



Guide for the Gas Shielded Arc Welding of Aluminum and Aluminum Alloy Pipe



**AWS D10.7M/D10.7:2008
An American National Standard**

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American National Standards Institute
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Guide for the Gas Shielded Arc Welding of Aluminum and Aluminum Alloy Pipe

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Prepared by the
American Welding Society (AWS) D10 Committee on Piping and Tubing

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This document presents information concerning those properties of aluminum which affect its weldability and which cause specific problems in the fabrication of aluminum pipe. Recommendations are made for solving these problems and suggested procedures are presented for welding aluminum pipe joints with the Gas Tungsten Arc and Gas Metal Arc Welding Processes.



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Foreword

This foreword is not part of AWS D10.7M/D10.7:2008, *Guide for the Gas Shielded Arc Welding of Aluminum and Aluminum Alloy Pipe*, but is included for informational purposes only.

The purpose of this guide is to facilitate the selection and specification of welding processes and procedures for aluminum and aluminum alloy pipe. These recommended practices are intended to provide information which may be used to minimize or avoid difficulties in the welding of such pipe. These recommended practices have been prepared by the Subcommittee on Aluminum Piping of the AWS Committee on Piping and Tubing. It is important to recognize that this publication does not present the only possible conditions for welding aluminum pipe. The data given are presented merely as initial guides to operating conditions.

The first edition of this document, AWS D10.7-60, was written to present the advances made in Aluminum Pipe welding during and subsequent to WWII. The second edition of this document was AWS D10.7-86 which updated AWS D10.7-60. AWS D10.7M/D10.7:2000, the third edition, changed the document from a *Recommended Practice* to a *Guide* and updated the processes and procedures. This fourth edition includes a comprehensive guide for selection of filler metal which incorporates selection criteria of weldability, strength, ductility, corrosion resistance, service temperature, and color matching.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS D10 Committee on Piping and Tubing, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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Guide for the Gas Shielded Arc Welding of Aluminum and Aluminum Alloy Pipe

1. Scope

This standard provides a summary of recommended industrial practices for welding piping¹ fabricated from aluminum alloys. Joint design, welding current, and shielding gas tables are included.

This standard makes use of both the International System of Units (SI) and the U.S. Customary Units. The latter are shown within brackets [] or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system must be used independently. Pipe sizes are listed as DN (diameter nominal) and NPS (nominal pipe size). The exact pipe diameters are listed in Annex A.

Safety and health issues and concerns are beyond the scope of this standard and therefore are not fully addressed herein. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

2. Normative References

The following standards contain provisions which, through reference in this text, constitute mandatory provisions of this AWS standard. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

AWS Documents:²

AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*

AWS A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*

AWS A5.10/A5.10M, *Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes*

AWS A5.12/A5.12M, *Specification for Tungsten and Tungsten Alloy Electrodes for Arc Welding and Cutting*

AWS A5.32/A5.32M, *Specification for Welding Shielding Gases*

AWS B2.1, *Standard for Welding Procedure and Performance Qualification*

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

3. History of Aluminum Pipe Welding

For many years, pipe was generally joined with threaded fittings. Improved welding techniques gradually caused a trend toward welded joints. Today, welded piping systems are specified in a wide variety of industries, including power, refrigeration, chemical, petroleum, industrial gas and air, and food processing.

Oxyfuel gas welding with oxyhydrogen or oxyacetylene was initially used for aluminum pipe. This process required the use of fluxes which had to be removed subsequent to welding, since they were a corrosion hazard to the pipe in the presence of moisture. Furthermore, welding, other than in the flat position, was very difficult. Both factors imposed a severe limitation on welded aluminum piping systems.

The development of the gas tungsten arc welding (GTAW) process during World War II provided a practical solution to the problems associated with oxyfuel gas welding aluminum pipe. The corrosion hazard resulting from the flux was eliminated by the inert gas shield and all-position welding techniques were developed. Subsequently, the gas metal arc welding (GMAW) process was

¹ The terms pipe and piping in this standard are intended to include tube and tubing where appropriate.

² AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

developed and provided a substantial reduction in pipe welding time for applications where this process was suitable.

4. Aluminum Pipe Alloys and Their Characteristics

Aluminum alloys have many characteristics which make them useful construction materials. Many of these properties, such as corrosion resistance, strength, light weight, protection of purity and color of the product transported, fracture toughness at cryogenic temperatures, and ease of fabrication are valuable in piping systems.

Many aluminum alloys are made in pipe form. The choice of the pipe alloy for a particular installation is made on the basis of the materials to be contained, the external exposure environment, and the service temperatures. For nominal chemical compositions, see Table 1. Alloy 3003-H112, a nonheat-treatable alloy containing manganese, provides adequate strength for many applications, together with high corrosion resistance. Alloy 6063-T6, a heat treated aluminum-magnesium-silicon alloy, provides higher strength and equivalent corrosion resistance. Alloy 6061-T6 is similar in characteristics to 6063-T6, but it has higher strength. In most environments, its corrosion resistance is equivalent to that of the 3003 and 6063 alloys. Alloys 5086 and 5083, non-heat-treatable aluminum-magnesium-manganese alloys, provide superior as-welded strength and high fracture toughness at ambient and cryogenic temperatures.

It should be noted that the heat associated with welding reduces both tensile strength and design allowable values for most aluminum alloys. For example, for 6061-T6 these values are reduced about one third. For nonheat-treatable alloys, the as-welded properties are normally those of the "O" temper (i.e., annealed) for that alloy, regardless of the starting temper.

Pipe in other alloys can be furnished for applications where high purity aluminum is required, where the design calls for higher strength, or where special corrosion resisting characteristics are desired. Alloys such as 1060, 5254, or 5652 may be used for high purity requirements. The 5254 and 5652 alloys are specially controlled purity versions of alloys 5154 and 5052. They belong to an important group of alloys which have magnesium as their principal alloying element.

Other alloys in this group are 5083, 5086, 5454, and 5456. These alloys are all nonheat-treatable but have excellent as-welded strength and ductility. They generally exhibit high corrosion resistance; however, maximum service temperature requirements must be carefully

investigated, since long time exposure to elevated temperature can adversely affect their corrosion resistance. Alloys 5052 and 5454 are recommended when sustained service temperatures are above 66°C [150°F]. Alloys 5083 and 5086 are used in marine applications. Alloy 5083 is favored for cryogenic applications.

Clad versions of the standard alloys are sometimes used for corrosion resistance under special conditions. In the clad products, an integral coating (usually 10% of the pipe wall thickness) of an alloy selected is used to provide cathodic protection to the core alloy. The presence of the cladding does not normally affect weldability. Combinations of alloys can be welded in most cases, and welding procedures should be based on core alloys. Annex A lists the diameters, wall thicknesses, and weights of aluminum pipe.

5. Welding Characteristics of Aluminum

The important characteristics of aluminum which affect its weldability are:

- (1) Refractory nature of aluminum oxide,
- (2) Lack of color change as the metal approaches the welding temperature,
- (3) High thermal conductivity, and
- (4) High coefficient of thermal expansion.

5.1 Aluminum Oxide. Aluminum and oxygen have a strong affinity for each other, and aluminum oxide instantaneously begins to form on aluminum surfaces exposed to air. This oxide film is thin, transparent, tenacious, and refractory with a melting temperature three times that of aluminum. An excessively thick oxide film that has become hydrated through exposure to moisture can cause welding difficulties and affect weld quality and should be removed by wire brushing before welding. The normal nonhydrated oxide film is removed progressively by the welding arc during the welding operation.

A flux is not required in gas tungsten arc welding (GTAW) or in gas metal arc welding (GMAW). The electric arc in both processes breaks up the aluminum oxide film, which is not an electrical conductor. A regulated flow of inert gas (either argon or helium, or a combination of both) around the arc area prevents reformation of oxide without contaminating the metal and permits the welder to deposit filler metal with a high degree of control. Gas purging of the pipe or gas shielding of the weld root is not normally necessary for aluminum pipe welds.

Table 1
Nominal Composition of Aluminum Alloys—Percent by Weight—
Aluminum and Normal Impurities Constitute Remainder

Alloy	Silicon	Copper	Manganese	Magnesium	Chromium	Zinc	Titanium	Aluminum and Others
Wrought Alloys								
1060								99.60 min.
1100 ^a		0.12						99.00 min.
1350								99.50 min.
2319 ^a	0.20	5.8–6.8	0.20–0.40	0.02		0.10		Remainder
3003		0.12	1.2					Remainder
3004			1.2	1.0				Remainder
4043 ^a	5.2							Remainder
4047 ^a	12.0							Remainder
4145 ^a	10.0	4.0						Remainder
4643 ^a	3.6–4.6	0.10	0.05	0.10–0.30		0.10		Remainder
5050				1.4				Remainder
5052				2.5	0.25			Remainder
5083			0.7	4.5	0.15			Remainder
5086			0.45	4.0	0.15			Remainder
5154				3.5	0.25			Remainder
5183 ^a			0.8	4.7	0.15			Remainder
5254				3.5	0.25			Remainder
5356 ^a			0.12	5.0	0.12		0.12	Remainder
5454			0.8	2.7	0.12			Remainder
5456			0.8	5.1	0.12			Remainder
5554 ^a			0.8	2.7	0.12		0.12	Remainder
5556 ^a			0.8	5.1	0.12		0.12	Remainder
5652				2.5	0.25			Remainder
5654 ^a				3.5	0.25		0.1	Remainder
6061	0.6	0.27		1.0	0.20			Remainder
6063	0.4			0.7				Remainder
6101	0.5			0.6				Remainder
6351	1.0		0.6	0.6				Remainder
7072						1.0		Remainder
Cast Alloys								
356.0	7.0			0.30				Remainder
443.0	5.2							Remainder
514.0				4.0				Remainder

^a Beryllium 0.0003% maximum for welding electrodes and rods only.

5.2 No Color Change. There is no visible color change in aluminum as it is heated from room temperature to welding temperature. Therefore, the welder must pay careful attention to the area being heated to observe when melting begins and control the flow of metal when visible melting begins.

5.3 High Thermal Conductivity. Since aluminum is an excellent heat conductor, a different welding technique is required from that for steel, which has lower heat conductivity. Welding currents and welding speeds are generally higher for aluminum. Stringer beads are generally used, although the final pass is sometimes welded with a weaving technique.

5.4 High Coefficient of Thermal Expansion. Aluminum expands about twice as much as steel for a given increase in temperature. This can be an advantage where the joint is loosely fitted in preparation for welding, since the joint will tend to close as the temperature rises. It can also be a disadvantage when joints are tightly fitted because expansion forces can increase the metal thickness at the joint. Measurements have shown that up to about 3 mm [0.12 in] shrinkage will occur when butt joints are welded in Schedule 40 pipe (see Table A.1) in sizes through DN 300 [NPS 12]. The gas metal arc welding process with its concentrated heat and its lower heat input generally causes less shrinkage than does the gas tungsten arc welding process.

5.5 Weldability of Aluminum Alloys. Aluminum is alloyed with small amounts of other metals to develop specific characteristics such as high strength. To the welder, aluminum and its weldable alloys appear much alike while being welded. During solidification, the contraction strains which occur may be sufficient to cause cracking unless proper procedures and filler metals are used. The cracks may occur either in the weld metal or in the heat-affected zone (HAZ) of the base metal. Commercially pure aluminum and the lower strength alloys (for example, 1100 and 3003) are not generally susceptible to cracking. However, the higher strength alloys such as 6061 or 6063 tend to be susceptible to hot cracking, especially if filler metal of the same composition as the base metal is used.

Welding these alloys autogenously (i.e., without filler metal) will almost always result in cracking. For this reason, 6061 and 6063 alloys are welded with filler metals having enough silicon or magnesium, for example 4043 or 5356, to produce a crack resistant composition in the weld. Because pipe is often exposed to particularly corrosive environments, filler metal alloys are often selected to give best corrosion resistance. When filler metals differing in composition from the base metal are used to eliminate solidification cracking (as in the case of 6061

or 6063 alloy), the weld metal should consist of about 70% added filler metal diluted with not more than 30% base metal. This may require beveling the joint, increasing the root opening, or limiting the amount of base metal melted.

6. Welding Processes and Equipment

6.1 Alternating Current Gas Tungsten Arc Welding (GTAW). A gas tungsten arc method commonly used for aluminum pipe welding uses alternating current (ac), a tungsten electrode, and argon gas or a mixture of argon and helium. The arc provides good cleaning and excellent oxide film dispersion with this method. Welding with the use of high frequency is power source dependent; high frequency may be necessary to aid arc initiation during reversal of current, thus stabilizing the arc. This process gives a clean, bright weld pool which is clearly visible and easily controlled.

