molten zinc. The total of the other elements (as identified in IS 209) in the molten zinc shall not exceed 1.5 percent by mass.

4.3 Safety

Venting and draining on the article shall be provided in accordance with requirement of design for appropriate safety of the process.

5 INFORMATION TO BE SUPPLIED BY THE PURCHASER TO THE HOT-DIP GALVANIZER

5.1 Essential Information

The following information shall be supplied by the purchaser to the hot-dip galvanizer:

- a) Reference of this Indian standard, and
- b) The composition and any properties of the base metal that may affect hot-dip galvanizing.

5.2 Additional Information

The following information may be required for particular purpose and if so shall be specified by the purchaser:

- a) Designation of steel;
- b) Description regarding size length, etc;
- c) Detail of its application, environment.
- d) Condition of delivery;
- e) Any special requirement;
- f) Test report (if required) may be supplied by the purchaser to the hot-dip galvanizer;
- g) An identification of significant surfaces, for example by drawings or by the provision of suitably marked samples;
- h) A drawing or other means of identifying surface unevenness; for example, round drops or contact marks, will make the coated;
- j) Article unacceptable for its intended purpose;
- k) A sample or other means of showing the finished required;
- l) Any special thickness of coating based on its application (*see* Table 5 and Table 6); and
- m) The external environment in which the article is intended to be used. (*see* 14)

6 SAMPLING AND CRITERIA FOR CONFORMITY

Unless otherwise agreed to, the sampling plan mentioned below shall be followed for ascertaining the conformity of galvanized coating on structural steel and other allied products.

6.1 Sampling

6.1.1 Lot

All the material of the same type in a coating bath having uniform coating characteristics shall be grouped together to constitute a lot.

6.1.2 Each lot shall be tested separately for the various requirements of the specification. The number of units to be selected from each lot for this purpose shall be as given in Table 1.

Table 1 Scale of Sampling
(Clause 6.1.2)

No. of Units in the Lot (1)	No of Units to be Selected in a Sample (2)	Acceptance No. (3)
Up to 25	3	0
26-100	5	0
101-150	8	1
151-500	13	1
501-1000	20	2
1001-10000	32	3
10001 and above	50	5

NOTES

1 The units shall be selected at random.

2 For details of acceptance number reference may be made to IS 2500 (Part 1).

7 COATING REQUIREMENTS

7.1 Mass of Zinc Coating

Requirements for the mass of the coating for different classes of materials are given in Table 3.

7.2 Thickness

7.2.1 General

Coatings applied by hot dip galvanizing are designed to protect the iron and steel products against corrosion. The length of time of corrosion protection by such coatings is approximately proportional to the coating thickness.

7.2.2 Test Methods

In case of dispute regarding the test method, the method of calculating the coating thickness shall be by the determination of the mean mass of hot dip galvanized coating per unit area using the magnetic testing method using elcometer (metallic coating on metallic surface) complying to Table 3, and the nominal density of the coating, 7.2 g/cm³, shall be used for calculation purposes.

Tests are most commonly carried out by one of the magnetic methods. Instruments for magnetic methods measure either the magnetic attraction between a permanent magnet and the base metal, as influenced by the presence of the coating, or the reluctance of the magnetic flux path passing through the coating and the base metal.

7.2.3 Reference Areas

The number and position of reference areas and their sizes for the magnetic test shall be chosen with regard to the shapes and sizes of the article(s) in order to obtain a result as representative as possible of mean coating thickness or mass per unit area, as applicable. On a long article in the control sample, the reference areas shall be cut approximately 100 mm from the edges and 100 mm from each end and the approximate centre, and shall comprise the whole cross-section of the article. The number of reference areas, dependent upon the size of the individual articles in the control sample, shall be as identified in Table 2.

Table 2 Required Number of Reference Areas for Testing
(Clauses 3.2.7 and 7.2.3)

Category	Size of Significant Surface Area	Number of Reference Areas to be Taken Per Article
a	> 2 m ²	≥ 3
b	> 100cm ² to ≤ 2m ²	≥ 1
c	> 10cm ² to ≤ 100cm ²	1
d	≤ 10 cm ²	1 on each article

NOTES

- 1 For articles in category 'a' in Table 2, with a significant surface area greater than 2 m² ('large' articles) for each article (taken separately) in the control sample, the mean coating thickness within the reference areas shall be equal to or greater than the mean coating thickness values as referred in Table 3
- 2 In categories 'b', 'c' and 'd' in Table 2, the average coating thickness on each reference area shall be equal to or greater than the 'local coating thickness' values referred in Table 3, as appropriate. The average coating thickness on all reference areas in a sample shall be equal to or greater than the 'mean coating thickness' values referred in Table 3, as appropriate.
- 3 Within each reference area of 10 cm², a minimum of five magnetic test readings taken with the help of elcometer (metallic coating on metallic surface) shall be taken on coated areas. If any of the individual readings is lower than the values in Table 3, this is irrelevant, as only the mean value over the whole of each reference area is required to be equal to or greater than the local thickness given in the table.
- 4 Thickness measurements shall not be taken on cut surfaces or areas less than 10 mm from edges, flame-cut surfaces or corners. 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 formed can exhibit decreased cohesion or adhesion.

Table 3 Mass of Zinc Coating
(Clause 7.1 and 7.2.2)

Sl. No.	Product	Local Coating Thickness (minimum) μm (micrometre)	Local Coating Mass (minimum) g/m ²	Mean Coating Thickness (minimum) μm (micrometre)	Mean Coating Mass (minimum) g/m ²
(1)	(2)	(3)	(4)	(3)	(4)
i	Castings				
	a) Castings-grey iron, malleable iron > 6 mm	70	505	80	575
	b) Castings-grey iron, malleable iron ≤ 6 mm	60	430	70	505
ii	Steel / Steel articles				
	a) ≥ 6 mm thick	70	505	85	610
	b) ≥ 3 mm to ≤ 6 mm	55	395	70	505

	c) ≥ 1.5 mm to ≤ 3 mm	45	325	55	395
	d) ≥ 1.2 mm ≤ 1.5 mm	35	250	45	325
iii	Threaded work other than tubes and tube fittings:				
	a) ≤ 10 mm dia.	45	325	55	395
	b) > 10 mm dia.	35	250	45	325
iv.	Other centrifuged articles (including castings):				
	a) ≥ 3 mm	45	325	55	395
	b) < 3 mm	35	250	45	325

NOTES

- 1 This table is for general use: individual product standards may include different requirements including different categories of thickness. Local coating mass and mean coating mass requirements are set out in this table for reference in such cases of dispute.
- 2 The requirements for the minimum mass of coating are for normal or rural atmosphere. In case of special atmosphere like marine and industrial atmosphere, the minimum mass of coating shall be increased as agreed to between the galvanizer and the purchaser and its feasibility. (Refer Table 5 & Table 6).
- 3 In case of fabricated steel structures, plates, etc, the coating mass is defined in terms of grams per square meter of the total surface area or average coating in micrometre.
- 4 Equivalent coating mass is derived by using a nominal zinc coating density of 7.2 g/cm^3 (rounded off).

8 COATING PROPERTIES

8.1 Appearance

At acceptance inspection, the significant surface(s) of all the hot dip galvanized article(s), when first examined by normal or corrected vision from a distance of not less than 1 m, shall be free from nodules, blisters (i.e. raised areas without solid metal beneath), roughness and sharp edges (if either can cause injury) and uncoated areas.

The primary purpose of the galvanized coating is to protect the underlying iron or steelwork against corrosion. Considerations related to aesthetics or decorative features should be secondary. Where these secondary features are also of importance, it is highly recommended that the galvanizer and customer agree upon the standard of finish that is achievable on the iron or steelwork (in total or in part), given the range of materials used to form the article. This is of particular importance where the required standard of finish is beyond that set out in this sub clause. It should be noted that ‘roughness’, ‘smoothness’ and ‘performance’ are relative terms and the roughness of coatings on articles galvanized after fabrication differs from that of mechanically wiped products, such as galvanized sheet, tube and wire carried out by continuous galvanizing process. In practice, it is not possible to establish a definition of appearance and finish covering all requirements. Also, the performance of coatings derived from “hot dip galvanizing” will differ from “continuous galvanizing” on basis of its process, application & its environment.

The occurrence of darker or lighter areas (e.g. cellular pattern or dark grey areas) or some surface unevenness shall not be a cause for rejection. The development of wet storage staining, primarily basic zinc oxide (formed during storage in humid & unventilated conditions after hot dip galvanizing), shall not be a cause for rejection, provided the coating thickness remains above the specified minimum value.

The zinc coating shall be uniform, adherent, reasonably smooth and free from such imperfections as flux, ash bare patches, black spots, pimples, lumpiness, runs, rust stains, bulky white deposits and blisters.

Articles that fail visual inspection shall be renovated in accordance with clause 9. Otherwise, the articles shall be re-galvanised and resubmitted for inspection.

9 RENOVATION OF UNCOATED OR DAMAGED AREAS

The total uncoated areas for renovation by the galvanizer shall not exceed 0.5 percent of the total surface area of the component. Each uncoated area for renovation shall not exceed 10 cm². If uncoated areas are larger, the article containing such areas shall be re-galvanised, unless otherwise agreed between the purchaser and the galvanizer.

Renovation shall be by a suitable zinc-rich paint that is a pre-mixed type paint, based on organic/ inorganic binders specially formulated for steel surface may be used. The dried film should contain aluminium along with 92 percent zinc dust by mass conforming to IS 11759, within the practical limits of such systems, or by suitable zinc- flake or zinc-paste products.

9.1 Repair Procedure for Using Zinc-Rich Paints

Below mentioned repair procedure for using Zinc Rich Paints shall be used:

- 1) Surfaces to be reconditioned with zinc-rich paint shall be clean, dry and free of oil, grease and corrosion products.
- 2) Areas to be repaired shall be cleaned with steel wire brush or grit / sand paper grinded to bright metal surface. Surface preparation should extend into neighbouring undamaged coating area. Flux residues and weld spatters shall be removed by chipping.
- 3) The zinc-rich paint shall be applied to the cleaned and prepared area by spraying or by means of a soft bristle brush. The paint should be applied, according to the paint manufacturer's recommendations, in a single application employing multi-spray passes to achieve the required dry film thickness, which shall be agreed upon between the contracting parties.
- 4) Storage precautions and the method for use of zinc-rich paints should be as per the recommendations of the paint manufacturer.

Where the purchaser advises a special requirement (e.g. a paint coating is to be applied subsequently), the proposed renovation procedure shall be advised in advance to the purchaser by the galvanizer.

The repair coating thickness on the renovated areas shall have a minimum average thickness of 100 µm unless otherwise agreed. In any case, the thickness of repaired coating shall not be less than the thickness of the coating of the galvanised article.

The above-mentioned repair procedure is also applicable for on-site repairs to damaged areas.

