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CHAPTER 2

Design, Specification & Inspection Of Galvanized Products

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galvanizers
ASSOCIATION OF AUSTRALIA

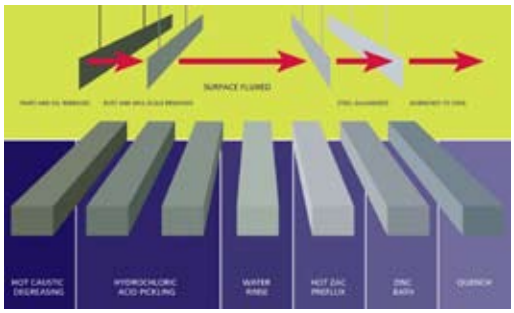
Design, Specification & Inspection of galvanized products

Consistently good galvanized steel products will be produced when the essential requirements listed are incorporated at the design and fabrication stages of production. **Design features should be discussed with the galvanizer. Close liaison between design engineer, materials engineer, specifier, fabricator and galvanizer will ensure high quality galvanized products, minimum cost and faster delivery.**

Galvanizing fundamentals

Hot dip galvanizing is an immersion process where steel sections and fabrications undergo the following operations:

1. **Hot caustic degreasing** (removal of oil, organic materials, selected mill primers and paint)
2. **Hydrochloric acid pickling** (removal of rust and mill scale)
3. **Rinsing** (removal of pickling acid residues)
4. **Prefluxing in zinc ammonium chloride solution** (surface conditioning)
5. **Hot dip galvanizing** (at 450-460°C)
6. **Quenching** (passivation of the zinc surface to prevent early oxidation)
7. **Surface clean up & inspection.** (eg. deburring)



Design considerations

Protection against corrosion begins on the drawing board. No matter what corrosion protection system is used, it must be factored into the design of the product.

Once the decision has been made to use hot dip galvanizing to provide corrosion protection for steel, the design engineer should ensure that the pieces can be suitably fabricated for high quality galvanizing. Adopting the following design practices will ensure the safety of galvanizing personnel, reduce coating cost, and produce optimum quality galvanizing.

It must be remembered that the process involves dipping in molten metal at 450°C and this can have effects on the material being processed or can be extremely hazardous to workers if there is any danger of molten metal being thrown out of the bath. Molten zinc and all processing solutions must be able to enter and drain from fabrications without difficulty and this may require additional holes for venting and draining.

If you have additional questions regarding design requirements, your galvanizer or the Galvanizers Association of Australia can provide the desired information.

Hot dip galvanizing is a self inspecting process that relies heavily on proper design of the steelwork to achieve a quality result.

- The zinc will not react with the steel to form the galvanized coating unless the surface of the steel is perfectly clean. Good design ensures this will occur.
- The hot dip galvanized coating will not form unless the zinc can intimately contact the steel surface
- The hot dip galvanized coating will not form unless the steel is heated to about 440°C
- Steel items to be processed must fit into the preparation tanks and galvanizing bath. This is not limited to the physical vessel dimensions but that space which results from double end dipping techniques, which normally meet the permissible road transport dimensions

Double end or depth dipping is a term used to describe the process of galvanizing an item which is longer or deeper than available bath dimensions. In this procedure the item is lowered into the bath so that half or more of its length or depth is immersed in the zinc bath. When the zinc coating has been achieved, the item is raised from the bath and adjusted in handling so that the ungalvanized part can be immersed in the bath. It should be noted that in this procedure an overlap of zinc coating will occur and this may have to be addressed in the case of visually obvious structural elements that require an aesthetic finish.

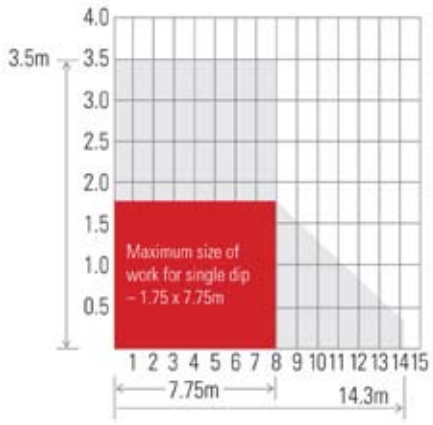
Guidance in these cases should be sought from the galvanizer.

Size and shape

Facilities exist to galvanize components of virtually any size and shape, depending on the handling facilities and layout of the galvanizing plant. Large cylindrical objects can often be galvanized by progressive dipping.

The chart below shows the dimensions of work that could theoretically be galvanized by double-end dipping in (for example) a bath 8m long x 2 m deep, assuming that the width of the work also suits the bath.

Schematic indication of double-end dipping capacity of a galvanizing bath 8 metres long x 2 metres deep



3.5m = Maximum size of work which can be coated by double-end dipping for excess depth: 3.5m x 7.75m

14.3m = Maximum size of work which can be coated by double-end dipping for excess length – up to 14.3m

The chart shows that a bath nominally 8m long x 2m deep could process work 7.75m x 3.5m, or long components of up to about 14m. *Note that the above chart is purely indicative and similar charts can be prepared for baths of different dimensions.* The maximum sizes which a particular galvanizer can process should always be checked at the design stage.

Modular design

Large structures are also galvanized by designing in modules for later assembly by bolting or welding. Modular design techniques often produce economies in manufacture and assembly through simplified handling and transport.

Weld areas in structures assembled by welding after galvanizing must be repaired to give corrosion protection equivalent to the galvanized coating as described under **Reconditioning damaged surfaces in galvanized steel.**

The size and shape of large or unusual structures should always be checked with the galvanizer early in the design process.

Materials suitable for galvanizing

Most ferrous materials can be galvanized. Mild and low alloy steels and iron and steel castings are all regularly and successfully galvanized. Steel fabrications which incorporate stainless steel parts and fittings are also readily galvanized.

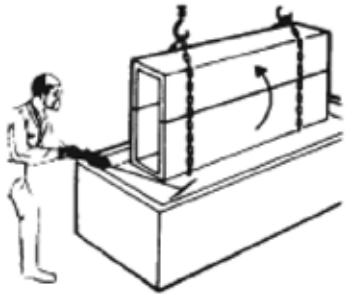
Soft-soldered assemblies or those with aluminium rivets cannot be galvanized. Brazed assemblies may be galvanized, but the galvanizer should be consulted at the design stage.

