Designation: A 385 – 08

Standard Practice for Providing High-Quality Zinc Coatings (Hot-Dip)[1]

This standard is issued under the fixed designation A 385; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope*

1.1 This practice covers the precautions that should be taken to obtain high-quality hot-dip galvanized coatings.

1.2 Where experience on a specific product indicates a relaxing of any provision, the mutually acceptable change shall be a matter for agreement between the manufacturer and purchaser.

1.3 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

A 143/A 143M Practice for Safeguarding Against Embrittlement of Hot-Dip Galvanized Structural Steel Products and Procedure for Detecting Embrittlement

A 384/A 384M Practice for Safeguarding Against Warpage and Distortion During Hot-Dip Galvanizing of Steel Assemblies

A 563 Specification for Carbons and Alloy Steel Nuts

3. Steel Selection

3.1 The production of a galvanized coating has as its basis the metallurgical reaction between the steel and the molten zinc, resulting in the formation of several iron-zinc compound layers, for example, gamma (not always visible microscopically), delta, and zeta in Fig. 1. In addition, a layer of the molten zinc adheres to the surface of the compound layers as the steel is withdrawn from the galvanizing bath. Upon solidification, this adherent zinc forms the eta layer.

3.2 It is known that the exact structural nature of the galvanized coating, as typified by Fig. 1, may be modified in accordance with the exact chemical nature of the steel being galvanized. Certain elements found in steels are known to have an influence on the coating structure. The elements carbon in excess of about 0.25 %, phosphorus in excess of 0.04 %, or manganese in excess of about 1.3 % will cause the production of coatings different from the coating typified by Fig. 1. Steels with silicon in the range 0.04 % to 0.15 % or above 0.22 % can produce galvanized coating growth rates much higher than those for steels with silicon levels below 0.04 % and between 0.15 % and 0.22 %. Recent studies have shown that even in cases where the silicon and phosphorous are individually held to desirable limits, a combined effect between them can produce a coating as shown in Fig. 2, which typically would have a mottled or dull gray appearance.

3.3 These elements manifest their structural effect as an accelerated growth of the compound layers, particularly the zeta layer, and the virtual elimination of the eta layer. Cosmetically this accelerated growth is seen as a gray matte finished coating as opposed to the usual bright and smooth appearance of galvanized coatings. Sometimes, a large surface may have adjacent areas of matte finish and bright finish leading to a mottled appearance.

3.4 There is some evidence that the coatings resulting from this accelerated growth are more brittle and less adherent than normal coatings. There is also evidence that these coatings are subject to a premature red staining in atmospheric exposure; however, this staining has been found not to be associated with corrosion of the substrate steel.

3.5 A problem with steel chemistry is not usually apparent until after an item has been galvanized. Not all combinations of silicon, phosphorus, carbon, and manganese can be galvanized successfully. When the steel chemistry is known beforehand, experienced galvanizers can in some, but not all, instances exercise limited control over the coatings as shown in Fig. 2. Also, the combination of two different steel types or thicknesses in one item may result in a nonuniform galvanizing finish. The experience of the steel supplier, designer, manufacturer, and galvanizer should determine the steel selection.

3.6 In general, galvanized coatings are specified because of their corrosion resistance, not because of their appearance. The relative corrosion resistance of the normal and abnormal coatings is, for all practical purposes, equal.

[1] This practice is under the jurisdiction of ASTM Committee A05 on Metallic-Coated Iron and Steel Products and is the direct responsibility of Subcommittee A05.13 on Structural Shapes and Hardware Specifications.

