

# Guidelines for Welding Galvanized Steel



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*Hot dip galvanizing of steel components after fabrication is well known as an inexpensive method of corrosion protection. The coating is metallurgically formed in a bath of molten zinc. The structure of the coating, formed by the interdiffusion of zinc and iron, provides good adhesion to the steel and, because the intermetallic layers are very hard, it also provides good abrasion resistance. Many structures are galvanized after they have been welded in order to achieve optimum corrosion protection from the galvanized coating. However, most products in the precast/prestressed industry can easily and satisfactorily be welded after fabrication by practicing the techniques outlined in this article. The following guidelines and information are intended to assist in employing the correct techniques to ensure a high quality product or job.*

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**T**he strength of a weld depends on reliable workmanship and the compatibility of welding materials with the metals to be joined (see Fig. 1). In the precast/prestressed concrete industry, zinc coated steel can be joined using the same methods employed for uncoated steel. The manual processes described in this article provide considerable flexibility in joining galvanized reinforcing steel.

Welding galvanized steel specifications are derived from the American Welding Society's (AWS) Specification D-19.0, *Welding Zinc Coated Steel*. (Note that this specification is no longer available from AWS.) This specification calls for welds to be made

on steel that is free of zinc, although already galvanized. The zinc coating should be removed for at least 2 to 4 in. (50 to 102 mm) from either side of the intended weld zone and on both sides of the workpiece, if possible.

Grinding with silicon abrasive discs is the most effective means of removing the galvanized coating. The zinc can also be removed by burning with a carbon arc or an acetylene torch while using an oxidizing flame, or by shot blasting with portable equipment. If common practice requires removal of the zinc coating, welding procedures for uncoated steel should be followed.

Removal of zinc where a weld is to be placed is the most conservative ap-



proach in welding galvanized steel. Welding procedures will then be the same as for uncoated steel.

When the galvanized coating is not removed, the weld should be made using the galvanized base metal with the thickest coating anticipated and qualified by test in accordance with AWS D1.1 or AWS D1.4. These Welding Procedure Specifications (WPS) will permit welding over surfaces with coatings equal to or less than the coating used in qualification testing. In general, to avoid zinc penetration of the welds, the procedure should involve greater root openings in joints, electrodes with low silicon content and slower welding speeds.

## MANUAL WELDING OF ZINC COATED STEELS

The manual and semi-automatic welding processes described below provide significant flexibility.

When manually welding zinc coated steels, it is beneficial, but not necessary, to remove the zinc coating on and around the weld areas. The weld metal may contain small quantities of zinc but this does not influence the mechanical properties.

The tensile, bend and impact properties of welds in galvanized steel are practically unchanged when compared to welds in uncoated steels, but galvanized coatings on steel surfaces may require different welding parameters. Different welding data calculations and different methods of fabrication are sometimes required for galvanized steel.

In general, manual metal arc welding procedures for galvanized steel are similar to welding uncoated steel. However, welding of galvanized steel generally requires that the welder receive specialized training. In addition, qualifications of the welder and welding procedure using the thickest coating anticipated is strongly recommended.

Uncertainty about fabrication differences and how problems connected with them can be solved has led to a reluctance to specify welding of zinc coated structures. Without more detailed knowledge, welders are often unwilling to weld zinc coated steel.



Fig. 1. Welding of galvanized steel.

## Gas Metal Arc Welding

Gas metal arc (GMA) welding, also known as CO<sub>2</sub> or Metal-Inert Gas (MIG) welding, is a versatile semi-automatic welding process that is convenient and easy to use. Fig. 2 shows an illustration of CO<sub>2</sub> welding. GMA welding is particularly suited to the welding of thinner materials.

In GMA welding of galvanized steel, the presence of the zinc coating has no effect on weld mechanical properties, although it may produce some appearance changes due to weld spatter. Arc stability is excellent and generally unaffected by the galvanized coating. Some reduction in welding speed is required.

Suitable conditions for CO<sub>2</sub> welding of butt joints using 1/4 in. (6.4 mm) galvanized plate and for welding tee

joints using 1/2 in. (12.7 mm) plate are given in Tables 1 and 2.

The weld takes place underneath a protective gas shield. A small diameter [1/32 to 1/16 in. (0.8 to 1.6 mm)] consumable wire electrode is fed automatically to the weld torch. The high current density resulting from the small diameter of the wire is in the region of 200 amperes per sq mm.

