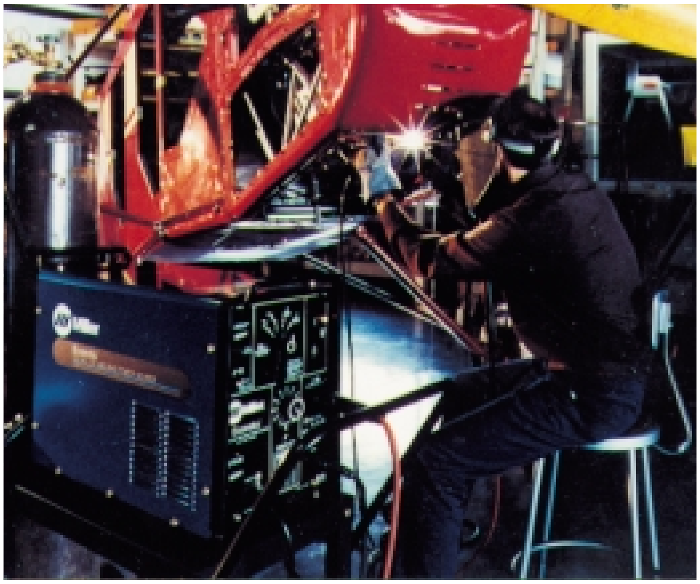
GTAW Tips for Aluminum

Aluminum: beautiful, lightweight, strong, versatile ... and a real challenge to weld. Fortunately, some newer GTAW welding systems have been designed specifically to address the challenges of welding aluminum. This article describes some of the new equipment available and its benefits, accessories required, points to consider before you weld, and the techniques required to make a good weld bead.

By Mike Sammons, Product Manager, Miller Electric Mfg. Co.



Designed for hobby work, Miller's Econotig® creates AC and DC arcs for TIG and Stick welding.

Power Sources

Generally speaking, GTAW power sources with an AC/DC output come in four categories.

1. Home hobbyist, light fabrication, maintenance. These machines usually have an AC output ranging from 20 to 165 amps and generally can be purchased for about $1,200 to $1,400. While they do not incorporate a Squarewave output or balance control technology, they do produce an arc suitable for a wide variety of work.

2. Light industrial, maintenance/repair, metal fabrication. This newer class of machine provides roughly a 15 to 180 AC output, a "professional-quality" arc at an affordable (perhaps $1,600 or less) price. Key features include: a Squarewave output, a fixed balance control set for more penetration than cleaning (a 60/40 electrode negative to electrode positive ratio; this works best for a majority of applications), built-in high frequency starting (for positive starts without arc wandering) and a built-in stabilizer (for a more consistent arc while welding).

3. Industrial production, fabrication, aerospace, repair. When most people think of "industrial" GTAW machines, they think of this class. Industrial GTAW power sources feature a Squarewave output with an a*djustable balance control.* Greater amounts of electrode negative (EN) create a deeper, narrower weld bead and better joint penetration. Greater electrode positive (EP) values remove more oxide and create a shallower, wider bead. Transformer-rectifier GTAW machines can adjust EN values from 45 to 68 percent.

Machines are available with a variety of outputs, typically rated at 250, 350 and 500 amps with a 40 or 60 percent duty cycle. The low-end amperage range listed for these machines is usually 3 or 5 amps. These machines are available with a variety of options, typically pulsing controls, sequence controls (start current, start time, crater time, final amperage trigger hold and spot). GTAW power sources in this category have created millions of code-quality welds. Prices vary widely depending on the complexity and output of the system, perhaps from $2,500 to $5,000.

4. Inverter based AC/DC GTAW machines. The capabilities and controls of inverters surpasses that of full-featured industrial machines; they are available with an output range of 1 to 375 amps. Although inverters cost more than conventional machines (perhaps 20 to 50 percent), their advanced technology provides an amazingly fast return on investment for many applications. Inverters solve difficult problems, and they can go places and weld joints that conventional machines cannot. Benefits include:

• ***Improved arc quality and arc stability.*** Inverters push the arc through the zero crossing *thousands* of times faster than conventional GTAW machines. Experienced operators immediately notice and appreciate improved arc quality and weld consistency throughout the entire amperage range.

• ***Extended Squarewave balance control.*** Inverters can adjust EN duration from 50 to 90 percent. Adding more EN to the cycle: may increase travel speed up to 20 percent; narrow the weld bead; achieve greater penetration; may permit using a smaller diameter tungsten (to more precisely direct the heat or

The Dynasty™ inverter eliminated arc instability and arc wandering, improving weld quality on these small, aluminum airplane components.

to make a narrower weld bead); and reduce the size of the etched zone for improved cosmetics.