A balanced wave ac arc gives adequate cleaning action for most applications and divides the arc heat about evenly between electrode and weld pool. There are some GTAW power sources for ac welding that allow for adjustment of the balance between polarities (% electrode positive and % electrode negative) this enables the user to choose either enhanced arc cleaning (Electrode Positive) or greater penetrating power (Electrode Negative).

The welding technique is not difficult for an experienced GTAW welder. Although pure tungsten electrodes may be used, zirconiated tungsten electrodes are often used for alternating current GTAW. They have higher current capacity than pure tungsten electrodes of equal size.

6.2 Direct Current Electrode Negative (DCEN). Another gas tungsten arc method uses direct current electrode negative, a tungsten electrode, and pure helium shielding gas. With this method, and the use of smaller electrodes of 1% or 2% thoriated tungsten (AWS A5.12/5.12M-98 (R2007), Classification EWTh-X) or 1.5% or 2% lanthanated tungsten (AWS A5.12/A5.12M-98 (R2007), Classification EWLX-X), a more concentrated arc is obtained. This results in deeper joint penetration than with ac (alternating current) welding. The weld pool does not appear as fluid as with an ac arc. This method requires much more skill by the welder, and for this reason, if used, is often mechanized. It also requires much more thorough precleaning of the joint, and interpass cleaning, since there is no arc cleaning action during the DCEN welding.

6.3 Gas Metal Arc Welding (GMAW). Gas metal arc welding uses direct current electrode positive (DCEP). Motor or engine driven generators, transformer-rectifier

machines, or inverter power supplies may be used and may be either constant current (drooping) or constant voltage type. Constant speed wire feeders are most commonly used. With constant current (drooping) power sources the wire feeder control requires a scratch or slow-speed starting feature. With true constant current power sources, i.e., having a vertical volt-ampere characteristic curve, voltage feedback from the arc is necessary to control electrode speed. The method of metal transfer should be spray transfer or pulsed spray transfer. Globular transfer is not appropriate for welding aluminum due to excessive spatter and unstable arc. Other than for specific applications, short circuiting transfer is not appropriate for welding aluminum because the weld may be prone to lack of fusion defects.

6.4 Automatic Welding. Equipment has been developed for both machine and automatic gas shielded welding of aluminum pipe. The design and operation of this type of equipment permit controlled use of the characteristic high speed of gas metal arc welding in the joining of pipe in the horizontal fixed (5G) position. Equipment of this type has been successfully used on a number of pipe line jobs in the field. Constant voltage, constant current, and pulsed current power sources have proved successful.

Automated equipment has also been developed for gas tungsten arc welding of aluminum pipe.

7. Welding Materials

7.1 Tungsten Electrodes. As discussed previously, pure tungsten or zirconiated tungsten electrodes are used for ac gas tungsten arc welding. For direct current gas tungsten arc welding, 1% or 2% thoriated tungsten [AWS A5.12/5.12M-98 (R2007), Classification EWTh-X] or 1.5% or 2% lanthanated tungsten electrodes [AWS A5.12/5.12M-98 (R2007), Classification EWLX-X] are used. Electrode sizes are listed in Table 2 and Tables 4 through 11.

7.2 Filler Metals. Often it is possible to weld one specific aluminum base alloy with a number of different filler alloys. In order to select the most appropriate filler alloy for a particular application, the various filler alloys and their specific performance characteristics must be understood. These characteristics are:

- (1) Weldability—Ease of welding/crack sensitivity,
- (2) Strength of welded joint,
- (3) Ductility,
- (4) Corrosion resistance,
- (5) Service temperature,

(6) Color match if the part is to be anodized after welding, and

(7) Ability to respond to postweld heat treatment.

The selection of a filler alloy for welding aluminum must be based on the welded component's performance requirements and the completed component's operating conditions. See Table 3 for a guide to the choice of filler metal for welding aluminum pipe.

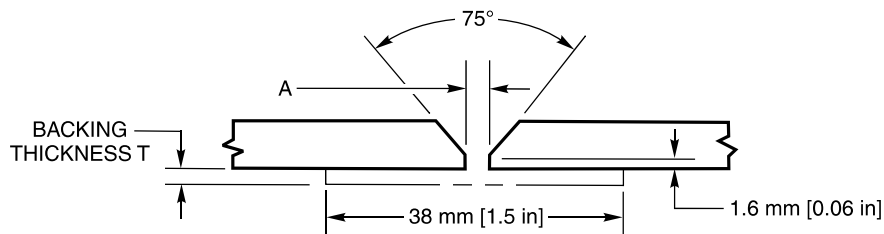
7.2.1 Weldability (W). Ease of welding describes the relative freedom from weld cracking. By use of solidification cracking sensitivity curves for the various aluminum alloys, and estimating the dilution between filler alloy and base alloy, it is possible to establish the filler alloy/base alloy crack sensitivity and probability rating. A good example is alloy 6061 which should not be GTAW welded autogenously (without filler material) as the chemical composition of the base material is such that it will crack during solidification. Filler alloy of a different chemical composition than the base alloy must be used in order to adjust the weld metal chemical composition and thereby reduce the crack sensitivity. This is the reason why there is no 6xxx series filler alloy.

7.2.2 Strength of Welded Joint (S). Consideration should be given to the variation in tensile strength of groove welds and shear strength of fillet welds when welded with different filler alloys. Typically in aluminum, the as-welded transverse tensile strength of a groove weld is controlled by the condition of the heat-affected zone (HAZ) of the base material. The condition of the HAZ is normally the fully-annealed strength of the base alloy in the case of the nonheat-treatable alloys and the partially-annealed and over aged strength in the case of the heat-treatable alloys. However, the shear strength of a fillet weld is largely determined by the filler alloy and not necessarily the condition of the base alloy. The typical shear strength properties of the various filler alloys are quite different and can be seen in Table 4.

7.2.3 Ductility (D). This can be a consideration when forming operations are to be used after welding. It can also be a design consideration for service. Typically the 5xxx series filler alloys will have improved ductility characteristics over that of the 4xxx series.

7.2.4 Corrosion Resistance (C). The environmental service conditions of the weld may influence the selection of filler metal. Although this is not usually of major consideration for normal operating environments, it can be of major importance when operating in corrosive chemical environments. There are some aluminum base alloys and filler alloys designed for specific chemical applications.

Table 2
Gas Tungsten Arc Welding—Alternating Current
in the Flat Position (With Backing)



EDGE PREPARATION

A = 0 FOR NO BACKING RING OR REMOVABLE BACKING RING

A = 6 mm [0.24 in] MAXIMUM FOR INTEGRAL BACKING RING

Piping Dimensions												
Nominal Pipe Diameter Size Number			Outside Diameter (OD)		Wall Thickness							Welding Rod Diameter
DN	NPS	Sch.	mm	[in]	mm	[in]	mm	[in]	amp	mm	[in]	
25	1	40	33.4	[1.31]	3.4	[0.13]	2.4–3.2	[0.094–0.125]	100–115	1.8	[0.07]	1–2
32	1-1/4	40	42.2	[1.66]	3.6	[0.14]	2.4–3.2	[0.094–0.125]	110–135	1.8	[0.07]	1–2
40	1-1/2	40	48.3	[1.90]	3.7	[0.14]	2.4–3.2	[0.094–0.125]	115–140	1.8	[0.07]	1–2
50	2	40	60.3	[2.37]	3.9	[0.15]	2.4–3.2	[0.094–0.125]	125–150	2.4	[0.09]	1–2
65	2-1/2	40	73.0	[2.87]	5.2	[0.20]	2.4–3.2	[0.094–0.125]	140–180	2.4	[0.09]	2
80	3	40	88.9	[3.50]	5.5	[0.22]	3.2–4.0	[0.125–0.156]	150–190	2.4	[0.09]	2
90	3-1/2	40	101.6	[4.00]	5.7	[0.23]	3.2–4.0	[0.125–0.156]	160–200	2.4	[0.09]	2
100	4	40	114.3	[4.50]	6.0	[0.24]	3.2–4.8	[0.125–0.188]	170–210	3.2	[0.13]	2
125	5	40	141.3	[5.56]	6.6	[0.26]	4.0–4.8	[0.156–0.188]	190–230	3.2	[0.13]	2
150	6	40	168.3	[6.63]	7.1	[0.28]	4.0–4.8	[0.156–0.188]	210–250	5	[0.20]	2
200	8	40	219.1	[8.63]	8.2	[0.32]	4.0–4.8	[0.156–0.188]	220–260	5	[0.20]	2–3
250	10	40	273.1	[10.75]	9.3	[0.37]	4.0–4.8	[0.156–0.188]	240–280	5	[0.20]	2–3
300	12	40	323.9	[12.75]	10.3	[0.41]	4.0–4.8	[0.156–0.188]	250–290	5	[0.20]	2–3

^a More passes are required when A = 6 mm [0.24 in].

Notes:

1. Tungsten electrode diameter is 3.2 mm [0.125 in] for DN 25 through 90 (NPS 1 through 3-1/2) pipe size and 5.0 mm [0.187 in] for DN 100 through 300 (NPS 4 through 12).
2. Gas nozzle orifice diameter is 11 mm [0.44 in] for DN 25 through 65 (NPS 1 through 2-1/2) pipe size and 13 mm [0.5 in] for DN 65 through 300 (NPS 2-1/2 through 12) pipe size.
3. Argon flow rate is 12 L/min to 20 L/min [25 ft³/h to 42 ft³/h].
4. The higher flow rate is needed for the overhead quadrant.

7.2.5 Sustained High Temperature Service (T). The reaction of some filler alloys and base alloys at sustained elevated temperatures may promote premature component failure due to stress corrosion cracking. High temperature applications for aluminum alloys are generally accepted as being operating temperatures above 65.5°C [150°F]. As a general rule, the magnesium base alloys and filler alloys with more than 3.0% Mg content are considered not suitable for these temperature applications. There are specific base alloys such as 5052 and 5454 and filler alloys such as 5554, which have been designed with controlled magnesium and are suitable for elevated temperature applications. The 4xxx series filler alloys are also suitable for elevated temperature applications.

7.2.6 Color Match After Anodizing (M). Base alloy and filler alloy color match after anodizing can be of major concern in some cosmetic applications. The most common problem is welding the 6xxx series base materials with the 4xxx series filler alloys. This will result in the weld turning a very dark gray color after the anodizing operation. If anodizing is to be performed after welding a 6xxx series base alloy a 5xxx filler alloy such as 5356 is probably the most appropriate to use.

7.2.7 Postweld Heat Treatment. The ability of the filler alloy to respond to postweld heat treatment is an important consideration. It is sometimes required that the filler metal be able to develop properties similar to the base metal after heat treatment. The common filler alloys are not heat-treatable alloys; however there are some specialized filler alloys, which have been designed to respond to heat treatment. The most common being filler alloy 4643, which was designed to weld the 6xxx series base materials and fully respond to postweld heat treatment. There are also heat-treatable filler alloys available for some of the 2xxx series heat-treatable base alloys and some of the heat-treatable aluminum castings.

7.2.8 Specialized Applications. In addition to the above, there are some general considerations with regard to fillers metals selection for specific applications; these are:

(1) Filler alloy 4043, which is a 5% silicon alloy, is used for some structural applications, but should not be used on 5xxx series base alloys containing more than 2.5% Mg;

(2) Filler alloy 4047, which is a 12% silicon alloy, has higher fluidity than 4043, and for this reason, is often used for creating leak-tight joints in thinner sections of material. 4047 should also not be used on 5xxx series base alloys containing more than 2.5% Mg;

(3) Filler alloy 5356 can be used for structural applications and will provide higher shear strength over that of 4043 (see Table 4); and

(4) Filler alloy 5554 is recommended for components that operate at elevated temperature above 65.5°C [150°F].

7.2.9 There are many considerations relating to the selection of the most suitable filler alloy for a specific base alloy and completed product application. The understanding of these variables is a significant aspect in the correct design and development of a successful welding procedure specification.

7.3 Inert Gas. Argon is the preferred gas for most gas shielded arc welding applications. A mixture of helium and argon is employed for some applications such as gas metal arc welding with 5XXX filler alloys and for greater penetration in ac GTAW. Helium is necessary for DCEN welding with the GTAW process. In all cases, welding grade gases are required (AWS Classification SG-A, AWS A5.32/A5.32M, *Specification for Welding Shielding Gases*).

8. Welding Preparation

Open root welding and consumable insert welding do not generally work well for aluminum piping. Because of this, the recommended practices are to weld using either temporary or permanent backing rings, shown in Tables 2, 5, and 9 through 12, or to weld using a U-groove extended land preparation, shown in Tables 6, 7, and 8. No back purge for the interior of the pipe is required if these recommended practices are used.

