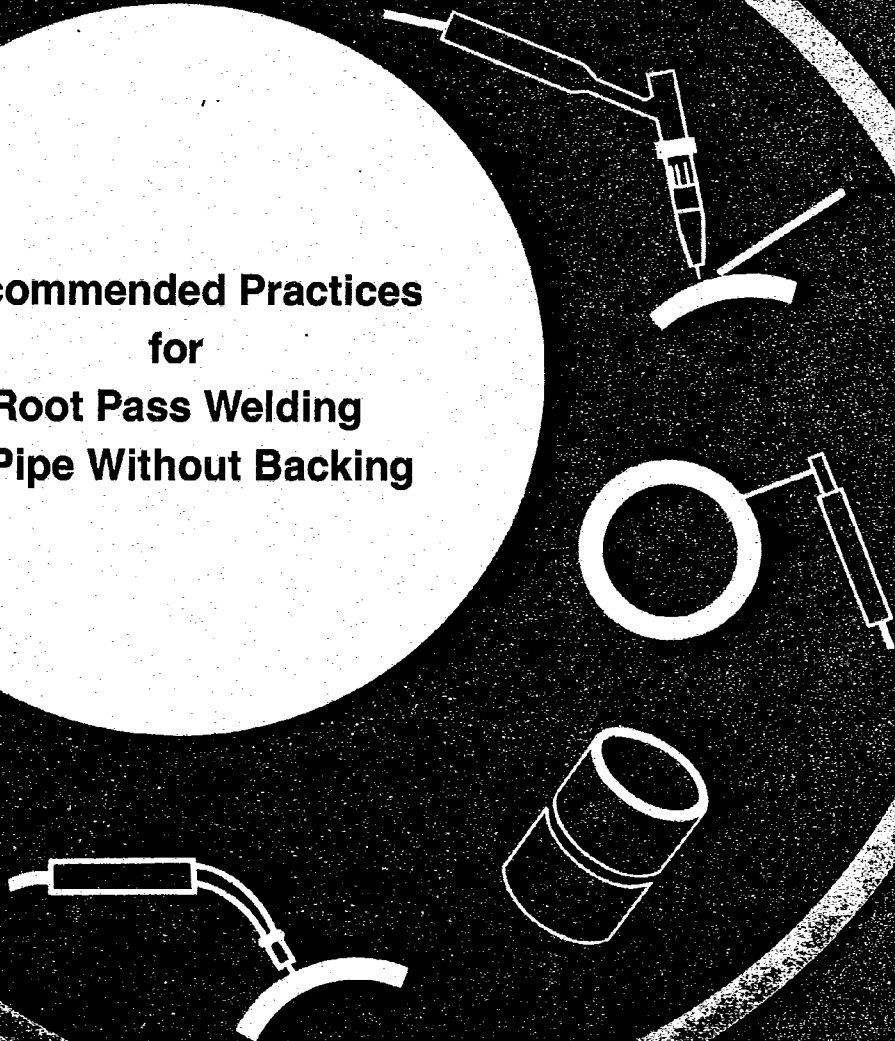


**Recommended Practices  
for  
Root Pass Welding  
of Pipe Without Backing**



**AMERICAN WELDING SOCIETY**

**Key Words**—Root pass welding, pipe, gas purging, consumable inserts, gas tungsten arc, gas metal arc, shielded metal arc, recommended practice

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**An American National Standard**

Approved by  
American National Standards Institute  
January 23, 1987

**Recommended  
Practices for  
Root Pass Welding  
of Pipe Without Backing**

Superseding  
AWS D10.11-80

Prepared by  
AWS Committee on Piping and Tubing

Under the Direction of  
AWS Technical Activities Committee

Approved by  
AWS Board of Directors  
October 17, 1986

**Abstract**

This standard presents recommended practices for welding the root pass of metal pipe butt joints with an open root or a consumable insert. Joint designs, assembly, consumable insert configurations, base metals, filler metals, and purging are discussed. Applicable arc welding processes and techniques are described.

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## Foreword

(This Foreword is not a part of D10.11, but is included for informational purposes only.)

The AWS D10 Committee on Piping and Tubing has been in existence for over thirty years, during which time, a great deal of information on many aspects of pipe welding has been published. The first document on root pass welding was approved in February, 1980 and published as AWS D10.11-80, *Recommended Practices for Root Pass Welding and Gas Purging*.

This publication was intended to be a "how to" guide in the use of open root and consumable insert welding techniques for root pass welding of groove welds joining metal pipe. Joint designs, fitting techniques, consumable insert configurations, filler and base metal combinations, purging, and welding processes were discussed. This publication made no provision for joints which include backing rings.

The present document, AWS D10.11-87, carries the revised title, *Recommended Practices for Root Pass Welding of Pipe Without Backing*. This version has been extensively revised and updated to provide the user with the latest available information.

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## Recommended Practices for Root Pass Welding Of Pipe Without Backing

### Introduction

When the pipe system designer has determined that the use of backing rings is unacceptable and that complete joint penetration, and a continuous root surface is needed, butt joints may be made from one side without backing using special groove designs and techniques described in this document. Although gas tungsten arc welding (GTAW) is commonly used for precise control in root pass welding, shielded metal arc welding (SMAW) and gas metal arc welding (GMAW) are also widely used to achieve complete joint penetration and an acceptable root surface.

### 1. Cleanliness

Cleanliness is important in all welding, and it is especially so in root pass welding. This includes groove faces and a minimum of 1 in. (25mm) from the groove on both inside and outside surfaces of the pipe. Grinding or other mechanical means should be used to remove all paint, scale, rust, and dirt. In addition, all parts of the joint should be free of grease and oil; these may be removed by use of a suitable solvent. A suitable solvent is one that does not leave a residue and is not harmful to the welder or the weldment. Most solvents require good ventilation, and many are flammable; therefore, proper precautions should be taken.

Grinding and cleaning operations should be done just prior to welding. After cleaning, the pipe should be handled with clean gloves to preserve cleanliness.

### 2. Preparations for Purging

The highest quality root welds are obtained by using GTAW either with or without consumable inserts. A purge (displacement of air at the inside surface of the weldment with a suitable gas) is required for stainless and nonferrous piping systems, except aluminum, if a smooth root surface is to be obtained. Carbon steels and most low alloy steels

can be welded, using an open root groove, without the use of an internal gas purge. Purging of joints with consumable inserts reduces the occurrence of defects resulting from oxidation of the insert. Purging will also increase welding speed.

**2.1 Purging Gases.** Welding grade argon is the gas most often used for internal purging. For some applications, nitrogen, carbon dioxide, helium, and mixtures of these gases are suitable purge gases. These gases can be used at lower cost than argon for specific applications, but they should be demonstrated as suitable by testing prior to use in production.