• ***Adjustable output frequency.*** Inverters let operators adjust the welding output frequency, generally in the range of 20 to 250 Hz. Increasing frequency produces a tight, focused arc cone; this narrows the weld bead, which helps when welding in corners, on root passes and fillet welds. It also permits greatly increasing travel speed on some joints. Decreasing output frequency produces a broader arc cone, which widens the weld bead profile and provides greater cleaning action.

• ***Input power flexibility, primary power savings.*** GTAW inverters accept single- or three-phase, 50 or 60 Hz, 230 or 460 V input power. This provides flexibility when moving the machine between job sites or around a large facility. Using three-phase power, welding at 300 amps (460 V primary), an AC/DC GTAW inverter requires only 18 amps of primary current; a conventional power source, which can only use single-phase power, draws three to four times more power.

• ***Lightweight.*** An inverter is easily portable: a 5 to 300 amp AC/DC GTAW machine weighs about 90 lb. A conventional machine with similar capabilities weighs 355 lb.

GTAW Accessories

In addition to a bottle of shielding gas, gas regulator and hose, and work clamp, two critical components complete your GTAW welding system: a GTAW torch and a remote control. If most of your welding will be done at 200 amps or less, an air-cooled torch works well. For welding above 200 amps, consider a water-cooled torch. If you plan to move the unit around the shop, note that water coolers can be mounted on a wheeled cart that also carries the power source and gas bottles.

Remote control capabilities usually include current (amperage) and contactor control (the contactor keeps the torch electrically cold until energized, as well as starts and stops the gas flow to the torch). The most popular remote control is a foot pedal that operates much like an auto's gas pedal; the more you depress it, the more amperage flows. Another type of control – one that affords greater mobility but is more difficult to learn – is a finger tip control, which is mounted on the torch.

If most of your work is done on a bench or around structures that permit mobility, the foot pedal remote control is probably a better option because it is easier to use. Conversely, if you do a lot of work in awkward positions that keep your feet occupied, go with a finger tip control.

Before You Weld

The following suggestions address the basic areas of GTAW welding set-up. However, they are no substitute for carefully reading the operator's manual, watching instructional videos, and following safety precautions (e.g., wearing protective gloves and glasses).

1. Determine amperage requirements for the job at hand. To do this, remember a simple rule of thumb: each .001 in. of metal to be melted requires about 1 amp of welding power. For example, welding 1/8 in. (0.125 in.) aluminum requires about 125 amps.

2. Select the correct current – AC for aluminum, magnesium and zinc die-cast. When exposed to air, these metals form an oxide layer that melts at a much higher temperature than the base metal. If not removed, this oxide causes incomplete weld fusion. Fortunately, AC current inherently provides a "cleaning" action. While the electrode negative portion of the AC cycle directs heat into the work and melts the base metal, the electrode positive – where current flows from the work to the electrode – portion of the AC cycle "blasts" off the surface oxides.

Narrow beads like this — created with the Dynasty inverter — take 25% less time to weld and 15% less time to polish.

3. Use the right gas – usually pure argon; thicker weldments may require an argon/helium or other specialty gas mix. If you use the wrong gas, such as the 75/25 argon/CO_2 mix commonly used for GMAW, the tungsten will immediately begin to consume itself.

4. Set the proper gas flow rate – 15 to 20 cfh (more is not better). Argon is about 1 1/3 times heavier than air. When welding in a flat position, the gas naturally flows out of the torch and covers the weld pool. For overhead welding, start at 20 cfh and make small increments of 5 cfh if necessary (going from 20 cfh to 40 cfh will cause more problems than it solves, as well as waste money).

In any position, if the gas flows out at too high a velocity, it can bounce off the work piece and start a swirling motion parallel to the torch cup called a venturi. A venturi can pull air into the gas flow, bring in contaminating oxygen and nitrogen, and create pinholes in the weld. In fact, some operators automatically increase the gas flow when they see a pinhole, worsening the problem they "fixed."

5. Select the right type of tungsten — NOT pure tungsten. For AC welding, the traditional practice called for selecting a pure tungsten electrode and forming a ball at the end of the electrode. Unfortunately, balling promotes arc wandering, less arc focus and poorer arc starts because electricity likes to come off a point.