For heat-treatable aluminum alloys, 3 mm [1/8 in] of material should be removed from plasma arc cut edges by machining, except that plasma-arc cut edges of heat-treatable aluminum alloy material may be used without machining when the cut area is separated from the immediate weld area and is not part of the welded joint.

The ends of the aluminum pipe are generally prepared for welding by machining. Oxyfuel gas cutting of the edge, as is done in steel, is not possible, but plasma arc cutting can be used for beveling. Pipe can be ordered with standard welding bevels, as shown in Figure 1, or with the preparation for a U-groove, shown in Figure 2, on special order. The U-groove preparation is recommended for manual gas tungsten arc welding using alternating current. Pipe ends must be thoroughly cleaned prior to assembly to remove all foreign substances that could cause porosity or weld inclusions. Solvents or other cleaning materials must not be used after the joint has been assembled due to the possibility that solvent

Table 3
Guide to Choice of Filler Metal for Welding Aluminum Pipe

Base Alloys	Filler Alloys	1060,1070, 1080,1350	1100	2014, 2036	2219	3003, ALCLAD 3003	3004	5005, 5050	5052, 5652
Characteristics		W S D C T M	W S D C T M	W S D C T M	W S D C T M	W S D C T M	W S D C T M	W S D C T M	W S D C T M
319.0,333.0, 354.0,355.0, C355.0,380.0	2319 4043/4047 4145	B A A A A A A A B A A A	B A A A A A A A B A A A	B A A A A A C C B C A A A B C B A A	B A A A A A C C B C A A A B C B A A	B B A A A A A A B A A A	B B A A A A A A B A A A	B B A A A A A A B A A A	A A A A A A
413.0,443.0, 444.0,356.0, A356.0,A357.0, 359.0	4043/4047 4145 A356.0 A357.0 5356	A A A A A A A A B B A A	A A A A A A A A B B A A	B B A A A A A A B A A A	B B A A A A A A B A A A	A A A A A A A A B B A A	A A A A A A A A B A A A	A A A A A A A A B A A A	A B A A A A
7005,7021, 7039,7046, 7146,710.0, 711.0	4043/4047 4145 5183 5356 5554 5556 5654	A A C A A A B A B A A A B A B A A A	A A C A A A B A B A A A B A B A A A	B B A A A A A A B A A A	B B A A A A A A B A A A	A B C A A A B A B A A A B A B A A A	A D C B A A B B A A A A C C A A A A B A B A A A C C A A A B	A B C B A A B A B A A A C A A A A A B A B A A A C A A A A A	B D C B A A A A B A A A B C A A A A A A B A A A B C A A A A
6061, 6070	4043/4047 4145 4643 (1) 5183 5356 5554 5556 5654	A A C A A A A A D B A A B A B A A A B A A A A A B A B A A A	A A C A A A A A D B A A B A B A A A B A A A A A B A B A A A	B B A A A A A A B A A A	B B A A A A A A B A A A	A B C A A A A A D B A A B A B A A A B A A A A A B A B A A A	A D C A A A B C D B A A B A B A A A B B A A A A B A B A A A	A B C A A A A B D B A A B A B A A A B A A A A A B A B A A A	A D C A A A B A B C B A B B A C B A C C A B C B C C A B A A
6005,6063, 6101,6151, 6201,6351, 6951	4043/4047 4145 4643 (1) 5183 5356 5554 5556 5654	A A C A A A A A D B A A B A B A A A B A A A A A B A B A A A	A A C A A A A A D B A A B A B A A A B A A A A A B A B A A A	B B A A A A A A B A A A	B B A A A A A A B A A A	A B C A A A A A D B A A B A B A A A B A A A A A B A B A A A	A D C A A A B C D B A A B A B A A A B B A A A A B A B A A A	A B C A A A A B D B A A B A B A A A B A A A A A B A B A A A	A D C A A A B A B C B A B B A C B A C C A B A B C C A B A A
5454	4043/4047 5183 5356 5554 5556 5654	B A B B A A C A A A A A C A A A A A B A B B A A	B A B B A A B A A B A A C A A A A A B A B B A A			B A B B A A B A A B A A C A A A A A B A B B A A	B A B B A A B B A B A A C C A A A A B A B B A A	B A B B A A B A A B A A C A A A A A B A B B A A	A A A B A A A B A B A A C C A A A A B C A B A A
511.0,512.0, 513.0,514.0, 535.0, 5154,5254	4043/4047 5183 5356 5554 5556 5654	B A B B A A B A A B A A C A A A A A B A B B A A C A A A A B	B A B B A A B A A B A A C A A A A A B A B B A A C A A A A B			B A B B A A B A A B A A C A A A A A B A B B A A C A A A A B	B A B B A A B B A B A A C C A A A A B A B B A A C C A A A B	B A B B A A B A A B A A C A A A A A B A B B A A C A A A A B	A A B B A A A B A B A A C C A A A A A C A B A A B C A A A A
5086,5056	4043/4047 5183 5356 5554 5556 5654	A A B A A A A A A A A A A A B A A A	A A B A A A A A A A A A A A B A A A			A A B A A A A A A A A A A A B A A A	A A B A A A A A B A A A A A B A A A	A A B A A A A A A A A A A A B A A A	A A B A A A A B A A A A C C A A A A A A B A A A B C A A A B
5083,5456	4043/4047 5183 5356 5554 5556 5654	A A B A A A A A A A A A A A B A A A	A A B A A A A A A A A A A A B A A A			A A B A A A A A A A A A A A B A A A	A A B A A A A A B A A A A A B A A A	A A B A A A A A A A A A A A B A A A	A A B A A A A B A A A A C C A A A A A A B A A A B C A A A B
5052,5652	4043/4047 5183 5356 5554 5556 5654	A B C A A A B A B A A A B A A A A A B A B A A A	A B C A A A B A B A A A B A A A A A B A B A A A			A B C A A A B A B A A A B A A A A A B A B A A A	A B C A A A B A B A A A B A A A A A B A B A A A	A B C A A A B A B A A A B A A A A A B A B A A A	A D C B A A A A B C B A A B A C A A C C A B C B B C A B A A
5005,5050	1100 4043/4047 4145 5183 5356 5556	C B A A A A A A C A A A B A D B A A C A B B A A C A B B A A C A B B A A	C B A A A A A A C A A A B A D B A A C A B B A A C A B B A A C A B B A A			C C A A A A A B C A A A B B D B A A C A B C B A C A B C B A C A B C B A	A B C A A A B A B A A A B A A A A A B A B A A A	B A A A A A A B D A A A B A C B A A B A B A A A B A B A A A B A B A A A	1100 4043/4047 4145 5183 5356 5556
3004	1100 4043/4047 4145 5183 5356 5554 5556	D B A A A A A A C A A A B A D B A A C A B B A A C A B B A A C A B B A A	D B A A A A A A C A A A B A D B A A C A B B A A C A B B A A C A B B A A			C C A A A A A B C A A A B B D B A A C B C B A A C A B C A A C B C B A A	A B D A A A B A C C A A B B B C A A C C A B A A B A C C A A	1100 4043/4047 4145 5183 5356 5554 5556	
3003, ALCLAD 3003	1100 4043/4047 4145	B B A A A A A A B A A A A A C B A A	B B A A A A A A B A A A A A C B A A	B A A A A A A A B A A A	B A A A A A A A B A A A	A A A A A A A A B A A A A A C B A A	B B A A A A A A B A A A A A C B A A		
2219	2319 4043/4047 4145	B A A A A A A A B A A A	B A A A A A A A B A A A	B A A A A A B C B C A A A B C B A A	B A A A A A B C B C A A A B C B A A	2319 4043/4047 4145			
2014,2036	2319 4043/4047 4145	B A A A A A A A B A A A	B A A A A A A A B A A A	C A A A A A B C B C A A A B C B A A	2319 4043/4047 4145				
1100	1100 4043/4047 5356	B B A A A A A A B A A A	B B A A A A A A B A A A	1100 4043/4047 5356					
1060,1070, 1080,1350	1100 1188 4043/4047	B B A A A A C C A A A A A A B A A A	1100 1188 4043/4047						

(Continued)

Table 3 (Continued)
Guide to Choice of Filler Metal for Welding Aluminum Pipe

5083, 5456	5086, 5056	511.0, 512.0, 513.0, 514.0, 535.0, 5154, 5254	5454	6005, 6063, 6101, 6151, 6201, 6351, 6951	6061, 6070	7005, 7121, 7039, 7046, 7146, 710.0, 711.0	413.0, 443.0, 444.0, 356.0, A356.0, A357.0, 359.0	319.0, 333.0, 354.0, 355.0, C355.0, 380.0	
W S D C T M	W S D C T M	W S D C T M	W S D C T M	W S D C T M	W S D C T M	W S D C T M	W S D C T M	W S D C T M	
A A A A A	A A A A A	A A A A A	A A A A A	B B A A A A A A B A A A	B B A A A A A A B A A A	B B A A A A A A B A A A	B B A A A A A A B A A A	B A A A A A A B B B A A	2319 4043/4047 4145
				A B A A A A A A B B A	A B A A A A A A B B A	A B B A A A A A B B A	A B A A A A A A B B A B A A A A A A A A A A A A	4043/4047 4145 A356.0 A357.0 5356	
A A B A A A B A A A A A B A A	A A B A A A B A A A A A B A A	A A B A A A B A A A B C A A A A A B A A B C A A A	A A B A A A B A A A B C A A A A A B A A B C A A A	A D C B A A A B A A A A B A A A A B C A A A A A A B A A A B C A A A A	A D C B A A A B A A A A B A A A A B C A A A A A A B A A A B C A A A A	B D C B A A A B A A A A B A A A A B C A A A A A A B A A A B C A A A A	4043/4047 4145 5183 5356 5554 5556 5654		
A A B A A A B A A A B C A A A A A B A A B C A A A	A A B A A A B A A A B C A A A A A B A A B C A A A	B A B C B B B A C A C C A A B B A B C B C C A A B	B A B C A B B A C A C C A A A B A B C A C C A A B	A C B A A A C B A A A B A A C A A B B A C A A C B A A B A B A A C A A C B A A B A	A C B A A A C B A A A B A A C A A B B A C A A C B A A B A B A A C A A C B A A B A	4043/4047 4145 4643 (1) 5183 5356 5554 5556 5654			
A B C A A A A B A A A A A A A B A A A A A A B A A B A A A A	A B C A A A A B A A A A A A A B A A A A A A B A A B A A A A	A B C A A B A B C A C A A A B B A B C A C A A A B	A B C B A B A B C A C A A A A B A B C A C A A A B	A C B A A A C B A A A B A A C A A C B A A B A B A A C A A C B A A B A	4043/4047 4145 4643 (1) 5183 5356 5554 5556 5654				
A A B B A A B A B A B C A A A A A B B A	A A B B A A B A B A B C A A A A A B B A	A A B B A A B A B A B C A A A A A B B A	A A B B A A B A B A B C A A A A A B B A	4043/4047 5183 5356 5554 5556 5654					
A A B A A A B A A A B C A A A A A B A A B C A A A	A A B A A A B A A A B C A A A A A B A A B C A A A	A A B B B A B A B A B C A A A A A B B A	4043/4047 5183 5356 5554 5556 5654						
A A B A A A B A A A B C A A A A A B A A	A A B A A A B A A A B C A A A A A B A A	4043/4047 5183 5356 5554 5556 5654							
A A B A A A B A A A B C A A A A A B A A	A A B A A A B A A A B C A A A A A B A A	4043/4047 5183 5356 5554 5556 5654							
A(2) B A A A A A A A A A B A A	4043/4047 5183 5356 5554 5556 5654								
4043/4047 5183 5356 5554 5556 5654									

Symbol	Characteristic
W	Weldability/Ease of welding (relative freedom from weld cracking)
S	Strength of welded joint ("as-welded" condition). (Rating applies particularly to fillet welds. All rods and electrodes rated will develop presently specified minimum strengths for butt welds)
D	Ductility (Rating is based upon the free bend elongation of the weld)
C	Corrosion resistance in continuous or alternative immersion in fresh or salt water
T	Temperature service (Recommended for service at sustained temperatures above 150°F [65.5°C])
M	Match in color after anodizing
A, B, C, and D are relative ratings in decreasing order of merit. The ratings have relative meaning only within a given block.	

How to Use

- Select base alloys to be joined (one from the side blue column, the other from the top blue row).
- Find the block where the column and row intersect.
- This block contains horizontal rows of letters (A, B, C, or D) representative of the alloy directly across from them in the filler alloy box at the end of each row. The letters in each line give the A-to-D rating of the characteristics listed at the top of each column—W, S, D, C, T, and M (see Legend at right for explanation of each letter).
- Analyze the weld characteristics afforded by each filler alloy. You will find that you can "trade off" one characteristic for another until you find the filler that best meets your needs.