Current edition approved May 1, 2008. Published June 2008. Originally approved in 1955. Last previous edition approved in 2005 as A 385 – 05.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

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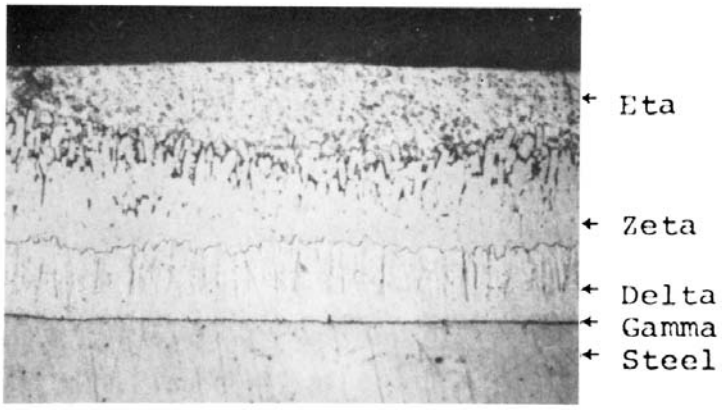


FIG. 1 Photomicrograph of Normal Galvanized Coating (X 400)

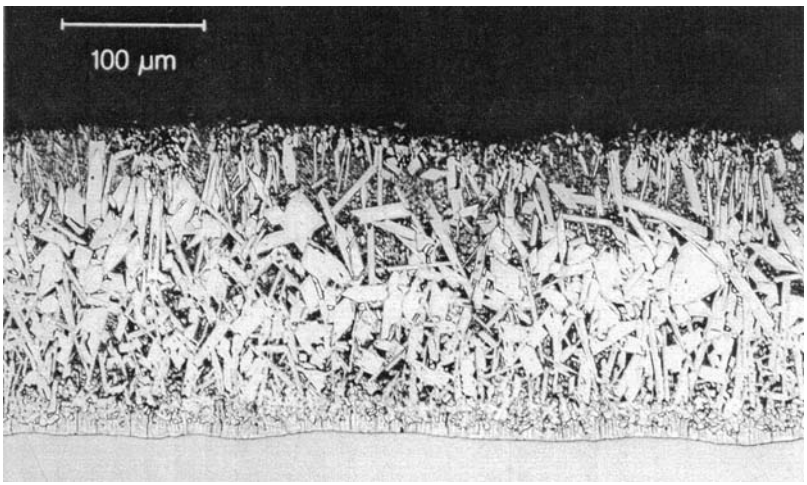


FIG. 2 Photomicrograph of Dull Gray, Thick-Galvanized Coating (X 200)

4. Assemblies of Different Materials or Different Surfaces or Both

4.1 Whenever possible, assemblies should consist of elements of similar steel chemistry and surface condition.

4.2 Whenever different analyses of steel or different surfaces of steel are united in an assembly the galvanized finish is not generally uniform in appearance. These differences include:

4.2.1 Excessively rusted surfaces.

4.2.2 Pitted surfaces.

4.2.3 Machined surfaces.

4.2.4 Cast iron (especially with sand inclusion).

4.2.5 Cast steel.

4.2.6 Malleable iron.

4.2.7 Hot-rolled steel.

4.2.8 Cold-rolled steel.

4.2.9 Steel containing chemical elements in excess of those recommended in 3.2.

4.3 Where combinations are unavoidable, thorough abrasive blasting of the entire assembly will normally improve galvanizing quality.

5. Overlapping or Contacting Surfaces

5.1 Overlapping or contacting surfaces that have not had all edges seal welded are undesirable.

5.2 When the distance between the overlapping surfaces is less than 3⁄32 in. (2.38 mm), these surfaces will not normally be wet by molten zinc. Furthermore, cleaning solution compounds that remain on these surfaces volatilize during the galvanizing process and may interfere with zinc wetting in adjacent areas. Such uncoated surfaces cause a rust staining after exposure to the environment. Traditionally however, steel grating has been manufactured without seal welding and when properly executed, this manufacturing means has permitted the galvanized coating to satisfy the quality requirements of the applicable ASTM specifications.

5.3 When the overlap surface area is large and the edges have been seal welded, air or moisture or both entrapped therein can develop destructive pressures when the assembly is heated to the galvanizing temperature, which is nominally 850°F (454°C). Vent holes or unwelded area around the adjoining surfaces should be provided through one or both sides into the lapped area per the following tables.