The purity of purging gases is important and should be included in the welding procedure specification. Argon, helium, and nitrogen of better than 99 percent purity are available commercially and should be used. The moisture content should be controlled by specifying a dew point of  $-40^{\circ}\text{F}$  ( $-40^{\circ}\text{C}$ ) maximum.

The purging procedures described in this document are based on the use of argon as the purging gas. If nitrogen or helium is used, modifications to the purging procedure may be necessary because both gases are less dense than air and argon.

**2.2 Purge Gas Containment.** Purging requires entrance and exit openings through which the purge gas can enter and leave the weld joint area at controlled rates. For piping where both ends can be capped, properly-sized wood or plastic disks can be taped to the pipe ends. Plastic caps that are used to prevent damage to pipe ends during shipment are commonly used as purge caps.

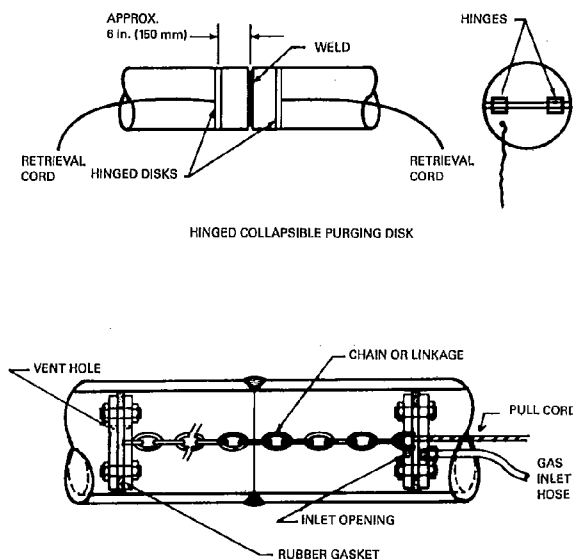
The cap on the entrance side requires a hole to receive the purge gas. The other cap requires a hole large enough to prevent build-up of gas pressure. Since air is lighter than argon, the exit hole should be at a higher elevation to minimize the entrapment of air. Precautions should be taken to ensure that all leak paths are blocked and that branch

pipes and other areas where air may be entrapped are well vented. Purge caps of the type discussed here are most commonly used when a large portion of a system or an entire system is purged.

Other purge containment techniques are available for situations where purging the entire system is impractical. One of these is the use of water soluble paper from which dams can be formed to contain the purge gas. These commercially available dams are in the form of water soluble paper disks that can be fastened inside the pipes on both sides of a weld joint prior to assembly. The disks should be approximately 6 to 12 in. (150 to 300 mm) from the weld joint. For small diameter piping or tubing, the soluble paper can be crumpled to the approximate inside diameter and stuffed into the pipe or tube, thus eliminating the need for taping in place. After welding, the disks can be dissolved with a water rinse or left in to be dissolved during hydrostatic testing. Soluble dams are particularly advantageous because they reduce the volume of air which must be purged on large piping systems. It is important that water soluble dam material be located far enough from the weld to prevent it from overheating or burning.

When the weld will be postweld heat treated, cardboard disks held in place with masking tape are suitable, since they will burn to ashes during heat-treating.

Hinged collapsible or rubber gasketed disks of the types shown in Figure 1 can also be fabricated and fit into piping. The purging techniques are similar to those used with soluble dams. At least one end of the pipe system must be left open for removal of the disks after welding.



**Figure 1—Purging Fixtures**

Commercially available inflatable bladders can also be used as a localized purge containment when an opening is available to remove the bladders after welding. One bladder is inserted on each side of the joint to be welded. The bladders are inflated with purge gas or air, after which purging can proceed as described previously.

Purge dams should be far enough away from the groove to prevent burning, melting, or other damage to dams from the heat of welding. Typically, a distance of 6 in. (150 mm) is adequate. Whenever preheating is used, this distance should be increased to keep the metal temperature at the dam no higher than 300°F (150°C). Care should also be taken when removing dams that the weld area is cool enough to prevent heat damage to bladders or the rubber or plastic of other type dams.

In addition to sealing branch connections and open ends of the pipe, it is also necessary to prevent the purging gas from escaping through the root opening at the weld groove itself. This is commonly done by wrapping a single layer of tape around the outside of the joint. The tape should not touch the groove face, and it should not leave residue after removal. Care should be taken to seal off all leak paths before introducing the purge gas into the piping system. All root openings in the system between the purge gas exit and entrance point should be taped closed. All branch pipes and other areas where air can become entrapped should be vented.

### 3. Purging Prior to Welding

Purging a piping system is a two-stage operation. During the first stage, prior to welding, the purge gas is used to displace the air in the pipe at relatively high flow rates. This high flow rate is maintained until the gas inside the pipe reaches an acceptably low oxygen level. During the second stage, the purge gas flow rate is reduced so that the purge maintains a slight positive pressure on the inside of the pipe. This reduced gas flow is maintained while the root pass is welded. This eliminates air re-entry into the pipe and minimizes oxidation of the root surface.

The time required for the first stage of purging depends on the maximum oxygen level permitted by the welding procedure, the volume of the system being purged, and the purge gas flow rate. However, the relationship between purge gas flow rates and time is not linear; i.e., a system that can be purged in one hour at a flow rate of 50 cfm (24 liters per minute) will not be purged to the same degree in one-half hour if the flow rate is increased to 100 cfm (48 liters per minute). An increase in the purge flow rate increases the turbulence within the system, which results in an increase in the mixing of air and the purge gas. This will require additional volume changes of gas within the pipe to achieve the desired level of purity.

At lower flow rates, less mixing occurs, and the heavier purge gas forces the air upward and out of the pipe system.

Higher purge flow rates will decrease the time required for preweld purging, but increase the amount of gas required.

In general, reasonable preweld flow rates and times can be arrived at from simple calculations of the system volume and by applying a time factor.

The time for one volume change of the system is found by dividing the volume by the purge gas flow rate. For example, the prepurge time for one volume change in a 20 ft (6 m) length of 18 in. (46 m) diameter pipe prepurged at 50 cfh (24 l/min) would be:

$$\text{Volume} = 0.785 \times (\text{pipe diameter})^2 \times \text{length}$$

$$0.785 \times (1.5 \text{ ft})^2 \times 20 \text{ ft} = 35.3 \text{ ft}^3$$

$$\frac{35.3 \text{ ft}^3}{50 \text{ cfh}} = 0.70 \text{ hour or 42 minutes}$$

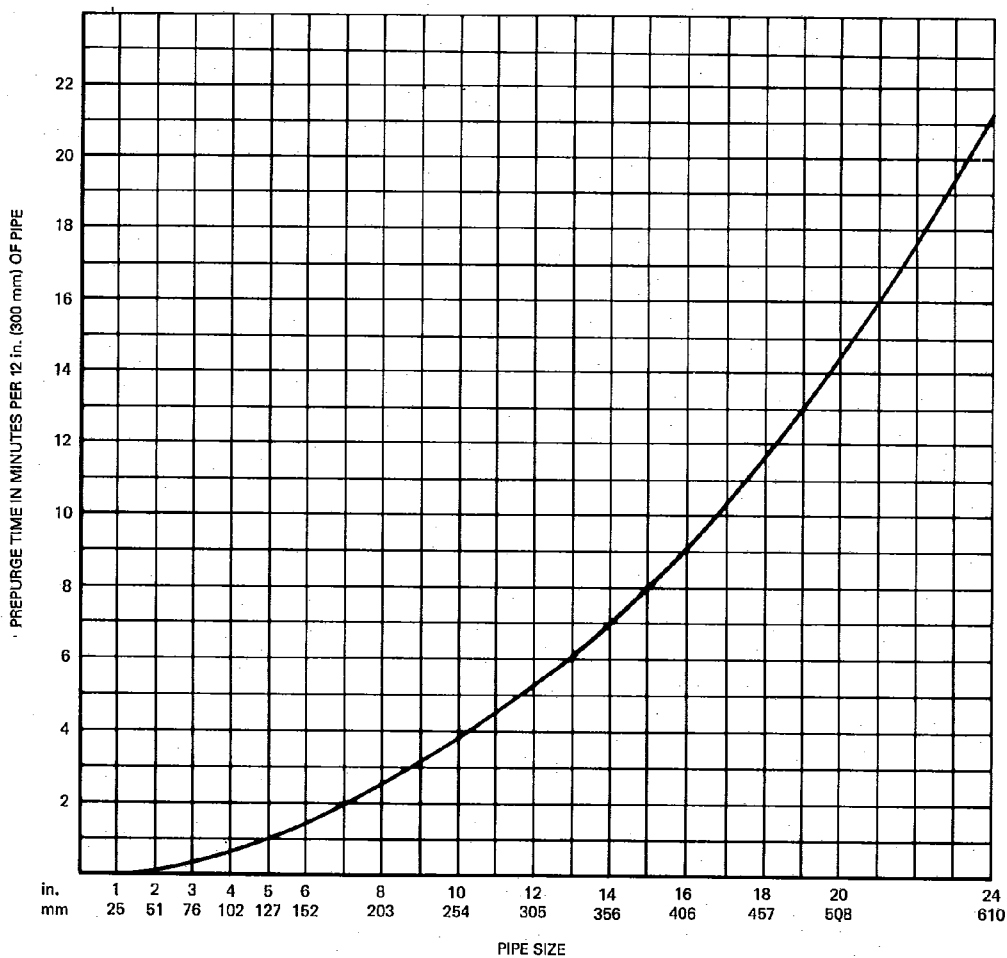
In SI units at 24 liters per minute, the purge time for one volume change of the same pipe would be:

$$0.785 \times (0.46 \text{ m})^2 \times (6 \text{ m}) = 0.98 \text{ m}^3$$

$$\frac{0.98 \text{ m}^3 \times 1000 \text{ l/m}^3}{24 \text{ l/min}} = 42 \text{ minutes}$$

A general rule is to preweld purge at flow rates and times that will produce 5 to 6 volume changes. In the example above, one volume change occurs approximately every 42 minutes. Six changes would require 252 minutes or about 4 hours.

Figure 2 shows minimum preweld purge time in minutes per 12 in. (300 mm) of pipe for varying pipe diameters at 50 cfh (24 liters per minute) flow rate. Suggested preweld purge times can be found quickly and easily from this graph.



Prepurge time for 12 in. (300 mm) of pipe at a flow rate of 50 CFH (24 liters per minute)

To calculate the prepurge time for any length of pipe, multiply the value obtained from the chart by the length of pipe.

**Example:** Find time required for prepurging of 200 ft (60 m) of 5 in. (127 mm) pipe. From chart at 5 in. (127 mm) pipe size, get one min per 12 in. (0.3 m) of pipe; hence, 200 ft (60 m) = 200 minutes or 3 hours 20 minutes.

**Figure 2—Preweld purge evacuation of air**

While the use of calculations and graphs such as those discussed above can simplify estimates for preweld purge applications, it is recommended that the residual oxygen level be measured prior to initiation of welding. This can be done quickly and easily with commercially available oxygen analyzers, which are accurate and easy to use. For steels and nickel alloys, an oxygen level of 1 percent or lower is usually adequate. Reactive metals, such as titanium, will require a lower oxygen level.

#### 4. Purging During Welding

Once the required oxygen level inside the pipe has been achieved, the flow rate of the entering purge gas should be reduced before root pass welding begins in order to eliminate excessive pressure on the inside of the pipe. Excessive pressure will cause unacceptable root surface concavity or holes through the root bead.

The proper purge flow rate during welding is one that is barely detectable at the gas exit port. When welding with consumable inserts, where the unfused insert serves to seal the root and prevent the escape of gas, flow rates on the order of 8 to 12 cfh (4 to 6 liters per minute) are required. It is usually necessary to reduce the flow rate as the root is closed to prevent blowout of weld metal. Higher flow rates will be required for open groove welds. For small diameter piping or tubing, it may be necessary to reduce flow rates below the values recommended above.

It is usually desirable to maintain the purge for the second and third layers of weld deposit to minimize internal oxidation during reheating of the root pass.

#### 5. Tack Welding

Tack welding is important in root pass welding. It should be done with care because the tack welds normally become part of the final weld. For this reason, tack welding is not usually performed until preweld purging has been completed for those materials requiring purging. At least four tack welds should be made at 90 degree intervals around the pipe. For 10 in. (250 mm) and larger diameters, tacks should be made at least every 6 in. (150 mm) around the pipe, and they should be long enough to resist weld shrinkage forces which will try to pull the root closed. When welding stainless steel, tacks should be spaced more closely. Tack welds should be checked by the welder as he progresses to be sure that they remain intact. Cracked tack welds should be carefully ground out before proceeding. Tack welds should be cleaned prior to root pass welding. For open root welds, both ends of each tack weld should be carefully ground and tapered to promote complete fusion of the remainder of the root face during root pass welding. If the root pass is not made immediately after tack welding, care should be taken to protect the joint and maintain its cleanliness.

### 6. Welding Using GTAW Without Consumable Inserts

The following factors should be considered when welding with the GTAW process.

**6.1 Joint Design.** A typical groove design for open root welding is shown in Figure 3. The internal misalignment [1/16 in. (1.6 mm) maximum] is very important and justifies counterboring heavy-walled pipe, or a weld build-up/grinding procedure on thin-walled pipe.