The cheapest and most widely used shielding gas for welding uncoated steel is carbon dioxide. Suitable conditions have been determined for GMA CO<sub>2</sub> welding galvanized steel with a short circuit arc. For welding uncoated mild steel, a more expensive shielding gas, comprising 75 percent argon and 25 percent CO<sub>2</sub>, is sometimes preferred because of its superior surface appearance, weld bead shape and re-

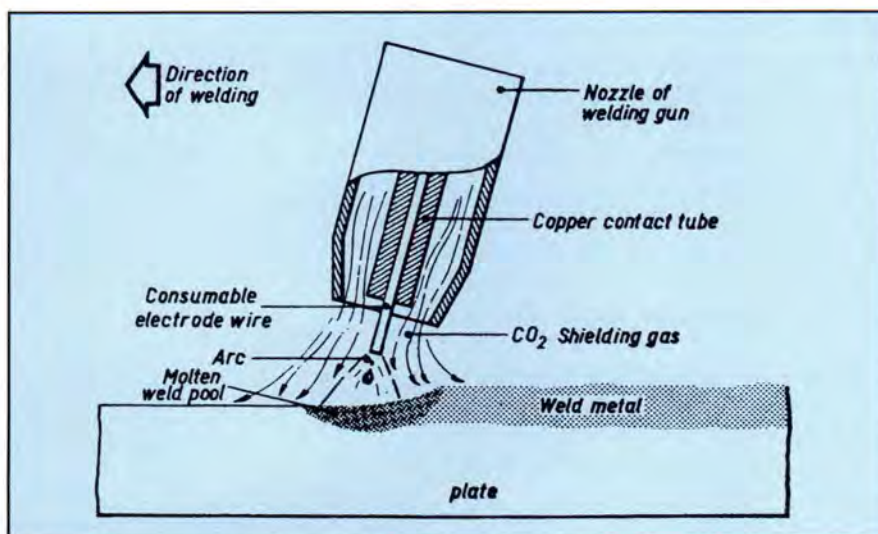


Fig. 2. Diagrammatic illustration of CO<sub>2</sub> welding (Courtesy AWS).



Table 1. Typical welding conditions for CO<sub>2</sub> welding butt joints — 1/4 in. galvanized steel.

Welder position	Number of passes	Pass number	Current (A)	Voltage (V)	Wire feed speed (in./minute)	Travel speed (in./minute)	Travel speed (uncoated) (in./minute)
Flat	2	1	135	19½	145	7	10
		2	165	21	210	8	11
Overhead	2	1	115	18	135	6	6
		2	115	18	135	5	7
Vertical up	1	1	135	19½	145	3	4½
Horizontal	3	1	135	19½	145	5	9
		2	135	19½	145	17	17
		3	135	19½	145	10	16

Taken from "Welding Zinc Coated Steel" — AWS D19.0-72.

Note: 1 in. = 25.4 mm.

Table 2. Typical welding conditions for CO<sub>2</sub> welding tee joints — 1/2 in. galvanized steel.

Welder position	Current (A)	Voltage (V)	Wire feed speed (in./minute)	Travel speed (in./minute)	Travel speed (uncoated) (in./minute)
Horizontal	135	20	145	5	8
Vertical down	135	20	145	10	10
Vertical up	135	20	145	5	5
Overhead	135	20	145	5½	8

Taken from "Welding Zinc Coated Steel" — AWS D19.0-72.

Note: 1 in. = 25.4 mm.

duced spatter. These advantages do not apply to galvanized steel and less expensive CO<sub>2</sub> may be used satisfactorily. However, most welding shops normally use an argon-CO<sub>2</sub> mixture for galvanized material.

GMA welding speeds should be slower to allow time for the galvanized coating to burn off at the front of the weld pool. The reduction in speed relates to the thickness of the zinc coating, the joint type and the welding position. Fillet welds in steel with thicker galvanized coatings may be welded more readily by increasing the current 10 amps. The increased heat input helps burn away the extra zinc at the front of the weld pool.

Penetration of the weld in zinc coated steels is less than for uncoated steels. Therefore, slightly wider gaps must be provided for butt welds. A slight side-to-side movement of the welding torch helps achieve consistent penetration when making butt welds in the flat position.

Spatter increases when welding galvanized steel using both CO<sub>2</sub> and an argon-CO<sub>2</sub> mixture shielding gas. Spatter particles adhere to the work-

piece and can cause an unsightly appearance. This can be avoided by applying a silicon, petroleum or graphite-based spatter release compound to the workpiece before welding. Spatter particles can then easily be brushed off; however, problems may be encountered due to the buildup of spatter in the nozzle of the welding gun. The application of an anti-spatter compound will reduce

the particles trapped by the welding nozzle.

Spatter formation increases with the thickness of the zinc coating and is therefore greater on batch-galvanized materials than on continuously coated sheet materials. When tee joints in batch galvanized steel are welded in the flat position, spatter particles tend to roll into the corner of the joint, causing difficulty in welding. Spatter formation is also troublesome when welding in the overhead position, resulting in spatter falling into the nozzle of the welding gun.