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TABLE 1 Vent Holes for Overlapped Areas for Steels ½ in. (12.75 mm) or Less in Thickness

Overlapped Area in.^{2}(cm^2)	Vent Holes	Unwelded Area
under 16 (103)	None	None
16 (103) to under 64 (413)	One ⅜ in. (1 cm)	1 in. (2.5 cm)
64 (413) to under 400 (2580)	One ½ in. (1.25 cm)	2 in. (5.1 cm)
400 (2580) and greater, each 400 (2580)	One ¾ in. (1.91 cm)	4 in. (10.2 cm)

TABLE 2 Vent Holes for Overlapped Areas for Steels Greater than ½ in. (12.75 mm) in Thickness

Overlapped Area in.^{2}(cm^2)	Vent Holes	Unwelded Area
under 16 (103)	None	None
16 (103) to under 64 (413)	None	None
64 (413) to under 400 (2580)	One ½ in. (1.25 cm)	2 in. (5.1 cm)
400 (2580) and greater, each 400 (2580)	One ¾ in. (1.91 cm)	4 in. (10.2 cm)

6. Sheet Steel Rolled Over a Wire or Rod Stiffener

6.1 All oil or grease should be removed from both the sheet steel and wire or rod before rolling (Fig. 3). Grease or oil becomes volatile at the galvanizing temperature and will generate gas which will prevent zinc from sealing the contact edges. All steel should be degreased before pickling and in the case of folded assemblies, before folding and assembling (see Fig. 4).

7. Weld Flux Removal and Welding Rods

7.1 Welding flux residues are chemically inert in normal pickling solutions. Thus, they will not be removed by standard galvanizing cleaning techniques and are best removed at the time of fabrication by grit or sand-blasting or by a wire needle gun.

7.2 It is desirable to choose a welding rod with a chemical composition as close as possible to the parent metal.

7.3 Welding rods high in silicon may cause excessively thick or darkened coatings or both to form in the welded area.

8. Flame Cut Cope Edges Preparation

8.1 Flame cut copes on beams can be extremely sensitive to residual stresses in the steel beam and, with the rough surface from the flame cutting operation, can be sources of cracking during the thermal cycling of the hot-dip galvanizing process. The steel beams start near ambient temperature then are immersed in the molten zinc and heated to above 800°F for usually 5 to 10 minutes. The steel beams are then cooled back to ambient temperature so the thermal cycling can create thermal stresses in the area of the cope.

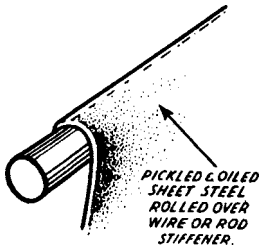


FIG. 3 Rolled Surfaces

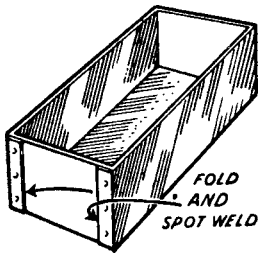


FIG. 4 Folded Surfaces

8.2 One method that has had fairly good success at minimizing the cracking at the edges of the flame cut cope is to weld a bead along the sides of the cope in the area where the flame cutting was done before hot-dip galvanizing. This welding operation will reheat the area and may relieve some of the residual stress near the cope edges. The weld bead will not eliminate all incidents of cracking but will greatly reduce the likelihood of cracking.

8.3 The weld rod material should be chosen as described in Section 7.

9. Cold Forming Before Galvanizing

9.1 Refer to the latest revision of Practice A 143/A 143M.

10. Shearing, Cutting and Punching Before Galvanizing

10.1 Refer to the latest revision of Practice A 143/A 143M.

11. Warpage and Distortion

11.1 Refer to the latest revision of Practice A 384.

12. Design Recommendations for Providing for the Free Flow of Cleaning Solutions, Fluxes, Air, and Zinc

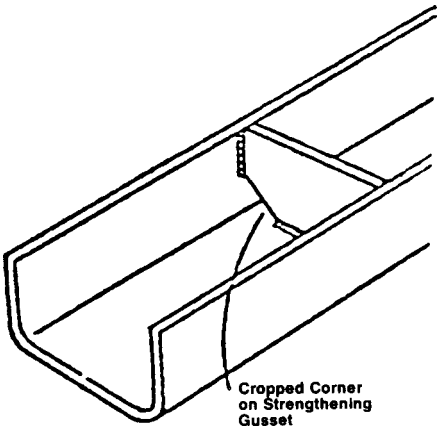
12.1 All fabricated assemblies shall be so designed with vent and drain holes such that no air is trapped during the immersion of the assemblies into cleaning solutions or molten zinc. Similarly these holes shall allow all solutions and molten zinc to drain freely from the assemblies. Failure to follow this practice will result in areas that will not galvanize properly, or that may retain entrapped flux or excessive amounts of zinc.