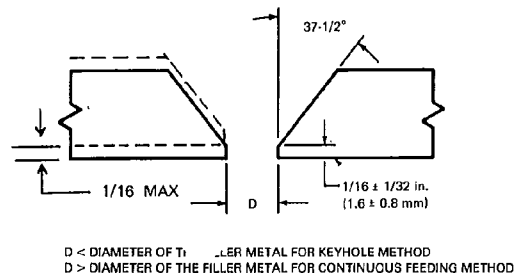


Figure 3—Typical Open Root Joint Design

**6.2 Root Opening – Open Root Groove.** The amount of root opening is determined by the method to be used in adding filler metal. A root opening equal to or slightly smaller than the filler metal wire diameter is used with the keyhole technique in which the filler metal is introduced intermittently. A larger opening is used with the continuous feed technique in which the filler metal is always in the opening and can be melted continuously if desired. Welders who prefer the continuous method should also be able to use the keyhole technique, since it is sometimes required when weld contraction significantly decreases the root opening. In either case, the filler metal can be used as a spacer or guide in determining the opening prior to tack welding. However, it should be noted that shrinkage during solidification and cooling of any tack weld will reduce this spacing. The amount of shrinkage varies with the coefficient of expansion for both base metal and filler metal and with changes in total heat input. For example, a stainless steel tack weld will cause more shrinkage than a carbon steel tack weld made under similar conditions since it has a larger coefficient of thermal expansion.

**6.3 Purge Containment.** Grooves should be covered with tape on the outside surface of the pipe to prevent the escape of the purge gas. During the welding of the root pass, the welder should peel the tape off the joint in increments just prior to welding that increment.

**6.4 Tungsten Electrode Type and Configuration.** For direct current electrode negative (dcen), 1 percent or 2 percent thoriated tungsten electrodes are recommended.

Better control of the arc is obtained if the electrode is tapered. However, a sharp point is undesirable because it increases the likelihood of breaking off the end of the tungsten electrode into the molten metal. The tungsten electrode should be tapered approximately 1/4 in. (6 mm) from the end to a point, and then the point should be slightly flattened. The flat face on the tungsten electrode should be approximately 0.020 in. (0.5 mm) for a 3/32 in. (2.4 mm) or 1/8 in. (3.2 mm) size electrode. For a 1/16 in. (1/6 mm) size tungsten electrode, the flat face can be somewhat smaller.

**6.5 Arc Initiation.** High frequency starting is used for easiest arc initiation. Where high frequency is not available and the touch-starting method is used, the arc should always be initiated against a groove face or a striking bar, not against the base metal outside the groove. The arc should then be moved into the joint root and held stationary until the root faces just begin to melt.

**6.6 Welding Technique—Open Root Groove.** When the arc is established, the filler metal should be introduced to the leading edge of the arc, a weld pool formed, and the filler metal fed into the pool as described in the following sections. The basic angular relationships between the workpieces, filler metal, and torch are shown in Figure 4; other relationships may be developed for specific situations. The method of adding filler metal depends upon which of two following techniques is used.

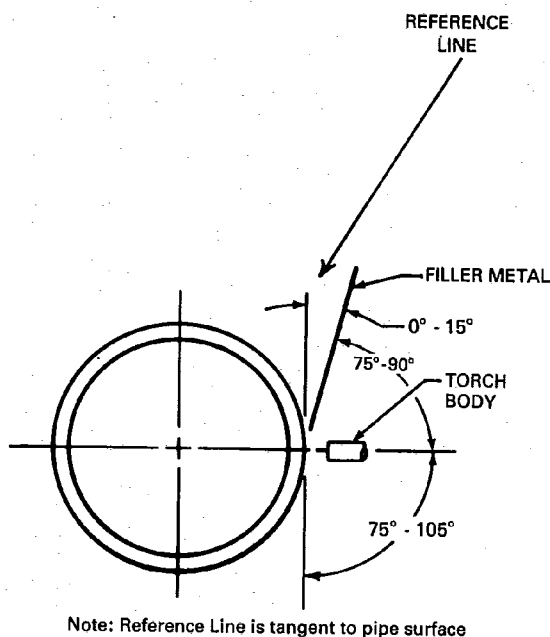
**6.6.1 Keyhole Method.** The filler metal should always rest on the joint root ahead of the leading edge of the arc. When additional filler metal is required, the wire filler metal is moved back into the leading edge of the arc, and a segment is melted off. The wire filler metal is then retracted while the pool is moved between the groove faces with an oscillating motion. With practice, welders can learn to "dab" wire into the pool and then retract the end of the wire far enough from the leading edge of the arc to prevent melting, but yet remain within the inert gas shield to prevent oxidation of the wire tip. Should the end of the filler metal become contaminated or oxidized, the end should be cut off before further welding.

**6.6.2 Continuous Feeding of Filler Metal.** This is the preferred technique which allows continuous feeding of the wire into the molten weld pool. The filler metal wire fits in between the root faces, and it is fed continuously into the weld pool. The filler metal wire is melted as the arc passes over it keeping the pool width to a minimum and still achieving complete penetration. The amount of root reinforcement varies with the amount of filler metal that is fed into the pool. There is no advantage to extra metal inside the pipe. In fact, excess root reinforcement is a detriment and should be avoided, the same as excess face reinforcement. Where the joint is being made in close quarters, it is also possible to feed the filler metal wire through the root

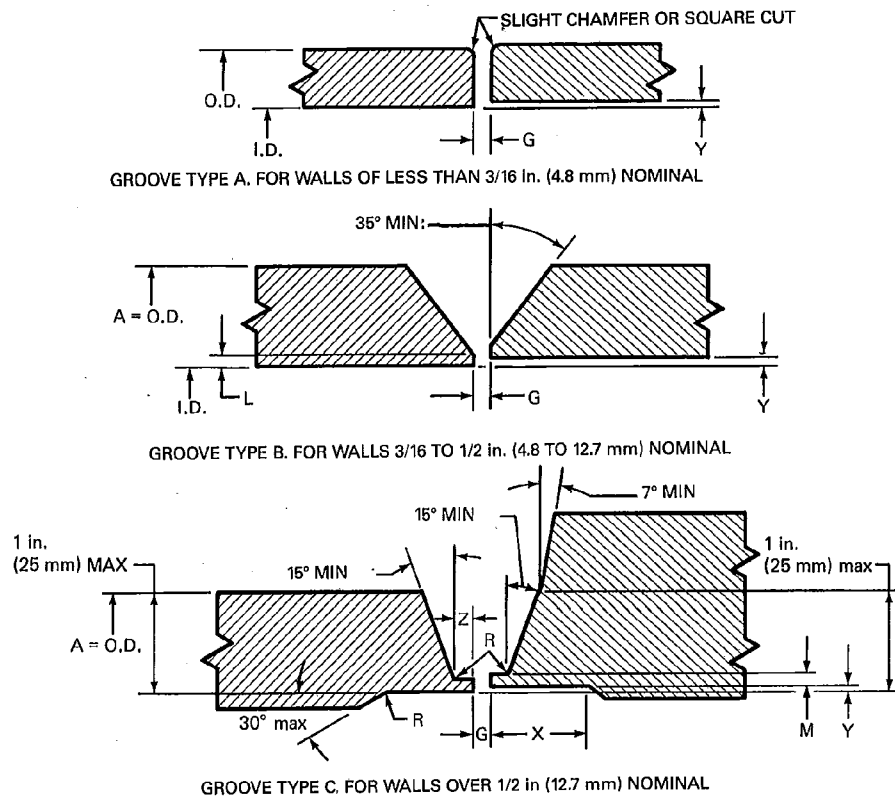
opening into the pool from the opposite side of the joint for at least part of the circumference.

