

## A Guide to Aluminum Welding

Reprinted courtesy of Welding Design and Fabrication magazine.

### Equipment Selection, Material Prep, Welding Technique...

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Follow the rules of thumb offered here for selecting welding equipment, preparing base materials, applying proper technique, and visually inspecting weldments to ensure high-quality gas-metal-arc and gas tungsten-arc welds on aluminum alloys.

Even for those experienced in welding steels, welding aluminum alloys can present quite a challenge. Higher thermal conductivity and low melting point of aluminum alloys can easily lead to burnthrough unless welders follow prescribed procedures. Also, feeding aluminum welding wire during gas-metal-arc-welding (GMAW) presents a challenge because the wire is softer than steel, has a lower column strength, and tends to tangle at the drive roll.



To overcome these challenges, operators need to follow the rules of thumb and equipment-selection guidelines offered here...

#### **Gas-metal-arc-welding:**

**Base-metal preparation:** To weld aluminum, operators must take care to clean the base material and remove any aluminum oxide and hydrocarbon contamination from oils or cutting solvents. Aluminum oxide on the surface of the material melts at 3,700 F while the base-material aluminum underneath will melt at 1,200 F. Therefore, leaving any oxide on the surface of the base material will inhibit penetration of the filler metal into the workpiece.

To remove aluminum oxides, use a stainless-steel bristle wire brush or solvents and etching solutions. When using a stainless-steel brush, brush only in one direction. Take care to not brush too roughly: rough brushing can further imbed the oxides in the work piece. Also, use the brush only on aluminum work-don't clean aluminum with a brush that's been used on stainless or carbon steel. When using chemical etching solutions, make sure to remove them from the work before welding.

To minimize the risk of hydrocarbons from oils or cutting solvents entering the weld, remove them with a degreaser. Check that the

degreaser does not contain any hydrocarbons.

**Preheating:** Preheating the aluminum workpiece can help avoid weld cracking. Preheating temperature should not exceed 230 F-use a temperature indicator to prevent overheating. In addition, placing tack welds at the beginning and end of the area to be welded will aid in the preheating effort. Welders should also preheat a thick piece of aluminum when welding it to a thin piece; if cold lapping occurs, try using run-on and run-off tabs.

**The push technique:** With aluminum, pushing the gun away from the weld puddle rather than pulling it will result in better cleaning action, reduced weld contamination, and improved shielding-gas coverage.

**Travel speed:** Aluminum welding needs to be performed "hot and fast." Unlike steel, the high thermal conductivity of aluminum dictates use of hotter amperage and voltage settings and higher weld-travel speeds. If travel speed is too slow, the welder risks excessive burnthrough, particularly on thin-gage aluminum sheet.

**Shielding Gas:** Argon, due to its good cleaning action and penetration profile, is the most common shielding gas used when welding aluminum. Welding 5XXX-series aluminum alloys, a shielding-gas mixture combining argon with helium - 75 percent helium maximum - will minimize the formation of magnesium oxide.

**Welding wire:** Select an aluminum filler wire that has a melting temperature similar to the base material. The more the operator can narrow-down the melting range of the metal, the easier it will be to weld the alloy. Obtain wire that is 3/64- or 1/16- inch diameter. The larger the wire diameter, the easier it feeds. To weld thin-gage material, an 0.035-inch diameter wire combined with a pulsed-welding procedure at a low wire-feed speed - 100 to 300 in./min - works well.

**Convex-shaped welds:** In aluminum welding, crater cracking causes most failures. Cracking results from the high rate of thermal expansion of aluminum and the considerable contractions that occur as welds cool. The risk of cracking is greatest with concave craters, since the surface of the crater contracts and tears as it cools. Therefore, welders should build-up craters to form a convex or mound shape. As the weld cools, the convex shape of the crater will compensate for contraction forces.

**Power-source selection:** When selecting a power source for GMAW of aluminum, first consider the method of transfer -spray-arc or pulse. Constant-current (cc) and constant-voltage (cv) machines can be used for spray-arc welding. Spray-arc takes a tiny stream of molten metal and sprays it across the arc from the electrode wire to the base material. For thick aluminum that requires welding current in excess of 350 A, cc produces optimum results. Pulse transfer is usually performed with an inverter power supply. Newer power supplies contain built-in pulsing procedures based on and filler-wire type and diameter. During pulsed GMAW, a droplet of filler metal transfers from the electrode to the workpiece during each pulse of current. This process produces positive droplet transfer and results

in less spatter and faster follow speeds than does spray-transfer welding. Using the pulsed GMAW process on aluminum also better-controls heat input, easing out-of-position welding and allowing the operator to weld on thin-gage material at low wire-feed speeds and currents.