12.2 Free flow of cleaning solutions and molten zinc shall also be provided for in assemblies of hot-rolled shapes. This is accomplished by cropping the corner to provide an opening with a minimum area of 0.3 in.^{2} (1.9 cm^2) at the corners of all stiffeners (Fig. 5), gussets, or bracing (Fig. 6).

12.3 Air or moisture, or both, entrapped within closed fabricated pipework, such as handrail, can develop destructive pressures when heated to the galvanizing temperature. Pipe handrail shall preferably be vented full open internally, as shown in Fig. 7. In addition, there shall be one ⅜-in. (9.5-mm) minimum diameter external hole at each intersection to prevent any possible explosions in the event that the fabricator neglects to provide internal venting. Where internal venting is not possible, external vents shall be provided with one vent hole in each side of each intersection. The vent openings shall be a minimum of ⅜ in. in diameter or 25 % of the diameter of the pipe that is used, whichever is larger (see Fig. 8).

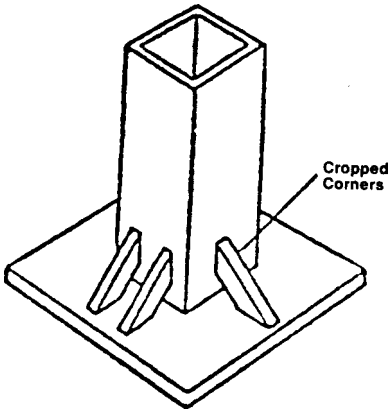
12.4 Figs. 9-12 show most of the conditions encountered with tubular product assemblies. The venting shall open

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NOTE 1—Strengthening gussets in channel sections should be cropped for zinc drainage.

FIG. 5 Cropped Corners—Channel Sections



NOTE 1—Crop corners of gussets on fabricated columns.

FIG. 6 Cropped Corners—Fabricated Columns

wherever possible. This is the most desirable situation. A minimum vent opening of 25 to 30 % of the cross-sectional area of tubular structure shall be specified where full-open venting is not possible. For small cross sections, larger percent vent openings are recommended. See attached drawings for specific recommendations. In box sections (Fig. 9) where gusset plates are used, the gusset plates shall be clipped at the four corners. In addition, a center hole shall be provided so that the cumulative area of the vent holes meets the recommended minimum. Gusset plates shall not be spaced closer than 36 in. (914 mm) apart. In the case of columns with end plates (Fig. 10) where the end plate must be closed, the shaft of the column shall be vented. The vent opening shall be a half circle with its diameter at the base plate (*D*, Fig. 10). This is much superior to putting a hole with the circumference of the hole tangential to the base plate. On trusses (Fig. 11 and Fig. 12) where tubular members intersect, vent holes are recommended at both sides of the intersection.

13. Moving Parts

13.1 When a galvanized assembly incorporates moving parts (such as drop handles, shackles, and shafts) a radial clearance of not less than 1/16 in. (1.59 mm) must be allowed to ensure full freedom of movement following galvanizing.

13.2 Moving parts such as handles or hinges should be galvanized separately and assembled after galvanizing. It may be necessary to post heat these parts in order to have them function freely. This heating may cause discoloration of the galvanized coating near the heated area.

14. Marking for Identification

14.1 Paint is not removed by pickling and must not be used when marking for identification material to be galvanized.

14.2 Satisfactory identification may be provided by welding the identifying marks on the material, by embossing the identifying marks on a steel tag of no less than No. 12 gage (0.105 in. (2.69 mm)) and securing to the material with a heavy wire such as No. 9 gage (0.148 in. (3.76 mm)), or by die stamping the identifying marks into the material with characters ½ in. (12.7 mm) high and a minimum of 1/32 in. (0.79 mm) deep.