**6.7 Welding Technique—Groove with Zero Root Opening.** Groove Types A and C, shown in Figure 5, are recommended for welding stainless steels and silicon killed carbon steels as an alternative to adding filler metal or using consumable inserts for root pass welding. When the arc has been located over the joint root, it should be held stationary until the weld pool width is two-thirds the width of the bottom of the groove. The torch should move smoothly around the joint, holding the pool width constant. Filler metal should be added only where the root opening is greater than zero. The pool should never be allowed to touch the groove radius. Care should be taken to keep the tungsten electrode centered over the joint root.

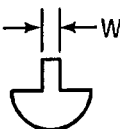
**6.8 Welding Pipe in the Horizontal Fixed (5G) Position.** Welding should be done in the upward direction when the pipe is in the 5G position, and the joint is in a vertical plane. (Refer to AWS A3.0, *Standard Welding Terms and Definitions*, for welding positions.) This normally requires starting the weld at the lowest point of the joint and proceeding upward from that point, although other starting points can be used to diminish shrinkage distortion.



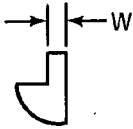
**Figure 4—Open Root Welding Angular Relations—Pipe, Torch, and Filler Metal**



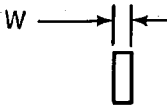
| Legend | Groove Type | Insert Classes                                |                                        |                                        |
|--------|-------------|-----------------------------------------------|----------------------------------------|----------------------------------------|
|        |             | Classes 1 and 4                               | Class 2                                | Classes 3 and 5                        |
| G      | A, B, C     | W + 1/32 in. (0.8 mm) max                     | W + 1/32 in. (0.8 mm) max              | W + 1/64 in. (0.4 mm) max              |
| Y      | A           | 0 to 1/32 in. max<br>(0 to 0.8 mm) max        | 0 to 1/16 in. (1.6 mm) max             | 0 to 1/32 in. (0.8 mm) max             |
| Y      | B, C        | 0 to 1/32 in. max<br>(0 to 0.8 mm) max        | 0 to 1/16 in. max<br>(0 to 1.6 mm) max | 0 to 3/32 in. max<br>(0 to 2.4 mm) max |
| R      | C           | 3/32 in. (2.4 mm) to 1/8 (3.2 mm)             |                                        |                                        |
| L      | B           | 3/32 in. + 0 - 1/32 in. (2.4 mm + 0 - 0.8 mm) |                                        |                                        |
| M      | C           | 3/32 in. ± 1/64 in. (2.4 mm ± 0.4 mm)         |                                        |                                        |
| X      | C           | 3/16 in. (4.8 mm) min                         |                                        |                                        |
| Z      | C           | 1/8 in (3.2 mm) min                           |                                        |                                        |



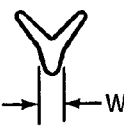
Class 1



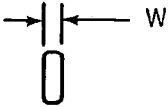
Class 2



Class 3



Class 4



Class 5

Figure 5—Groove Design and Tolerances for Use with Consumable Inserts

**6.9 Stop and Start Areas.** As the weld progresses around the pipe, it becomes necessary for the welder to stop welding and reposition himself. A foot control or a manual remote current control can be used to gradually reduce the current level and extinguish the arc. If such equipment is not available, the arc should be slowly moved up the groove face and gradually increased in length until it is extinguished. Rapid arc extinguishing may produce crater cracks.

## 7. Welding Using GTAW with Consumable Inserts

Consumable inserts are used for root pass welding of pipe where consistently high quality welds are required with minimum repairs or rejects. Detailed information on chemical composition, and dimensions, sizes, and styles are given in AWS A5.30, *Specification for Consumable Inserts*. The five shapes of consumable inserts and their mismatch tolerances are illustrated in Figure 6. Recommended groove designs for inserts are given in Figure 5.

For wall thicknesses of 0.20 in. (5 mm) or less, the smaller insert sizes are generally used; i.e., 1/8 in. (3.2 mm) size for classes 1, 2, and 4, and 1/16 x 1/8 in. (1.6 x 3.2 mm) size for classes 3 and 5. There is no thickness where the use of one insert size abruptly becomes unfeasible and another size becomes mandatory. There are ranges of thicknesses where two different sizes of the same shape of insert may be used. The choice may depend upon fabricator preference, the pipe chemical composition, or the economics of the job.

For general consideration, assembly tolerances for the various shape inserts are shown in Figure 6.

In many critical applications, the fabricator's internal process specifications for assembly tolerances may be more restrictive than those listed here. Some alloys, such as copper-nickel or nickel-copper, require closer tolerances for successful use of the inserts. Assembly tolerances may also be related specifically to wall thickness as shown in Figure 5.

All insert shapes are supplied in a wide variety of alloys covering many weldable pipe compositions. Normally, the chemical composition of the consumable inserts meets the same specification limits for filler metal used with inert gas welding processes.

Residual elements, inclusions, and gas content of the insert should be carefully controlled to minimize any weld defects. For carbon steel inserts, properly deoxidized material should be employed to assure sound, low-porosity welds, especially if a purge gas is not used. Contamination of Type 1 and Type 2 inserts by dirt or hydrocarbons is a common source of porosity; therefore, inserts should be cleaned using a solvent immediately prior to being tack welded in place.

**7.1 Welding Techniques for Consumable Inserts.** Figures 7 and 8 illustrate typical steps required for root pass welding with consumable inserts. Arc initiation should be as previously described; i.e., either high frequency starting or striking the arc on the groove face.

The electrode should be kept perpendicular to the work and be pointed radially toward the center of the pipe. An arc length of about 1/8 in. (3 mm) is satisfactory. Forward progression is governed by the melting rate of the consumable insert and the characteristics of the weld pool. Evidence of sufficient melting is shown by the increased fluidity and rising of the pool. When this occurs, the arc is advanced in a step-wise fashion.

When the arc is extinguished, a current decay device should be used to prevent crater cracks. If such a device is not available, the torch should be manipulated slowly up toward the groove face before the arc is extinguished.

**7.2 Pipe Axis Horizontal.** When the pipe axis is horizontal and the pipe is not rotated, the class 3 and 5 inserts are positioned eccentrically to promote good weld bead shape on the internal surface of the pipe. Figure 9 illustrates this.

## 8. Welding with SMAW and GMAW

Both the shielded metal arc welding process and the gas metal arc welding process are frequently used for open root welding of carbon and some low alloy steels, such as carbon-molybdenum.