Castings. The galvanizing of sound stress-free castings with good surface finish will produce high quality galvanized coatings. The following rules should be applied in the design and preparation of castings for galvanizing:

1. Design for uniform section thicknesses wherever possible.
2. Use large radii at junctions with webs, fillets and raised features such as cast-in part and pattern numbers.
3. Avoid deep recesses and sharp corners.
4. Large grey iron castings should be normalised by the fabricator.
5. Castings should be abrasive blast cleaned by the fabricator to remove foundry sand and surface carbon. Alternatively castings may be cleaned electrolytically using the Kolene process.

Combinations of ferrous materials and surfaces. There may be appreciable variation in the pickling times of various ferrous metals and differing surface conditions. Fabricated assemblies containing a mixture of materials and surfaces such as a combination of castings with other steels, or new or machined steel surfaces with rusted or scaled steel surfaces, must be abrasive blast cleaned to minimise differences in pickling time.

Omission of abrasive blast cleaning will result in combined under- and over-pickling of the different surfaces, producing galvanized coatings of inconsistent appearance.



Double-end dipping for excess depth

Double-end dipping for excess length

Note: A directory listing the dimensions of all galvanizing baths operated by GAA members is available on the website www.gaa.com.au

Heavy mill scale on rolled steel surfaces should be removed by abrasive blast cleaning before galvanizing.

Thicker than normal galvanized coatings are produced when abrasive blast cleaned surfaces are galvanized as discussed in Factors influencing coating thickness.

Steel pipe for fabrication of galvanized assemblies should be specified by the fabricator when ordering from the merchant as 'Not oiled or painted'. Manufacturers produce steel pipe with clear varnish or black bituminous coatings which are by design extremely resistant to chemical removal and necessitate expensive manual stripping before pickling to ensure satisfactory galvanizing.

Heavy gauge seamless pipe must also be clearly specified in the unoiled, unpainted condition when ordering.

Weld areas. Due to the silicon content of some welding rods, weld areas may produce localised grey coatings when galvanized. The galvanized coating is likely to be slightly thicker in these areas and will have no detrimental effect on coating life.

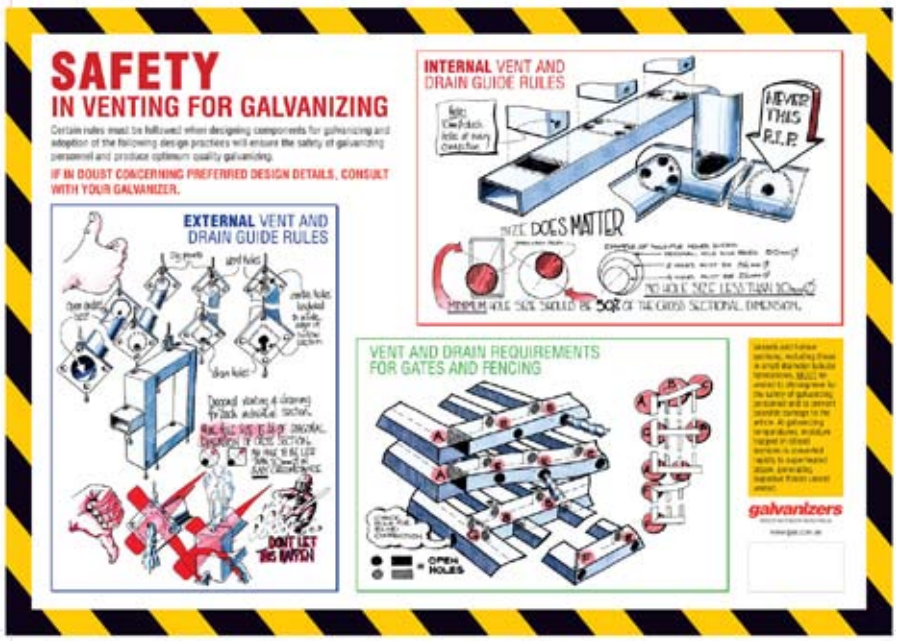
The development of grey coatings due to silicon steels is entirely related to steel composition and cannot be controlled by the galvanizer. Even when these weld areas are ground flush prior to galvanizing, heavier grey coatings may still result. Low silicon welding rods can be used to reduce this effect.

Welding slags. Arc welding slags are chemically inert in acid cleaning solutions and must be mechanically removed before articles are delivered to the galvanizer. The fabricator should remove these by chipping, wire brushing, flame cleaning, grinding or abrasive blast cleaning.

Welding electrode manufacturers supply general purpose electrodes coated with fluxes which produce virtually self-detaching slags and their use is recommended.

Good joint design with adequate access facilitates the welding process to produce sound continuous welds, avoiding locked-in slag, and easing slag removal.

Design and fabrication of components for galvanizing



New Safety in Venting for Galvanizing A1 Poster available from GAA, email gaa@gaa.com.au

Safety

Vessels or hollow structures which incorporate enclosed sections must have provision for adequate venting during galvanizing. At galvanizing temperatures any moisture present in closed sections is rapidly converted to superheated steam, generating explosive forces unless adequately vented to the atmosphere. **For the safety of galvanizing personnel, equipment and the work being galvanized, it is essential that venting is provided.**

Correct venting ensures that the entire internal surface of work is properly galvanized and fully protected. This also ensures that lighter items will not float in the zinc bath due to trapped air pockets

Closed vessels which are not to be galvanized inside, such as certain types of heat exchanger, must be provided with snorkel-type vent pipes long enough to project above the level of pickling, fluxing and galvanizing baths when the work is fully immersed. The exact venting requirement should be discussed with the galvanizer.