**Wire feeder:** The preferred method for feeding soft aluminum wire long distances is the push-pull method, which employs an enclosed wire-feed cabinet to protect the wire from the environment. A constant-torque variable-speed motor in the wire-feed cabinet helps push and guide the wire through the gun at a constant force and speed. A high-torque motor in the welding gun pulls the wire through and keeps wire-feed speed and arc length consistent.

In some shops, welders use the same wire feeders to deliver steel and aluminum wire. In this case, the use of plastic or Teflon liners will help ensure smooth, consistent aluminum-wire feeding. For guide tubes, use chisel-type outgoing and plastic incoming tubes to support the wire as close to the drive rolls as possible to prevent the wire from tangling. When welding, keep the gun cable as straight as possible to minimize wire-feed resistance. Check for proper alignment between drive rolls and guide tubes to prevent aluminum shaving.

Use drive rolls designed for aluminum. Set drive-roll tension to deliver an even wire-feed rate. Excessive tension will deform the wire and cause rough and erratic feeding; too-little tension results in uneven feeding. Both conditions can lead to an unstable arc and weld porosity.

**Welding guns:** Use a separate gun liner for welding aluminum. To prevent wire chaffing, try to restrain both ends of the liner to eliminate gaps between the liner and the gas diffuser on the gun.

Change liners often to minimize the potential for the abrasive aluminum oxide to cause wire-feeding problems.

Use a contact tip approximately 0.015 inch larger than the diameter of the filler metal being used - as the tip heats, it will expand into an oval shape and possibly restrict wire feeding. Generally, when a welding current exceeds 200 A use a water-cooled gun to minimize heat buildup and reduce wire-feeding difficulties.

# How To Successfully Weld Aluminum with a Compact MIG Welder

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When it comes to welding aluminum items around the home or garage, there are a few misconceptions we hope to clear up: 1) That you need to invest in a \$4,000 welding machine and be highly skilled to have success; 2) With no practice you can make excellent welds the first time the wire feed welder is taken out of the box; and 3) You need an expensive spool gun suited for aluminum.

The truth is that with practice, the right equipment and proper set-up, a compact MIG welder will be able to tackle occasional aluminum welding jobs. Using your MIG welder, you will be able to work on a variety of items around your home and yard, such as grills, railings, backyard furniture, boat docks and even decorative elements. Compact MIG welders, such as the SP, Weld-Pak or Pro models from Lincoln Electric, are available at distributors and retail outlets.

## **A Word About Aluminum**

Even home welding enthusiasts who have experience welding steel may find a switch to aluminum challenging. Here's why: Because of the softness of aluminum wire, it is more difficult to feed. In addition, wire diameters and machine settings normally used for steel may not be appropriate for aluminum. In order to be successful, ask yourself these questions:

### **What Machine Do I Need?**

The first decision is what type of machine is right for the job. Keep in mind that a 115 volt wire feeder welder can handle jobs that range from 22 to 12 gauge and with moderate



preheating, you can probably weld as thick as 1/8". Be aware that preheating should be limited to 250 degrees F maximum.

Another option is a 230 volt machine which can weld from 22 gauge all the way to 3/16". Proper preheat can take the range to 1/4". If you will need to weld a broader range of aluminum thicknesses, consider investing in the 230v machine.

Remember, if you plan on doing regular aluminum fabrication, you will need a heavy duty machine. The 115 volt and 230 volt compact MIG welder models are acceptable for occasional aluminum jobs, but not recommended for heavy duty aluminum use. For daily production welding on heavier aluminum, consider a welder that has greater than 200 amps output.

After you have chosen your input voltage, another common question you will be asked when selecting a welder is whether you want a continuous or tapped voltage control model.

A continuous voltage control model lets you set an infinite range of voltage within the rating of the machine, allowing more adjustability, fine tuning and precise control. This permits you to more easily adapt the voltage to your application and particular skill level.

If you're on a budget, opt for the tapped control unit. This machine has a rotary switch with four or five fixed voltage choices. It will not give you the control of a continuous model, but it can be slightly easier to get up to speed with and costs less to purchase and will be adequate for most applications.

### **What Type of Welds Can be Made?**

For these types of machines, it is best to make welds in the horizontal and flat positions. In general, fillet welds in lap joints are made more easily than groove welds in butt joints. Fillet welds in tee joints are preferred over corner joints. Keep in mind that home welding by an amateur is not recommended for critical welds where failure could result in serious injury.

### **What Type of Shielding Gas is Required?**

MIG welding aluminum is different than welding steel when it comes to shielding gas requirements. For aluminum, 100 percent argon is the gas of choice, whereas steel welding calls for a mixed gas or 100 percent CO2 gas. The good news is that no special equipment is needed - your existing regulators (with the exception of CO2 regulators) and gas hoses can be used for both pure blends and mixed gases.