10 EFFECT OF STEEL ARTICLE & ITS CONDITION ON QUALITY OF HOT DIP GALVANIZING

10.1 General

Most steels can be hot dip galvanized in accordance with this standard. This includes mild steels, unalloyed carbon steels, quenched and tempered steels, hollow / pipe sections, sections that are hot finished, sections that are cold finished, reinforcement steels, fasteners, grey cast iron and malleable cast iron.

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.

Sulphur-containing free-cutting steels are normally unsuitable. Stainless steels are unsuitable.

10.2 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 (*see* Table 4). The prior history of the steel

(e.g. whether hot rolled or cold rolled) can also affect its reaction with molten zinc. Where aesthetics is 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 4 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 4 Coating Characteristics Related to Steel Composition
(Clause 10.2)

Category	Typical Levels of Reactive Elements % (Mass Fraction)	Additional Information	Typical Coating Characteristics
A	≤ 0.03 % Si and < 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. 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 darker appearance with a course 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	

NOTES

- 1 Steels with compositions satisfying the formula $Si \leq 0.03$ % and $Si + 2.5P \leq 0.09$ % 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 $Si + 2.5P \leq 0.04$ %.
- 2 The presence of alloying elements (e.g. nickel or aluminium) in the zinc bath can have a significant effect on the coating characteristics indicated in this table.
- 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.
- 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.
- 5 The design of the article to be galvanized can also influence coating characteristics.

11 DESIGN FOR HOT DIP GALVANIZING

11.1 General

It is essential that the design of any article required to be galvanized should consider not only the function of the article and its method of manufacture, but also the limitations imposed by the finish. 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 to the construction of the article for the hot dip galvanizing process.

11.2 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, pre-treatment liquids and zinc to all surfaces of the article. Air pockets prevent local surface preparation and give uncoated surfaces. Suitable articles, e.g. heat exchangers and gas cylinders (bullets), 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 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.

11.3 Design for Process Safety & Health Along with Surface Quality of Coatings

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 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. Symmetrical sections are preferred and, as far as possible, large variations in thickness or cross-section, e.g. thin sheet welded to thick angles or other sections, should be avoided (*see* Fig 2). 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 to assist the access and drainage of molten zinc 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 (*see* Fig. 4 and Fig. 5).

Internal venting of hollow sections should be avoided. If internal venting is unavoidable, it should be agreed in advance with the galvanizer and the customer should ensure that:

- a) the holes are of maximum possible size; and
- b) provision for internal venting is adequately documented (e.g. by photography) before assembly.

11.4 Threaded Parts

Hot dip galvanized fasteners are recommended for use with hot dip galvanized subassemblies and assemblies. Galvanized nuts, bolts in common sizes are readily available from commercial suppliers. Bolted assemblies should be sent to the galvanizer in a disassembled condition. Nuts, bolts, or studs to be galvanized also should be supplied disassembled.

Because hot-dip galvanizing is a coating of corrosion-inhibiting, highly abrasion-resistant zinc on bare steel, the original steel becomes slightly thicker. When talking about tapped holes and fasteners, the increased thickness is important. Bolts are completely galvanized, but internal threads on nuts must be tapped oversize after galvanizing to accommodate the increased diameter of the bolts. While chasing or retapping the nuts after galvanizing results in an uncoated female thread, the zinc coating on the engaged male thread will protect both components from corrosion. For economy, nuts are usually galvanized as blanks and the threads tapped oversize after galvanizing (*see* Fig. 1).

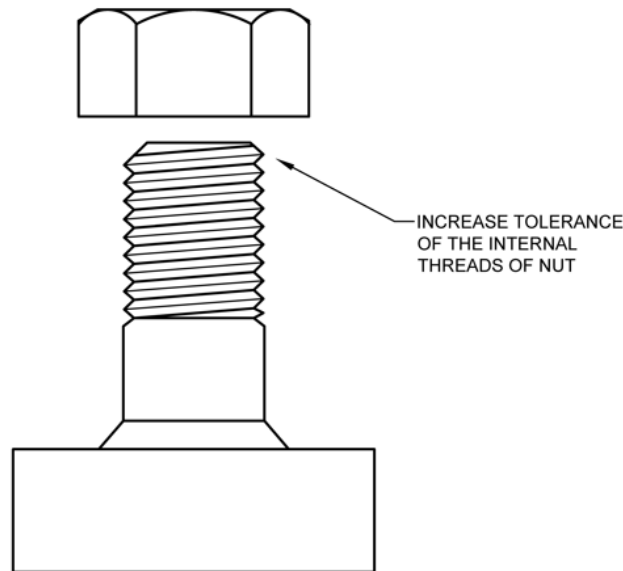


FIG. 1 OVER TAPPED NUT

To maintain free fit, oversize tapping of nuts and tapped holes is required when the bolt or male thread is hot-dip galvanized. In this regard, allowance on diameter for female threads as recommended in IS 1367 (Part 13) shall be followed.

11.5 Pipe Assemblies

On welded pipe assemblies, full open mitre joints should always be used. Under no circumstances should a blind section be included in any pipe assembly (*see* Fig. 6). Steel floor flanges instead of cast iron floor flanges should be used in pipe railings.

11.6 Labels and Markings

Permanent identification mark should be deeply punched or embossed in a 'standard' position on each of the members. An effective method is to put the identification on weld metal, which may be done, in some cases, using dots of weld metal as a code to reduce the number of letters and figures required. Alternatively, the identification can be punched on a light metal tag which can be welded to the structure at a suitable location.

Temporary identification marks for use during fabrication should be made with a material, which is removed during acid pickling.

11.7 Assemblies of Different Materials

11.7.1 If a uniform galvanized finish is required, combinations of cast iron, cast steel, malleable iron and steels of different analysis or surface condition should not be used in the same assembly. If cast materials are included in the assembly, they may require to be shot- or sand-blasted before pickling.

11.7.2 If any surface of a part is machined or if any members of an assembly are excessively rusted, the entire assembly should be sand or shot-blasted or wire brushed.

11.8 Minimizing Distortion

11.8.1 Some fabricated assemblies may distort at galvanizing temperature as a result of relieving stresses induced during steel production and in subsequent fabricating operations. For example, a channel frame with a plate should be galvanized separately and bolted later rather than welded together before galvanizing, or it can be welded after galvanizing.

11.8.2 Tips for Minimizing Distortion

To minimize changes to shape and /or alignment, design engineer should observe the following recommendations:

- a) Wherever possible, use symmetrically rolled sections in preference to angle or channel frames. I-Beams are preferred to angles or channels.
- b) Use parts in an assembly that are of equal or near equal thickness, especially at joints. Fig. 2 shows distortion/warpage has occurred due to use of uneven thicknesses in the structure.
- c) Use temporary bracing or reinforcing on thin-walled and asymmetrical designs (*see* Fig. 3)
- d) Bend members to the largest acceptable radii to minimize local stress concentration.
- e) Staggering welding techniques to produce a structural weld are acceptable. For staggered welding of 4 mm or lighter material, weld canters should be closer than 10 cm.
- f) Avoid designs that require progressive/double-dip galvanizing. It is preferable to build assemblies and sub-assemblies in suitable modules so that they can be immersed quickly and galvanized in a single dip operation. In this way the entire fabrication can expand and contract uniformly. Where progressive/double-dip galvanizing is required consult your galvanizer.

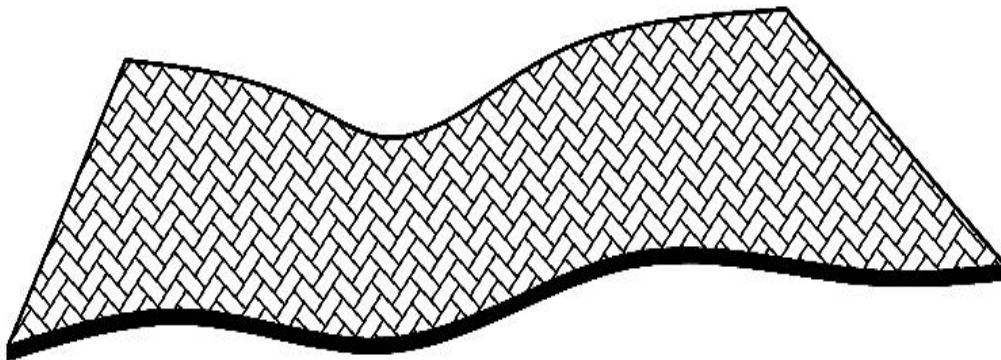


FIG. 2 DISTORTION/WARPAGE DUE TO UNEVEN THICKNESS

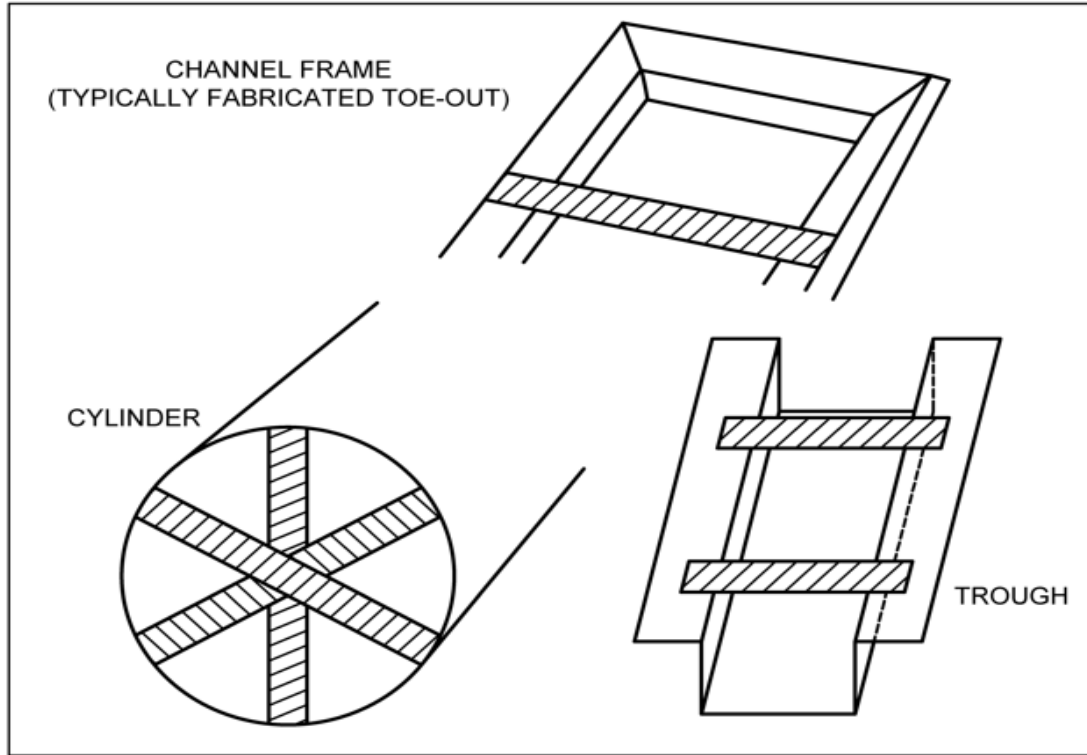


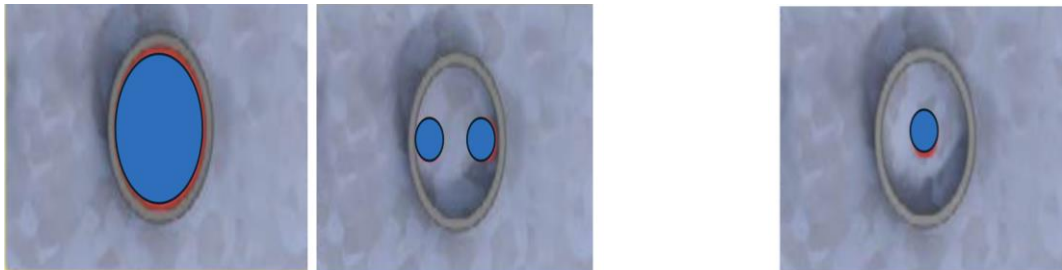
FIG. 3 TEMPORARY BRACINGS

11.9 Proper Venting & Drainage of Enclosed & Semi-Enclosed Fabrications

Tanks and enclosed vessels should be designed to allow cleaning solutions, fluxes, and molten zinc to enter at the bottom and air to flow upward through the enclosed space and out through an opening at the highest point. This prevents air from being trapped as the article is immersed. The design must also provide for complete drainage of both interior and exterior details during withdrawal. The location and size of fill and drain holes are important. As a general rule, the bigger the hole the better the air and zinc flow.