Example

When joining base alloys 3003 and 1100, find the intersecting block. Note that filler alloy 1100 provides an (A) rating for ductility (D), corrosion resistance (C), performance at elevated temperatures (T), and color match after anodizing (M), and a (B) rating for ease of welding (W) and strength (S). However, if ease of welding and shear strength are important, and ductility and color match can be sacrificed slightly, then filler alloy 4043 can be used.

Note: Combinations having no rating are not usually recommended. Ratings do not apply to these alloys when heat treated after welding.

(1) 4643 is a heat-treatable filler alloy and gives higher strength in 6xxx series weldments after postweld solution heat treatment and aging.

(2) An "A" rating for alloy 5083 to 5083 and 5083 to 5456. No rating for alloy 5456 to 5456.

4047 can be used in lieu of 4043. Alloy 4047 provides increased fluidity for welding leak-tight joints, minimizes solidification cracking, and has a slightly higher fillet weld shear strength.

Table courtesy of Alcoa Wire Corp., a member of the ESAB Group, Inc.

Table 4
Typical Shear Strength of Filler Alloys

Filler Alloy	Longitudinal Shear Strength MPa [ksi]	Transverse Shear Strength MPa [ksi]
1100	52 [7.5]	52 [7.5]
2319	112 [16.0]	112 [16.0]
4043	80 [11.5]	105 [15.0]
4643	95 [13.5]	140 [20.0]
5183	130 [18.5]	196 [28.0]
5356	120 [17.0]	182 [26.0]
5554	105 [15.0]	160 [23.0]
5556	140 [20.0]	210 [30.0]
5654	84 [12.0]	126 [18.0]

Note: These are typical shear strengths and not intended to be used for design purposes. Information for allowable shear strength for design is available in the *Aluminum Design Manual Specification for Aluminum Structures*—Aluminum Association.

will become trapped in a crevice in the joint prep and catch fire and/or pose a health hazard during welding. Joint edges can be wiped with solvent-soaked rags to remove surface oil, grease, and dirt. This should be sufficient cleaning for most joints.

Suitable solvent must be nonflammable, nontoxic, and stable in the presence of an arc. The provisions of the latest edition of ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society) must be followed. Particular reference is made to subclause 5.5.4, “Cleaning Compounds,” in that standard. Solvent cleaning is most effective on smooth surfaces. If solvent wiping will not remove imbedded dirt, files, chisels, wire brushes, or metal scrapers should be used. These tools should be clean and free from oil. When using grinding wheels, make certain special high-speed wheels for aluminum are used. A clean stainless steel wire brush can be used to remove heavy oxide coatings.

If pneumatic tools are selected for any mechanical cleaning, care should be taken that the exhaust is free of water, oil, or similar products, since contaminated air will contaminate the weld and is very likely to result in deposits with porosity.

9. Welding Conditions

9.1 Machine Settings and Other Variables. When using ac gas tungsten arc welding, the diameter of the tungsten electrode used should be small enough to cause the end to form a hemisphere at the required welding cur-

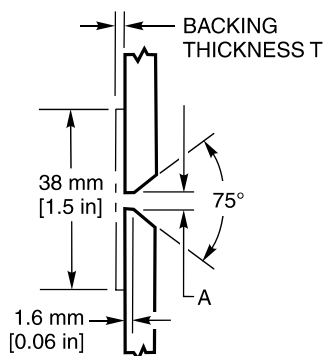
rent, but not so small that it overheats, causing the end to become unstable and fall from the electrode. It is also necessary to select the proper current setting for the thicknesses of base metal. Table 2 and Tables 5 through 11 show several of the factors which should be controlled, including tungsten electrode diameter, gas nozzle orifice, welding current, gas flow rate, filler rod diameter, and number of welding passes. These values can be varied, depending upon the actual weldment. However, they provide a good starting point to consistently provide welds of good quality.

9.2 Edge Preparation. Complete root penetration must be obtained by the root pass of a pipe weld. This can be facilitated by a combination of proper edge preparation and welding technique. Complete root penetration can be obtained in welds in the flat position with a 1.6 mm [0.06 in] root face and V-groove angles of 75° to 90°.

When welding in the horizontal fixed position without backing, the U-groove should be used (see Figures 2 and 3). A U-groove decreases the joint’s heat conducting capacity and permits complete root penetration and fusion with a smaller weld pool. This smaller weld pool is more easily held in the overhead position by surface tension and the inert gas flow.

Tables 2 and 5 through 12 show the variables which apply to gas tungsten arc and gas metal arc welding of schedule 40 pipe in the various positions. Table 12 indicates typical welding conditions for gas metal arc welding in the horizontal rolled position. The use of edge preparations other than those shown may require changes in the welding conditions listed.

Table 5
Gas Tungsten Arc Welding—Alternating Current
in the Vertical Position (With Backing)



EDGE PREPARATION

A = 0 FOR NO BACKING RING OR REMOVABLE BACKING RING

A = 6 mm [0.24 in] MAXIMUM FOR INTEGRAL BACKING RING

Piping Dimensions							Welding Rod Diameter		Current ac	Argon Flow ^a		Backing Thickness T		Number of Passes ^b
Nominal Pipe Diameter Size Number			Outside Diameter (OD)		Wall Thickness									
DN	NPS	Sch.	mm	[in]	mm	[in]	mm	[in]	amp	L/min	[ft ³ /h]	mm	[in]	A = 0
25	1	40	33.4	[1.31]	3.4	[0.13]	2.4–3.2	[0.094–0.125]	95–115	12–40	[25–85]	1.8	[0.07]	1–2
32	1-1/4	40	42.2	[1.66]	3.6	[0.14]	3.2–4.0	[0.125–0.156]	105–125	12–40	[25–85]	1.8	[0.07]	1–2
40	1-1/2	40	48.3	[1.90]	3.7	[0.15]	3.2–4.0	[0.125–0.156]	115–135	12–40	[25–85]	1.8	[0.07]	1–2
50	2	40	60.3	[2.37]	3.9	[0.15]	3.2–4.0	[0.125–0.156]	125–145	15–40	[32–85]	2.4	[0.09]	1–2
65	2-1/2	40	73.0	[2.87]	5.2	[0.20]	3.2–4.0	[0.125–0.156]	135–155	15–40	[32–85]	2.4	[0.09]	2
80	3	40	88.9	[3.50]	5.5	[0.22]	3.2–4.0	[0.125–0.156]	150–170	20–40	[42–85]	2.4	[0.09]	2
90	3-1/2	40	101.6	[4.00]	5.7	[0.22]	3.2–4.0	[0.125–0.156]	155–175	20–40	[42–85]	2.4	[0.09]	2
100	4	40	114.3	[4.50]	6.0	[0.24]	3.2–4.0	[0.125–0.156]	165–185	20–40	[42–85]	3.2	[0.13]	2
125	5	40	141.3	[5.56]	6.6	[0.26]	4.0–4.8	[0.156–0.188]	185–195	25–40	[53–85]	3.2	[0.13]	2
150	6	40	168.3	[6.63]	7.1	[0.28]	4.0–4.8	[0.156–0.188]	200–222	25–40	[53–85]	5	[0.20]	2
200	8	40	219.1	[8.63]	8.2	[0.32]	4.0–4.8	[0.156–0.188]	215–235	30–40	[64–85]	5	[0.20]	2–3
250	10	40	273.1	[10.75]	9.3	[0.37]	4.0–4.8	[0.156–0.188]	235–255	30–40	[64–85]	5	[0.20]	2–3
300	12	40	323.9	[12.75]	10.3	[0.41]	4.0–4.8	[0.156–0.188]	250–270	35–40	[74–85]	5	[0.20]	2–3

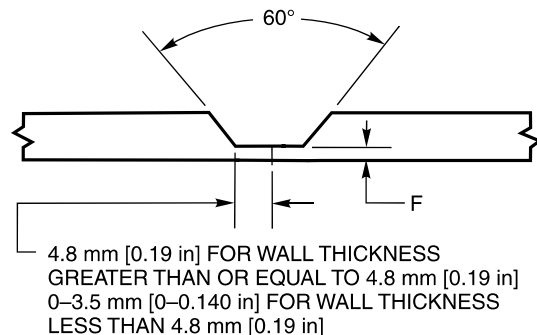
^a The higher flow rate is needed for the overhead quadrant.

^b Greater number of passes for bottom 90° of pipe when A = 6 mm [0.24 in].

Notes:

1. Tungsten electrode diameter is 3.2 mm [0.125 in] for DN 25 through 90 (NPS 1 through 3-1/2) pipe size, and 5.0 mm [0.187 in] for DN 100 through 300 (NPS 4 through 12) pipe size.
2. Gas nozzle orifice diameter is 11 mm [0.44 in] for DN 25 through 65 (NPS 1 through 2-1/2) pipe size and 13 mm [0.5 in] for DN 80 through 300 (NPS 3 through 12) pipe size.

Table 6
Gas Tungsten Arc Welding—Alternating Current
in the Flat Position (Without Backing)



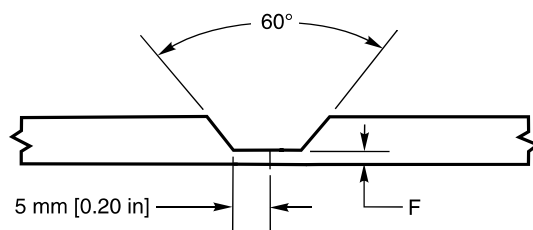
EDGE PREPARATION

Piping Dimensions							Welding Rod Diameter		Current ac	Argon Flow		F		Number of Passes
Nominal Pipe Diameter Size Number			Outside Diameter (OD)		Wall Thickness									
DN	NPS	Sch.	mm	[in]	mm	[in]	mm	[in]	amp	L/min	[ft³/h]	mm	[in]	A = 0
25	1	40	33.4	[1.31]	3.4	[0.13]	2.4-3.2	[0.094-0.125]	80-100	12-20	[25-53]	1.6	[0.06]	1-2
32	1-1/4	40	42.2	[1.66]	3.6	[0.14]	2.4-3.2	[0.094-0.125]	90-110	12-20	[25-53]	1.6	[0.06]	1-2
40	1-1/2	40	48.3	[1.90]	3.7	[0.14]	2.4-3.2	[0.094-0.125]	100-120	12-20	[25-53]	1.6	[0.06]	1-2
50	2	40	60.3	[2.37]	3.9	[0.15]	2.4-3.2	[0.094-0.125]	110-130	12-20	[25-53]	1.6	[0.06]	3-4
65	2-1/2	40	73.0	[2.87]	5.2	[0.20]	3.2-4.0	[0.125-0.156]	120-140	14-20	[30-42]	2.4	[0.09]	3-4
80	3	40	88.9	[3.50]	5.5	[0.22]	3.2-4.0	[0.125-0.156]	135-155	14-20	[30-42]	2.4	[0.09]	3-4
90	3-1/2	40	101.6	[4.00]	5.7	[0.23]	3.2-4.0	[0.125-0.156]	140-160	14-20	[30-42]	2.4	[0.09]	3-4
100	4	40	114.3	[4.50]	6.0	[0.24]	3.2-4.0	[0.125-0.156]	150-170	14-20	[30-42]	2.4	[0.09]	3-4
125	5	40	141.3	[5.56]	6.6	[0.26]	4.0-4.8	[0.156-0.188]	170-190	14-20	[30-42]	2.4	[0.09]	3-4
150	6	40	168.3	[6.63]	7.1	[0.28]	4.0-4.8	[0.156-0.188]	185-205	15-20	[32-42]	2.4	[0.09]	3-5
200	8	40	219.1	[8.63]	8.2	[0.32]	4.0-4.8	[0.156-0.188]	200-220	15-20	[32-42]	2.4	[0.09]	3-5
250	10	40	273.1	[10.75]	9.3	[0.37]	4.0-4.8	[0.156-0.188]	220-240	15-20	[32-42]	2.4	[0.09]	3-5
300	12	40	323.9	[12.75]	10.3	[0.41]	4.0-4.8	[0.156-0.188]	235-255	15-20	[32-42]	2.4	[0.09]	3-5

Notes:

1. Tungsten electrode diameter is 3.2 mm [0.125 in] for DN 25 through 90 (NPS 1 through 3-1/2) pipe size, and 5.0 mm [0.187 in] for DN 100 through 300 (NPS 4 through 12) pipe size.
2. Gas nozzle orifice diameter is 11 mm [0.44 in] for DN 25 through 65 (NPS 1 through 2-1/2) pipe size and 13 mm [0.5 in] for DN 80 through 300 (NPS 3 through 12) pipe size.