Venting, filling and draining

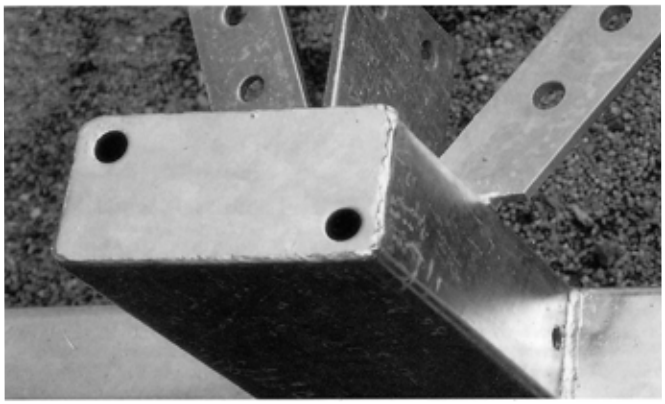
Basic venting rules

(Note: the bigger the holes the better)

1. No vent hole should be less than **10mm** in diameter unless otherwise agreed with the galvanizer
2. Preferred **minimum** vent hole size is **12mm**
3. Vent holes should not be located in the centre of end plates and connections
4. Vent holes should be located at the edges of hollow sections oriented in the same plane as the fabrication
5. Large hollow vessels require **1250mm²** of vent hole area for each cubic metre of enclosed volume. This is equivalent to a **40mm** diameter hole for every cubic metre of volume
6. Hollow sections (pipe, RHS, and SHS) ideally require vent holes equivalent to **25%** of the sections' cross section, made up of single or multiple vent holes. The preferred design option is to leave the ends of hollow sections completely open
7. Hollow sections that are connected require external vent holes as close to the connection as possible. If internal vent holes are used, they should be a total of at least 50% of the internal diameter of the connecting section
8. Large seal welded overlapping surfaces will require venting if the enclosed area may contain condensation or allow process chemicals to enter the overlap during the galvanizing process. Overlaps between **10,000mm²** and **40,000mm²** should be vented with a **10mm** vent hole. Overlaps under **10,000mm²** generally do not require venting. Intermediate sized overlaps should be judged on the basis of weld integrity and residual welding heat in the joint to ensure total dryness at time of sealing. Longer or larger overlapping areas require spaced holes for progressive venting. Very large overlapping areas should be avoided as an undesirable design for galvanizing or corrosion protection in general
9. Vent and drain holes must be located as close to the high and low points of the hollow section as possible to prevent air locks, entrapment of pre-treatment chemicals and zinc puddling.

Basic draining rules

- No drain hole should be less than 10mm
- Preferred minimum drain hole size is 25mm particularly for items with a large internal volume
- Large hollow sections (tanks, pressure vessels) require a 10,000mm² diameter of drain hole area for each cubic metre of enclosed volume
- Drain holes should be at the edges of hollow sections
- Hollow sections such as tube, RHS and SHS require minimum drain hole area equivalent to 25% of the section' diagonal cross section. The preferred design option is to leave the ends of tubes, RHS and SHS open



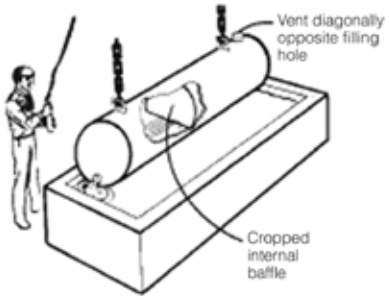
Adequate hole sizes in sealed hollow sections in the correct locations ensure galvanizing quality

Tanks and closed vessels

As illustrated, design must allow for pickle acids, fluxes and molten zinc to enter, fill and flow upwards through the enclosed space and out through an opening at the highest point so that no air is trapped as the article is immersed. The design must also provide for complete drainage of both interior and exterior details during withdrawal.

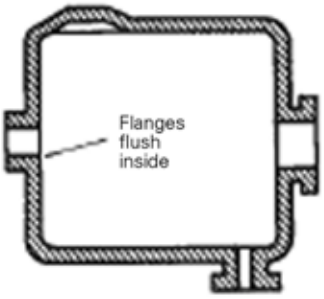
A vent hole of equal dimensions should be provided diagonally opposite the filling hole to allow the escape of enclosed air and to facilitate draining.

Tanks and closed vessels should have at least one filling/draining hole with a vent diagonally opposite.



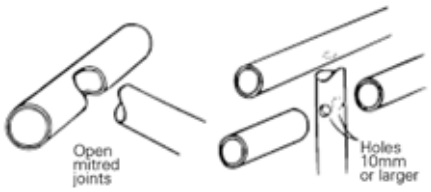
Internal baffles in tanks should be cropped on the bottom and top or provided with suitable drainage holes to permit free flow of molten zinc and air venting. Access ports, bosses and openings should be finished flush inside.

Openings should finish flush inside and should be positioned so that all pickle acid and molten zinc can be drained out during the galvanizing operation.



Hollow structurals and fabricated columns

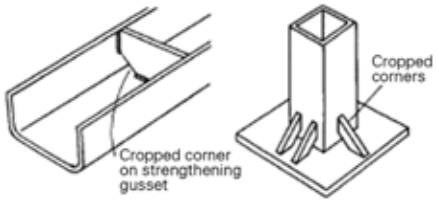
Closed sections must never be included in tubular fabrications. Vent holes at least 50% of internal diameter or diagonal dimension and a minimum of 10 mm diameter should be provided by the fabricator at locations agreed with the galvanizer.



All welded sections in fabricated pipe work should be interconnected with open tee or mitre joints. Alternatively each closed section must be provided with a vent hole of not less than 10 mm diameter. Pipe ends or flanges should always be left open, or provided with removable vent plugs.

Closing of unwanted vent holes.
Small vent holes which are necessary for galvanizing but not wanted in the finished job may be closed by hammering in lead plugs after galvanizing and filing off flush with surrounding surfaces, or by the use of threaded plugs. Threads may need re-tapping after galvanizing.

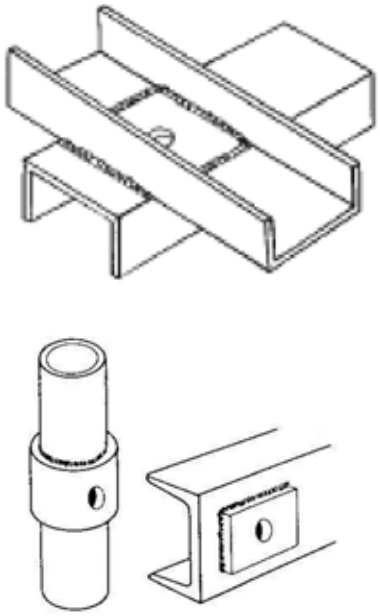
Welded strengthening gussets on fabricated columns and strengthening gussets in members fabricated from channel sections should have corners cropped to allow free flow of zinc during galvanizing as illustrated.