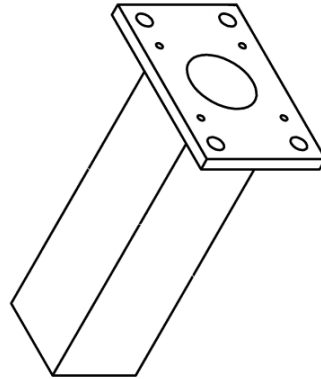
When both internal & external surfaces are to be galvanized, at least one fill/drain hole and one vent hole must be provided. The fill/drain hole should be as large as the design will allow, but at least (75 mm) in diameter for each cubic yard (100 mm in diameter for each cubic meter) of volume. The minimum diameter is (50 mm). Provide vent holes of the same size diagonally opposite the.

For complete protection molten zinc should be able to flow freely to all parts of the surfaces of the item to be galvanized. Accessibility to molten zinc requires means for the access and drainage of molten metal and means for the escape of gases and sillage from internal compartments and pockets (venting). Some typical examples for the design details for venting and draining are illustrated in Fig. 4 to Fig. 7.



a) Correct Method of Drain Holes

B) Incorrect Method



c) Correct Drain Holes

FIG. 4 CORRECT DRAIN HOLES FOR ENCLOSED POCKETS IN STRUCTURES

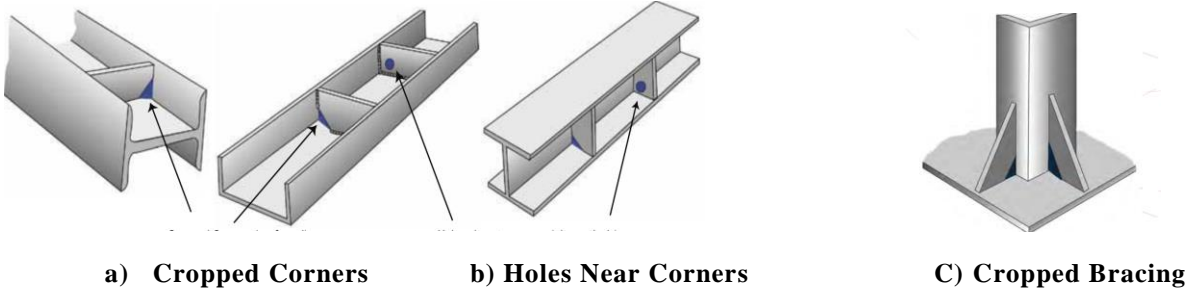


FIG. 5 PATTERN OF DRAINAGE HOLES IN SEMI-ENCLOSED & OPEN WELDED STRUCTURES

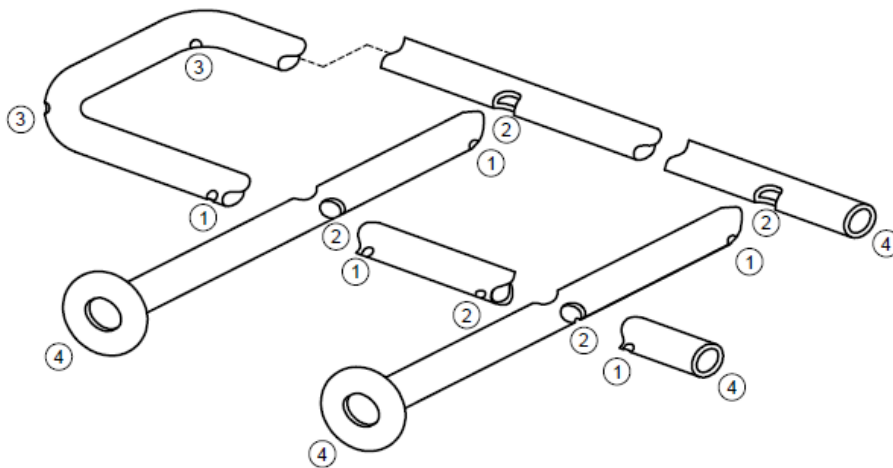


FIG. 6 VENT HOLES & DRAIN HOLES PROVISION IN HANDRAILS

(NOTE: Vent holes should be visible on the outside marked as no 3 & drain holes are on inside surface marked as no. 1 & 2)

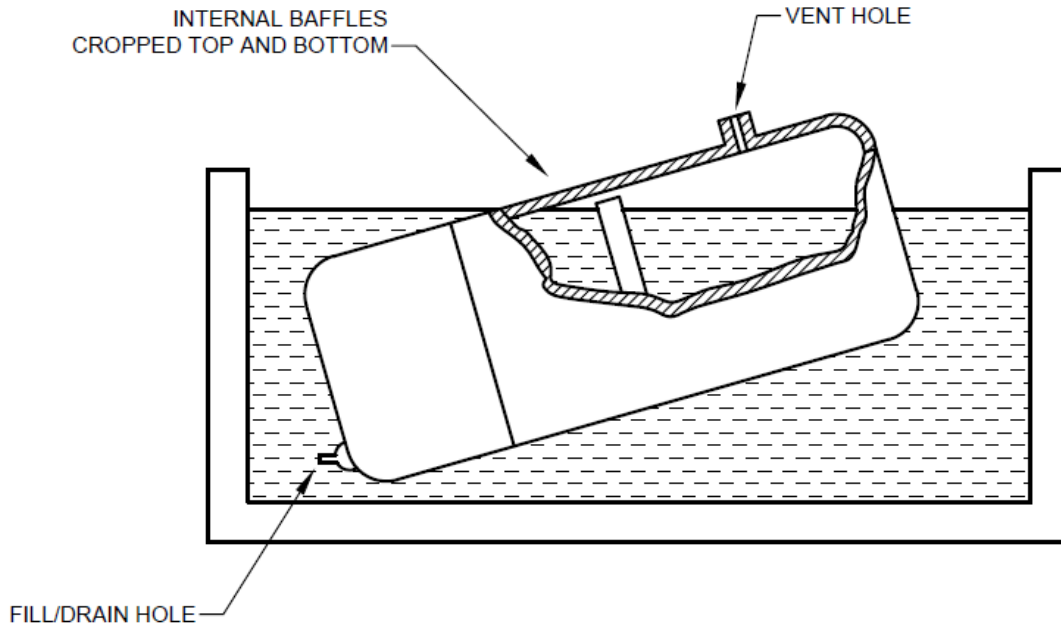


FIG. 7 TANK WITH PROVISION OF DRAIN HOLE AT BOTTOM & VENT HOLE ON THE TOP

11.10 Movable Parts

The design should provide sufficient clearance to permit free movement of movable parts after galvanizing. Generally, a clearance of 0.8 mm is sufficient.

11.11 Castings

The quality of galvanized coatings on castings depends largely on the design, surface finish and preparation for galvanizing. The following practices are recommended:

- a) Use large fillet radii. Sharp corners and deep recesses should be avoided.
- b) Use large pattern members.
- c) If any machining is done on a portion of the casting, the entire casting should be thoroughly sand- or shot-blasted if a uniform finish is required.
- d) Internal threading should be done after galvanizing in case of through holes and threading shall be done after galvanizing in case of blind holes; and
- e) Malleable and Grey iron castings should be heat-treated to prevent embrittlement during galvanizing.
- f) Following the heat treatment and prior to galvanizing, castings should be sand- or shot-blasted.

11.12 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 & unventilated

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).

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. *see* Fig. 8 for ideal stacking and storage for avoidance of wet storage stains.

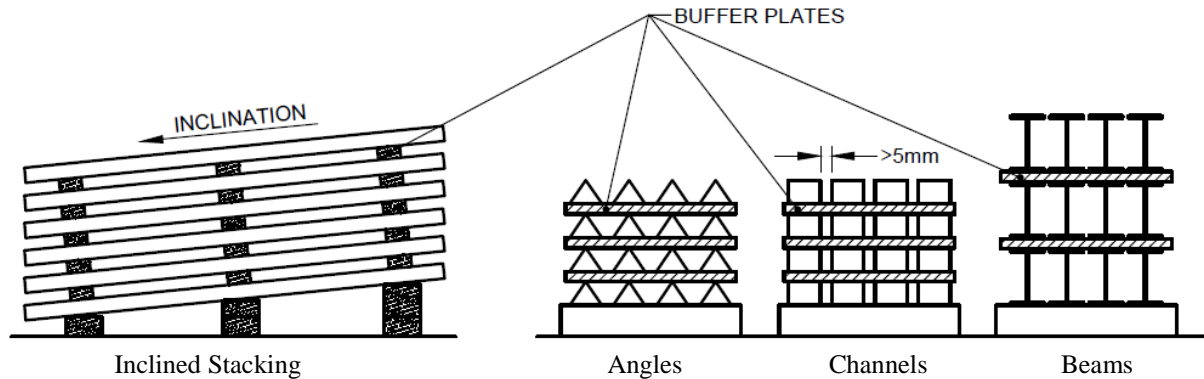


FIG. 8 STACKING & STORING FOR AVOIDANCE OF WET STORAGE STAINS

12 SURFACE CONDITION REQUIREMENTS OF ARTICLES TO BE GALVANISED

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 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.

12.1 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.

12.2 Influence of Thermal Cutting Processes and Welding

12.2.1 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. 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.

12.2.2 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.

12.2.2.1 Welding Procedure & Welding Flux removal

When weld items are galvanized, the cleanliness of the weld area and the metallic composition of the weld itself influence the galvanized coating's characteristics. Galvanized materials may easily and satisfactorily be welded by all common welding techniques.

