

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



American Welding Society



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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*

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.

[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

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.