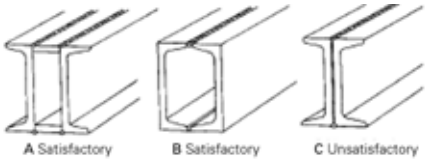
Overlapping surfaces. Narrow gaps between plates and in particular, overlapping surfaces and back-to-back angles and channels should be avoided. As discussed under **Design and fabrication of components for galvanizing - 'Safety'**, any pickle acid or rinse water trapped in narrow gaps between members is rapidly converted to superheated steam at galvanizing temperatures, with the possibility of an explosion.

Where small overlapping areas are unavoidable, edges should be sealed after consultation with the galvanizer, by a continuous pore-free weld to prevent penetration of pickle acid. For the safety of galvanizing personnel the sealed area **must** be provided with a vent hole for every 10,000 mm^2 of sealed area according to the following table:

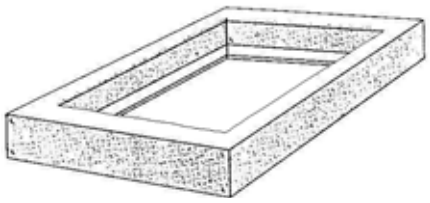
Steel plate thickness	Vent hole size
Up to 6 mm	At least 10 mm diameter
Over 6 mm	Hole diameter to be 10 mm or greater



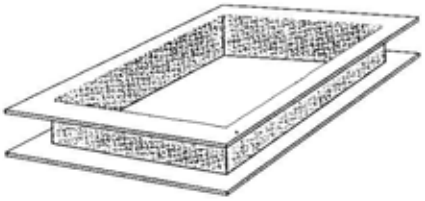
Back-to-back channels should be avoided. C below is potentially dangerous because of the risk of explosion.



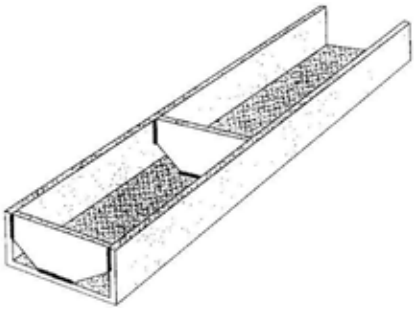
Some basic design and venting recommendations



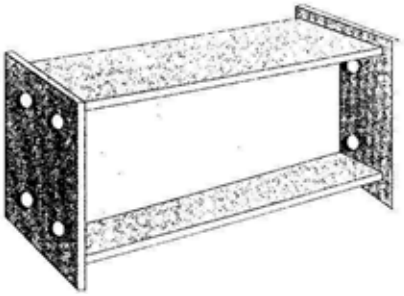
Channel frames require at least four and preferably eight vent/drain holes using conventional design.



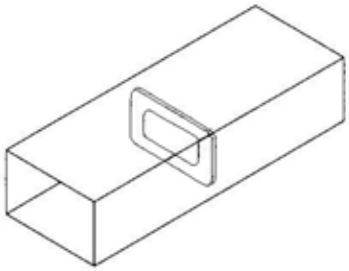
By using outward facing channels, no special venting or draining provisions are required.

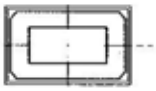


Gussets and stiffeners should be cropped prior to assembly for good drainage.

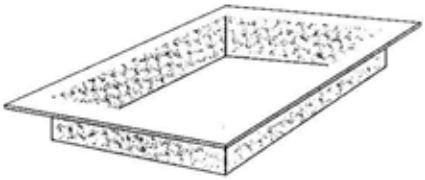


End plates should have vent/drain holes in the corner(s) of the connecting angle, channel or beam.

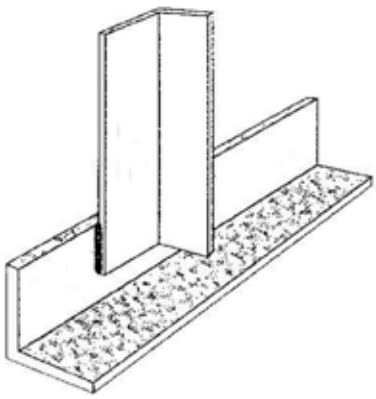




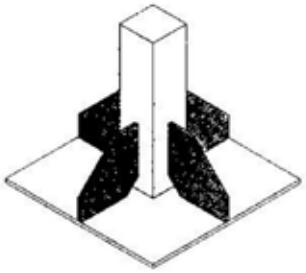
In fabricated box sections, internal diaphragms should be corner cropped and if possible have a central hole.

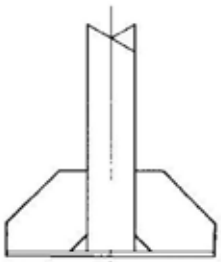


Outward facing angles and channels in fabricated frames reduce venting and drainage problems.



Terminating bracing short of adjacent flanges will allow free flow of zinc through the connection and eliminate pockets in service.

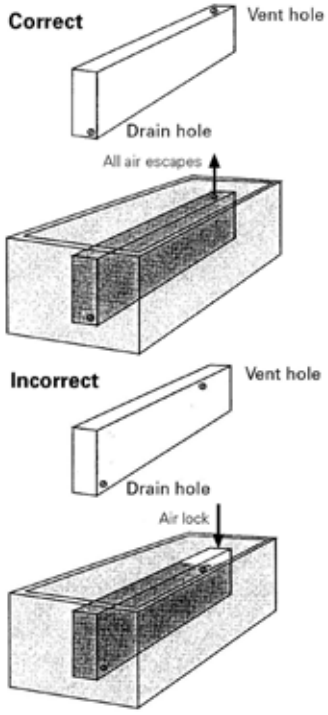




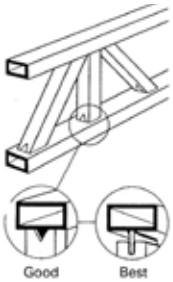
Gussets to base plates should be corner cropped.