The major difference between welding zinc coated steel and uncoated steel using the gas metal arc welding process arises from the need for higher heat input to remove the zinc from the weld pool and slower welding speeds to burn off as much as possible of the zinc coating. The presence of the zinc coating should have no adverse affect

Table 3. Typical shielded metal arc welding condition for the root pass in butt welds in 1/4 and 1/2 in. thick galvanized steel with rutile electrodes.

Plate thickness (in.)	Electrode size (in.)	Welder position	Root opening (in.)	Welding current (ac) (A)
1/4	3/32	Flat	3/32	73 to 89
1/4	3/32	Vertical up	1/16	73 to 89
1/4	3/32	Horizontal	3/32	70 to 83
1/4	1/8	Horizontal	1/16	109
1/4	3/32	Overhead	3/32	89
1/2	1/8	Flat	3/32	95 to 109
1/2	1/8	Vertical up	3/32	83 to 95
1/2	5/32	Vertical up	3/32	101 to 117
1/2	1/8	Horizontal	1/16	117
1/2	3/32	Overhead	3/32	89

Taken from "Welding Zinc Coated Steel" — AWS D19.0-72.

Note: 1 in. = 25.4 mm.



on the weld properties. Using a shielding gas of argon and carbon dioxide can give a more stable arc and produce smoother weld deposits with minimum spatter and zinc loss.

### Shielded Metal Arc Welding

Shielded metal arc welding (SMAW) is a manual welding process in which flux covered electrodes of 10 to 18 in. (254 to 457 mm) in length and  $\frac{1}{16}$  to  $\frac{1}{2}$  in. (1.6 to 12.7 mm) in diameter are used. This is the most common of all arc welding processes. The SMAW process is shown in Fig. 3.

Suitable welding conditions for making the root pass of butt joints in  $\frac{1}{4}$  and  $\frac{1}{2}$  in. (6.4 to 12.7 mm) galvanized steels are given in Tables 3 and 4. The rutile electrodes for Table 3 are AWS E7013. The basic electrodes for Table 4 are AWS E7016. These conditions are similar to those used on uncoated steel. Normal welding procedure involves gouging out the joint from the rear side after a root pass on the front side. It is possible to obtain full penetration in the flat position on galvanized steel with the  $\frac{1}{16}$  in. (1.6 mm) root opening normally used on uncoated steel if the following conditions exist: (1) the angle of the electrode to the plate is reduced from the usual 70 to 30 degrees; (2) the electrode is moved backward and forward in a whipping motion in line with the joint. This method of manipulation results in a decreased travel speed of 40 percent from the travel speed on uncoated steel.

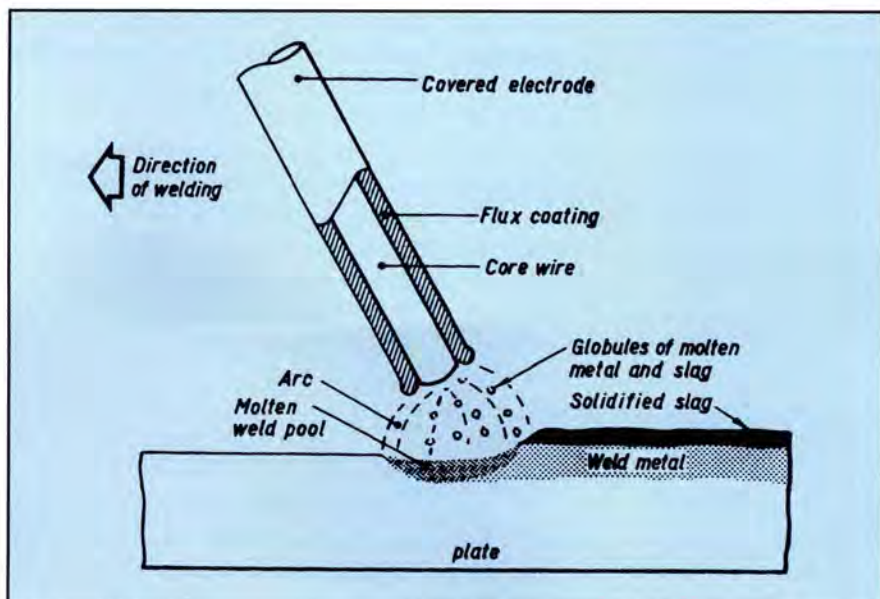


Fig. 3. Diagrammatic illustration of shielded metal arc welding (Courtesy AWS).