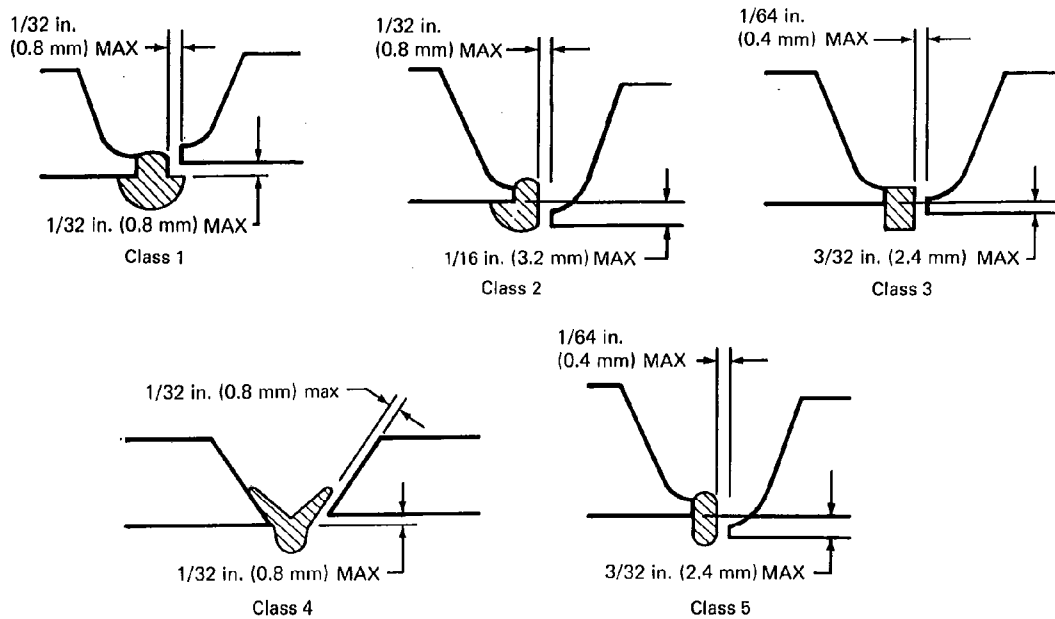
For additional information, see the latest edition of AWS D10.12, *Recommended Practices and Procedures for Welding Plain Carbon Steel Pipe*.

**8.1 Shielded Metal Arc Welding (SMAW).** E6010, E6011, E7011, or E7010-A1 electrodes are frequently used for welding a shielded metal arc root pass in carbon steel pipe. Low hydrogen type electrodes are not usually used for root pass welding.

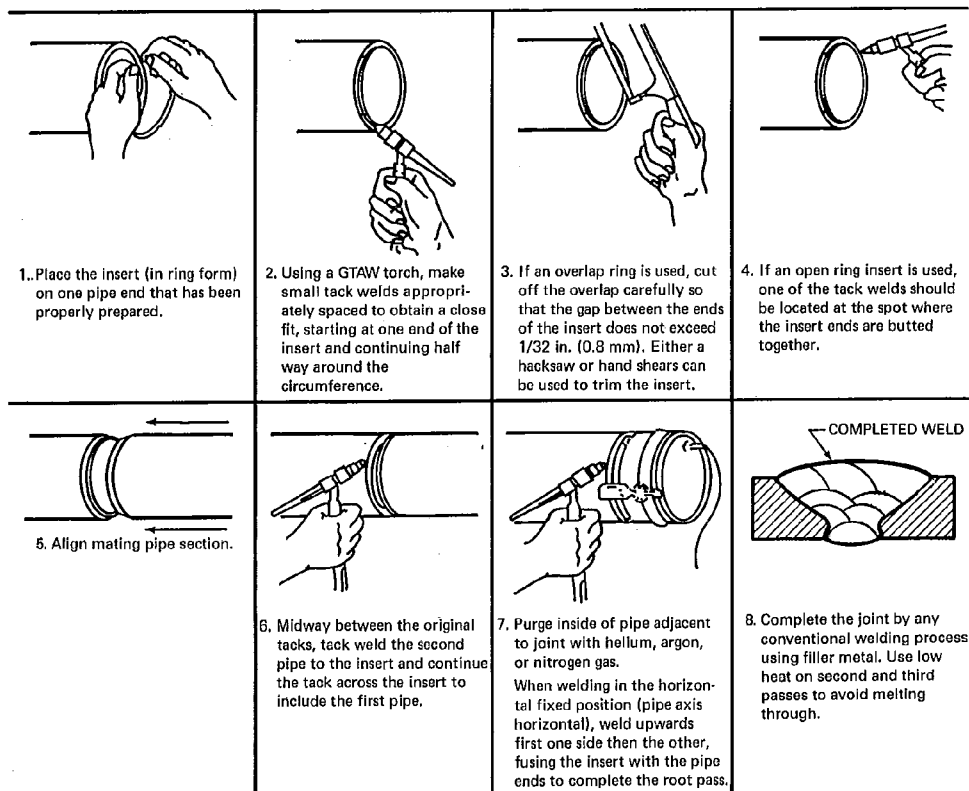
The SMAW process is not recommended for root pass welding alloys such as chromium-molybdenum steels, stainless steels, nickel, or copper alloys because most SMAW electrodes for these base metals are of the low hydrogen type, and complete joint penetration is difficult to obtain.

Purging of SMAW open root joints is not done. The turbulence of the arc defeats attempts at shielding the underside of the root bead by aspirating large amounts of air into the weld and negating the effects of the purge.

The most common joint design is a V-groove with a nominal 75-degree groove angle, a 1/16 in. (1.6 mm) root face, and a 1/16 in. (1.6 mm) root opening. To control heat input and prevent excessive root reinforcement, 3/32 in. (2.4 mm) diameter electrodes should be used. Travel speed and weaving technique should concentrate the force of the arc on the leading edge of the weld pool.