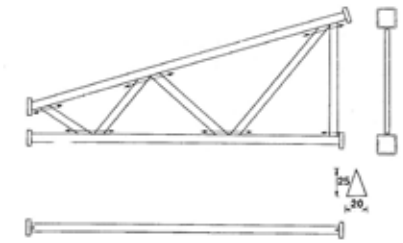
NOTE: Water, process solutions and molten zinc enter hollow sections during fabrication or during the galvanizing process. If the drain holes are not located at the lowest point on both sides in the fabrication:

- Process chemicals will be trapped internally and cause an explosion hazard when immersed in the molten zinc
- Zinc will be trapped internally and will freeze in the undrained area. This may interfere with assembly, it will add to the weight of the item in service and it is a waste of zinc which adds to the cost of galvanizing.

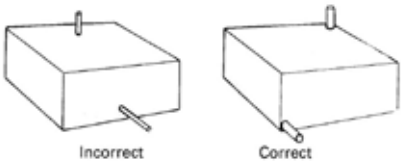


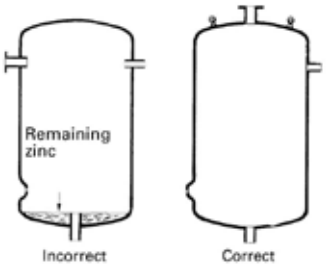
Vent and drain holes must be located as close to the high and low points of the hollow section as possible to prevent air locks, entrapment of pre-treatment chemicals and zinc puddling.





In welded structures venting holes must be inserted at all junctions. The holes must enable the zinc to run in and out freely. Closed tubes incur the risk of explosion!





Inwardly projecting pipe connections prevent containers from being completely emptied of zinc and flux. Locate pipe connections near corners and diagonally. It will also be easier for the zinc to run out if the pipe connections are not too small. On large containers lifting eyes should be applied for easier handling.

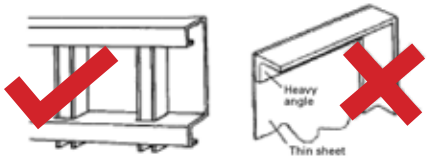
Dimensional stability

In certain cases, fabricated assemblies may be liable to loss of shape at galvanizing temperatures due to the release of stresses induced during manufacture of the steel and in subsequent fabricating operations. These stresses may be compounded by bad design incorporating unequal thicknesses or non-symmetrical sections. Observance of the following recommendations will improve dimensional stability:

1. Avoid designs which require double-end dipping to fit into the galvanizing bath. It is preferable to build assemblies and sub-assemblies in suitable modules so that they can be immersed quickly and fully in a single dip.
2. Use symmetrical sections in preference to angles or channels.
3. Use sections of near equal thickness at joints.
4. Bend members to the largest acceptable radii.
5. Accurately preform parts to avoid force or restraint during joining.
6. Continuously weld joints if possible using balanced welding techniques to reduce uneven thermal stresses. Balanced, staggered welding is permissible. For staggered welding of material of 3 mm and lighter, weld centres should be closer than 100 mm.
7. Design castings to conform to the rules listed under **Materials suitable for galvanizing – Castings**. Large grey iron castings should always be normalised by the fabricator and then abrasive blast cleaned prior to galvanizing.

Advice on design to minimise distortion is available from the galvanizer.

NOTE: GAA Advisory Note GEN 13/1 – "Distortion becoming a diminishing event" is available on the GAA website.

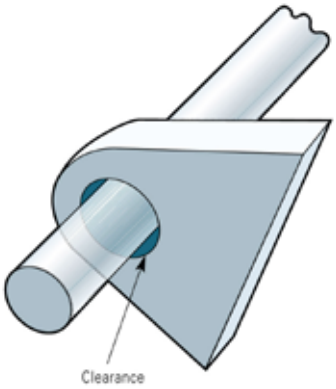


Use of symmetrical sections minimises distortion during galvanizing. Avoid combinations of thick and thin materials. Such designs should preferably have the items galvanized separately and then bolted together.

Clearance for moving parts

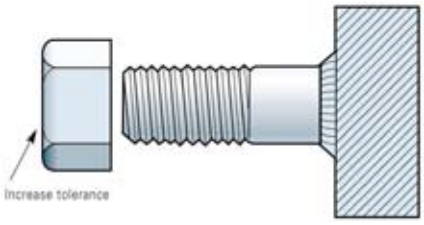
Moving parts such as drop handles, hinges, shackles and shafts must incorporate minimum radial clearances as detailed below:

Shaft or spindle size	Minimum radial clearance
Up to 10 mm diameter	1.0 mm
10 to 30 mm diameter	2.0 mm
Over 30 mm diameter	2.5 mm



Galvanized threads

When assemblies to be galvanized incorporate threaded components, the tolerance normally allowed on internal threads must be increased to provide for the thickness of the galvanized coating on external threads. Standard practice is to tap nuts oversize after galvanizing, according to figures in the table under Oversize tapping allowances for galvanized nuts (listed in the Bolting galvanized steel section).



Nuts for galvanized studs must be tapped oversize. The galvanized coating on the stud provides corrosion protection for the internal thread.

Bolted assemblies should be presented for galvanizing in the disassembled condition. Nuts and bolts or studs for galvanizing should also be supplied disassembled.

When internal pre-tapped threads included in components are required not to be galvanized they may be plugged temporarily by means of bolts or studs screwed fully in, after discussion with the galvanizer.

For safety reasons, high strength bolts must not be welded to galvanized structures for use as high strength studs. Galvanized bolts and the bolting of galvanized structures are discussed in detail in the Bolting galvanized steel section.

Handling parts for galvanizing

Parts may require suspension holes if there is no convenient point to attach a jig or hook. No special requirements apply if the work can be handled by chains, baskets, tongs or racks. Your galvanizer will advise of necessary provision to suit the handling equipment available.

Large pipe sections, open top tanks and similar structures may require cross stays to maintain the shape of the article during handling and galvanizing.

Marking for identification

For temporary identification, water soluble paints or paint markers can be used. There are a wide variety of pens that can be used in such applications, for example Pentel Paint Marker XMMP20. Oil-based paints should not be used as they must be removed manually before galvanizing.

For permanent identification intended to remain legible after galvanizing, the fabricator should provide heavily punched or embossed figures (indentation depth of 0.8 – 1 mm) either on the work or on steel (not aluminium) tags wired to the work.

Design for maximum corrosion protection

Galvanized coatings provide outstanding corrosion protection for steel. Treatment of design details in accordance with good corrosion design practice as discussed below will further increase the life of galvanized steel fabrications.