Several welding processes and techniques have been found to be successful for items to be galvanized:

- a) Welding flux residues are chemically inert in the pickling solutions commonly used by galvanizers; therefore, their existence will produce rough surfaces and coating voids.
- b) If a coated electrode is used, all welding flux residues must be removed by wire brushing, chipping, pneumatic needle gun, or abrasive blast cleaning. It is recommended to use chisel shaped hammer for removal of welding slag (*see* Fig. 10).
- c) Welding processes such as metal inert gas (MIG), tungsten inert gas (TIG), Carbon dioxide (CO₂) shielded are recommended since they essentially produce no slag. A gap of minimum 2.5 mm should be maintained between two welded articles (*see* Fig. 9). However, there can still be small flux like residues that need to be chipped off.

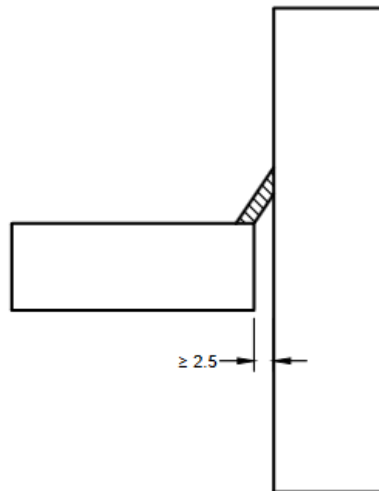


FIG. 9 GAP AFTER WELDING (2.5 MM, *min*)

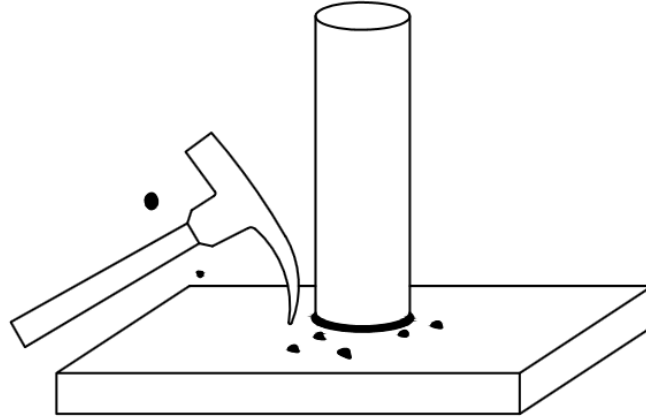


FIG. 10 CHIPPING OFF WELD FLUX RESIDUE

12.2.3 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 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.

12.3 Effect of Internal Stresses in the Steel Article

12.3.1 General

The hot-dip galvanizing process involves dipping of clean, pre-treated, 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 their control) unless the distortion has occurred through inappropriate handling (e.g. mechanical damage or incorrect suspension of the article).

12.3.2 Mechanical Properties of Galvanized Steel

The process of hot dip galvanizing has no effect on the tensile, bend or impact properties of any of the structural steels investigated when these are galvanized in the ‘as manufactured’ condition.

12.3.3 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. 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.

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.

12.3.4 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.

12.3.5 Strain Age Embrittlement

To reduce the risk of embrittlement, local cold deformation or cold working 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. The risks inherent to cold-work embrittlement can be reduced by selecting a steel grade with higher toughness properties.

12.4 Large Objects or Thick Steels

Longer handling times are needed in the galvanizing bath for large articles to maintain the normal zinc coatings and avoid excess coating. 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 of zinc coating. Combinations of significantly different section thicknesses in large articles will produce different coating thicknesses. As far as possible uniform thicknesses of sections must be incorporated in design for better coating finish.

13 AFTER-TREATMENTS POST DIPPING IN ZINC BATH

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 bath 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 (like passivation) 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 discussed between the customer and purchaser.

14 CORROSIONS IN DIFFERENT ENVIRONMENTS

14.1 Atmospheric Exposure

14.1.1 The corrosion rate of a zinc coating is affected by the time for which it is exposed to wetness, air pollution and contamination of the surface, but the corrosion rates are much slower than for steel and often decrease with time. General information on the atmospheric corrosion rate for zinc is given in IS 14321.

14.1.2 When the relative humidity is higher than 60 % or where they are exposed to wet or immersed conditions or prolonged condensation then, like most metals, iron and steel are subject to more serious corrosion. Contaminants deposited on the surface, notably chlorides and sulphates, accelerate attack.

14.1.3 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 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 general 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). Buildings containing industrial processes, chemical environments, wet or contaminated environments should be given special consideration. Table 5 also sets out an indication of the likely range of corrosion rates which are applicable to zinc coatings exposed to the different types of corrosivity category dealt with in IS 14191.

Table 5 Description of Typical Atmospheric Environments Related to the Estimation of Corrosivity Categories
(Clause 14.1)

Corrosivity category C	Corrosion rate for zinc (based upon first year of exposure), r_{corr} in $\mu\text{m}\cdot\text{a}^{-1}$ and corrosion level	Indoor	Outdoor
C1	$r_{\text{corr}} \leq 0.1$ Very low	Spaces with low relative humidity and insignificant pollution, e.g. offices, schools, museums	Regions with low humidity, no industrial pollution, and limited exposure to corrosive agents, exhibit relatively low corrosion rates. E.g. regions with arid climate and low humidity levels
C2	$0.1 < r_{\text{corr}} \leq 0.7$ Low	Unheated spaces with varying temperature and relative humidity. Low frequency of condensation and low pollution, e.g. storage warehouses, sport complexes.	Temperate zone, atmospheric environment with low pollution), e.g. rural areas, small towns.
C3	$0.7 < r_{\text{corr}} \leq 2.1$ Medium	Spaces with moderate frequency of condensation and moderate pollution from production process, e.g. food-processing plants, laundries, breweries, dairies.	Temperate zone, atmospheric environment with medium pollution or some effect of chlorides, e.g. urban areas, coastal areas with low deposition of chlorides. Subtropical and tropical zones with atmosphere with low pollution.
C4	$2.1 < r_{\text{corr}} \leq 4.2$ High	Spaces with high frequency of condensation and high pollution from production process, e.g. industrial processing plants, swimming pools.	Temperate zone, atmospheric environment with high pollution or substantial effect of chlorides, e.g. polluted urban areas, industrial areas, coastal areas without spray of salt water.
C5	$4.2 < r_{\text{corr}} \leq 8.4$	Spaces with very high frequency of condensation and/or with high pollution from production process, e.g. mines, unventilated sheds in sub-tropical and tropical zones.	Temperate and subtropical zones, atmospheric environment with very high pollution and/or important effect of chlorides, e.g. industrial

Very high	areas, coastal areas, sheltered positions on coastline.
CX $8 < r_{\text{corr}} \leq 25$	Spaces with almost permanent condensation or extensive periods of exposure to extreme humidity effects and/or with high pollution from production process, e.g. unventilated sheds in humid tropical zones with penetration of outdoor pollution including airborne chlorides and corrosion-stimulating particulate matter.
Extreme	Subtropical and tropical zones (very high time of wetness), atmospheric environment with very high pollution (SO_2 higher than $250 \mu\text{g}/\text{m}^3$), including accompanying and production pollution and/or strong effect of chlorides, e.g. extreme industrial areas, coastal and offshore areas with occasional contact with salt spray.

NOTES

- 1 'r_{corr}' is relative corrosivity in micrometre per year
- 2 Deposition of chlorides in coastal areas is strongly dependent on the variables influencing the transport inland of sea salt, such as wind direction, wind velocity, local topography, offshore platforms beyond the coast, distance of the sites from the sea, etc.
- 3 Corrosivity classification of specific service atmospheres, e.g. in chemical industries, is beyond the scope of IS 14191.
- 4 Sheltered and not rain-washed surfaces, in a marine atmospheric environment where chlorides are deposited, can experience a higher corrosivity category due to the presence of hygroscopic salts (compounds having high affinity for absorption of water & moisture).
- 5 The thickness-loss values are identical to those given in IS 14191.
- 6 The zinc reference material is characterized in IS 14297.
- 7 Corrosion rates exceeding the upper limits in category C5 are considered as extreme.
- 8 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. The data is related to data on flat sheet given in IS 14191 and IS 14321.
- 9 The corrosion rate for zinc and for zinc-iron alloy layers are approximately the same. Corrosivity category CX refers to specific marine and marine/industrial environments.
- 10 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. The data is related to data on flat sheet given in IS 14191 and IS 14321.
- 11 Change in atmospheric environments occurs with time. For many regions, the concentrations of pollutants (particularly SO₂) in the atmosphere have reduced with time. This has led to a lowering of the corrosivity category for these regions. This has, in turn, led to the zinc coatings experiencing lower corrosion rates compared to historical corrosion performance data. Other regions have experienced increasing pollution and industrial activity and therefore would be expected to develop environments more accurately described by higher corrosivity categories.
- 12 The corrosion rate for zinc and for zinc-iron alloy layers are approximately the same.

14.1.4 Table 6 indicates the life to first maintenance for a selection of zinc coatings exposed to the range of these corrosivity categories. The minimum and maximum life expectancies are indicated for each chosen system and durability class indicated. Durability is classified into the following classes:

- | | | |
|-------------------|---|------------------|
| a) Very low (VL) | : | 0 to < 2 years |
| b) Low (L) | : | 2 to < 5 years |
| c) Medium (M) | : | 5 to < 10 years |
| d) High (H) | : | 10 to < 20 years |
| e) Very high (VH) | : | ≥ 20 years |

NOTES

- 1 The figures for life have been rounded to whole numbers. The allocation of the durability designation is based upon the average of the minimum and maximum of the calculated life to first maintenance, e.g. 85 μm zinc coating in corrosivity category "C4" (corrosion rate for zinc between 2.1 μm per annum and 4.2 μm per annum), gives expected durability of $85/2.1 = 40.476$ years (rounded to 40 years) and $85/4.2 = 20.238$ years (rounded to 20 years). Average durability of $(20 + 40)/2 = 30$ years (designated "VH").
- 2 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.

- 3 Thickness of hot dip galvanizing on products: This standard specifies the hot dip galvanized coating at the equivalent of 85 µm minimum for steel >6 mm thick. Thinner steel, automatically hot dip galvanized tubes and centrifugal work (usually threaded work and fittings) have thinner coatings, but these are 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.
- 4 Hot dip galvanized coatings thicker than 85 µm are not specified in this standard but the general provisions of the current Standard apply and, together with specific thickness figures, may form a specification capable of 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.

Table 6 Life to First Maintenance for a Selection of Zinc Coatings (In Micrometre) in a Range of Corrosivity Categories (C3, C4 & C5)
(Clause 14.1.4)

System	Minimum Thickness µm	Selected Corrosivity Category Life Minimum/Maximum (Years) and Durability Class (VL, L, M, H, VH)							
		C3		C4		C5		CX	
Hot Dip Galvanizing	85	40/>100	VH	20/40	VH	10/20	H	3/10	M
	140	67/>100	VH	33/67	VH	17/33	VH	6/17	H
	200	95/>100	VH	48/95	VH	24/48	VH	8/12	H

14.2 Exposure to Water

The type of water — soft or hard, fresh water / salt water — has a major influence on the corrosion of iron and steel in water and the selection of protective zinc coatings. With zinc coatings, corrosion is affected primarily by the chemical composition of the water, but also temperature, pressure, flow rate, agitation and oxygen availability are all important.