Table 7
Gas Tungsten Arc Welding—Alternating Current
in the Horizontal Fixed Position (Without Backing)



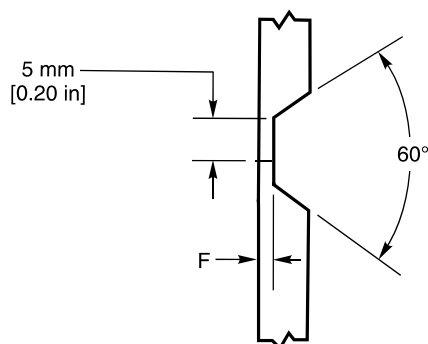
EDGE PREPARATION

Piping Dimensions							Welding Rod Diameter		Current ac	Argon Flow		F	
Nominal Pipe Diameter Size Number			Outside Diameter (OD)		Wall Thickness								
DN	NPS	Sch.	mm	[in]	mm	[in]	mm	[in]	amp	L/min	[ft³/h]	mm	[in]
25	1	40	33.4	[1.31]	3.4	[0.13]	2.4	[0.094]	80–100	14–40	[30–85]	1.6	[0.06]
32	1-1/4	40	42.2	[1.66]	3.6	[0.14]	2.4	[0.094]	80–110	14–40	[30–85]	1.6	[0.06]
40	1-1/2	40	48.3	[1.90]	3.7	[0.14]	2.4	[0.094]	80–120	14–40	[30–85]	1.6	[0.06]
50	2	40	60.3	[2.37]	3.9	[0.15]	2.4	[0.094]	80–130	14–40	[30–85]	1.6	[0.06]
65	2-1/2	40	73.0	[2.87]	5.2	[0.20]	3.2	[0.125]	80–140	14–40	[30–85]	1.6	[0.06]
80	3	40	88.9	[3.50]	5.5	[0.22]	3.2	[0.125]	135–155	14–40	[30–85]	2.4	[0.06]
90	3-1/2	40	101.6	[4.00]	5.7	[0.23]	3.2	[0.125]	135–160	14–40	[30–85]	2.4	[0.06]
100	4	40	114.3	[4.50]	6.0	[0.24]	3.2–4.0	[0.125–0.156]	135–170	15–40	[32–85]	2.4	[0.06]
125	5	40	141.3	[5.56]	6.6	[0.26]	3.2–4.0	[0.125–0.156]	135–190	15–40	[32–85]	2.4	[0.06]
150	6	40	168.3	[6.63]	7.1	[0.28]	3.2–4.0	[0.125–0.156]	135–205	25–40	[53–85]	2.4	[0.06]
200	8	40	219.1	[8.63]	8.2	[0.32]	4.0–4.8	[0.156–0.188]	135–220	25–40	[53–85]	2.4	[0.06]
250	10	40	273.1	[10.75]	9.3	[0.37]	4.0–4.8	[0.156–0.188]	135–240	25–40	[53–85]	2.4	[0.06]
300	12	40	323.9	[12.75]	10.3	[0.41]	4.0–4.8	[0.156–0.188]	135–255	25–40	[53–85]	2.4	[0.06]

Notes:

1. Tungsten electrode diameter is 3.2 mm [1/8 in] for DN 25 through 90 (NPS 1 through 3-1/2) pipe size, and 5.0 mm [0.187 in] for DN 100 through 300 (NPS 4 through 12) pipe size.
2. Gas nozzle orifice diameter is 13 mm [0.5 in].
3. Number of passes is 3 to 6 for DN 25 through 300 (NPS 1 through 12) pipe size.

Table 8
Gas Tungsten Arc Welding—Alternating Current
in the Vertical Position (Without Backing)



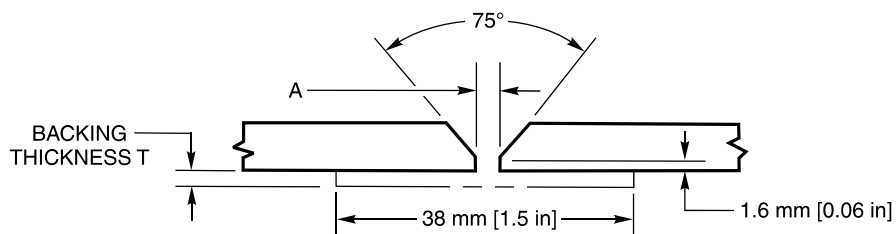
EDGE PREPARATION

Piping Dimensions							Welding Rod Diameter	Current ac	Argon Flow	F		Number of Passes		
Nominal Pipe Diameter Size Number			Outside Diameter (OD)		Wall Thickness									
DN	NPS	Sch.	mm	[in]	mm	[in]							mm	[in]
25	1	40	33.4	[1.31]	3.4	[0.13]	2.4	[0.094]	80–100	12–24	[25–50]	1.6	[0.06]	3–4
32	1-1/4	40	42.2	[1.66]	3.6	[0.14]	3.2	[0.125]	80–110	12–24	[25–50]	1.6	[0.06]	3–4
40	1-1/2	40	48.3	[1.90]	3.7	[0.14]	3.2	[0.125]	80–120	12–24	[25–50]	1.6	[0.06]	3–4
50	2	40	60.3	[2.37]	3.9	[0.15]	3.2	[0.125]	80–130	14–30	[30–64]	1.6	[0.06]	4–5
65	2-1/2	40	73.0	[2.87]	5.2	[0.20]	3.2	[0.125]	80–140	14–30	[30–64]	1.6	[0.06]	4–5
80	3	40	88.9	[3.50]	5.5	[0.22]	3.2	[0.125]	135–155	20–30	[42–64]	2.4	[0.09]	4–5
90	3-1/2	40	101.6	[4.00]	5.7	[0.23]	3.2	[0.125]	135–160	20–30	[42–64]	2.4	[0.09]	4–5
100	4	40	114.3	[4.50]	6.0	[0.24]	3.2	[0.125]	135–170	20–30	[42–64]	2.4	[0.09]	4–5
125	5	40	141.3	[5.56]	6.6	[0.26]	4.0–4.8	[0.156–0.188]	135–190	25–30	[53–64]	2.4	[0.09]	4–5
150	6	40	168.3	[6.63]	7.1	[0.28]	4.0–4.8	[0.156–0.188]	135–205	25–30	[53–64]	2.4	[0.09]	5–6
200	8	40	219.1	[8.63]	8.2	[0.32]	4.0–4.8	[0.156–0.188]	135–220	30–40	[64–85]	2.4	[0.09]	5–6
250	10	40	273.1	[10.75]	9.3	[0.37]	4.0–4.8	[0.156–0.188]	135–240	30–40	[64–85]	2.4	[0.09]	5–6
300	12	40	323.9	[12.75]	10.3	[0.41]	4.0–4.8	[0.156–0.188]	135–255	35–40	[74–85]	2.4	[0.09]	5–6

Notes:

1. Tungsten electrode diameter is 3.2 mm [0.125 in] for DN 25 through 90 (NPS 1 through 3-1/2) pipe size, and 5.0 mm [0.187 in] for DN 100 through 300 (NPS 4 through 12) pipe size.
2. Gas nozzle orifice diameter is 13 mm [0.5 in].

Table 9
Gas Tungsten Arc Welding—Direct Current
Electrode Negative in the Horizontal Rolled Position (With Backing)



EDGE PREPARATION

A = 0 FOR NO BACKING RING OR REMOVABLE BACKING RING
A = 6 mm [0.24 in] MAXIMUM FOR INTEGRAL BACKING RING

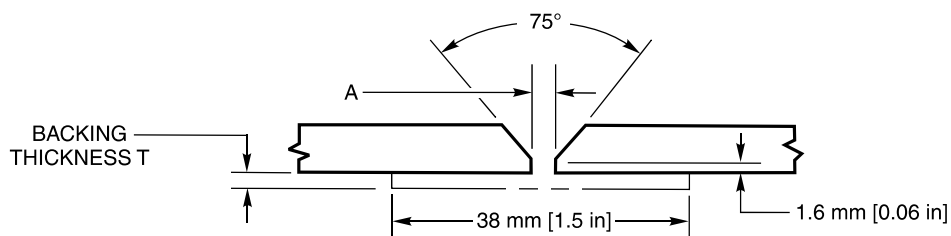
Piping Dimensions							Current DCEN	Backing Thickness T		Number of Passes ^a
Nominal Pipe Diameter Size Number			Outside Diameter (OD)		Wall Thickness					
DN	NPS	Sch.	mm	[in]	mm	[in]	amp	mm	[in]	A = 0
25	1	40	33.4	[1.31]	3.4	[0.13]	40–50	1.8	[0.07]	1
32	1-1/4	40	42.2	[1.66]	3.6	[0.14]	40–50	1.8	[0.07]	1
40	1-1/2	40	48.3	[1.90]	3.7	[0.14]	50–60	1.8	[0.07]	1
50	2	40	60.3	[2.37]	3.9	[0.15]	50–60	2.4	[0.09]	1
65	2-1/2	40	73.0	[2.87]	5.2	[0.20]	60–90	2.4	[0.09]	1–2
80	3	40	88.9	[3.50]	5.5	[0.22]	60–90	2.4	[0.09]	1–2
90	3-1/2	40	101.6	[4.00]	5.7	[0.23]	80–105	2.4	[0.09]	1–2
100	4	40	114.3	[4.50]	6.0	[0.24]	80–105	3.2	[0.13]	1–2
125	5	40	141.3	[5.56]	6.6	[0.26]	80–105	3.2	[0.13]	1–2
150	6	40	168.3	[6.63]	7.1	[0.28]	80–105	5	[0.20]	2–3
200	8	40	219.1	[8.63]	8.2	[0.32]	90–120	5	[0.20]	2–3
250	10	40	273.1	[10.75]	9.3	[0.37]	90–120	5	[0.20]	2–4
300	12	40	323.9	[12.75]	10.3	[0.41]	90–120	5	[0.20]	2–4

^a More passes are required when A = 6 mm [0.24 in].

Notes:

1. Tungsten (1% or 2% thoriated) electrode diameter is 1.5 mm [0.060 in].
2. Gas nozzle orifice diameter is 5.6 mm [7/32 in].
3. Welding rod diameter is 3.2 mm [1/8 in].
4. Helium flow rate is 20 L/min to 30 L/min [42 ft³/h to 63 ft³/h].

Table 10
Gas Tungsten Arc Welding—Direct Current
Electrode Negative in the Horizontal Fixed Position (With Backing)



EDGE PREPARATION

A = 0 FOR NO BACKING RING OR REMOVABLE BACKING RING
A = 6 mm [0.24 in] MAXIMUM FOR INTEGRAL BACKING RING

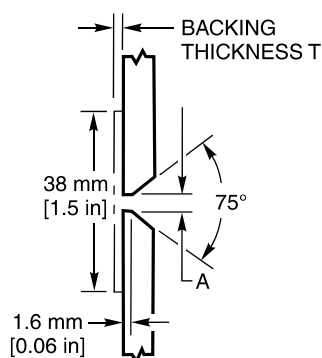
Piping Dimensions							Current DCEN	Backing Thickness T		Number of Passes ^a
Nominal Pipe Diameter Size Number			Outside Diameter (OD)		Wall Thickness					
DN	NPS	Sch.	mm	[in]	mm	[in]	amp	mm	[in]	A = 0
25	1	40	33.4	[1.31]	3.4	[0.13]	40–50	1.8	[0.07]	1–2
32	1-1/4	40	42.2	[1.66]	3.6	[0.14]	40–50	1.8	[0.07]	1–2
40	1-1/2	40	48.3	[1.90]	3.7	[0.14]	50–60	1.8	[0.07]	1–2
50	2	40	60.3	[2.37]	3.9	[0.15]	50–60	2.4	[0.09]	1–2
65	2-1/2	40	73.0	[2.87]	5.2	[0.20]	60–90	2.4	[0.09]	2–3
80	3	40	88.9	[3.50]	5.5	[0.22]	60–90	2.4	[0.09]	2–3
90	3-1/2	40	101.6	[4.00]	5.7	[0.23]	70–105	2.4	[0.09]	2–4
100	4	40	114.3	[4.50]	6.0	[0.24]	70–105	3.2	[0.13]	2–4
125	5	40	141.3	[5.56]	6.6	[0.26]	70–105	3.2	[0.13]	2–4
150	6	40	168.3	[6.63]	7.1	[0.28]	70–120	5	[0.20]	2–6
200	8	40	219.1	[8.63]	8.2	[0.32]	70–120	5	[0.20]	2–6
250	10	40	273.1	[10.75]	9.3	[0.37]	70–120	5	[0.20]	2–8
300	12	40	323.9	[12.75]	10.3	[0.41]	70–120	5	[0.20]	2–8

^a Greater number of passes for bottom 90° of pipe circumference and when A = 6 mm [0.24 in].