Many of the design requirements for good galvanizing detailed earlier, such as the provision of flush-finished internal flanges in tanks and vessels will also ensure good drainage in service and optimum corrosion resistance.

Fabricated assemblies should be designed to eliminate undrained areas which will collect water and sediment in service, producing localised corrosion pockets. The following rules should be followed:

1. Use butt welds in preference to lap welds.
2. Where lap welds are used face joints downwards to avoid collection of moisture and sediment.
3. Avoid use of horizontal boxed sections, ledges, seams and flat undrained areas.
4. Use rounded internal corners rather than squared corners in vessels and containers to avoid build up of sediment.
5. Design to eliminate crevices and unnecessary openings.
6. Avoid contact of galvanized surfaces with brass or copper as discussed under 'Bimetallic corrosion'.
7. Provide ventilation where possible in condensation areas.
8. Under conditions of extreme humidity use an inhibitive jointing compound between contacting galvanized surfaces such as roof overlaps.
9. Provide maintenance access where anticipated service life of certain components is less than that of the complete structure.

Educational seminar on hot dip galvanizing for corrosion protection

GAA technical staff are available for in-house seminars and discussions on "Hot Dip Galvanizing for Corrosion protection". These sessions will assist you to understand the galvanizing process, specifications and grades of galvanizing.

The seminars and discussions can be tailored to specific areas as required.

If you would like more information or to request a seminar presented by GAA technical personnel, please contact the GAA by phoning +61 3 9654 1266

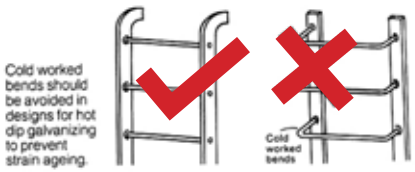
Galvanizing design aids

As an aid to designers and specifiers, the Association publishes and distributes free of charge the colour wall chart 'Design for Galvanizing' and 'Safety in Venting for Galvanizing'.

Contact GAA, Level 5, 124 Exhibition Street, Melbourne, Victoria 3000.
Phone +61 3 9654 1266
or email gaa@gaa.com.au

Metallurgical aspects of design

The galvanizing process has no effect on the mechanical properties of the structural steels commonly galvanized. In susceptible steels the galvanizing process may accelerate the onset of strain ageing which, with ageing, would occur naturally due to earlier cold working operations.



Strain ageing can be avoided by the use of non-susceptible steels, or when susceptible steels must be used, by adopting the procedures specified in relevant standards, as discussed in more detail under Mechanical properties of galvanized steels.

Minimum edge distances for holes in structural members

In bolted connections minimum edge distances from the centre of any bolt to the edge of a plate or the flange of a rolled section should be used as specified in the table below, taken from the Australian Standard 4100 'Steel structures'.

Sheared or hand Flame-cut edge,	Rolled plate, machine flame-cut, sawn or planed edge flat bar or section,	Rolled edge of a rolled flat bar or section
$1.75d_f$	$1.50d_f$	$1.25d_f$

NOTE. Edge distance may also be affected by clause 9.3.2.4, AS 4100

Inspection of work before despatch to the galvanizer

Fabricated assemblies, castings and other components for galvanizing should be inspected before despatch to the galvanizer to ensure that the following points conform to design requirements detailed earlier. This may avoid costly rectification and delays at the galvanizing plant.

Size and shape. Check that work is suitably sized and dimensioned for the handling and galvanizing facilities of the selected galvanizer. It may be too late to make changes to the design, but it is costly to despatch work which the galvanizer cannot process.

Structural steel. Check that bending, punching and shearing have been carried out in conformity with the recommendations under Embrittlement.

Satisfactory galvanizing

Observance of the points listed below and described in more detail previously in this section will ensure optimum galvanized product quality and minimise extra costs or delays:

1. Check that closed vessels and hollow structures are vented for safety and satisfactory galvanizing.
2. Check that welding slags have been removed.
3. Check that assemblies comprising castings and steels of widely differing surface conditions have been abrasive blast cleaned to minimise differences in galvanized finish.
4. Check that castings are abrasive blast cleaned before despatch unless otherwise arranged. Check that large grey iron castings have been normalised.
5. Check that appropriate temporary or permanent markings are provided.

Standards for galvanized products

Coating reinstatement

Areas of significant surface that are uncoated shall, by agreement between the purchaser and the galvanizer, be reinstated by following the recommendations contained in AS/NZS 4680 - Repair after Galvanizing, or by other methods nominated by the galvanizer and approved by the contractor. Similar repair methods shall be used for areas damaged by welding or flame cutting, or during handling, transport and erection.

The size of the area able to be repaired shall be relevant to the size of the object and the conditions of service but shall normally be in accordance with the provisions of AS/NZS 4680 - Repair after Galvanizing.

SWEEP (BRUSH) BLAST CLEANING OF GALVANIZED STEEL PRIOR TO PAINTING

Refer AS/NZS 4680 Appendix I

GENERAL INFORMATION ON FACTORS THAT AFFECT THE CORROSION OF GALVANIZED STEEL

Refer AS/NZS 4680 Appendix H

Galvanized products should be specified in accordance with the appropriate national standards, which have been drawn up to provide minimum standards to ensure optimum performance of galvanized products and to give guidance in selection, application, and design.

AS/NZS 2312 'Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings' is a particularly valuable reference in the selection of the most practical, economic coating in particular applications.

Relevant Australian standards

AS/NZS 4680	Hot dip galvanized (zinc) coatings on fabricated ferrous articles.
AS 1214	Hot dip galvanized coatings on threaded fasteners.
AS 2309	Durability of galvanized and electrogalvanized zinc coatings for the protection of steel in structural applications – Atmospheric.
AS/NZS 2312	Guide to the protection of structural steel against atmospheric corrosion by the use of protective coatings.
AS 2331.1.3	Methods of test for metallic and related coatings Method 1.3: Local thickness tests – Magnetic method
AS 2331.1.4	Methods of test for metallic and related coatings Method 1.4: Local thickness tests – Magnetic induction and eddy current methods
AS 4312	Atmospheric corrosivity zones in Australia.

New Zealand standards

AS/NZS 4680	Hot dip galvanized (zinc) coatings on fabricated – ferrous articles.

British standards

BS/EN/ISO 1461	Hot-dipped galvanized coatings on fabricated iron and steel articles – Specifications and Test methods.