**Figure 6—Assembly Tolerances for Welding Pipe—Using Five (5) Classes of Consumable Inserts**



**Figure 7—Steps for Root Pass Welding with Classes 1, 2, 3, and 5 Consumable Inserts**

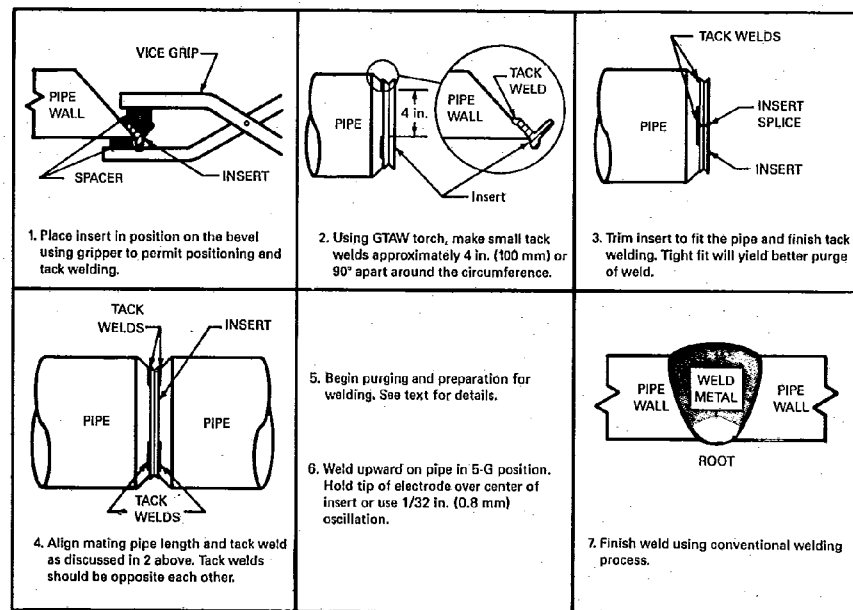


Figure 8—Steps for Root Pass Welding with Class 4 Consumable Inserts

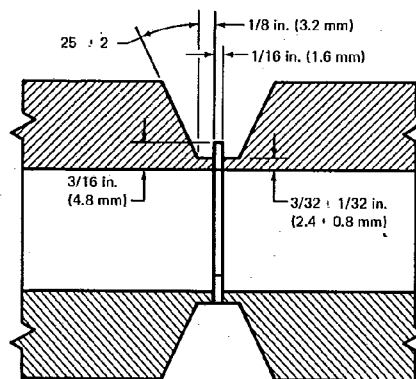


Figure 9—Eccentric Positioning of Class 3 and 5 Consumable Inserts in 5G Position to Prevent Sag

The root beads may be welded using either an upward or downward progression for the horizontal fixed position. Uphill welding usually produces fewer defects than downhill welding. It should be noted that the progression of root pass welding is an essential variable for the qualification of the welding procedure in AWS codes and for the welder in both AWS and ASME codes<sup>1</sup>. Therefore, for conformance to these codes, it is necessary to use in production the same direction of welding which was used in the qualification test.

**8.2 Gas Metal Arc Welding (GMAW).** When the gas metal arc welding process is used, short circuiting arc transfer is usually used on steel with an open root groove type. Welding voltages of 18 to 21 V and wire feed speeds in the vicinity of 150 in./min (64 mm/s) will provide a good starting point in the development of the welding procedure. The recommended wire diameter is either 0.035 in. (0.9 mm) or 0.030 in. (0.8 mm). Progression of vertical welds for root pass welding is usually downward. Purging is recommended for stainless and low alloy steels and nonferrous alloys, except aluminum. A V-groove design with a 75 degree groove angle, nominal 3/32 in. (2.4 mm) root face and a 3/32 in. (2.4 mm) root opening is recommended. Heat input and travel speed should be controlled to prevent excessive root reinforcement. The arc should be kept at the leading edge of the pool to ensure complete joint penetration.

When welding aluminum, copper or nickel alloy pipe using GMAW, normal practice is to weld the root using GTAW, and fill the weld using GMAW.

## 9. Intermediate Weld Layers

Once the root has been welded, visual inspection is recommended; thereafter, care should be taken to prevent melting through the root when making the second and third weld layers. Gas purging, when used, should be maintained until at least two additional layers have been welded. Maintaining the purge for these two layers is necessary, regardless of which welding process is used. These intermediate layers may be made with the GTAW, SMAW, or GMAW process. When using the SMAW process, small diameter electrodes [3/32 in. (2.4 mm)] should be used.

## 10. Welding of Aluminum Alloys

Techniques for welding aluminum alloy pipe should be designed around the fundamental characteristics of aluminum. The most relevant ones are

- the high melting temperature of aluminum oxide

- the tenacious attachment of the oxide to the metal and its rapid reformation when removed
- the high thermal conductivity of aluminum – about 2-1/2 times that of steel
- the high fluidity of molten aluminum
- the ability of molten aluminum to dissolve large quantities of hydrogen gas which, when trapped in the solidifying metal, causes porosity

Successful techniques have been developed using the gas shielded arc welding processes (GTAW, PAW, and GMAW) which remove the oxide and prevent its reformation by shielding the weld pool under an inert gas. They are high energy processes so that they permit relatively high welding speeds to overcome the effects of high thermal conductivity and the fluidity of the molten weld metal. A joint design consisting of a V-groove with a wide bottom (Figure 10), has been developed to permit control of the root pass and to ensure that a sound weld can be made with the gas shielded arc welding processes. Control of porosity is mainly a matter of ensuring thorough joint cleanliness before welding. Any residual oily substance or moisture can cause porosity. For this reason, the pipe ends should be carefully cleaned with a solvent just before assembly and wire brushed to remove the oxide just before welding. The details of these and all other necessary factors are given in AWS D10.7 *Recommended Practices for Gas Shielded Arc Welding of Aluminum Alloy Pipe*.

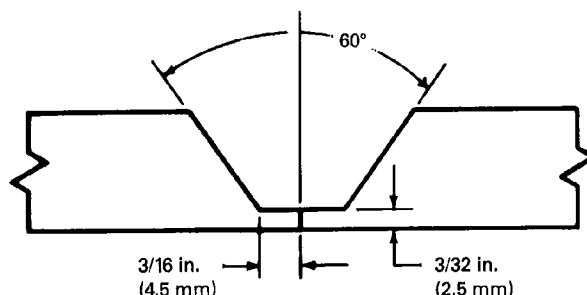


Figure 10—Joint design for Aluminum Pipe

## 11. Welding Equipment

**11.1 GTAW Torches.** An assortment of gas tungsten arc torches is readily available from welding equipment suppliers. Torches are either air-cooled or water-cooled. For most root pass welding, an air-cooled torch is adequate. The water-cooled torches require an auxiliary water supply. Water-cooled torches should be considered whenever high currents are used, such as for fill passes in large diameter piping, and for aluminum or copper welding.

1. Published by the American Society of Mechanical Engineers, 345 E. 47th St., New York, NY 10017.

**11.2 Gas Nozzles.** Gas nozzles are available in various sizes and configurations, including those with long nozzles for reaching into deep groove joints. For most root pass welding applications, gas nozzles with 3/8 in. (9.5 mm) or 1/2 in. (12.7 mm) orifice diameters should be used.

**11.3 Gas Lenses.** A gas lens is a screen insert which attaches to the torch body inside the gas nozzle. These lenses promote lamellar flow of the shielding gas and reduce turbulence and mixing of shielding gas with air. This reduces the possibility of porosity and provides a cleaner weld surface. Gas lenses are widely used in welding critical systems, particularly where radiographic inspection is required.