## What Polarity Setting is Needed?

All MIG welding, including on aluminum materials, requires electrode positive polarity, while flux-cored processes typically use electrode negative. If you are switching your wire feed welder between processes, make sure to switch your polarity. This is a common mistake that many beginning welders make.

## What Aluminum Wire Electrode Alloy Type Should I Buy?

You will not obtain good results attempting to weld on aluminum with a steel wire electrode.

Instead, our recommendation is that compact MIG welders should be limited to .035" diameter 4043 aluminum alloy

filler metal. A 5356 aluminum alloy electrode may commonly be recommended by retailers and distributors, since it is a stiffer wire and can be easier to feed. However, with these types of wire feed welders, there is often not enough amperage to achieve a good weld with 5356. Even though 4043 is a softer wire, following the proper steps outlined below will ensure good feedability.



Do not use other diameter wires. Specifically, you should avoid 0.030" wire (it is difficult to feed) and 3/64" wire (these compact machines do not typically produce enough current to reliably melt this diameter of wire).

## How Do I Set-Up My Machine to Weld Aluminum?

Now that you know the type of machine you want and its capabilities/limitations, it is important to know how best to set it up. Follow these tips:

### ***Purchase an Aluminum Feeding Kit***

Attention to feeding issues is much more critical when it comes to aluminum welding. It is highly recommended that you purchase an aluminum feeding kit, which includes the following items:

- *Non-metallic liner* - designed to minimize the amount of friction on the wire
- *U-shaped drive rolls* - to avoid crushing or deforming the soft aluminum wire. These drive rolls do not shave the wire like V-groove drive rolls. Using V-groove drive rolls, the resulting wire shavings can clog the liner and lead to feeding problems.
- *Inlet and outlet guides* - designed specifically to avoid wire shaving.
- *Contact tips* - as compared to those used for the same diameter of steel wire electrode, contact tips for aluminum have larger diameter holes, since as aluminum heats up, it expands more than steel. Therefore, contact tips for aluminum applications are sized small enough to maintain good electrical contact, but large enough to allow for expansion.

### ***Load Wire Into the Machine***

There is a trick to properly loading aluminum wire into a wire feed welder. While the same technique should be used with steel wire electrodes, it is especially important with aluminum wire loading, to avoid feeding problems during welding.

With one hand, hold the wire spool securely so it doesn't unravel. Once you remove the cellophane wrapping, hold the loose end of the wire with the other hand - don't let go until you lock the wire into the drive roll.

Inexperienced operators commonly let go of the loose end and the spool starts to unravel. If this happens, it cannot be wound back up and still perform properly - you will have to purchase another spool.

#### **Set the Wire Brake Tension**

The idea is to have just enough tension to keep the wire from unraveling, but not too much tension so that it causes a drag on the wire. To do this, set the wire spool brake tension for a minimum setting. Then, load the spool on and feed it through the drive rolls. With everything stopped, if the spool keeps turning by itself, there is not enough brake tension. Be careful though, since too much brake tension can put excessive force on the wire.

And, operators shouldn't be surprised at the end of the spool if they cannot feed the last few turns; usually the wire is too stiff to come off easily.



#### ***Set the Drive Roll Tension***

This step is probably the most important in the whole set-up process. The experts from Lincoln recommend holding the nozzle about 1" away from an electrically insulated surface at a slight angle. Then, set the drive roll tension close to minimum. Pull the trigger and watch the behavior - as the wire touches the insulated surface, the drive rolls should slip. Tighten down from that point until the wire stops slipping. Again, a word of caution, as wire that is set too

tight will tend to 'birdnest'. This means the wire stops at the gun but the drive rolls are still turning. The result is wire feeds out of the drive rolls and birdnests, or backs up and tangles, anywhere along the drive path - at the guide tubes, in the gun liner, etc.

Remember, as you set the drive roll tension in the manner described above, that when the gun trigger is pressed, the wire is electrically hot, so always wear a quality pair of welding gloves.

#### ***Ensure Good Electrical Connections***

The work clamp should be securely attached to the welding piece in an

area free from paint and contaminants. To clean the piece, use a degreasing solvent to remove any oil and grease. Be sure that the surface is dry before you weld. Also, do not weld with flammable material nearby, such as a container of solvent or paint. As a second step, use a clean, stainless steel wire brush to remove all oxides from the surface of the aluminum.

### **Position Is Important**

As you are welding, keep the gun cable as straight as possible to minimize feeding restrictions on the soft aluminum wire. A bend in the gun cable can make the wire kink and feed poorly.

### **Practice, Practice, Practice!**

There is no substitute for practice. Just as a high-quality musical instrument won't make you a good player without practice, a welding operator needs to hone his or her skills as well. Before too long, you and your welder will be making beautiful music (or at least welds) together!