American (ASTM) standards

A 36	Specification for Structural Steel
A 123 / A A 123 M	Specification for zinc (hot-dip galvanized) coatings on iron and steel products
A 143	Practice for safeguarding against embrittlement of hot-dip galvanized structural steel products and procedure for detecting embrittlement.
A 153 / A 153 / M	Specification for zinc coating (hot-dip) on iron and steel hardware.
A 384	Practice for safeguarding against warpage and distortion during hot-dip galvanizing of steel assemblies.
A 385	Practice for providing high quality zinc coatings (hot dip).
A 767 / A 767 M	Specification for zinc coated (galvanized) steel bars for concrete reinforcement.
D 6386	Practice for preparation of zinc (hot dip galvanized) coated iron and steel products and hardware surfaces for painting
E 376	Practice for measuring coating thickness by magnetic-field or eddy-current (electromagnetic) test method

Inspection of galvanized products

Visual inspection is the simplest and most important means of assessing 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, with a zinc coating mass of at least 600 g/m^2 on fabricated articles over 6 mm thick, as discussed in more detail under Coating Thickness.

Appearance

A galvanized coating is normally smooth, continuous and free from gross surface imperfections and inclusions. While the heavy zinc coating on general galvanized articles should be smooth and continuous it cannot be compared for surface smoothness to continuously galvanized sheet steel or wire since these are produced by processes which permit close control of coating thickness and appearance.

Differences in the lustre and colour of galvanized coatings do not significantly affect corrosion resistance and the presence or absence of spangle has no effect on coating performance. As discussed under 'Dull grey coating' below, uniform or patchy matt grey galvanized coatings give equal or better life than normal bright or spangled coatings.

It is recommended that inspection of galvanized work should be carried out by a designated party at the galvanizer's works in accordance with the following guidelines, and tested when necessary as detailed under 'Non-destructive testing for coating thickness'.

Variations in appearance and their relationship to coating quality

Variations in appearance of galvanized coatings listed below and their influence on coating quality are discussed on the following pages.

Dull grey coating

General comment: Acceptable.

A dull grey appearance is caused by growth of the zinc-iron alloy layers through to the surface of the galvanized coating. Grey coatings may appear as localized dull patches or lacework patterns on an otherwise normal galvanized coating or may extend over the entire surface.

Dull grey coatings usually occur on steels with relatively high silicon content which are reactive to molten zinc as discussed under 'Composition of steel'

Welds made with steel filler rods containing silicon may also produce localised grey areas in an otherwise normal galvanized coating, as discussed under Welding galvanized steel.

Dull grey coatings are often thicker than the normal bright or spangled coatings and therefore give longer life. It is rarely possible for the galvanizer to minimise or control the development of dull grey coatings which are dependent basically on steel composition.

A dull grey coating can also result where air cooling rather than quenching is requested.

Rust stains

General comment: Acceptable when present as a surface stain.

Rust staining on the surface of galvanized coatings is usually due to contact with or drainage from other corroded steel surfaces. Steel filings or saw-chips produced during erection and fabrication operations should be removed from galvanized surfaces to prevent possible localised rust staining. Rust staining may also be caused by the weeping of pickling acid from seams and joints causing damage to the galvanized coating, and in such cases requires a modification in design as discussed under 'Overlapping surfaces'.

A thin brown surface staining sometimes occurs in service when the galvanized coating comprises entirely zinc-iron alloys as discussed in 'Dull grey coating' above. Staining arises from corrosion of the iron content of the zinc-iron alloy coating and is therefore outside the control of the galvanizer. It has no effect on the corrosion resistance of the coating. Long term exposure testing has shown that the corrosion resistance of zinc-iron alloys is similar to that of normal galvanized coatings.

General roughness and thick coatings on welds

General comment: Acceptable, unless otherwise agreed.

Rough galvanized coatings usually result from uneven growth of zinc-iron alloys because of the composition or surface condition of the steel. Where welding electrodes containing silicon have been used, the galvanized coating on the weld area may be thicker than normal and may also be brittle. Rough coatings of this type are usually thicker than normal and therefore provide longer protective life.

In some applications where a smooth finish is aesthetically or functionally required, the steel composition and surface preparation should be closely discussed with the galvanizer at an early stage. It is virtually impossible for the galvanizer to improve the appearance after galvanizing.

Lumpiness and runs

General comment: Acceptable unless otherwise specified.

Australian/New Zealand Standard 4680 'Hot dip galvanized (zinc) coatings on fabricated ferrous articles' demands that a galvanized coating shall be as smooth and evenly distributed as possible but points out that smoothness is a relative term and that coatings on fabricated articles should not be judged by the same standards as those applied to continuously galvanized products such as sheet steel and wire, since these are produced by processes which permit a high degree of control over coating thickness and appearance. Lumps and runs arising from uneven drainage are not detrimental to coating life.

When zinc drainage spikes are present on galvanized articles and their size and position is such that there is a danger they may be knocked off in service removing the coating down to the alloy layers, they should be filed off by the galvanizer and, where necessary, the coating should be repaired as described in Reconditioning damaged surfaces in galvanized steel.

For special applications the galvanizer can sometimes achieve a smoother finish than the normal commercial coating, depending on the shape and nature of the product. The steel should be carefully specified and the galvanizer consulted at the design stage and advised when the order is placed. Extra cost may be involved.

Pimples

General comment: May be grounds for rejection depending on size and extent.

Pimples are caused by inclusions of dross in the coating. Dross, which comprises zinc-iron alloy particles, has a similar corrosion rate to the galvanized coating and its presence as finely dispersed pimples is not objectionable. Gross dross inclusions may be grounds for rejection as they tend to embrittle the coating.

Bare spots

General comment: Acceptable if small in area and suitably repaired, depending on the nature of the product.

Small localised flaws up to about 3 mm wide in a galvanized coating are usually self-healing because of the cathodic protection provided by the surrounding coating as discussed under Cathodic Protection. They have little effect on the life of the coating.

Australian/New Zealand Standard 4680 – section 8 'Repair after Galvanizing' specifies that "…the sum total of the damaged or uncoated areas shall not exceed 0.5% of the total surface area or 250 cm^2, whichever is the lesser, and no individual damaged or uncoated area shall exceed 40cm^2. Uncoated areas greater than 40cm^2 which have been caused by unavoidable air locks or prior contamination of the steel surface shall be repaired. Repairs shall be carried out in accordance with Clause 8.2".