Zones of fluctuating water level (i.e. the area in which the water level changes because of natural fluctuations — e.g. tidal movements, or splash zones should be given special consideration as, in addition to water attack, there can also be atmospheric attack and abrasion. In temperate sea water, the average zinc corrosion rate will usually lie between 10 µm per annum and 20 µm per annum. Hot dip galvanized tube, hot dip galvanized sheet and fittings normally have additional protection when used in sea water.

14.3 Exposure to pH Levels

A primary factor governing corrosion behaviour of zinc coatings in liquid chemical environments is the pH of the chemical solution. Zinc coatings, such as galvanizing, perform well in solutions of pH above 5.5 and below 12.5. Factors such as agitation, aeration, temperature, polarization and the presence of inhibitors may affect the specific rate of corrosion experienced by the coating. Within the pH range of 5.5 to 12.5, a protective film forms on the zinc surface and the corrosion rate is very slow. The precise chemical composition of the protective film is somewhat dependent upon the specific chemical environment. Since many liquids fall within the pH range of 5.5 to 12.5, galvanized steel containers are widely used in storing and transporting many chemical solutions. Prolonged or frequent direct contact with acids or strong alkalis is not recommended. Many organic solvents have little effect on non-ferrous metals but specific advice should be sought for each chemical.

14.4 Contact with Concrete

Unprotected steel articles in contact with concrete can corrode as moisture penetrates the concrete through cracks and pores. The oxidation products from the reaction between the steel and the oxygen/moisture present can create sufficient pressure to cause damage to the concrete (spalling). Zinc coatings (usually applied in the form of a hot dip galvanized

coating to reinforcement — *see* IS 12594), can be used to prevent this type of deterioration for long periods of time, dependent upon the specific exposure environment.

The corrosion protection afforded by galvanized rebar in concrete is due to a combination of beneficial effects. Of primary importance is the substantially higher chloride threshold (2 to 4 times) for zinc coatings to start corroding compared to uncoated steel. In addition, zinc has a much greater pH passivation range than steel, making galvanized rebar resistant to the pH lowering effects of carbonation as the concrete ages. Even when the zinc coating does start to corrode, its corrosion rate is considerably less than that of uncoated steel.

Zinc remains passive at significantly lower pH levels than for black steel (9.5 versus 11.5) making galvanized rebar far less susceptible to corrosion due to carbonation of the concrete.

Zinc reacts with wet concrete to form calcium hydroxy zincate accompanied by the evolution of hydrogen. This corrosion product is insoluble and protects the underlying zinc (provided that the surrounding concrete mixture is below a pH of about 13.3).

14.5 Bimetallic Contact

When two dissimilar metals come into direct contact and an electrolyte such as moisture is present, there is a potential for bimetallic corrosion to take place with the more electronegative or anodic metal, as determined from the electro-chemical series, corroding preferentially to prevent corrosion of the other metal (*see* Table7).

**Table 7 Galvanic Series (Based Upon Electrode Potentials in Sea Water)
Showing Relative Position of Zinc to Other Metals.**

Anodic — more prone to corrosion
Magnesium
Zinc
Aluminium
Carbon and low-alloy steels
Cast iron
Lead
Tin
Copper, brass, bronze
Nickel (passive)
Titanium
Stainless steel
Cathodic — less prone to corrosion

The bimetallic effect is the basis for the sacrificial protection that a zinc coating (e.g. hot dip galvanizing) offers to small areas of exposed steel if the coating becomes damaged. Zinc coatings will corrode preferentially to protect any metal below it, in the electro-chemical series.

The level of bimetallic corrosion that will take place will depend upon several factors, including: the specific metals in contact, the ratio of the surface area of the two metals and the exposure conditions. Generally, the level of bimetallic

corrosion will increase with a greater difference in electrode potential between the two metals, e.g. the further apart the two metals are in the electro-chemical series mentioned in Table 7.

15 PREPARATIONS OF THE METAL SURFACE FOR GALVANIZING (PROCESS OF HOT-DIP GALVANIZING) — PRE-TREATMENT PROCESS

15.1 Cleaning – Degreasing Solution

If an article is contaminated by oil, grease or paint, pre-treatment in special solvents will be necessary for their removal. Several proprietary reagents are available. Generally, a sodium hydroxide solution obtained by dissolving 10 kg to 15 kg of sodium hydroxide in 100 litres of water is used. “Acid based degreaser” is also alternatively used and is in practice with 8 -15 litres of phosphoric acid diluted in 100 litres of water.

15.1.1 The work should be so handled in the degreasing bath as to allow complete immersion of the work in the solution, to ensure cleaning of the surface scum, light surfacents that may collect on the job. If necessary, the work should be raised and lowered in order to allow the degreasing solution to enter inaccessible areas, threaded sections, etc, for a thorough cleaning action. When using sodium hydroxide solution, the temperature of the solution may be usually kept between 85 and 90 °C and the immersion time varying from 1 to 20 minutes depending on the nature and degree of contamination. When using other proprietary acid-based degreasing agents; manufacturers’ recommendation should be followed and, where acidic degreasing agents are used, maintaining of temperature may not be necessary.

15.1.2 Immediately after degreasing, the work should be rinsed in water followed (in case of alkaline degreaser, hot water at 60 °C must be used), if possible, by a final rinse in cold running water. An ideal arrangement for rinsing would be to provide an inlet and outlet on two opposite sides of the rinsing tank; the inlet should be at the bottom of the tank and water should overflow from the top. This way the rinse water is in a dynamic state thereby ensuring an efficient and a thorough rinsing operation.

15.1.3 When lubricating materials, bituminous paints, etc. have contaminated the surface of the metal, it may be necessary to flame heat the part to bluing or at scaling temperature to burn off the surfacents on the material. Since this is an expensive and inconvenient process, prior care should be taken to avoid such surface contamination that cannot be cleaned by degreasing alone.

15.2 Cleaning of Castings

Grey iron and malleable iron castings if not properly cleaned before annealing, develop burnt-on and patches on the surface which are not removed by normal pickling. Except in the case of light castings which would be damaged, all castings should be shot or grit blasted prior to galvanizing. It is generally recommended to give a quick rinse in running water followed by cleaning with one of the pickling acids. It is then processed according to normal fluxing practice.

15.3 Pickling

Both hydrochloric acid (*see 15.3.1*) and sulphuric acid (*see 15.3.2*) solutions may be used for pickling. Hydrochloric acid is used at room temperature while with sulphuric acid best results are obtained when it is hot (60 °C to 80 °C).

15.3.1 Hydrochloric Acid Solution (100 g/l to 150 g/l)

Dilute technical grade acid conforming to IS 265 with an equal volume of water. The actual concentration of hydrochloric acid solutions and the time of immersion will depend on the nature of the work to be pickled.

A suitable inhibitor should be used with hydrochloric acid.

15.3.2 Sulphuric Acid Solution

Dilute 6 ml to 8 ml of technical grade acid conforming to IS 266 to 100 ml. The actual concentration of sulphuric acid solutions, the temperature of the bath and the time of immersion will depend on the nature of the work to be pickled.

A suitable inhibitor should be used with sulphuric acid.

15.3.3 Agitation

Mild agitation of the work in the pickling tank reduces the time of pickling. Raise or lower the work once or twice to change the acid layer in contact with the work. Air agitation is not recommended.

15.3.4 Control of the Acid Solution

To make the best use of the solution, reasonably close control of its acid content is necessary. The solution should be tested for acid and iron contents at regular intervals in accordance with the methods given in Annex C. The strength of the solution should be maintained by periodic addition of fresh concentrated acid. The iron salts in the pickling bath gradually accumulate with continued working and when the iron content reaches to about 100 g/l to 120 g/l, the solution should be discarded.

15.3.5 Disposals of Waste Liquor

The acid and iron compounds may be recovered from the waste pickling solution. Where this is not done the pickling solution should be neutralized before sending for further treatment of effluent & solid waste treatment as per stipulated pollution board control norms.

15.4 Rinsing

After pickling, the article should be rinsed in running water to ensure that carry over acid salts & oxides are cleaned from surface. Two rinse tanks are preferable, the water cascading from one into the other, that is cascading from the second tank into the first tank.

15.5 Fluxing

15.5.1 The rinsed article, in case of the dry process, is dipped in a strong solution of zinc ammonium chloride ($ZnCl_2 \cdot 3NH_4 Cl$), although ammonium chloride is also used to a certain extent. The actual concentration of the flux solution and its temperature depend on the work being undertaken and on individual circumstances. The working level is generally between 200 g to 400 g of zinc ammonium chloride per litre. Some wetting agent is usually added to the flux solution. The temperature may range from room temperature to 80 °C to maintain effective fluxing.

15.5.1.1 When dry galvanizing is adopted the article shall be thoroughly dried after fluxing over a hot-plate or in an air-oven / drying pit. The temperature should be about 120 °C and should not exceed 150 °C as the surface flux decomposes above this temperature.

15.5.1.2 In the wet process, a deep flux cover is used on the zinc bath and the work is immersed through the flux blanket layer with or without fluxing. In this case drying is not considered essential.

15.5.2 The article that has been pre-fluxed and dried should be galvanized without delay, as the flux coating picks up moisture from the air and tends to oxidize. The recommended time limit for galvanizing is within an hour of fluxing.

15.5.3 Control of Fluxing Solution

The specific gravity of the flux solution should be controlled by adding required quantities of flux crystals and water to make up for the drag-out losses.

Free acid content of the solution should also be checked, particularly if rinsing is not proper then the pickle salts is carried over. The method described in 'Annex C' may be used for determination of free acid, but the actual titration should be made on a 100 ml sample as the concentration of acid in the solution will be very low. When more than 2 g of free acid per litre of the solution is present, it should be neutralized by adding ammonia solution or addition of zinc spelter to check the pH content.

16 GALVANIZING

16.1 Quality of Zinc

Zinc used for galvanizing shall be of the grade Zn99.95 and Zn99.99 as specified in IS 209.

16.1.1 Galvanizing Bath

The molten zinc metal in the galvanizing bath should contain not less than 98.5 percent by mass of zinc.

16.2 Aluminum Additions

Aluminium may be added to the galvanizing bath in the dry process to the extent of about 0.005 percent (0.007 percent Max) (0.05 g/kg to 0.07 g/kg of zinc) to reduce the rate of oxidation of the molten metal and brighten the appearance of the article.