In the case of vertical and overhead butt joints in galvanized steel, a root opening of  $\frac{3}{32}$  in. (2 mm) is necessary to obtain full penetration. A root opening of  $\frac{1}{16}$  in. (1.6 mm) is sufficient to give full penetration in the horizontal position but the root pass tends to have a peaky or bulbous shape, resulting in slag entrapment at the edges of the weld. This slag can only be removed by grinding. Increasing the root opening from  $\frac{1}{16}$  to  $\frac{3}{32}$  in. (1.6 to 2 mm) can prevent slag entrapment.

A reduction of 10 to 20 percent travel speed is necessary when making the root pass in flat or vertical butt joints in galvanized steel. Welds made in the horizontal or overhead positions

can be made at similar speeds to welds on uncoated steel.

When the root pass has been made, subsequent weld passes can be made with similar techniques to those used for uncoated steel because the weld beads are deposited largely on previously uncoated weld metal and only partially on the galvanized beveled edges. There is usually insufficient zinc present to affect the welding operation. If excessively thick zinc coatings are present, an oscillating motion of the electrode should be used to slightly reduce travel speed.

The SMAW process uses a flux covered electrode to stabilize the arc. The amount of spatter formed with SMAW galvanized steel is slightly greater than compared with welding uncoated steel. Generally, it is not sufficiently extensive to warrant the use of anti-spatter compounds. Welding currents for SMAW galvanized steel are usually the same as those used for uncoated steel. The major differences are that the root opening must be increased to give full weld penetration and that the electrode must travel slower to remove the zinc.

### Manual Metal Arc Welding

Manual metal arc welding is recommended for galvanized steels of  $\frac{1}{2}$  in. (12.7 mm) or greater thickness. GMAW is recommended for steels lighter than  $\frac{1}{2}$  in. (12.7 mm). In general, manual metal arc welders can use

Table 4. Typical shielded metal arc welding condition for the root pass in butt welds in  $\frac{1}{4}$  and  $\frac{1}{2}$  in. thick galvanized steel with basic electrodes.

Plate thickness (in.)	Electrode size (in.)	Welder position	Root opening (in.)	Welding current (ac) (A)
$\frac{1}{4}$	$\frac{3}{32}$	Flat	$\frac{1}{16}$	85 to 90
$\frac{1}{4}$	$\frac{3}{32}$	Vertical up	$\frac{3}{32}$	85
$\frac{1}{4}$	$\frac{3}{32}$	Horizontal	$\frac{1}{16}$	83
$\frac{1}{4}$	$\frac{3}{32}$	Horizontal	$\frac{3}{32}$	78
$\frac{1}{4}$	$\frac{1}{8}$	Horizontal	$\frac{3}{32}$	109
$\frac{1}{2}$	$\frac{3}{32}$	Overhead	$\frac{3}{32}$	73 to 89
$\frac{1}{2}$	$\frac{1}{8}$	Flat	$\frac{3}{32}$	100
$\frac{1}{2}$	$\frac{1}{8}$	Vertical up	$\frac{3}{32}$	100
$\frac{1}{2}$	$\frac{1}{8}$	Horizontal	$\frac{3}{32}$	95
$\frac{1}{2}$	$\frac{3}{32}$	Overhead	$\frac{3}{32}$	83 to 95

Taken from "Welding Zinc Coated Steel" — AWS D19.0-72.

Note: 1 in. = 25.4 mm.



the same procedures for galvanized steel as for uncoated steel, although the following should be noted:

- The welding electrode, EXX10 and EXX11, should be applied slower than normal, with a whipping action that moves the electrode forward  $\frac{1}{8}$  to  $\frac{5}{16}$  in. (3.2 to 7.9 mm) along the seam in the direction of weld and then back into the molten pool. All volatilization of the galvanized coating should be complete before bead progress. This will prevent zinc entrapment in the weld metal. After volatilization, welding is the same as for uncoated steel.
- Weaving and multiple weld beads should be avoided. Heat input into the joint should be kept to a minimum to avoid undue damage to the adjacent coating.
- A short arc length is recommended for welding in all positions to give better control of the weld pool and to prevent either intermittent excessive penetration or undercutting.
- Slightly wider gaps up to  $\frac{3}{32}$  in. (2 mm) are required in butt joints or a 15-degree angle on the edge of a standing plate in order to ensure complete penetration. The gap also allows for the zinc and its gases to escape and reduces cracking caused by restraint as the plate thickness increases.
- Grinding off edges prior to welding reduces fuming from the galvanized coating. Welding procedures will then be the same as for uncoated steel.
- After welding is complete, apply zinc touch-up material to the weld bead and the adjacent area to complete the corrosion protection.