Notes:

1. Tungsten (1% or 2% thoriated) electrode diameter is 1.5 mm [0.060 in].
2. Gas nozzle orifice diameter is 5.6 mm [7/32 in].
3. Welding rod diameter is 3.2 mm [1/8 in].
4. Helium flow rate is 20 L/min to 30 L/min [42 ft³/h to 63 ft³/h].
5. 110° angle required on bottom 90° of pipe—can be applied to full 360°.

Table 11
Gas Tungsten Arc Welding—Direct Current
Electrode Negative in the Vertical Position (With Backing)



EDGE PREPARATION

A = 0 FOR NO BACKING RING OR REMOVABLE BACKING RING
a = 6 mm [0.24 in] MAXIMUM FOR INTEGRAL BACKING RING

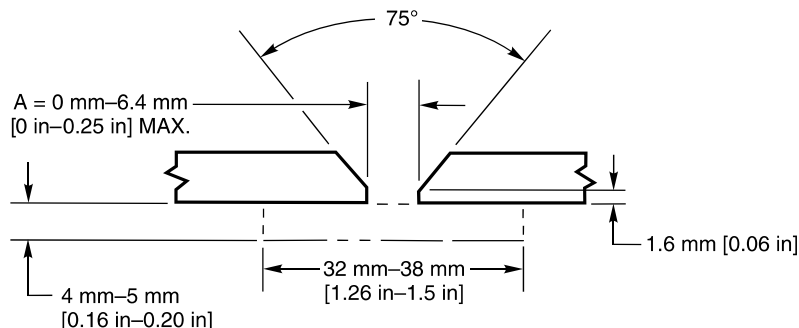
Piping Dimensions							Current DCEN	Backing Thickness T		Number of Passes ^a
Nominal Pipe Diameter Size Number			Outside Diameter (OD)		Wall Thickness					
DN	NPS	Sch.	mm	[in]	mm	[in]	amp	mm	[in]	A = 0
25	1	40	33.4	[1.31]	3.4	[0.13]	40–50	1.8	[0.07]	1
32	1-1/4	40	42.2	[1.66]	3.6	[0.14]	40–50	1.8	[0.07]	1
40	1-1/2	40	48.3	[1.90]	3.7	[0.14]	50–60	1.8	[0.07]	1
50	2	40	60.3	[2.37]	3.9	[0.15]	50–60	2.4	[0.09]	1–2
65	2-1/2	40	73.0	[2.87]	5.2	[0.20]	60–90	2.4	[0.09]	1–2
80	3	40	88.9	[3.50]	5.5	[0.22]	60–90	2.4	[0.09]	1–2
90	3-1/2	40	101.6	[4.00]	5.7	[0.23]	80–105	2.4	[0.09]	1–2
100	4	40	114.3	[4.50]	6.0	[0.24]	80–105	3.2	[0.13]	2–3
125	5	40	141.3	[5.56]	6.6	[0.26]	80–105	3.2	[0.13]	2–3
150	6	40	168.3	[6.63]	7.1	[0.28]	80–105	5	[0.20]	2–3
200	8	40	219.1	[8.63]	8.2	[0.32]	100–130	5	[0.20]	2–3
250	10	40	273.1	[10.75]	9.3	[0.37]	100–130	5	[0.20]	3
300	12	40	323.9	[12.75]	10.3	[0.41]	100–130	5	[0.20]	3

^a More passes are required when A = 6 mm [0.24 in].

Notes:

1. Tungsten (1% or 2% thoriated) electrode diameter is 1.5 mm [0.060 in].
2. Gas nozzle orifice diameter is 5.6 mm [7/32 in].
3. Welding rod diameter is 3.2 mm [1/8 in].
4. Helium flow rate is 20 L/min to 30 L/min [42 ft³/h to 63 ft³/h].

Table 12
Gas Metal Arc Welding in the Horizontal Rolled Position

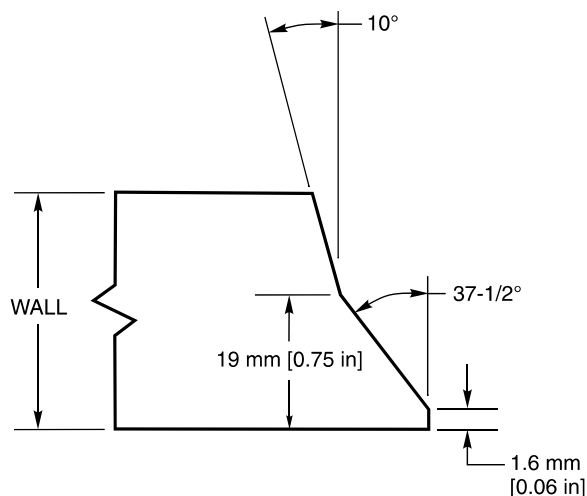


EDGE PREPARATION

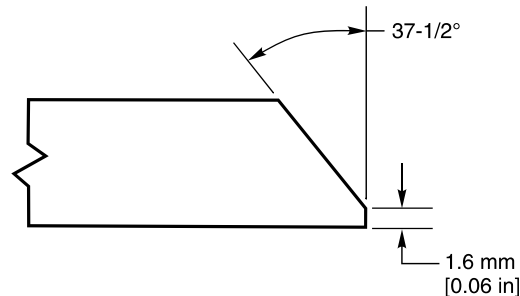
Piping Dimensions							Electrode Diameter		Current DCEP	Argon Flow		Number of Passes ^a
Nominal Pipe Diameter Size Number			Outside Diameter (OD)		Wall Thickness							
DN	NPS	Sch.	mm	[in]	mm	[in]	mm	[in]	amp	L/min	[ft ³ /h]	A = 0
100	4	40	114.3	[4.50]	6.0	[0.24]	1.2	[3/64]	190–210	20	[42]	2
125	5	40	141.3	[5.56]	6.6	[0.26]	1.2	[3/64]	205–225	20	[42]	2
150	6	40	168.3	[6.63]	7.1	[0.28]	1.2	[3/64]	215–235	20	[42]	2
200	8	40	219.1	[8.63]	8.2	[0.32]	1.6	[1/16]	215–235	25	[53]	3
250	10	40	273.1	[10.75]	9.3	[0.37]	1.6	[1/16]	215–235	25	[53]	3
300	12	40	323.9	[12.75]	10.3	[0.41]	1.6	[1/16]	240–260	25	[53]	3

^a More passes required when A = 6 mm [0.24 in].

Note: Root opening = 0 for no backing ring or removable backing ring and 6 mm [0.24 in] for permanent backing ring.

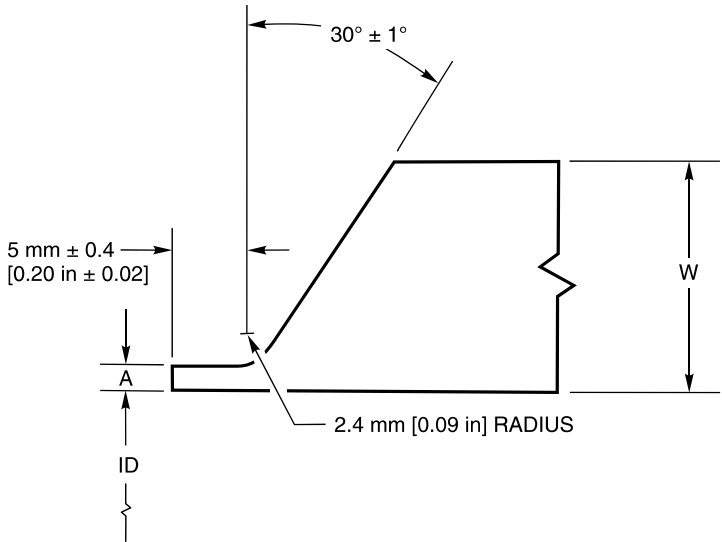


(A) COMPOUND BEVEL—FOR WALL THICKNESS OVER 19 mm [0.75 in]



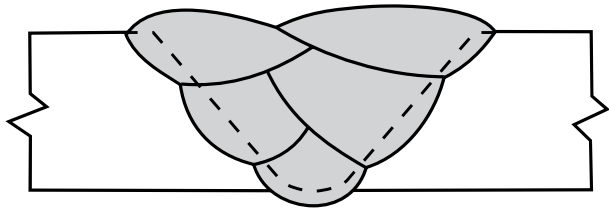
(B) STRAIGHT BEVEL—FOR WALL THICKNESS 19 mm [0.75 in] OR LESS

Figure 1—Standard V-Groove Bevels



Piping Dimensions				A		W, maximum	
Nominal Pipe Diameter Size Number		Outside Diameter (OD)					
DN	NPS	mm	[in]	mm	[in]	mm	[in]
6 through 65 80 through 300	1/8 through 2-1/2 3 through 12	10.3 through 73.0 88.9 through 324	[0.405 through 2.875] [3.50 through 12.75]	1.6 ± 0.4 2.4 ± 0.4	[0.06 ± 0.02] [0.09 ± 0.02]	7.01 12.7	[0.276] [0.500]

**Figure 2—Pipe End Preparation for U-Groove
(Recommended for Manual AC Gas Tungsten Arc Welding)**



Advantages

1. Smooth, complete root penetration.
2. No concave root surfaces (suck-back).
3. No backing required.
4. Good for all fixed pipe positions.
5. Preheating not required.

**Figure 3—Finished Weld in
U-Groove Showing Weld Beads
(Advantages are Given of the U-Groove
with Dimensions Shown in Figure 2
and Techniques Shown in Figure 5)**

10. Weld Backing

Either permanent or removable backing may be used in the fabrication of pipe welds. Integral backings generally are not recommended for fluid flow because of the possibility of crevice corrosion; however, they commonly are used for electrical bus or structural applications.

10.1 Permanent Backings. Permanent backings should be of an alloy in the same Material Number Grouping as the pipe being welded. They should be free of any projection into the joint (for root opening control), since the oxides on the faying surfaces will not break up, and incomplete root fusion will result. Flat or grooved aluminum backings are preferred and can be tack welded in place to maintain the root opening.

10.1.1 Spacing. Spacing between flat, permanent backings and the pipe ID is important. If a tight fit does not exist, the root opening should be adequate to permit a root pass to be made along each side as illustrated in

Figure 4(A). This would require a wider root opening than the 6 mm [0.24 in] maximum permitted in Tables 9 through 12.

10.1.2 Single Root Pass. If a single root pass is made with a tight fit between pipe and backing, either of the following problems can occur:

(1) A narrow root opening may cause bridging of the root and minimal fusion to the backing as shown in Figure 4(B). A root opening of 5 mm to 6 mm [0.20 in to 0.24 in] should allow room for thorough arc cleaning and complete fusion to the backing.

(2) A wider root opening may result in root undercut as shown in Figure 4(C). The condition can be

improved by providing for a space between the backing and the uneven tube surface as shown in Figures 4(D) and 4(E).

10.2 Removable Backings. A removable backing can be a grooved and segmented collapsible unit or a tapered unit allowing a controlled root reinforcement, as shown in Figure 4(E). The root opening should be a maximum of 1.6 mm [0.06 in] to avoid direct impingement of the arc upon the backing material. Nonmagnetic stainless steel or “hard coat” anodized aluminum are commonly used backing materials. Grooved ceramic backings can also be employed. These are broken upon completion of the weld and flushed from the pipe.