16.3 Bath Temperature

The control of bath temperature is essential if the quality of the product is to be consistent and zinc is to be used economically. Articles should be galvanized at the lowest possible temperature which will allow the free drainage of zinc from the work piece during withdrawal. A low temperature reduces the formation of ash and dross, besides safeguarding the pot life and conserving fuel. The bath temperature may vary from 440 °C to 460 °C and a working temperature of 450 °C is commonly used. The temperature of the molten metal should not ordinarily exceed 475 °C to prevent excessive attack of molten zinc on the work as well as on the zinc bath.

16.4 Suspended Dross

Dross should be allowed to settle at the bottom of the zinc bath, and should not be disturbed more than necessary during the dipping operation (*see 5.5*). As far as practical the article should not be sunk to the bottom of the bath during galvanizing. After drossing operations, while dipping the articles once again, sometime should be allowed for the probable dross remaining in the kettle to settle down. A lead bed (limiting to 1%) may be maintained in the bath as it assists in settling of agitated dross in the bath & further in drossing operation itself.

16.5 Rate of Immersion

16.5.1 The work should be immersed as rapidly as possible however with due regard to operator's safety. This is especially important in wet galvanizing, where the amount of dross increases with the time of contact with the flux blanket. The speed of immersion also influences the uniformity of coating, particularly with long work piece where the difference in immersion time between the first and the last part to enter the bath may be considerable, affecting the coating thicknesses at both ends.

Top zinc ash (oxide) must be removed at regular interval from the surface of the bath to avoid carryover of zinc ash on the surface of materials while withdrawal from zinc bath.

16.5.2 Time of Immersion

The time of immersion for a job depends on several factors like its chemistry, size, thickness, type of job, etc. In most cases the article shall be left in the bath until it reaches the temperature of the bath which is usually indicated by the stopping of the boiling action. It is then withdrawn without much delay.

16.6 Rate of Withdrawal

The rate of withdrawal, which determines the thickness of the unalloyed zinc layer left on the article, varies according to the type of the process being operated and the form & type of article. With long article for which withdrawal occupies a large part of the total handling time, speeds are necessarily maintained at higher levels to ensure a reasonable rate of production. It is better to use special jigs and carriers for dipping and withdrawing the work in batches. The rate of withdrawal should be gradual & controlled so that zinc drains freely from the surface.

Articles are withdrawn through a bath of molten zinc to avoid contamination by flux. However, withdrawal through a flux blanket has also its advantages in the removal of excess zinc from the surface and in producing a uniform coating

at relatively higher speeds. In the latter case it is recommended to quench the material to remove flux residues (*see* 16.8).

16.7 Relation between Life and Thickness of Hot-Dip Galvanized Coatings

The life of hot-dip galvanized coatings (whether light grey or dull grey) is approximately proportional to the coating thickness and the surface condition of the material to be galvanized.

For extremely aggressive conditions and/or an exceptionally long service life, thicker coatings may be required. The specification of the coating is subject to mutual agreement between the galvanizer and the purchaser. Some increase in coating thickness may be obtained, for example, if steel surface are grit-blasted before galvanizing, or if hot-rolled steels containing more than 0.3 percent silicon are used.

16.8 Water Quenching

Where the article is withdrawn through a flux blanket, the quench water needs to be changed frequently to prevent the accumulation of corrosive salts. For this purpose, tanks having overflow mechanism with introduction of fresh water that may be used as an advantage of proper adhesion of zinc coating on the job.

16.8.1 Light gauge articles should be spun quickly through the surface of water so that they retain sufficient heat after quenching to enable quick drying. Heavy articles retain sufficient heat for drying.

16.9 Centrifuging

Small articles handled in baskets should be centrifuged to remove excess of zinc immediately after galvanizing while the coating is still in the molten condition. The quality of the finish depends on the rapidity with which the material is transferred from the galvanizing bath to the centrifuge. It is also important that the centrifuge should be powered by a high starting torque electric motor to give rapid acceleration to peak speed within 2 s to 3 s. After centrifuging, the articles should be immediately tipped into water to allow the coating to set and prevent the articles from sticking to each other.

16.9.1 Thread Brushing

Threads on articles which are unsuited for centrifuging shall be cleaned with a rotating wire brush immediately after galvanizing and before the coating sets. This process reduces the thickness and the protective value of the coating. It should only be confined to the threaded portions of the article.

16.10 Post-Treatment

The zinc coating on freshly galvanized surfaces when exposed to humid, poorly ventilated conditions during storage and/or transport react with the moisture, carbon dioxide, oxygen, etc, in the atmosphere forming a mixture of salts which are white in colour, however, it is to be noted that zinc may not react with chloride. This is known as, 'wet storage stain'. Normally a post-treatment like chromating is recommended. This is a temporary treatment and retards oxidation of pure surface zinc layer. The chromating solution must not exceed 0.5 percent - 0.7 percent sodium dichromate (ideally trivalent chromates) and half percent sulphuric acid solution – the solution is kept at room temperature and its temperature should never be allowed to rise above 65 °C. The galvanized articles are dipped into the chromating solution after the galvanizing and water quenching operations.

16.11 Stacking

Articles should be allowed to dry and may be stacked in ventilated condition immediately after quenching to avoid flaking of coating. The galvanized articles should be dry before any further handling operation.

17 TESTING AND INSPECTION

17.1 Freedom from Defects

The zinc coating shall be adherent, smooth, reasonably bright, continuous, and free from such Imperfections as flux, ash and dross inclusions, bare and black spots, pimples, lumpiness and runs, rust stains, bulky white deposits, and blisters.

17.2 Test for Uniformity of Zinc Coating in Thickness

Galvanized articles shall be tested for uniformity in thickness of coating in accordance with Preece test as indicated in IS 2633. For quick approximate measurements of thickness, magnetic gauges may be used, but such instruments shall be suitably calibrated before use.

17.2.1 Preece test

Preece test is designed for newly coated items. Preece test shall not be used for determining mass of zinc coatings as these are produced by different processes and have widely different rates of solubility in copper sulphate solution. Electroplated and sprayed zinc coatings which consist essentially of pure zinc, dissolve rapidly than hot-dipped coatings which are composed of zinc iron alloy layer next to steel, and nearly pure zinc layer in the outer part of the coating. The rate of reaction increases with increase in temperature. It has been found that to obtain accuracy of about 10 percent in this test, it is necessary to maintain temperature of copper sulphate solution at $18\text{ }^{\circ}\text{C} \pm 2\text{ }^{\circ}\text{C}$. The number of samples to be tested shall be as specified in Table 1. The material passes this test if at the end of the specified number of dips (4 dips of 1 min duration each), when the test piece is finally rinsed and wiped dry by soft bristle brush, it does not show any adherent red deposit of copper upon the base metal. Any red deposit of copper on the test sample shall be interpreted as a failure of the sample.

NOTES

- 1 If no running water is available, the rinse water shall be changed often enough, preferably after each dip, to ensure that it is reasonably free from copper sulphate. The temperature of the rinse water should be $15\text{ }^{\circ}\text{C}$ to $20\text{ }^{\circ}\text{C}$.
- 2 Soft bristle brush conforming to IS 1104 may be used for the purpose.

17.3 Tests for Mass of Coating

The mass of zinc coating shall be determined in accordance with IS 6745.

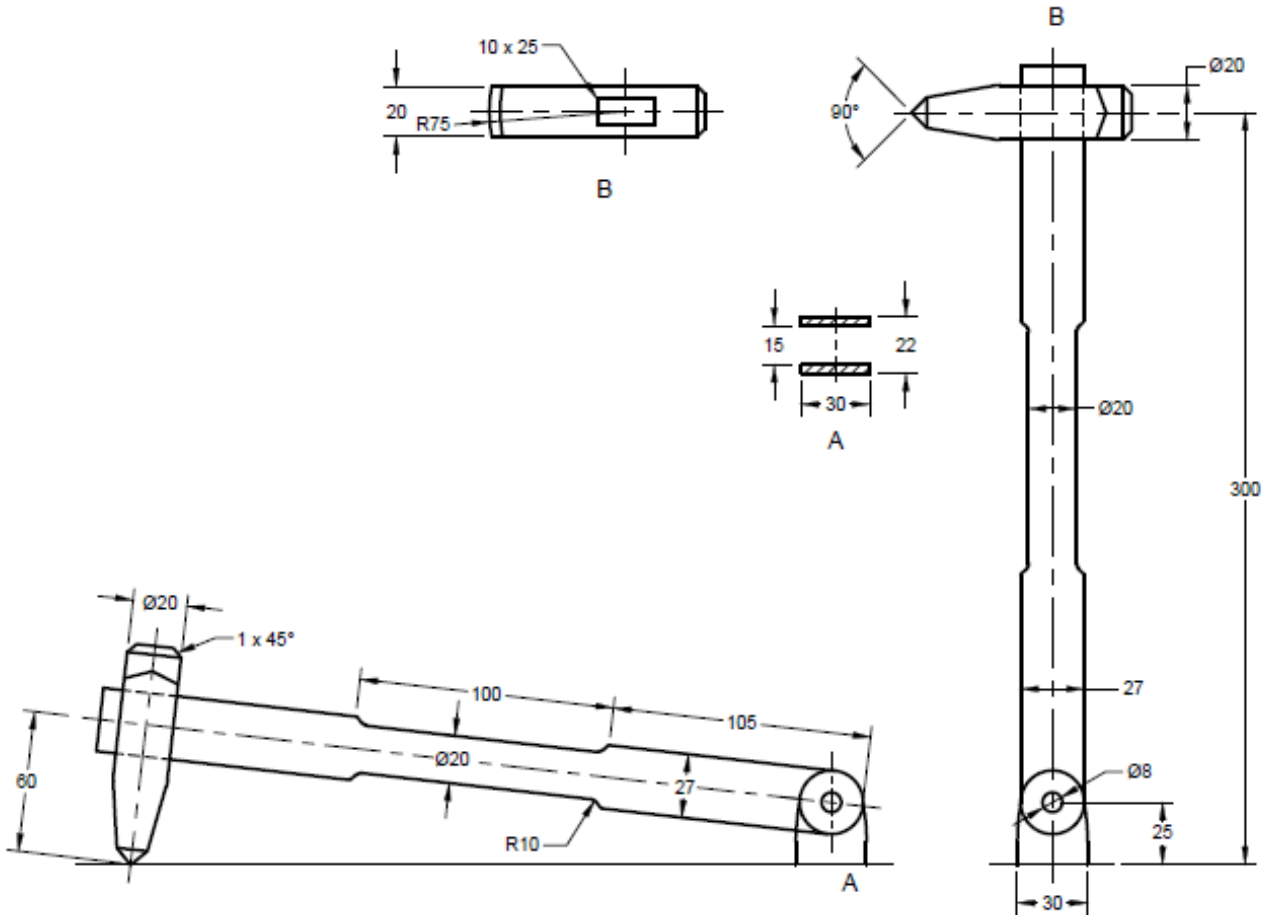
17.3.1 Stripping test

For determining the mass of zinc coating, stripping method has been prescribed for galvanized articles, such as sheet and strip, wire, tube, rolled steels, bolts and nuts, castings, forging etc. Direct method of determining the mass of zinc coating by weighing the articles before and after galvanizing and subtracting the first mass from the second and dividing the result by surface area. Sampling of the material shall be done in accordance with the stated specification. The procedure and the calculation method is detailed in IS 6745 to determine the mass of zinc coating in g per Sq. metre to ascertain coating requirement as per Clause 6.