#### 11.4 Power Supplies

**11.4.1 Standard Power Supplies.** Standard dc power supplies with drooping volt-ampere curves (the type commonly used for shielded metal arc welding) can be used for gas tungsten arc welding. Machines best suited for gas tungsten arc welding of root passes are those in which the 10 to 15 V and 75 to 150 A ranges are well within the operating capacity of the power supply. Power supplies equipped with high frequency arc initiation and current upslope and downslope capabilities, or a remote current control (e.g., a foot pedal), have distinct advantages and should be used whenever possible.

While constant current power supplies are used for the GTAW and the SMAW processes, they are not suitable for GMAW. The latter requires a constant potential (constant voltage) power supply. This applies to both automatic and semiautomatic application.

**11.4.2 Pulsed Power Supplies.** GTAW and GMAW power supplies with pulsed current capabilities are available. These power supplies pulse the welding current from a low background level to a high peak level. The pulsing frequency and current wave shapes vary among different types of power supplies. The pulsed current provides easier control of the weld pool. It allows the use of a lower total heat input which reduces distortion, especially in stainless steel.

**11.5 Machine and Automatic Welding Equipment.** Equipment is commercially available for welding root and fill passes in both fixed position and the rolled positions. Equipment for welding pipe that can be rolled is mounted on a boom or a side-beam carriage, and the pipe is rolled beneath it. Equipment for welding in fixed positions is more sophisticated and can require considerable capital expenditure. Most designs have a motorized orbital welding head which is fastened to the pipe. Voltage sensing and automatic torch oscillating capabilities are available.

Automatic voltage control is essential for maintaining a constant arc length when the surface of the workpiece is uneven. Oscillation of the welding head allows the use of weaving instead of stringer beads. This may reduce the

number of weld passes required to fill the joint. The total welding time may thereby be reduced.

Pulsed current equipment is also available. It is especially useful for fixed position welding where greater weld pool control is required.

## 12. Safety and Health

Use of the welding processes and consumables described in this document is safe, provided proper procedures are followed and precautions taken. If these procedures and precautions are followed, welding can be done safely with minimal health risk.

**12.1 Fumes and Gases.** Fumes and gases can be dangerous to health. The welder's head should be kept out of the fumes. Use of enough ventilation, exhaust at the work, or both, to keep fumes and gases from the breathing zone and the general area is very important.

**12.2 Radiation.** Arc rays can injure the eyes. Infrared (heat) radiation can cause burns. Ultraviolet radiation can cause skin injury similar to sunburn.

**12.3 Electric Shock.** Electric shock can kill. Contact with live electrical components should be strictly avoided. Reading and understanding manufacturer's instructions and employer's safety practices should be mandatory.

**12.4 Fire Prevention.** A high-temperature heat source is always present in arc welding processes. Sparks can travel horizontally up to 35 ft (10.7 m) and fall much greater distances. They can pass through or lodge in cracks or holes in floors and walls.

Combustibles should always be removed from the work area or shielded from the welding operation.

**12.5 Explosion.** Flammable gases, vapors, and dust can form explosive mixtures with air or oxygen. Welding should never be done in an atmosphere where such materials could possibly be present.

**12.6 Burns.** Burns of the eye and body are serious hazards in arc welding. Recommended eye protection, welding helmets, and appropriate protective clothing should always be worn.

**12.7 Further Information.** It should be recognized that the above paragraphs give only a very brief coverage of the subject of safety in welding. Detailed coverage is available in the publications listed in Appendix A.

The primary source is ANSI/AWS Z49.1, *Safety in Welding and Cutting*, available from the American Welding Society, 550 NW LeJeune Road, P.O. Box 351040, Miami, Florida 33135.

## Appendix A

### Safety and Health

There are many factors involved in welding and allied processes which may have adverse effects on the safety and health of those individuals who work in, or who spend time in, areas where welding and allied operations are being performed.

Individuals and organizations using the processes described in this document should familiarize themselves with the safety and health aspects of the work to be done.

A series of twelve Fact Sheets on various aspects of welding safety originally published in the *Welding Journal*, is now available as part of the Safety and Health Information Packet compiled and distributed by the American Welding Society.

#### Supplementary Reading List

1. *Arc welding and cutting noise*. Miami Florida: American Welding Society, 1979.
2. Blachin, N.C. *Health and safety in welding and allied processes*, 3rd Ed. England: The Welding Institute, 1983.
3. *Cutting and welding processes*, ANSI/NFPA 51B-1977. Quincy, Massachusetts: National Fire Protection Association, 1979.
4. Dalziel, Charles F. Effects of electric current on man. *ASEE Journal*. June 1973: 18-23.
5. *Effects of welding on health I, II, III, and IV*. Miami, Florida: American Welding Society, 1979, 1981, 1983.
6. *Fumes and gases in the welding environment*. Miami, Florida: American Welding Society, 1979.
7. *Handbook of compressed gases*, 2nd. Ed. New York: Compressed Gas Association, 1981.
8. *Safe handling of compressed gases in containers*, P-1. New York: Compressed Gas Association, 1974.
9. *The facts about fume*. England: The Welding Institute, 1976.
10. *The welding environment*. Miami, Florida: American Welding Society, 1973.
11. *Ultraviolet reflectance of paint*. Miami, Florida: American Welding Society, 1979.
12. *Welding fume control with mechanical ventilation*, 2nd Ed. San Francisco: Fireman's Fund Insurance Companies, 1981.

Further detailed information may be found in one or more of the publications of the following organizations:

1. American Welding Society  
550 N. W. LeJeune Road  
P. O. Box 351040  
Miami, FL 33135
2. Occupational Safety and Health Administration (OSHA). All publications available from:  
Superintendent of Documents  
U. S. Printing Office  
Washington, DC 20402
3. American Conference of Governmental Industrial Hygienists (ACGIH)  
6500 Glenway Avenue  
Building D-5  
Cincinnati, Ohio 45211
4. National Institute for Occupational Safety and Health (NIOSH)  
4676 Columbia Parkway  
Cincinnati, Ohio 45211
5. National Fire Protection Association (NFPA)  
Batterymarch Park  
Quincy, Massachusetts 02269

## Appendix B

### Document List

The following is a complete list of the documents prepared by the AWS Committee on Piping and Tubing:

- AWS D10.4 Austenitic Chromium Nickel Stainless Steel Piping and Tubing, Recommended Practices for Welding
- AWS D10.6 Titanium Piping and Tubing, Recommended Practices for Gas Tungsten Arc Welding
- AWS D10.7 Aluminum and Aluminum Alloy Pipe, Recommended Practices for Gas Shielded Arc Welding
- AWS D10.8 Chromium-Molybdenum Steel Piping and Tubing, Recommended Practices for Welding
- AWS D10.9 Qualification of Welding Procedures and Welders for Piping and Tubing, Specification for
- AWS D10.10 Piping and Tubing, Local Heat Treatment of Welds in
- AWS D10.11 Root Pass Welding, Recommended Practices for
- AWS D10.12 Plain Carbon Steel Pipe, Recommended Practices and Procedures for Welding