Electrodes similar to those used for arc welding uncoated steel can be used, along with the same electrode size and

current. The major difference between manual arc welding galvanized steel and uncoated steel arises from the need for higher heat input to remove the zinc from the weld pool and slower welding speed to burn off as much as possible of the zinc coating in front of the weld pool. This is achieved by giving the electrode a whipping motion. A more disturbed weld pool results, as well as a greater fluidity of the slag and an increase in spatter.

## STUD WELDING

Arc stud welding is a rapid method for attaching a stud or other suitably shaped part to a metal surface. An arc is initiated between the end of the stud and the surface. The stud is held against the surface in a hand operated stud welding gun. After a length of time, depending on the area of the stud or attachment at the point of welding, the current is automatically switched off and the stud is forced, under spring pressure, into the molten pool on the surface to which it is to be attached. The full cross-sectional area of the stud is welded to the surface and the resultant tensile strength of the weld should be equivalent to that of the stud material.

Conditions for welding  $\frac{1}{4}$  and  $\frac{1}{2}$  in. (6.4 and 12.7 mm) uncoated and galvanized steel are given in Table 5. If galvanized studs are used, it is essential to remove the zinc from the end of the face of the stud before welding and from the surface of the plate in the area where the stud is to be welded. If the end face is still zinc-coated, the weld metal may be violently expelled from the joint because of volatilization of the zinc from the faying surface.

## WELDING GALVANIZED REINFORCING BARS

Welding of galvanized reinforcing bars without removal of the coating can be carried out using either shielded metal arc welding or carbon dioxide gas metal arc welding performed in accordance with AWS D1.4.

Welding of galvanized metal may also be done after removing all the coating from within 2 in. (50.8 mm) of the weld joint.

The bar ends may be prepared to the required profile by sawing, grinding or oxygen cutting. Cold shearing is not recommended and bars prepared in this way should be carefully inspected to ensure that the ends have not been damaged by the shearing process. If any damage is found, the ends must be cut back beyond the area deformed by shearing.

Fusion faces should be free from irregularities that would interfere with the deposition of the specified size of weld, or cause defects.

If the ends of the reinforcing bars are prepared at the site, the prepared edges will be free from zinc and welding will be the same as for uncoated bars. The presence of zinc on the end of the bars to be welded has no significant effect on the welding procedure or the time required to make the joints. The only difference occurs in the formation of fumes when the prepared edges are coated with zinc. Table 6 gives typical welding procedures for either uncoated or galvanized bars.

The cold bending of reinforcing bars that are very high in strength can cause an embrittlement condition in the area of the bend. Galvanizing and welding can act as some stress relief for this area, but in many cases the further bending or handling of these bars can cause cracking or complete failure. Extremely high strength bars should be stress relieved after bending and before galvanizing or they should be bent in a heated condition.

## QUALITY OF WELDED JOINTS

Welding procedures are described in this paper for obtaining sound joints in zinc coated steels. It is necessary to consider the mechanical properties of

Table 5. Arc stud welding conditions for  $\frac{1}{2}$  in. thick galvanized steel plate (Phillips Welding Gun).

Stud diameter (in.)	Zinc coating weight (oz. per sq ft)	Spring coarse	Tensions fine	Current (A)
$\frac{1}{4}$	Nil	2	5	300
$\frac{3}{4}$	2 $\frac{1}{2}$	2	5	350
$\frac{5}{8}$	Nil	3	10	750
$\frac{3}{8}$	2 $\frac{1}{2}$	2	10	750

Taken from "Welding Zinc Coated Steel"—AWS D19.0-72.

Note: 1 in. = 25.4 mm.



sound welds on zinc coated steel and also the mechanical properties of welded joints containing typical defects that can be caused by the presence of the zinc coating.

It is not uncommon to find small cracks in a fillet weld on galvanized steel, extending from the root toward the face of the bead. Whether cracking will occur depends on many factors such as the silicon content of the weld metal, the degree of penetration of the weld, the thickness of the base metal that influences restraint of the joint, and the coating weight of the zinc and the microstructure of the zinc coating, which are both influenced by the composition of the base plate, particularly with respect to silicon content. Low-silicon or rutile (non-low-hydrogen) base electrodes with low silicon content (0.2Si or lower) generally reduce cracking.

Undercut is the most prevalent defect found in fillet welds deposited in the horizontal and vertical positions with either rutile or basic covered electrodes. This defect can occur at either side in vertical welds, but in the

horizontal position, it generally is restricted to the vertical plate.