17.4 Adhesion Tests

17.4.1 Pivoted Hammer Test for Zinc Coated Fabricated Products

The adherence of the zinc coating on steel shall be determined by the pivoted hammer test. The hammer used shall conform to the drawing shown in Fig 11. The hammer shall be made of normalized 0.3 percent to 0.4 percent carbon steel. The hammer blow shall be controlled by holding the pivoted base of the handle on a horizontal surface of the galvanized member and allowing the hammer head to swing freely through an arc from vertical position to strike the horizontal surface. The test shall consist of two or more standards blows forming parallel impressions with 6 mm spacing and a common axis, as illustrated in Fig. 11. No part of an impression shall be closer than 12 mm to the edge of the member. Removal or lifting of the coating in the area between the impressions shall constitute failure. An extruded ridge less than 2 mm wide immediately adjacent to the impression shall be disregarded. The specimen is tested in several places throughout its length.



All dimensions in millimeters

FIG. 11 PIVOTED RIVETING HAMMER

17.4.2 Knife Test for Zinc Coated Hardware and Assembled Steel Products

When the coating is cut or pried into, such as with a stout knife applied with considerable pressure in a manner tending to remove a portion of the coating, it shall only be possible to remove small particles of the coating and it shall not be possible to peel any portion of the coating to expose the underlying iron or steel.

17.4.3 Accelerated Test Methods (Salt Spray Tests) Applied to Zinc Coatings

Salt spray tests cannot be used to accurately test zinc-coated steel because they accelerate the wrong failure mechanism. Without a proper wet/dry cycle, the zinc coating cannot form intermetallic layers (generally referred as patina layers). The absence of a patina layer allows constant attack of the zinc metal and gives a very low prediction of the zinc coating lifetime.

18 STORING, PACKING AND HANDLING.

18.1 Sufficient care should be exercised while storing, packing, and handling of galvanized products. While storing and transporting them, adequate ventilation should be provided as otherwise ‘white rust’ or ‘wet storage stain’ may result when galvanized coatings react with humidity and atmospheric gases. It is sometimes necessary to store galvanized articles with spacers in between them; they are also kept at an inclination to facilitate drainage of water collected on the articles. In areas where there is a substantial variation in day and night temperatures and hence

condensation, the storage area kept warm by provision of heaters. In many cases, it will be advisable to give a post-treatment like chromating to minimize the chances for formation of wet storage stains.

ANNEX A

DEFECTS, THEIR CAUSES AND REMEDIAL MEASURES*(Foreword)*

The galvanized coating applied to steel should be ideally continuous, adhering, and consisting of a thickness that will provide years of maintenance free or low maintenance service life. However, there are a number of common defects that may arise in the galvanizing process. These are readily visible and have a variety of causes - many of which can be avoided through good communication and this standard referred compliant operations.

Hot Dipped Galvanized Coatings on Ferrous Articles, shall be: -

- a) Continuous, and as smooth and evenly distributed as possible.
- b) Free from defects that may affect the stated use of the article.
- c) Free from blisters, roughness, sharp edges and flux residues.


Lumps and zinc ash are not permitted where they may affect the intended end use of the galvanized product. Visual inspection is the simplest and most important method to assess the quality of galvanized coatings. A useful characteristic of the galvanizing process is that if the coating is continuous and has a satisfactory appearance it will be sound and adherent.

The following legends indicates the category of galvanizing defects whether the hot dip galvanized materials is accepted or rejected as:

“A” – Accept / “R” – Rejected / “N” – Negotiate / “C” – Clean / “REP” – Repairs

Responsibility Index: “G” – Galvanizer / “D” – Design engineer / “M” – Manufacturer / Fabricator of article / “St” – Steel Type / “S” - Surface / “U” – User.

18 DEFECTS, THEIR CAUSES AND REMEDIAL MEASURES

Figure	Defects	Causes	Recommended Actions	Guidance for Acceptance /Rejection
	<p>Bare spots or Black spots – <i>(Responsibility -“G”)</i></p>	<ul style="list-style-type: none"> Paint grease or oil Scale or rust residues Residual welding slag Breakdown of flux coating Aluminum content of bath too high Rolling defects in basis steel Articles in contact during galvanizing 	<ul style="list-style-type: none"> Check cleaning practices, degreasing recommended Check pickling practices Adopt mechanical cleaning avoid coated rods Check preflux and drying conditions particularly the temperature on the job being dried Regulate aluminum additions Check steel supply Keep articles separated 	<p>May be rejected “R”, except where bare spots are small (less than 100 mm) and suitable for patching by treatments like zinc rich paints zinc spraying, etc. subject to prior agreement between the galvanizer and the buyer. Zinc can sacrificially protect bare areas measuring about 4 mm across but here again the allowable size of bare spot should be agreed upon between the galvanizer and the buyer</p>



General roughness-

(Responsibility-
"G" & "M")

- Analysis or original surface condition of steel
- Over pickling.
- High galvanizing temperature or long immersion time or both

Check steel supply
Reduced pickling time or acid concentration, use inhibitor

May be accepted "A" except by prior agreement between galvanizer and purchaser



Pimples

(Responsibility
"G")

- Entrapped dross particles

Avoid agitation of dross layer check carryover of pickle salts

May be accepted "A" unless dross contamination is heavy



Lumpiness and runs (uneven drainage) –

(Responsibility
"G")

- Withdrawal speed too high
- Cold galvanizing bath
- Delayed run-off seams, joints, bolt holes, etc.

Remove work slowly

Increase temperature

Remove work slowly

Only by prior agreement "N"

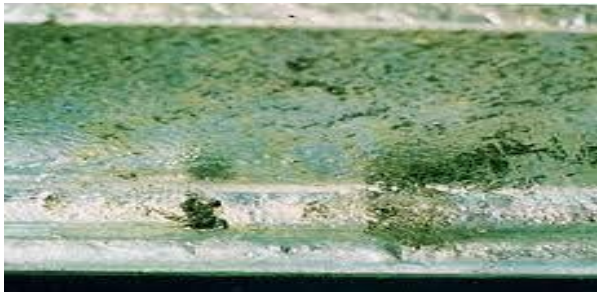


Flux inclusions-

(Responsibility "G")

- Articles in contact during withdrawal → Keep articles separated
- Surface residues on steel → Check steel preparation
- Flux picked up from top of bath → Skim before withdrawal

Accepted "A" – If Flux stain left over on the job after flux removal, is not considered as flux inclusion and hence should be accepted.



Ash inclusions-

(Responsibility "G")

- Ash burnt on during dipping → Skim bath before dipping
- Ash picked up from top of bath → Skim bath before withdrawal

Shall be rejected "R", if in gross lumps.



Dull grey coating (all alloy no free zinc) –

(Responsibility "M" and "St")

- Steel composition (high silicon, phosphorus or carbon) or severe cold work → Check steel supply for composition in order to adjust for galvanizing
- Slow cooling after galvanizing → Avoid hot staking, quench
- Release of absorbed hydrogen during solidification of coating → Avoid over-pickling, use inhibitor

"A" Accepted if due to steel composition or condition or limited to occasional areas control by prior agreement. Grey coating is only displeasing to the eye and is, not a defect at all. In fact, grey coating, compared to a bright coating, is abrasion resistant, chemically more protective in some environment for instance, aggressive environments.



Rust stains –

(Responsibility “M”)

<p>Weeping of acid, etc, from seams and folds</p>	<p>Check Product design and fabrication</p>	<p>} May be accepted “A”</p>
<p>Storage near rusty material</p>	<p>Check storage condition</p>	



Bulky white deposit (wet storage stain, white rust) –

(Responsibility “G” & “U”)

<p>Confinement of close packed articles under damp conditions</p>	<p>Store and ship in dry well-ventilated conditions, separate articles with spacer. A temporary treatment like chromating is recommended</p>	<p>} May be accepted “A”, if thin white deposits can be removed by hand rubbing, brushing, etc. If deposits are heavier, they shall be removed and the zinc coating beneath should be tested for thickness before accepting or rejecting the “white rust attacked” galvanized products</p>
<p>Packing of articles while damp</p>	<p>Dry before packing, include desiccant A temporary protective treatment like chromating is recommended</p>	



Blisters –
(Responsibility “G”)

<p>Expansion of entrapped hydrogen and moisture in-flaws</p>	<p>Check steel quality</p>	<p>} May be rejected “R”,</p>
<p>Driving off of hydrogen absorbed during pickling</p>	<p>Use shot blast instead of pickle check steel supply</p>	
<p>Improper malleablizing (for malleable iron castings only)</p>	<p>Check malleablizing practice</p>	



Tiny blisters –
(Responsibility “G”)

<p>Effect sometimes observed on quenched work</p>	<p>Use shot blast instead of pickle. Check malleablizing treatment should have no combined carbon near surface of casting</p>	<p>} May be rejected “R”, if blistering is generally widespread</p>
<p>May be caused by gas evolved from the work resulting from absorbed hydrogen or breakdown of combined carbon near surface</p>		

ANNEX B

(Foreword)

WORKING CONDITIONS AND SAFETY MEASURES

B-1 WORKING CONDITIONS

B-1.1 The galvanizing shop should be kept neat and tidy. Where possible, increased use should be made of hoods, extraction ducts and exhaust fans to give as good an atmosphere as possible.

B-1.2 Prioritizing the well-being of employees, following work conditions along with health and safety measures have to be implemented within galvanizing units.

B-2 SAFETY MEASURES

B-2.1 All safety measures should be properly exhibited.

B-2.2 The workers at the galvanizing bath should be provided with:

- a) eye or face shield,
- b) rubber boots,
- c) steel-capped boots,
- d) leather or leather on woolen base gloves,
- e) rubber and leather aprons, and
- f) long rubber or PVC or neoprene gloves.

B-2.3 While cleaning the articles with sodium hydroxide solution, the operators should be warned that it produces severe flash burns. Special precautions should be taken to protect them from splashes of sodium hydroxide solution.

B-2.5 Arrangement should be made to protect the galvanizer from the fumes over the zinc bath.

ANNEX C

(Clauses 7.2.2 and 17)

CHEMICAL ANALYSIS OF PICKLING ACID

In the hot-dip galvanizing process, pickling is a critical step where the surface of the steel article is cleaned and prepared for the application of the zinc coating. Compliance of test methods help ensure that pickling operations are carried out efficiently and in accordance with best practices for hot-dip galvanized coatings. The specific gravity & iron content are important parameters that can influence the effectiveness and efficiency of the pickling process.

C-1. SPECIFIC GRAVITY:

Specific gravity is a measure of the density of the pickling solution, typically an acidic solution containing hydrochloric acid (HCl) or sulfuric acid (H₂SO₄).