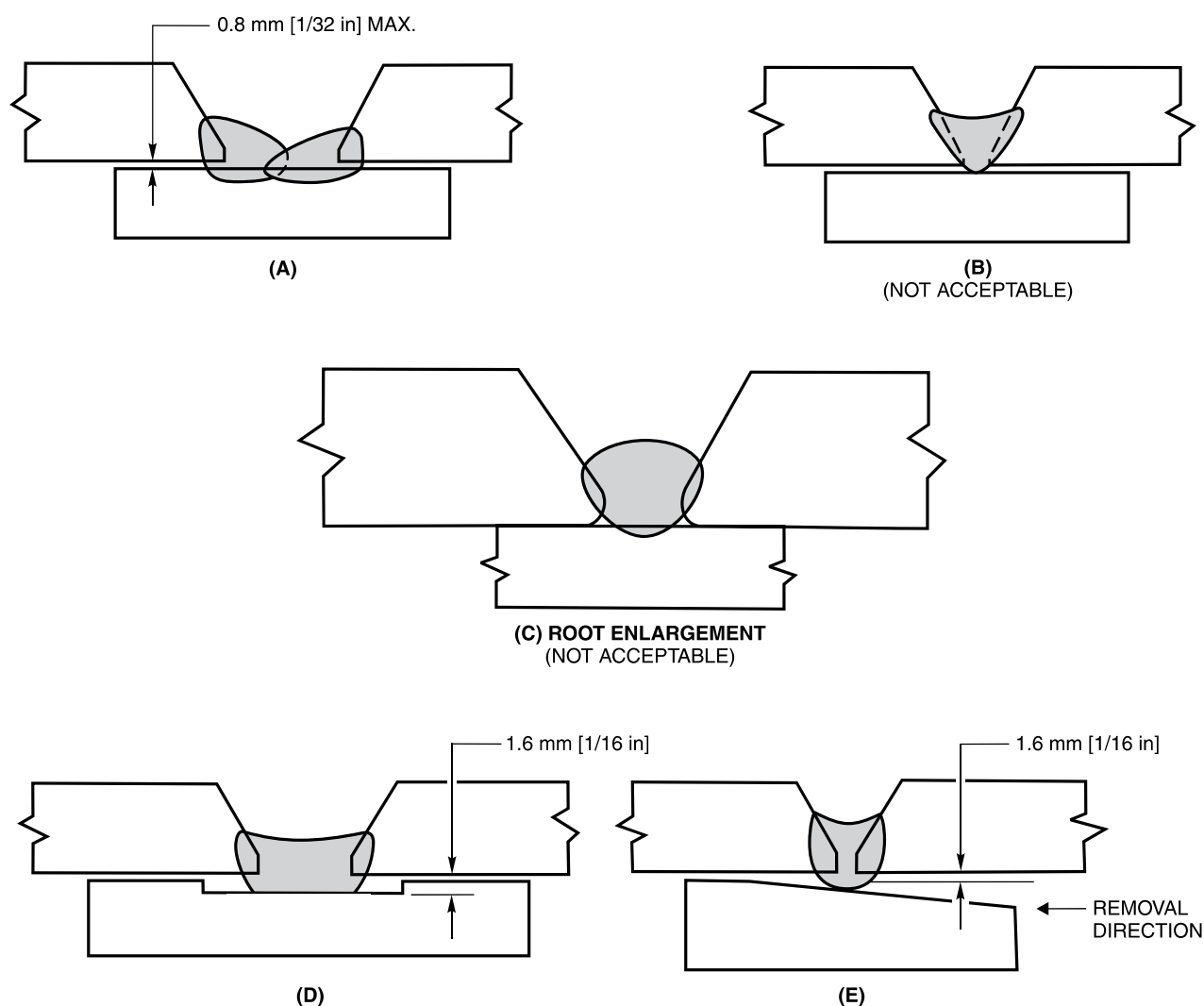


Figure 4—Possible Backing Arrangements for Use with V-Groove Welds

11. Welding Technique

11.1 Gas Tungsten Arc Welding (Manual Welding).

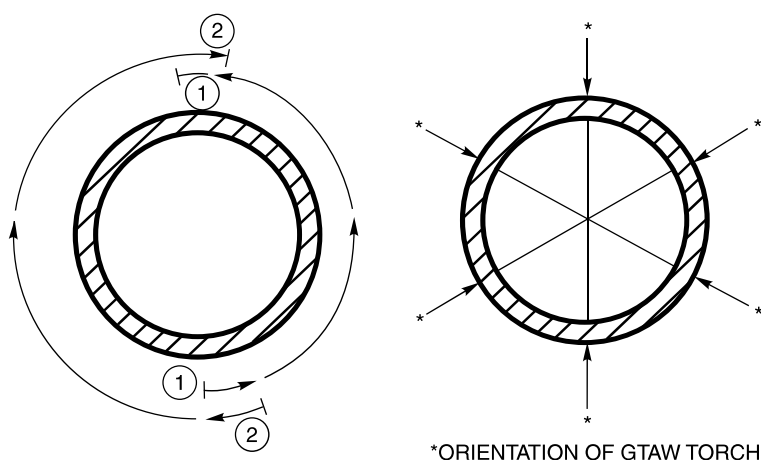
The sound welding of any joint requires proper edge preparation, cleanliness, and a good fit. Tungsten electrodes contaminated with aluminum should not be used. The prepared edges should be cleaned to remove all traces of foreign material before the joint is assembled. After the joint has been properly aligned, it should be tack welded at three or more locations. The tack welds should have complete root penetration and be rather flat and should not exceed 25 mm [1 in] in length. Three such welds equally spaced around the joint will usually suffice to maintain alignment. The arc is started by the use of a high frequency or capacitive discharge type starting circuit. Touch starting should not be used because it will leave a tungsten inclusion in the weld.

When making a weld in the flat position (1G), either with or without backing, the first pass should be applied at about the one o'clock position as the pipe moves clockwise because vertical welding on aluminum should always be done in the upward direction. This provides a better opportunity to obtain complete root penetration and improved weld quality. The starts and stops of subsequent passes should be staggered. When completing the weld, the end should be tapered for about 38 mm [1.5 in] to avoid shrinkage craters. Stringer beads are used, except for the last or cover pass which can be weaved to

suit. With direct current, electrode negative however, only stringer beads should be used. When welding with the pipe in the vertical position (2G), only stringer beads should be used. When welding pipe in the horizontal fixed position (5G), the root pass should be started near the bottom dead center (6:00 position); the weld should progress across the bottom, up the side, and across top dead center (past the 12:00 position). The root pass is welded on the remaining circumference in a similar manner with the second bead overlapping the ends of the first bead (see Figure 5).

The tungsten electrode should be pointed toward the center line of the pipe or tube (i.e., for butt joints, the electrode axis should be perpendicular to the pipe surface). The arc should be maintained at a controllable length, usually 5 mm to 6 mm [0.20 in to 0.24 in], or just long enough to prevent contamination of the electrode when the welding rod is added. The inert gas should be adjusted to flow at a rate which will provide good shielding.

The welding rod should be used in such a manner that it does not interfere with the stability of the arc. For ac welding, the best way to accomplish this is to direct the welding rod nearly tangent to the pipe at the location of the arc, and periodically insert the tip of the rod into the leading edge of the pool. The end of the rod must always remain within the gas shield. For DCEN welding, the welding rod is added to the pool continuously. Smooth,



1. Weld vertically upward.
2. Overlap ends of first bead 25 mm [1 in] minimum.
3. Maintain torch direction toward pipe center.
4. Alternate sides of pipe for successive passes.

Figure 5—Gas Tungsten Arc Welding Torch Directions, Horizontal Fixed Position

uniform forward motion of the arc will cause best results; short, jerky movements will promote inclusions, rough appearance, and incomplete root penetration.

11.2 Gas Metal Arc Welding. Semiautomatic gas metal arc welding is generally limited to the flat position. The pipe ends should be properly prepared for this process as shown in Table 12. The pipe ends and the backing ring should be thoroughly cleaned to remove all traces of foreign material. The backing ring edges should be properly aligned and fitted, and three or more tack welds made to maintain alignment and root opening. Usually, the root opening is 3.2 mm to 6 mm [0.12 in to 0.24 in] depending on wall thickness. Tack welds should be small, have complete penetration, and be up to 25 mm [1 in] in length. Three equally spaced tacks will maintain alignment.

For 1G (rolled) welding, welding should begin at the top center while the pipe is rotating at a uniform speed. The arc should be established in the groove, and it can be started ahead of the start of welding which will permit the weld bead to cover the arc strikes. A leading torch angle of 10° or 15° is used. The first pass should be a stringer bead, taking care to obtain complete fusion to the backing.

When terminating any weld bead, the arc should be manipulated to reduce the depth of fusion and weld pool size, thereby decreasing the final shrinkage area. This can usually be accomplished by rapidly increasing the speed of welding for the final 25 mm to 50 mm [1 in to 2 in] of the weld length.

The current settings shown in Table 12 will provide a good starting point for welding the various sizes of pipes. These values can be modified, depending upon the welder's experience. It should be noted that the arc voltage has an important influence on the smooth deposition of filler metal. It may not always be possible to measure arc voltage, but there will be ample evidence of its influence. Spatter which accompanies welding usually is caused by low voltage, and the voltage should be increased to correct this condition. The voltage setting will also influence the size of the weld bead, since a high voltage will form a wider bead than will a lower voltage.

11.3 Weld Termination. The arc for both GTAW and GMAW should be terminated smoothly by using an electronic crater fill on the power supply, or a foot or hand control to smoothly decay the arc. Terminating the arc abruptly can result in an excessive weld crater and/or crater crack. A gas postflow should be used to protect

both the tungsten electrode and the weld as they cool. Gas postflow is also recommended in GMAW. When completing the weld, the end should be tapered for about 38 mm [1.5 in] to avoid shrinkage craters.

12. Heat Treatment

12.1 Preheating. Preheating is generally not recommended for aluminum pipe. However, preheat may be required because of very low ambient temperatures or heavy base metal thicknesses. When fabricating the heat-treatable aluminum alloys or the 5000-series aluminum-magnesium alloys containing more than 3% magnesium, the preheat and interpass temperatures should not exceed 120°C [250°F]. Holding times at this temperature should not exceed 15 min. Time at temperature should be held to a minimum to minimize impairment of base metal properties. Local overheating should be avoided.

12.2 Postweld Heat Treatment. Postweld heat treatment of aluminum piping systems is seldom practical, but if conducted, should be carried out in accordance with suitable procedures.

13. Code Requirements—Welding Qualifications and Design

Several national standards and specifications contain requirements which apply to the welding of aluminum. Some examples include AWS D1.2, *Structural Welding Code—Aluminum*, and the ASME *Boiler and Pressure Vessel Code*, of which Sections I, III, and VIII and related code cases provide requirements for materials, design, fabrication and inspection of boilers, pressure vessels, and nuclear components. The ASME B3, *Code for Pressure Piping*, also contains similar requirements. Requirements for qualification of welding procedures and welders are contained in ASME Section IX, *Welding and Brazing Qualifications*.

Other standards applying to aluminum alloys include:

AWS B2.1, *Standard for Welding Procedure and Performance Qualification*.

ANSI B31.1, *Power Piping*

ASME B31.3, *Process Piping*

ASME B31.5, *Refrigeration Piping*

API 620, *LNG Storage Tanks*, Appendix Q

Annex A (Normative)

Pipe Diameters, Wall Thicknesses, and Weights of Aluminum Pipe

This annex is part of AWS D10.7M/D10.7:2008, *Guide for the Gas Shielded Arc Welding of Aluminum and Aluminum Alloy Pipe*, and includes mandatory elements for use with this standard.

Table A.1
Pipe Diameters, Wall Thicknesses, and Weights of Aluminum Pipe

Piping Dimensions										
Nominal Pipe Diameter Size Number			Outside Diameter (OD)		Inside Diameter (ID)		Wall Thickness ^a		Weight ^a	
DN	[NPS]	Sch.	mm	[in]	mm	[in]	mm	[in]	kg/m	[lbs/ft]
6	1/8	40	10.3	0.41	6.8	0.27	1.7	0.07	0.13	0.09
6	1/8	80	10.3	0.41	5.5	0.22	2.4	0.10	0.16	0.11
8	1/4	40	13.7	0.54	9.2	0.36	2.2	0.09	0.22	0.15
8	1/4	80	13.7	0.54	10.0	0.39	3.0	0.12	0.28	0.19
10	3/8	40	17.1	0.68	12.5	0.49	2.3	0.09	0.29	0.20
10	3/8	80	17.1	0.68	10.7	0.42	3.2	0.13	0.38	0.26
15	1/2	5	21.3	0.84	18.0	0.71	1.7	0.07	0.28	0.19
15	1/2	10	21.3	0.84	17.1	0.67	2.1	0.08	0.34	0.23
15	1/2	40	21.3	0.84	15.8	0.62	2.8	0.11	0.44	0.29
15	1/2	80	21.3	0.84	13.8	0.55	3.7	0.15	0.56	0.38
15	1/2	160	21.3	0.84	11.8	0.47	4.7	0.19	0.67	0.45
20	3/4	5	26.7	1.05	23.4	0.92	1.7	0.07	0.35	0.24
20	3/4	10	26.7	1.05	22.5	0.88	2.1	0.08	0.44	0.30
20	3/4	40	26.7	1.05	20.9	0.82	2.9	0.11	0.58	0.39
20	3/4	80	26.7	1.05	18.8	0.74	3.9	0.15	0.76	0.51
20	3/4	160	26.7	1.05	15.6	0.61	5.5	0.22	1.00	0.67
25	1	5	33.3	1.31	30.1	1.19	1.7	0.07	0.45	0.30
25	1	10	33.3	1.31	27.9	1.10	2.8	0.11	0.72	0.49
25	1	40	33.3	1.31	26.6	1.05	3.4	0.13	0.86	0.58
25	1	80	33.3	1.31	24.3	0.96	4.5	0.18	1.12	0.75
25	1	160	33.3	1.31	20.7	0.82	6.4	0.25	1.46	0.98