Bare spots may be caused by under-preparation by the galvanizer and by a number of factors outside his control, and for which he cannot be responsible, including the presence of residual welding slags, rolling defects such as laps, folds and laminations in the steel, and non-metallic impurities rolled into the steel surface.

Wet storage stain or bulky white deposit

General comment: Not the galvanizer's responsibility unless present before first shipment. Acceptable if non-adherent deposit is removed and the coating meets coating mass requirements.

A bulky white or grey deposit, known as wet storage stain may form on the surface of closely stacked freshly galvanized articles which become damp under poorly ventilated conditions during storage or transit. In extreme cases, the protective value of the zinc coating may be seriously impaired but the attack is often very light despite the bulky appearance of the deposit.

Initiation and development of wet storage staining on new galvanized surfaces is readily prevented by attention to conditions of storage and transport and by application of a chromate passivation treatment.

Where the surface staining is light and smooth without growth of the zinc oxide layer as judged by lightly rubbing fingertips across the surface, the staining will gradually disappear in service and blend in with the surrounding zinc surface as a result of normal weathering.

When the affected area will not be fully exposed in service, particularly on the underside of steelwork and in condensation areas, or when it will be subject to a humid environment, wet storage staining must be removed as detailed below, even if it is superficial. Removal is necessary to allow formation of the basic zinc carbonate film, which normally contributes to the corrosion resistance of galvanized coatings.

Medium to heavy build up of white corrosion product must be removed to allow formation of a basic zinc carbonate film in service. Light deposits can be removed by brushing with a stiff bristle brush. Heavier deposits can be removed by brushing with a 5 percent solution of sodium or potassium dichromate with the addition of 0.1% by volume of concentrated sulphuric acid. This is applied with a stiff brush and left for about 30 seconds before thorough rinsing and drying.

A check should be made to ensure that the coating thickness in affected areas is not less that the minimum specified in relevant standards for the various classes of galvanized coatings.

In extreme cases, where heavy white deposit or red rust has been allowed to form as a result of prolonged storage under poor conditions, corrosion products must be removed by thorough wire brushing and the damaged area repaired as detailed under Reconditioning damaged surfaces in galvanized steel.

Dark spots

General comments: Acceptable if flux residues have been removed.

Smuts of dirt may be picked up on the surface of the galvanized coating from floors and trucks or from contact with other articles. These smuts are readily washed off to reveal a sound coating and are not harmful.

Blisters

General comment: Small intact blisters acceptable.

Extremely rare. Small blisters in galvanized coatings are due to hydrogen absorbed by the steel during pickling being expelled as a result of the heat of the galvanizing process. Their occurrence is due to the nature of the steel, usually low strength, and is outside the control of the galvanizer. Blisters do not reduce the corrosion resistance of the coating.

Non-destructive testing for coating thickness

Magnetic gauges provide simple non-destructive testing methods for coating thickness, which are reliable and more convenient than the physical tests given under the various national standards listed under Standards for galvanized products.

Most gauges described are compact and can be used very quickly. They give coating thickness readings over very small areas and several readings should be taken and averaged. Uniformity as well as actual thickness can thus be easily checked.

These magnetic gauges give reliable thickness readings although some require frequent recalibration against non-magnetic coatings of known thickness and the makers' instructions are followed precisely. Accurate readings cannot be obtained near edges of work and obvious peaks or irregularities in the coating should be avoided. Surface curvature, surface area and steel thickness all affect readings in a predictable manner and allowances must be made.

Guidance on the use of these instruments is given in AS 2331.1.3 "Methods of test for metallic and related coatings Method 1.3: Local thickness tests – Magnetic method", and AS 2331.1.4, "Methods of test for metallic and related coatings, method 1.4: Local thickness tests – Magnetic induction and eddy current methods".

PosiTector 6000

The PosiTector 6000 is an easy-to-use digital readout single-point coating measurement instrument which works on a magnetic field simulation principle. It needs no calibration and gives accurate results unaffected by shock, vibration, or temperature.

Elcometer coating thickness gauge 456

This Elcometer contains a horseshoe magnet with its two poles exposed and works on a magnetic induction principle. When the instrument is placed with both poles touching the surface to be tested, changes of magnetic field brought about by variations in coating thickness move the bar magnet and the pointer. A mean thickness reading is given over the two points of contact.

The Inspector magnetic balance

The magnetic balance is based on the calibration of magnetic attraction to the steel beneath a coating. The same principle is used by pull-off type gauges, but the magnetic balance gives a stable reading and incorporates a counterbalanced magnet, allowing use in any position.

Pull-off type gauges

Simple pull-off magnetic thickness testing gauges such as the Tinsley Pencil Gauge and the Elcometer Pull-off Magnetic Gauge Model 157 are convenient and inexpensive, but require greater operator skill and in general do not provide the accuracy of the gauges described above.

Reconditioning damaged surfaces in galvanized steel

When severe damage to the galvanized coating has occurred during welding or as the result of rough handling in transport or erection, protection must be restored.

Small areas of the basis steel exposed through mechanical damage to galvanized coatings, are protected from corrosion cathodically by the surrounding coating and may not need repair, depending on the nature of the product and the environment to which it is exposed. Small exposed areas normally have little effect on the life of the coating as discussed under 'Bare spots' and 'Cathodic protection'.

Repair methods

The coating repair methods detailed below are in accordance with AS/NZS 4680 section 8 – Repair after Galvanizing. They include:

Zinc rich paints. The application of an organic zinc rich paint is the most rapid and convenient method of repair. The paint should conform to AS/NZS 3750.9 'Paints for steel structures – Organic zinc-rich primer' applied in two coats by brush to provide a total film thickness of a minimum of 30 µm more than the local coating thickness requirements in AS/NZS 4680 and for optimum performance should contain not less than 92% zinc in the dried paint film.

Where colour matching is required aluminium paint may be applied over the hardened zinc rich paint.

Zinc metal spraying. In certain circumstances, by prior agreement, zinc metal spraying may be used as a method of coating repair. The damaged area must be grit blasted to Class 3 followed by zinc metal spraying to a coating thickness equivalent to that of the undamaged coating, and seal coated using an aluminium vinyl paint.