The specific gravity of the pickling solution is important as it affects the pickling rate and the ability of the solution to remove oxides, scale, and other contaminants from the steel surface.

Generally, a specific gravity range of 1.10 to 1.27 g/l is maintained for pickling solutions in hot-dip galvanizing processes. This range ensures that the solution has the right concentration of acid for effective pickling without causing excessive metal loss.

C-1.1 Determination of Acid Density (Specific Gravity)**C-1.2 Quality of Reagents**

C-1.2.1 Unless otherwise specified, pure chemicals shall be employed in tests and distilled water shall be used when the use of water as a reagent is intended, it shall conform to IS 1070.

NOTE – ‘Pure chemicals’ shall mean chemicals that do not contain impurities which affect the results of analysis.

C-1.2.2 *Standard Sodium Carbonate Solution* – Approximately 0.5 N.

C-1.2.3 *Methyl Orange Indicator Solution* – Dissolve 0.05 g of methyl orange in 100 ml of alcohol.

C-1.3 Procedure

Filter exactly 25 ml sample of the pickle liquor into 250 ml measuring cylinder and make up to 250 ml by adding distilled water mix thoroughly. Pipette out 25 ml of this solution in a 250 ml conical flask. Add a few drops of methyl orange indicator and titrate it with the standard sodium carbonate solution to yellow end point.

C-1.4 Calculation

$$\text{Mass of hydrochloric acid in g/l} = \frac{A \times B \times 36.5}{2.5}$$

$$\text{Mass of sulphuric acid in g/l} = \frac{A \times B \times 49}{2.5}$$

where

A — volume in ml of the standard sodium carbonate solution required, and

B — normality of the standard sodium carbonate solution.

Example

If HCL titration is 12ml, then HCl = 12% w/v or HCl g/l = 120g/l

C-2. Iron Content:

C-2.1 The iron content in the pickling bath is an important parameter to monitor, as it indicates the level of iron removed from the steel substrate during the pickling process and, maintaining it prevents over-pickling, which can lead to excessive metal loss. The iron content in the pickling solution is typically measured using methods such as titration or colorimetric analysis.

C-2.2 The limit for iron content in the pickling bath is recommended to be below 120 g/l for effective pickling in hot-dip galvanizing processes. This range ensures efficient removal of oxides and contaminants from the steel surface without excessive metal loss.

C-2.3 Determination of Iron Content of the Pickling Solution (Nomographic Method)

C-2.3.1 Principle

Measure density of the pickling solution with a hydrometer, then on the corresponding nomograph (*see* Fig. 12 and Fig.13) depending on the acid used for pickling, join with a transparent ruler the point representing this reading shown on the left-hand line with the point on the right-hand line representing the acid content of the pickle. Read off the iron content on the middle line.

C-2.3.2 Equipment Required

- a) Hydrometer for specific gravity (density range 1000 to 1200, with 0005 subdivisions),
- b) 100 ml measuring cylinder,
- c) Nomograph, and
- d) 30 cm ruler.

C-2.3.3 Method

- a) Take a 100 ml sample from the pickling bath and allow it to stand to cool to room temperature and settle any sediment.
- b) Pour about 60-70 ml of the clear sample into the clean measuring cylinder.
- c) Place the hydrometer in the measuring cylinder and spin it to eliminate surface tension effects.
- d) Read off the specific gravity (S.G.) at the fluid line.
- e) Record the specific gravity of the pickling sample.
- f) Determine the HCl concentration by the method described previously.
- g) Get a ruler and line up the "Specific Gravity (Density)" on the left-hand side of the graph with the "Hydrochloric Acid Content" on the right-hand side of the graph.
- h) The "Iron Content" can be read off the middle column where the line intersects the column.

Example

If the specific gravity was measured to be 1.165 and the HCl content was determined to be 115 g/l (11.5% w/v), then the line between the two outer columns intersects the middle column at Fe content = 55 g/l

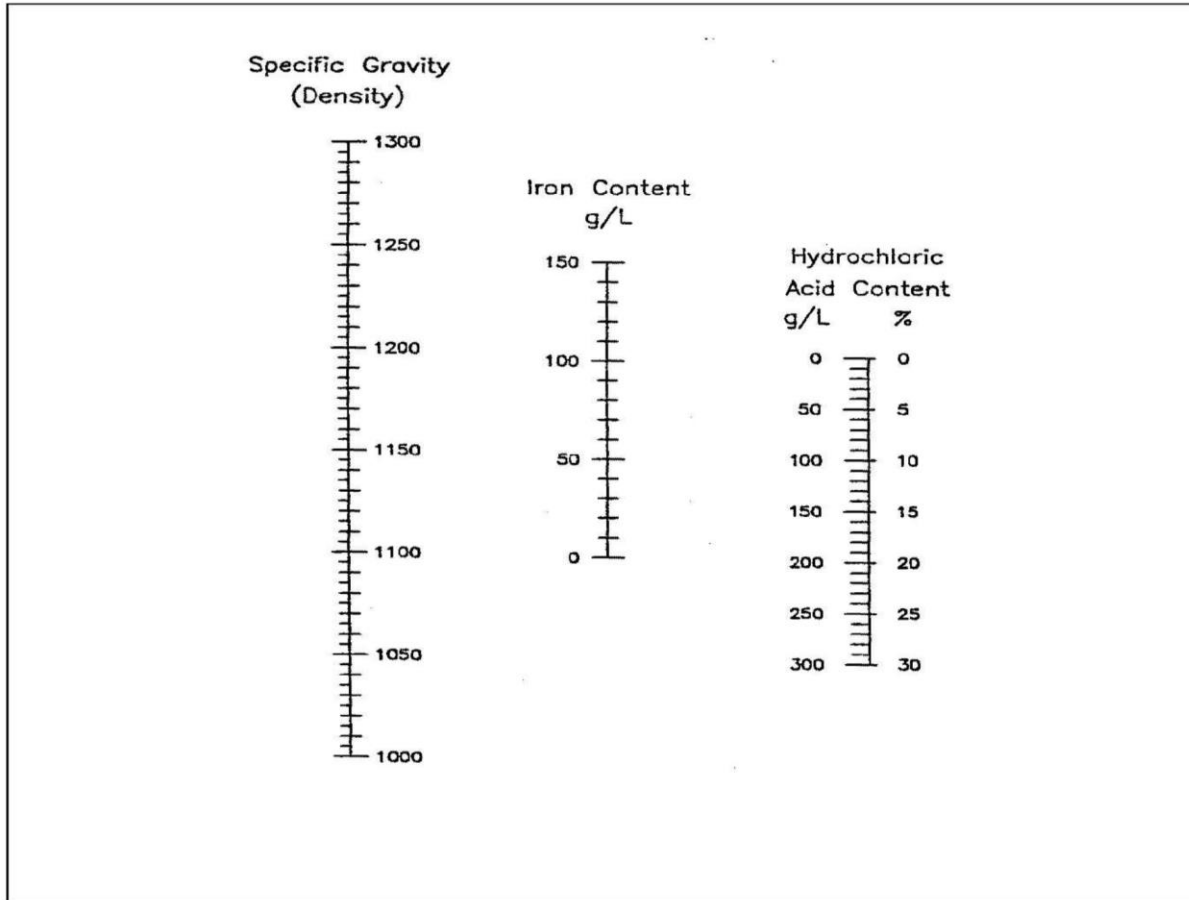


FIG. 12 NOMOGRAPH RELATING THE IRON CONTENT OF HYDROCHLORIC ACID PICKLE TO THE ACID CONTENT AND DENSITY

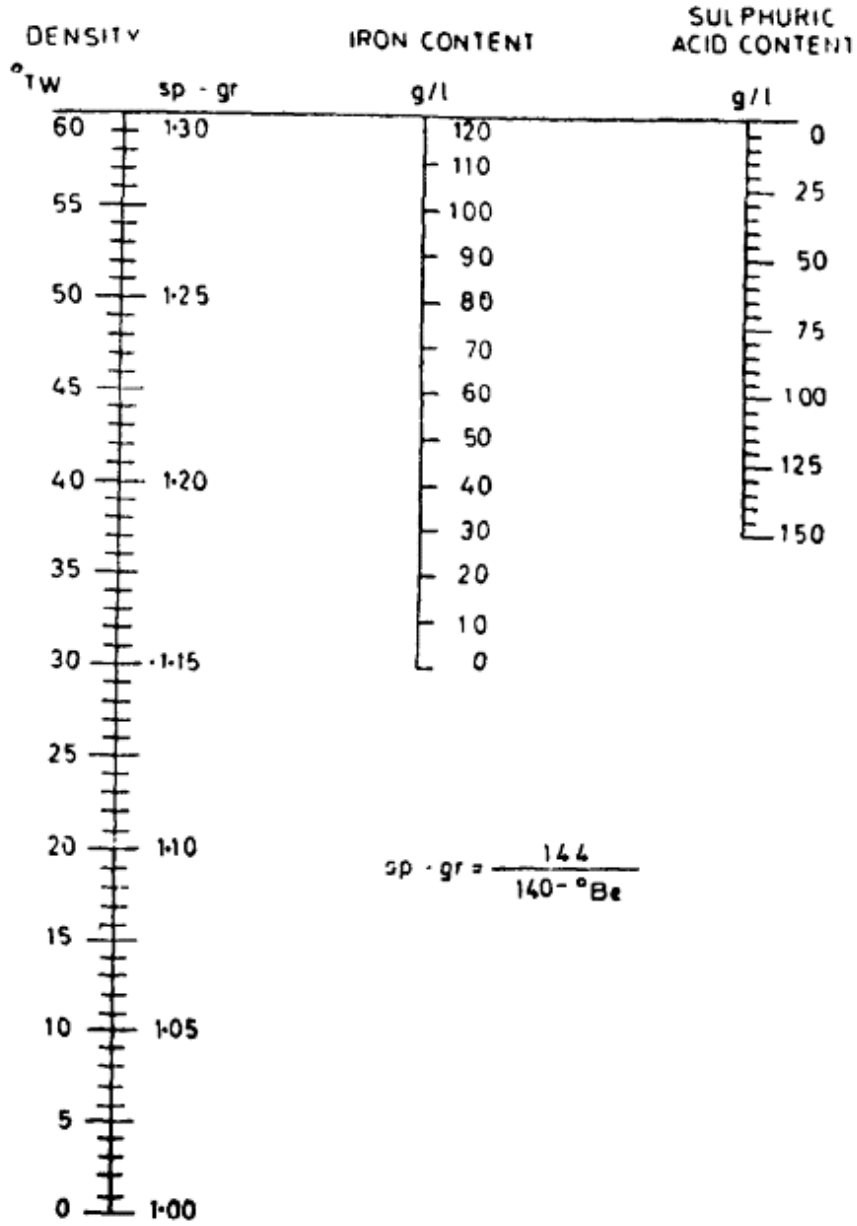


FIG. 13 NOMOGRAPH RELATING THE IRON CONTENT OF SULPHURIC ACID PICKLE TO THE ACID CONTENT AND DENSITY