14.3 All markings shall remain legible after galvanizing.

15. Galvanized Steel in Concrete

15.1 Galvanized steel can be placed in direct contact with concrete as the galvanized coating forms an excellent bond with the concrete materials. When embedding steel parts in concrete, the highest quality system is produced when all of the steel parts are coated with the same corrosion protection system. If there are galvanized parts in concrete near steel parts with no corrosion protection, there can be active corrosion cells whenever moisture is present. This will lessen the corrosion protection offered by the galvanized coating. The highest quality system contains all galvanized steel parts.

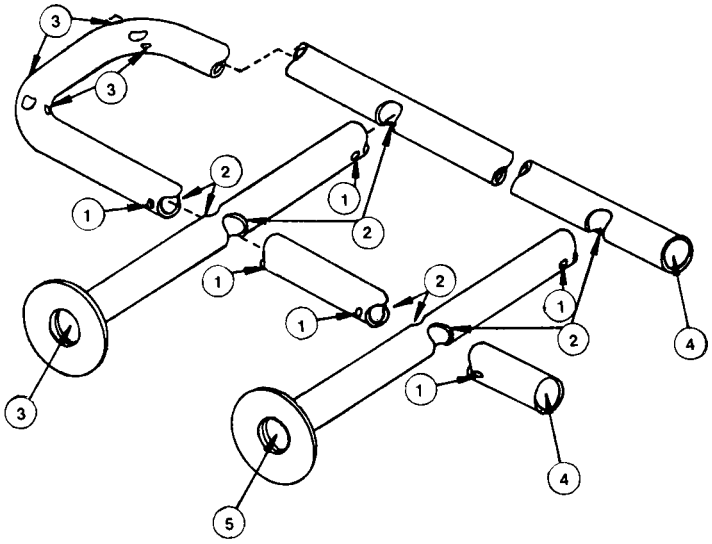
15.2 Galvanized steel parts when placed in concrete are normally passivated either by natural weathering prior to placement, by applying a passivation coating after the hot-dip galvanizing process, or, effectively, by the presence of more than 100 PPM of chromate in the concrete mix. When no passivation layer is on the surface of the galvanized coating and no chromates are in the concrete, there is a slight chance of a reaction between the zinc metal and the concrete water solution. The reaction between zinc metal and concrete water solution can release small quantities of hydrogen gas bubbles. When the concrete cover is designed to be thin and the surface area of the galvanized part in the concrete is large, these escaping gas bubbles could cause rough concrete surfaces. These rare situations can be avoided by allowing the parts to weather for a few weeks before placement, adding chromates to the concrete, or applying a passivation layer onto the galvanized coating.

16. Galvanized Nuts, Bolts, and Tapped Holes in Galvanized Products

16.1 Oversize tapping or retapping of nuts and tapped holes is required when the bolt or male thread is galvanized. While tapping or retapping after galvanizing results in uncoated female threads, the zinc coating on the engaged male thread will retard corrosion of both components.

16.2 Refer to the sections on dimensions of zinc-coated nuts in Specification A 563.

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The above drawing illustrates desirable design features for fabrication of handrail that requires galvanizing.

① Vent holes shall be as close to the weld as possible and not less than ⅜ in. (9.5 mm) in diameter.