Undercut is more likely to occur with rutile electrodes when the slag is allowed to solidify slowly or when the weld produced has a concave profile. A weld with a more convex profile that is frozen faster has a lower tendency to produce this defect. Rutile electrodes that have less fluid slag produce a weld profile that is convex and can be manipulated more readily to avoid any undercut.

An extra thick zinc coating may cause trouble in the vertical position because when it is molten, it tends to run down into the weld pool and makes the slag difficult to control. This can be prevented by maintaining as short an arc length as possible.

Also, when welding galvanized steel, hydrogen induced cracking of the heat-affected zone may occur in the base plate adjacent to the weld. The precautions necessary for the avoidance of cracking include such measures as reduction in cooling rate of the joint by the use of preheat or the


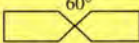

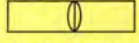
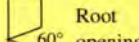
use of large diameter electrodes at high currents. The hydrogen content of a weld can be increased when it is deposited on galvanized or zinc-rich primed steel.

This extra hydrogen originates from the pickling process in galvanizing, or from the decomposition products of primers. It may be necessary to either remove primers from the vicinity of the joint before welding or use a higher preheating temperature than would be used on uncoated steel.

Zinc-rich paints are available that have been specially formulated such that it is not necessary to remove the coating from the weld path prior to welding. A letter should be obtained from the paint manufacturer stating it to be "weldable."

A fairly extensive amount of research has been carried out over many years on the mechanical properties of welds in zinc coated steels. Research performed by the International Lead Zinc Research Organization has shown that the tensile, bend and impact properties of welds on galvanized

Table 6. Typical shielded metal arc welding conditions for uncoated or galvanized reinforcing bars (Courtesy AWS).

Detail	Bar size (in.)	Electrode size (in.)	Current (ac) (A)	Number of passes	Technique	Time to complete (minutes)
 60° Rooting opening 1/16 in.	1/4	1/8	100	3	Bead	3
	3/8	1/8	120	6	Weave	3 1/2
	3/4	1/8	127	9	Weave	4
	1	5/32	127	8	Weave	5
 60° Rooting opening 1/16 in.	3/4	1/8	127	8	Weave	2 1/2
	1	5/32	113	8	Weave	3
 Copper mold root opening 3/8 in.	1/4	1/8	100	2	Weave	1/2
Root opening 3/8 in.	3/8	1/8	100	2	Weave	3/4
Root opening 5/8 in.	3/4	5/32	135	3	Weave	3 1/2
Root opening 5/8 in.	1	5/32	136	3	Weave	4
 60° double-V vertical welds	1	1/8	95	6	Weave	4
 60° Root opening 1/16 in.	3/8	1/8	95	4	Weave	2 1/2
	1	1/8	95	10	Weave	9

Note: 1 in. = 25.4 mm.



steels are equivalent to the properties of welds on uncoated steels.

## Fracture Toughness

Critical crack opening displacement measurements and drop weight tests have established that the fracture toughness properties of welds are unaffected by the presence of galvanized coatings.

## Fatigue Strength

The fatigue strength of arc welds in galvanized steel is equivalent to welds in uncoated steel made by CO<sub>2</sub> welding, as shown in Fig. 4. This shows that the fatigue strength of the defect-free joint made with low silicon filler metal is equivalent to that of a joint made in uncoated steel.

## Properties of Weld Containing Porosity

Porosity will occur in certain weld joint designs in galvanized steel depending on the coating thickness, volatilization of the zinc coating and the entrapment of gas in the weld. Whatever welding process is used, the extent of porosity will depend on the solidification rate of the weld metal, which is governed by heat input. The heat input is dependent on the current, voltage and welding speed.

Joint type will affect porosity formation because gases can escape more readily from butt joints than from tee

joints. In the case of tee or butt joints, a V-groove preparation or square-groove with a gap will facilitate the escape of gases, minimizing porosity, more than a close square-groove joint. Pore formation is also influenced by the thickness of the galvanized coating relative to the base steel.

Close attention to welding conditions will reduce the extent of porosity but complete elimination is not always possible. It is important to consider the effect of porosity on static strength and cracking of the weld joint.

## Effect of Porosity on Fatigue Strength

When joints are subject to fatigue loading, welds in galvanized steel should be made oversized to reduce the influence of any porosity in the weld metal. In evaluating the effect of porosity on the fatigue strength of a fillet weld, it is necessary to consider both the function of the joint and the size of the weld.

When a fillet weld in galvanized steel is large enough relative to plate thickness to fail by fatigue from the toe of the weld in the same manner as in uncoated steel, the presence of porosity in the weld does not reduce the fatigue strength of the joint. Where the dimensions of a weld are just large enough to cause fatigue failure from the toe in a sound weld, a weld containing porosity

at the root may fail preferentially through the throat of the weld.

