



American Welding Society

The Practical Reference Guide for

Welding Aluminum



High-Quality Fusion Welding

THE PRACTICAL REFERENCE GUIDE for HIGH-QUALITY FUSION WELDING of ALUMINUM

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BASIC SAFETY PRECAUTIONS

Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpiece should be grounded. The workpiece lead is not a ground lead. It is used only to complete the welding circuit. A separate connection is required to ground the workpiece. The workpiece should not be mistaken for a ground connection.

Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Avoid breathing the air in the fume plume directly above the arc. Do not weld in a confined area without a ventilation system. Use point-of-welding fume removal when welding galvanized steel, zinc, lead, cadmium, chromium, manganese, brass, or bronze. Do not weld on piping or containers that have held hazardous materials unless the containers have been inerted properly.

Compressed Gas Cylinders. Keep caps on cylinders when not in use. Make sure that gas cylinders are chained to a wall or other structural support. Do not weld on cylinders.

Radiation. Arc welding may produce ultraviolet, infrared, or light radiation. Always wear protective clothing and eye protection to protect the skin and eyes from radiation. Shield others from light radiation from your welding operation.

Special Precautions. In the following conditions when welding aluminum alloys:

- (1) High levels of fumes are produced when using the 5XXX (magnesium-bearing) aluminum filler metals.
- (2) The use of argon-based shielding gas blends results in the production of ozone, especially with 4XXX filler metals.

The use of filtering masks or airline respirators will be required if it is determined that personnel are being exposed to excessive pollutants.

Caution must also be observed in the reaction between aluminum and certain solvents and cleaners. Consult information provided by manufacturers for the necessary safe practices in the use of their products.

AWS also recommends a personal copy of "Arc Welding Safely," "Fire Safety in Welding and Cutting," and "Safety in Welding, Cutting, and Allied Processes."

Introduction

Aluminum is one of the most underrated and misunderstood metals in welding. It “gets no respect,” as a well-known comedian has often said. Aluminum weldments have become commonplace commercially, largely due to their corrosion resistance and light weight. Since aluminum weldments are in abundance, the degree of difficulty when welding aluminum is considered so minimal that basic preparations and precautions are often neglected. Fusion welding of aluminum is similar to welding titanium in the sense that, when the basic rules and preparations are followed, good welds are not difficult to obtain. Cleanliness is most critical.

In this guide we are going to concentrate on obtaining high quality aluminum weldments with the fusion processes, in particular gas tungsten arc welding (GTAW), electron beam welding (EBW), and gas metal arc welding (GMAW). These procedures are more critical when utilizing the GTAW process in the direct current electrode negative mode (GTAW, DCEN) which produces a narrower deeper penetrating weld than the alternating current (AC) mode. The intent is to build in the quality during fabrication rather than inspecting in the quality. Too often when high quality is required the inspection requirements are made more stringent rather than making the fabrication procedures more stringent. If an X-ray quality weld is desired you don’t just X-ray the weld. The welding procedure must be planned to obtain X-ray quality weldments.

These guidelines were basically utilized for the following applications:

- *Grumman Aerospace*—for mechanized gas tungsten arc welding (GTAW, DCEN) 2219 aluminum alloy for the Lunar Module for Project Apollo that landed men on the moon. These weldments required X-ray quality, helium leak-tight and pressure testing.
- *General Dynamics Corporation, Quincy Shipbuilding Division*—for gas metal arc welding of 5083 aluminum alloy for the 120-foot diameter Liquid Natural Gas Spheres requiring radiographic quality and pressure tested weldments.
- *General Dynamics, Convair Division*—for Tomahawk Cruise Missile 2219 aluminum alloy weldments utilizing the electron beam welding, gas tungsten arc and gas metal arc welding processes. They were also used for the gas metal arc

welding (GMAW) of the 5083 aluminum alloy Aft and Forward Equipment Boxes for the Tomahawk Ground Launches. The electron beam and gas tungsten arc welds were 100% X-rayed.

These guidelines should be followed to produce high quality weldments, even when radiographic or ultrasonic inspection is not required. An example is the GMAW structural plug welds of the Tomahawk Cruise Missile Mid-Body Section. Consistent high-quality was mandatory in this fuel section, although the design was not suitable for X-ray inspection.

Preweld Preparation

Sawing

Band saws, hacksaws, or cut-off saws are normally used for rough cuts followed by machining or draw filing.