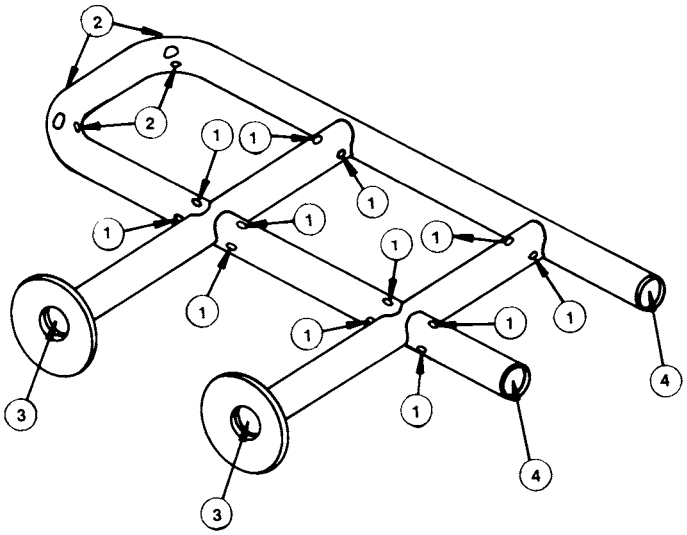
② Internal holes shall be the full inside diameter of the pipe for best galvanizing quality and lowest galvanizing cost.

③ Vent holes in end sections or similar section shall be a minimum ½ in. (12.7 mm) in diameter.

④ and ⑤ Any device used for erection in the field that prevents full openings on ends of horizontal rails and vertical legs shall be attached after galvanizing.

Vent holes should be visible on the outside of any pipe assembly.

FIG. 7 Handrail



The above drawing illustrates an acceptable alternative if full internal holes (the full inside diameter of the pipe) are not incorporated in the design of the handrail.

① Each vent hole shall be as close to the weld as possible, must be 25 % of the inside diameter of the pipe, but not less than ⅜ in. (9.5 mm) in diameter. The two holes at each end and at each intersection shall be 180° apart and in the proper location as shown.

② Vent holes in end sections or in similar sections shall be at least ½ in. (12.7 mm) in diameter.

③ and ④ Any device used for erection in the field that prevents full openings on end of horizontal rails and vertical legs shall be attached after galvanizing.

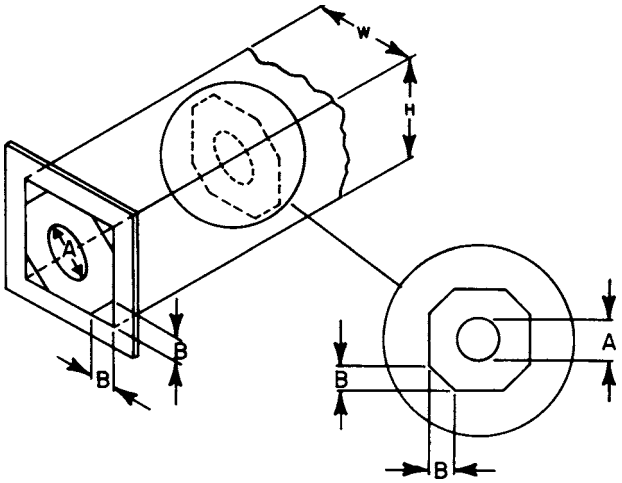
Vent holes shall be visible on the outside of any pipe assembly.

FIG. 8 Handrail—Alternative

16.3 Manufacturers or specifiers are cautioned to consider the plus tolerance that has been taken on the nominal pitch diameter of the bolt when establishing the degree of oversize tapping of the nut that is required for proper fit.

16.4 Hot-formed heading or bending may cause development of a scale that requires an extended time of pickling to remove. Should this occur on screws, scale removal prior to threading is desirable in order to avoid overpickling of the threaded area.

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Drawing shows location of holes and clipped corners, which must be flush. Using the following formulas, the chart shows typical sizes of holes and clipped corners.
Internal Gussets—Should be spaced a minimum of 36 in. (914 mm).
Box Sections—$H + W = 24$ in. (610 mm) or larger-Area of hole plus clips shall be at least equal 25 % of the area of the box ($H \times W$).
Box Sections—$H + W$ less than 24 in. to and including 16 in. (384 mm)-use 30 %.
Box Sections—$H + W$ less than 16 in. to and including 8 in. (192 mm)-use 40 %.
Box Sections—$H + W$ under 8 in. leave completely open; no end plates or internal gussets.

The following chart is for *square box sections only*. For rectangular sections, calculate required area and check with galvanizer for positioning of openings.