## Cracking

Intergranular cracking of fillet welds containing porosity, sometimes referred to as zinc penetrator cracking, may also affect the strength of welded joints. As a precaution, it is advisable to carry out procedural and welder tests on materials and samples.

## Reconditioning Welded Joints

When galvanized steel is welded, some of the zinc coating is volatilized on each side of the weld and, while a thin layer of zinc-iron alloy remains, there is a loss in corrosion resistance. In the case of zinc-rich painted steel, welding causes decomposition of the paint film which is burnt off for some distance on each side of the weld. The width of the damaged zone will depend on the heat input and preheat.

Damage to the zinc coating or bare steel areas after welding should be repaired with a coat of zinc-rich paint (95 percent zinc) or epoxy paint immediately after welding and chipping of slag to replace the removed galvanizing. Hardware should be properly cleaned prior to application of a protective treatment. Restorations should be carried out in accordance with ASTM A780, *Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings*.

The conditioned or repaired area of the zinc coating will have no effect on the overall lifetime of the part. Repair materials and their coating thickness have been chosen to give comparable lifetimes to the coating minimums required in ASTM A123, *Standard Specification of Zinc (Hot-Dip Galvanized) Coating on Iron and Steel Products*.

There may be some visual differences between the original hot-dip galvanized coating and the repair areas, but the corrosion lifetime should be unaffected. Over a period of time, the visual differences will become less obvious as the zinc coating weathers.

## WELDING GALVANIZED STEEL WITH OTHER METALS

Galvanized steel can be welded to other metals, including stainless steel, when the welding techniques dis-

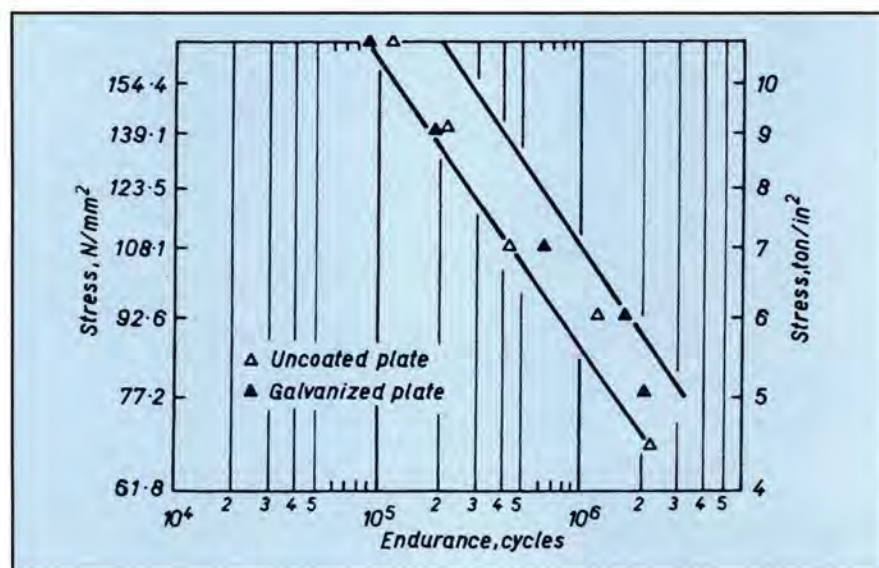


Fig. 4. SN curves showing fatigue tests on cruciform joints. CO<sub>2</sub> short-circuiting arc welds on uncoated and galvanized 1/2 in. (12.7 mm) Lloyds Grade A steel; AWS E60S-3 filler wire (Courtesy AWS).



cussed in this article are utilized. For best results with dissimilar metal welding, the zinc coating should always be removed from around the area of the weld.

If the zinc metal penetrates the stainless steel, for instance, there can be an embrittlement problem under stress. After the welding has been accomplished with the dissimilar metals, the weld area should be coated with a zinc touch-up product in order to prevent the onset of corrosion.

## **SAFETY AND HEALTH EFFECTS**

All welding processes produce fumes and gas to a greater or lesser extent. Fumes from cutting and welding are a controversial topic in today's environmentally conscious culture and should be a concern of all welders and fabricators. Manufacturers and welders must identify the hazards associated with welding coated and uncoated steels, and workers must be trained to maintain work practices complying with the Occupational Safety and Health Administration (OSHA) regulations.

Fumes from welding galvanized steel primarily contain zinc, iron and lead. The fume composition and amount typically depend on the composition of material as well as the current, voltage and welding process type.

Studies on the effects of human exposure to cutting and welding fumes have presented contradictory and inconclusive evidence. Quantifying the effects is difficult for several reasons. Working conditions vary widely, even for the same process.