(Continued)

Table A.1 (Continued)
Pipe Diameters, Wall Thicknesses, and Weights of Aluminum Pipe

Piping Dimensions										
Nominal Pipe Diameter Size Number			Outside Diameter (OD)		Inside Diameter (ID)		Wall Thickness ^a		Weight ^a	
32	1-1/4	5	42.2	1.66	38.9	1.53	1.7	0.07	0.57	0.38
32	1-1/4	10	42.2	1.66	36.6	1.44	2.8	0.11	0.93	0.63
32	1-1/4	40	42.2	1.66	35.1	1.38	3.6	0.14	1.17	0.79
32	1-1/4	80	42.2	1.66	32.5	1.28	4.9	0.19	1.54	1.04
32	1-1/4	160	42.2	1.66	29.5	1.16	6.4	0.25	1.94	1.30
40	1-1/2	5	48.3	1.90	45.0	1.77	1.7	0.07	0.66	0.44
40	1-1/2	10	48.3	1.90	42.7	1.68	2.8	0.11	1.07	0.72
40	1-1/2	40	48.3	1.90	40.9	1.61	3.7	0.15	1.40	0.94
40	1-1/2	80	48.3	1.90	38.1	1.50	5.1	0.20	1.87	1.26
40	1-1/2	160	48.3	1.90	34.0	1.34	7.1	0.28	2.50	1.68
60	2	5	60.2	2.37	57.0	2.25	1.7	0.07	0.83	0.56
60	2	10	60.2	2.37	54.8	2.16	2.8	0.11	1.36	0.91
60	2	40	60.2	2.37	52.5	2.07	3.9	0.15	1.88	1.26
60	2	80	60.2	2.37	49.3	1.94	5.5	0.22	2.58	1.74
60	2	160	60.2	2.37	42.9	1.69	8.7	0.34	3.83	2.58
65	2-1/2	5	72.9	2.87	68.8	2.71	2.1	0.08	1.27	0.86
65	2-1/2	10	72.9	2.87	66.9	2.64	3.0	0.12	1.82	1.22
65	2-1/2	40	72.9	2.87	62.7	2.47	5.2	0.20	2.98	2.00
65	2-1/2	80	72.9	2.87	59.0	2.32	7.0	0.28	3.94	2.65
65	2-1/2	160	72.9	2.87	54.0	2.13	9.5	0.38	5.15	3.46
80	3	5	88.9	3.50	84.7	3.33	2.1	0.08	1.55	1.04
80	3	10	88.9	3.50	82.8	3.26	3.0	0.12	2.23	1.50
80	3	40	88.9	3.50	77.9	3.07	5.5	0.22	3.90	2.62
80	3	80	88.9	3.50	73.7	2.90	7.6	0.30	5.27	3.55
80	3	160	88.9	3.50	66.7	2.63	11.1	0.44	7.35	4.95
90	3-1/2	5	101.6	4.00	97.4	3.83	2.1	0.08	1.79	1.20
90	3-1/2	10	101.6	4.00	95.5	3.76	3.0	0.12	2.56	1.72
90	3-1/2	40	101.6	4.00	90.1	3.55	5.7	0.23	4.68	3.15
90	3-1/2	80	101.6	4.00	85.4	3.36	8.1	0.32	6.43	4.33
100	4	5	114.3	4.50	110.1	4.33	2.1	0.08	2.01	1.35
100	4	10	114.3	4.50	108.2	4.26	3.0	0.12	2.89	1.94
100	4	40	114.3	4.50	102.3	4.03	6.0	0.24	5.55	3.73
100	4	80	114.3	4.50	97.2	3.83	8.6	0.34	7.71	5.18
100	4	120	114.3	4.50	92.1	3.63	11.1	0.44	9.75	6.56
100	4	160	114.3	4.50	87.3	3.44	13.5	0.53	11.58	7.79
125	5	5	141.3	5.56	135.8	5.35	2.8	0.11	3.26	2.20
125	5	10	141.3	5.56	134.5	5.30	3.4	0.13	4.00	2.69
125	5	40	141.3	5.56	128.2	5.05	6.6	0.26	7.52	5.06
125	5	80	141.3	5.56	122.3	4.81	9.5	0.38	10.69	7.19
125	5	120	141.3	5.56	115.9	4.56	12.7	0.50	13.90	9.35
125	5	160	141.3	5.56	109.6	4.31	15.9	0.63	16.95	11.40

(Continued)

Table A.1 (Continued)
Pipe Diameters, Wall Thicknesses, and Weights of Aluminum Pipe

Piping Dimensions										
Nominal Pipe Diameter Size Number			Outside Diameter (OD)		Inside Diameter (ID)		Wall Thickness ^a		Weight ^a	
150	6	5	168.3	6.63	162.7	6.41	2.8	0.11	3.90	2.62
150	6	10	168.3	6.63	161.5	6.36	3.4	0.13	4.78	3.21
150	6	40	168.3	6.63	154.1	6.07	7.1	0.28	9.76	6.56
150	6	80	168.3	6.63	146.3	5.76	11.0	0.43	14.69	9.88
150	6	120	168.3	6.63	139.7	5.50	14.3	0.56	18.72	12.59
150	6	160	168.3	6.63	131.8	5.19	18.2	0.72	23.30	15.67
200	8	5	219.1	8.63	213.5	8.41	2.8	0.11	5.10	3.43
200	8	10	219.1	8.63	211.6	8.33	3.8	0.15	6.89	4.64
200	8	20	219.1	8.63	206.4	8.13	6.4	0.25	11.50	7.74
200	8	30	219.1	8.63	205.0	8.07	7.0	0.28	12.70	8.54
200	8	40	219.1	8.63	202.7	7.98	8.2	0.32	14.68	9.87
200	8	60	219.1	8.63	198.5	7.81	10.3	0.41	18.33	12.33
200	8	80	219.1	8.63	193.7	7.63	12.7	0.50	22.31	15.01
200	8	100	219.1	8.63	189.0	7.44	15.1	0.59	26.17	17.60
200	8	120	219.1	8.63	182.6	7.19	18.2	0.72	31.18	20.97
200	8	140	219.1	8.63	177.8	7.00	20.6	0.81	34.85	23.44
200	8	160	219.1	8.63	173.1	6.81	23.0	0.91	38.42	25.84
250	10	5	273.1	10.75	266.2	10.48	3.4	0.13	7.81	5.26
250	10	10	273.1	10.75	264.7	10.42	4.2	0.17	9.59	6.45
250	10	20	273.1	10.75	260.4	10.25	6.4	0.25	14.42	9.70
250	10	30	273.1	10.75	257.5	10.14	7.8	0.31	17.60	11.84
250	10	40	273.1	10.75	254.5	10.02	9.3	0.37	20.81	14.00
250	10	60	273.1	10.75	247.7	9.75	12.7	0.50	28.14	18.93
250	10	80	273.1	10.75	242.9	9.56	15.1	0.59	33.08	22.25
250	10	100	273.1	10.75	236.6	9.31	18.2	0.72	39.56	26.61
300	12	5	323.9	12.75	315.5	12.42	4.2	0.17	11.41	7.67
300	12	10	323.9	12.75	314.7	12.39	4.6	0.18	12.43	8.36
300	12	20	323.9	12.75	311.2	12.25	6.4	0.25	17.17	11.55
300	12	40	323.9	12.75	303.2	11.94	10.3	0.41	27.53	18.52
300	12	60	323.9	12.75	295.3	11.63	14.3	0.56	37.61	25.30
300	12	80	323.9	12.75	289.0	11.38	17.4	0.69	45.52	30.62

^a All weights and dimensions are nominal.

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Annex B (Informative)

Guidelines for the Preparation of Technical Inquiries

This annex is not part of AWS D10.7M/D10.7:2008, *Guide for the Gas Shielded Arc Welding of Aluminum and Aluminum Alloy Pipe*, but is included for informational purposes only.

B1. Introduction

The American Welding Society (AWS) Board of Directors has adopted a policy whereby all official interpretations of AWS standards are handled in a formal manner. Under this policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is directed through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

B2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

All inquiries shall contain the name, address, and affiliation of the inquirer, and they shall provide enough information for the committee to understand the point of concern in the inquiry. When the point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and in the format specified below.

B2.1 Scope. Each inquiry shall address one single provision of the standard unless the point of the inquiry involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the inquiry

along with the edition of the standard that contains the provision(s) the inquirer is addressing.

B2.2 Purpose of the Inquiry. The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be to obtain an interpretation of a standard's requirement or to request the revision of a particular provision in the standard.

B2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to understand the point of the inquiry. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annex) that bear on the inquiry shall be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry shall provide technical justification for that revision.

B2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry or provide the wording for a proposed revision, if this is what the inquirer seeks.

B3. Interpretation of Provisions of the Standard

Interpretations of provisions of the standard are made by the relevant AWS technical committee. The secretary of the committee refers all inquiries to the chair of the particular subcommittee that has jurisdiction over the portion of the standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire committee for review and approval. Upon approval by the committee, the interpretation is an official

interpretation of the Society, and the secretary transmits the response to the inquirer and to the *Welding Journal* for publication.

B4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal* and will be posted on the AWS web site.

B5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The AWS Board of Directors' policy requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can

be obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

B6. AWS Technical Committees

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees or to consideration of revisions to existing provisions on the basis of new data or technology. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on (1) specific engineering problems, (2) requirements of standards applied to fabrications outside the scope of the document, or (3) points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

Annex C (Informative)

Bibliography

This annex is not part of AWS D10.7M/D10.7:2008, *Guide for the Gas Shielded Arc Welding of Aluminum and Aluminum Alloy Pipe*, but is included for informational purposes only.

AWS Documents:³

AWS D1.2, *Structural Welding Code—Aluminum*

AWS PHB-8, *The Everyday Pocket Handbook for Gas Metal Arc Welding (GMAW) of Aluminum*

AWS WHB-3, *Welding Handbook*, Volume 3, Chapter 1; *Aluminum and Aluminum Alloys*

Aluminum Association Documents:⁴

Aluminum Association, *Welding Aluminum: Theory and Practice*

ASME Documents:⁵

ASME *Boiler and Pressure Vessel Code*, Sections II, VIII, and IX. New York, New York: American Society of Mechanical Engineers

ANSI B31.1, *Power Piping*

ANSI B31.3, *Chemical Plant and Petroleum Refinery Piping*

ANSI B31.5, *Refrigeration Piping*

American Petroleum Institute Documents:⁶

API 620, *LNG Storage Tanks*, Appendix Q, Compressed Gas Association Documents⁷:

Compressed Gas Association, Inc., *Handbook of Compressed Gases*, 2nd Ed., New York: Von Nostrand Reinhold Co., 1981

³ AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

⁴ Aluminum Association standards are published by the Aluminum Association, Inc., 1525 Wilson Blvd., Suite 600, Arlington, VA 22209.

⁵ ASME standards are published by ASME International, Three Park Avenue, New York, NY 10016-5990.

⁶ API standards are published by the American Petroleum Institute, 1220 L Street NW, Washington, DC 20005-8029.

⁷ CGA standards are published by the Compressed Gas Association, 4221 Walney Road, 5th Floor, Chantilly, VA 20151-2923.

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List of AWS Documents on Piping and Tube

Designation	Title
D10.4	<i>Recommended Practices for Welding Austenitic Chromium Nickel Stainless Steel Piping and Tubing</i>
D10.6/D10.6M	<i>Recommended Practices for Gas Tungsten Arc Welding Titanium Piping and Tubing</i>
D10.7M/D10.7	<i>Guide for the Gas Shielded Arc Welding of Aluminum and Aluminum Alloy Pipe</i>
D10.8	<i>Recommended Practices for Welding Chromium Molybdenum Steel Piping and Tubing</i>
D10.10/D10M	<i>Recommended Practices for Local Heating of Welds in Piping and Tubing</i>
D10.11M/D10.11	<i>Recommended Practices for Root Pass Welding of Pipe Without Backing</i>
D10.12M/D10.12	<i>Guide for Welding Mild Steel Pipe</i>
D10.13M/D10.13	<i>Recommended Practices for the Brazing of Copper Pipe and Tubing for Medical Gas Systems</i>
D10.18M/D10.18	<i>Guide for Welding Ferritic/Austenitic Duplex Stainless Steel Piping and Tubing</i>

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