Box Size *H+W*, in. (mm)	Holes *A*-Diameter, in. (mm)	Clipped Corners *B* in. (mm)
48 (1219)	8 (203)	6 (152)
36 (914)	6 (152)	5 (127)
32 (813)	6 (152)	4 (102)
28 (711)	6 (152)	3 (76)
24 (610)	5 (127)	3 (76)
20 (508)	4 (102)	3 (76)
16 (406)	4 (102)	2 (51)
12 (305)	3 (76)	2 (51)

FIG. 9 Box Section

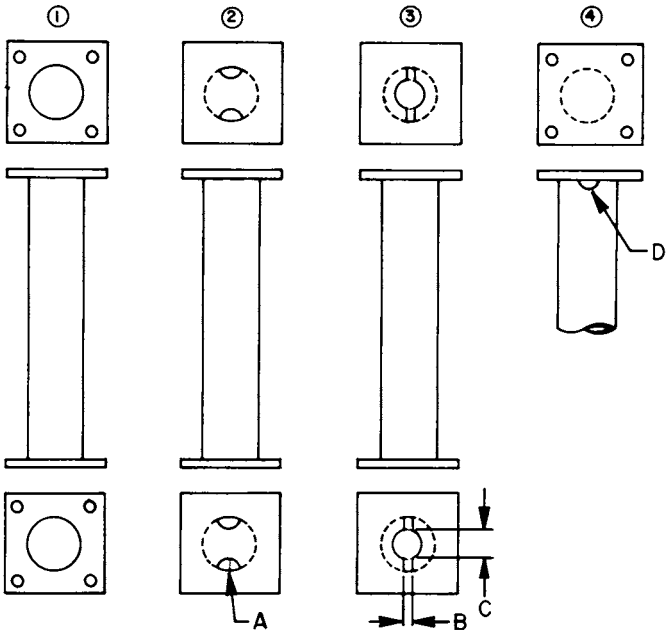
17. Critical Dimensions

17.1 When an assembly of steel parts or an individual steel part has been designed and fabricated with critical dimensions and must be subsequently hot-dip galvanized, the designer should be aware that the hot-dip galvanizing process uses chemical cleaning to prepare the surfaces for coating and this may alter the critical dimensions. In addition the hot-dip galvanized coating can increase the base steel material thickness from 2.0 to over 10.0 thousandths of an inch (50 to over 250 micrometres) depending on the steel chemistry as described in Section 3. This should be accounted for in the critical dimension design. Re-machining or otherwise reprocessing of critical dimensions after hot-dip galvanizing may be required.

18. Keywords

18.1 coatings-zinc; galvanized coatings; steel products-metallic coated; zinc coatings-steel products

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Location of Openings:

① Most desirable-completely open "same diameter" as section top and bottom.

② and ③ Equal substitutes if full opening not allowed.

④ Must be used together with ② or ③ if holes are not allowed on top of sections. Two half circles 180° apart in line with cutouts on ② and ③.

Dimensions:

Openings each end shall be at least 30 % of inside diameter area of pipe for over 3-in. (76-mm) pipe and 45 % of area for 3-in. pipe or smaller.

The following is an example of sizes for a 6-in. (152-mm) diameter section: Allow 30 % of the area of the inside diameter for hole sizes each end.

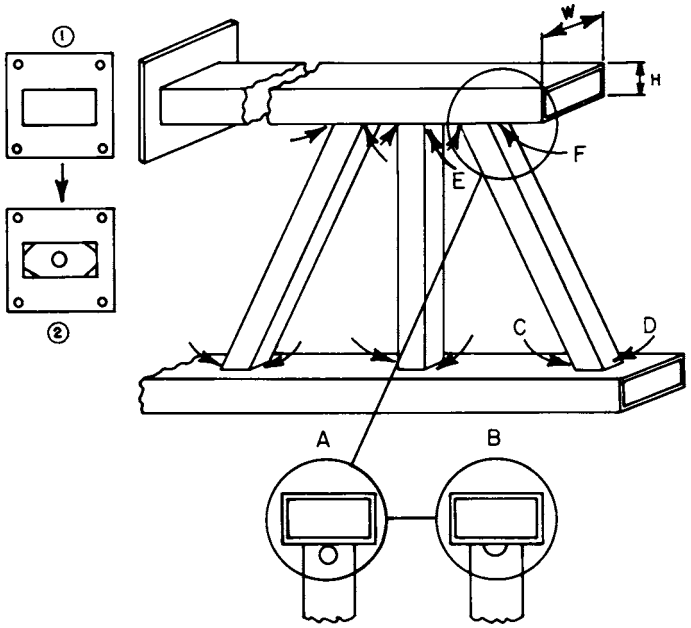
② Half circle A = 1 ¾-in. (44-mm) radius