Saw-cut edges are not normally suitable for welding, as the jagged edge is a dirt, lubricant, and/or oxide trap that is difficult to clean.

Sharp, circular saw-blade cuts can produce a fine nongalled finish suitable for welding. Power feeding helps to achieve good cuts. However, lubricants should be avoided for final preweld cuts. Alcohol spray mists have proven to be effective when necessary to obtain better surface finishes and minimize the attachment of the aluminum chips to the saw blade.

Machining

Machined surface finishes should not exceed 125 μin . Ra (Root average).

Dry machining (no lubricants) is recommended for surfaces to be consumed by the weld puddle. Alcohol or liquid nitrogen spray mists have proven to be effective when necessary to obtain better surface finishes and minimize the attachment of the aluminum chips to the tool bits. Sharp tools should be used.

Shearing

“As-sheared” edges are not normally suitable for welding. The first portion of the sheared edge surface is cut and tends to smear (gall) while the second portion is a fracture surface. Both conditions

are dirt and oxide traps. While the molten weld most probably would consume transverse cracks from the sheared edge on sheet metal, the remaining dirt traps may well yield porosity and poor fusion. Sheared edges in 5XXX and 7XXX alloys that are left unwelded can initiate stress-corrosion cracking due to the effect of work hardening.

Grinding

Grinding as a final finish prior to welding is a concern as the grinding material and binders have a tendency to embed themselves into the aluminum surface and become contaminants producing porosity.

Laser Cutting

Laser cutting of aluminum tends to produce a rough cut with a surface finish exceeding 125 Ra, which are potential dirt traps. When laser cutting is utilized it should be performed on clean material so as not to spread surface contaminants into the molten cut zone.

Plasma Arc Cutting

Plasma arc cutting is normally used for rough cuts of large plates. The "recast" cut surface is then machined for final preparation. Intergranular cracking can occur as deep as 0.090 in. from the cut edge of 2XXX, 6XXX, and 7XXX aluminum alloys, so machining must remove this zone.

Work Gloves

Work gloves, while important, are a common source of contamination. Obviously dirty gloves are a contaminant. However "clean gloves" can be misleading as lint and other particles may be transferred to the weld zone surface. Lint and other foreign material entrapped in the weld can produce porosity. Lint has been known to produce fine "chain porosity." For handling preweld clean surfaces, including weld details and tooling within the weld zone, use lint-free gloves, low-lint gloves, plastic throwaway gloves, or "kitchen-type" latex gloves. These gloves can also be used when manually feeding filler wire. The kitchen-type latex gloves are relatively thin with textured fingertip surfaces aiding in feeling and feeding the filler

wire. They can also be washed and dried with warm air blow dryers while on the hand. The insides of the gloves are coated minimizing sweating and easing insertion of the hand. A clean, smooth leather glove is recommended for the hand that is holding the welding torch. When high amperages are employed a clean, smooth leather glove can also be used to feed the filler wire. True lint-free gloves can be expensive and difficult to work in. Low-lint gloves are normally adequate and absorb body moisture and oils better. However, never turn the gloves inside out when removed in order to reuse them. This glove surface may appear clean, but will have been contaminated from contact with the skin.

Preweld Cleaning

It should be understood that contaminants will produce porosity. Common contaminants normally encountered are oxides, water stains, dirt, oil, grease, paint, fingerprints, pencil or ink marks, lint, and other foreign materials. Anodizing and other surface protections can produce contaminants too. Sometimes you can weld over these contaminants and get away with it but most times you cannot. It is not always consistent. However, clean conditions with good welding parameters will produce clean welds on weldable alloys. The entrapment of contaminants in the molten weld puddle causes the contaminants to out-gas or become inclusions. The out-gassing is then entrapped within the solidifying weld metal creating gas pockets (porosity). Porosity is a void, which reduces the cross-sectional area of the weldment.

The purpose of preweld cleaning is to prevent porosity and lack of fusion. One cause of lack of fusion on aluminum is contamination preventing the molten weld from alloying with the parent metal or the previously solidified weld metal. The contamination can act as a boundary membrane preventing alloying. Lack of fusion is similar to a man-made crack which is subject to propagation (growing) under thermal or mechanical stress conditions.

Aluminum oxides melt at 3600°F, as compared to 1200°F max. for the parent metal. Therefore rather than melting, they become inclusions to prevent fusion. Out-gassing of these inclusions can also produce porosity.