For example, helmets that cover the front of the neck allow less fume infiltration than an open neck helmet. Posture also can greatly affect exposures. A welder working with his head in the fume plume is exposed to much higher concentrations than a welder with his head back away from the plume. Good ventilation minimizes the amount of the fume the worker breathes. Poor

ventilation can result in overexposure.

Welding of galvanized steel should always be done in well ventilated locations to prevent the inhalation of fumes. If adequate ventilation cannot be provided, personnel who may be exposed to fumes must be equipped with hose masks or air respirators. Workers in confined areas should be provided with a positive air supply. In enclosed areas, each worker should be required to wear an approved air-supplied respirator.

The potential hazards associated with welding and cutting of galvanized steel are similar to those associated with welding most uncoated steels.

Welding of zinc coated steel also produces fumes and gases. The most dramatic effect of welding fume is metal fume fever, which is more commonly known as zinc chills, zinc shakes or galvanize poisoning. The illness begins a few hours after exposure or, more frequently, during the night. Some of the symptoms are a sweet taste in the mouth, dryness of the throat, fatigue, nausea, vomiting, chills, or a fever [rarely exceeding 102°F (39°C)]. Although complete recovery normally occurs within 24 to 48 hours, it is important to avoid repeated exposure to zinc oxide.

To reduce hazards to workers, contaminants can be diluted to safe levels, captured at the source or filtered from the air. Fans dilute contaminants by mixing clean air with the contaminated air. Fume exhaust hoods capture and contain contaminants and draw fumes away from workers.

Stationary hoods, typically used in workshops where the welder stands in one location, are used to keep the air below the exposure limits. Air cleaners are also used to collect and filter particulates and re-circulate the air.

The threshold limit value (TLV) for zinc exposure has been set at 5 mg/m<sup>3</sup> by the American Conference of Governmental Industrial Hygienists. This means that a worker may be exposed to this TLV over an 8-hour period

without harmful effects. Higher amounts can be inhaled for short periods of time, providing the time-weighted average of the exposure does not exceed the TLV.

Providing suitable ventilation can control the concentration of fumes that might be harmful if inhaled and can keep the concentrations below the TLV, thus avoiding the danger of over-exposure. When conducting welding outdoors where there is free ventilation, concentrations of fumes above the TLV are not likely beyond 1 ft (0.3 m) from the welding torch.

Welding and cutting operations involve much heat, emit a considerable amount of light and are often liable to throw out particles of molten metal called spatter. Protection of personnel is, therefore, required for the body, head and especially the eyes of the welder or any persons nearby.

## **CONCLUDING REMARKS**

The excellent long-term protection of steel by galvanizing has led to the specification and application of zinc coatings to small and large projects such as bridge decks, industrial buildings, retaining walls and other precast/prestressed concrete structures. Because these structures are sometimes too large to fit into galvanizing kettles, it is essential to be able to weld zinc coated steels and to produce joints with qualities equivalent to joints in uncoated steel.

Welding and cutting galvanized steel can be accomplished safely and effectively if proper procedures are followed. Most of these procedures should be standard practices used when welding uncoated steels. The American Welding Society's publication, ANSI/ASC Z-49.1, *Safety in Welding, Cutting and Allied Processes*, covers all aspects of safety and health in the cutting and welding environment. It contains information on protection of personnel and the general area, ventilation, fire prevention and protection, and confined spaces.



## SELECTED REFERENCES

1. Bland, Jay, "Welding Zinc-Coated Steel," American Welding Society, Miami, FL, 1972.
2. Oates, William, *Welding Handbook — Materials and Applications*, Part 1, V. 3, Eighth Edition, American Welding Society, Miami, FL, 1996.
3. Porter, Frank, "Galvanizing and Welding Structural Steel," *Metal Construction*, October 1983.
4. Livelli, Greg, "Galvanized Steel Cutting Tips — Process Primer on Thermal Cutting," *Welding Design and Fabrication*, August 1997.
5. Gregory, E. N., "Welding Zinc Coated Structural," ILZRO Project ZM-115, 1970.

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## RELATED SPECIFICATIONS

1. American Welding Society Specification D-19.0, *Welding Zinc Coated Steel*.
2. ANSI/ASC Z-49.1, *Safety in Welding, Cutting and Allied Processes*.
3. ASTM A123, *Standard Specification of Zinc (Hot-Dip Galvanized) Coating on Iron and Steel Products*.
4. ASTM A780, *Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings*.

### DISCUSSION NOTE

The Editors welcome discussion of reports and papers published in the PCI JOURNAL. The comments must be confined to the scope of the article being discussed. Please note that discussion of papers appearing in this issue must be received at PCI Headquarters by September 1, 1998.