③ Slot B= ¾ in. (19 mm) -- Center hole C = 3 in. (76 mm) Diameter

④ Half circle D = 1 ⅝-in. (41-mm) radius

FIG. 10 Pipe Columns, Pipe Girders, Street Light Poles, and Transmission Poles with Base Plates with or without Cap Plates

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Vertical and Angled Sections:

Hole location for vertical and angled sections shall be located as shown in Examples A and B, and by arrows on drawing.

Each vertical and angled section shall have two holes at the top and bottom, 180° apart in line with horizontal members as indicated by arrows. Size of holes preferably should be equal and the combined area of the two holes at either end of the vertical and angled sections (that is, area *C* and *D*, or area *E* and *F*) should be at least 30 % of the cross-sectional area.

End Plate—Horizontal:

① Most desirable—completely open.

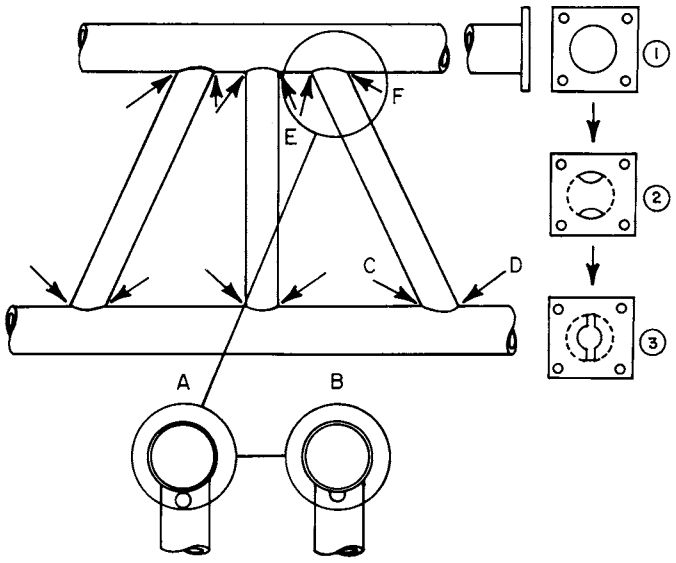
② If $H+W = 24$ in. (610 mm) or larger, area of hole plus clips should equal 25 % of the area of the tube ($H \times W$).

If $H+W$ less than 24 in. (610 mm) to and including 16 in. (406 mm) -- use 30%.

If $H+W$ less than 16 in. to and including 8 in. (203 mm) -- use 40 %.

If $H+W$ under 8 in. -- leave open.

FIG. 11 Rectangular Tube Truss



Hole location for vertical and angled sections shall be located as shown in examples A and B and by arrows on drawing.

Each vertical and angled section shall have two holes at the top and bottom, 180° apart in line with horizontal members as indicated by arrows. Size of holes preferably should be equal and the combined area of the two holes at either end of the vertical and angled sections (that is, area *C* and *D*, or area *E* and *F*) should be at least 30% of the cross-sectional area.

End Plates - Horizontal:

①Most desirable - completely open "same diameter."

② and ③Equal substitutes -- openings as shown should be 30 % of the areas of the inside diameter.

FIG. 12 Pipe Truss 3 in. (76 mm) and Larger

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SUMMARY OF CHANGES

Committee A05 has identified the location of selected changes to this standard since the last issue, A 385 - 05, that may impact the use of this standard. (May 1, 2008)

(*1*) Added Section 15.

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