Today, new recommendations call for treating the tungsten almost as if the weld were being made in the DC mode: select a 2%-type tungsten (thorium, cerium, etc.), grind the electrode to a point (grind in the long direction, make the point roughly two times as long as the diameter), and put a .010 to .030 in. flat on the end to prevent balling and tungsten from being transferred across the arc.

With a pointed electrode, a skilled operator can place a 1/8 in. bead on a fillet weld made from 1/8 in. aluminum plates. Without this technology, the ball on the end of the electrode would have forced the operator to make a larger weld bead, then grind the bead down to final size.

6. Select the right diameter of tungsten. The current carrying capacity of a tungsten is directly proportional to the area of its cross-section. For example, a 2% thoriated, 3/32 in. (0.093 in.) tungsten has a current carrying capacity of 150 to 250 amps, where a 2% thoriated, 0.040 in. diameter tungsten has a current carrying 15 to 80 amps.

There is no such thing as an all-purpose electrode, despite the reputation of the 3/32 in. electrode. Attempting to weld at 48 amps with a 3/32 in. electrode will create arc starting and arc stability problems; the current is insufficient to "drive through" the electrode. Conversely, attempting to use a 3/32 in. tungsten to weld at 300 amps creates tungsten spitting — the excess current causes the tungsten to migrate to the work piece.

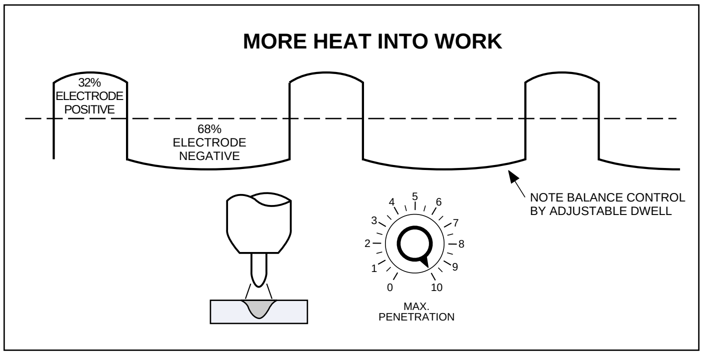
7. Tungsten contamination – avoid it. If the tungsten electrode becomes contaminated (by accidentally touching it to the weld pool), you must stop welding; a contaminated electrode can produce an unstable arc. To break off the contaminated portion, remove the tungsten from the torch, place it on a table with the contaminated end hanging over the edge, and firmly strike the contaminated portion with a hard object. Resharpen the tungsten.

8. Set the proper tungsten extension – one electrode diameter. While electrode extension may vary from flush with the gas cup to 1/2 in., a general rule is to start with one electrode diameter, or about 1/8 in. Joints that make the root of the weld hard to reach will require additional extension (however, farther than 1/2 in. may result in poor gas coverage).

9. Select the filler metal. The filler rod needs to match the base metal in both type and hardness of metal. The filler rod should be the same diameter as the tungsten electrode.

10. Select a high frequency (HF) mode. For AC welding with transformer-rectifier type machines, continuous HF is required to start and maintain the arc, which has a tendency to go out when the AC Squarewave travels through the zero amperage point. [HF bridges the gap between the electrode and the work, forming a path for the current to follow.] Inverters require HF for arc starting only, as they drive the arc through the zero point so quickly that the arc does not have a chance to go out (which is why you'll notice much less arc flutter with an inverter). Inverters also offer a Lift-Arc™ starting method that avoids the use of HF altogether.

11. Control HF emissions. High frequency is considered a necessary evil because it interferes with computers, printed circuit boards, televisions and other electronic equipment. To minimize HF: hook the work clamp as close to the weldment as possible; keep the welding torch and work clamp cables close together (spreading them apart is like creating a big broadcast dish); and keep the cables repaired to prevent current leaks.



Setting the squarewave balance control for maximum penetration, shown above, helps when welding thick sections.

12. Set the balance control. There are no hard rules about setting balance control, but the typical error involves over-balancing the cycle. Too much cleaning action (electrode positive duration) causes excess heat build-up on the tungsten. This creates a large ball on the end of the tungsten. Subsequently, the arc loses stability and the operator loses the ability to control the direction of the arc and the weld puddle. Arc starts begin to degrade as well. Too much penetration (or, more precisely, insufficient electrode positive current) results in a scummy weld puddle. If the puddle looks like it has black pepper flakes floating on it, add more cleaning action to remove these impurities.

13. Set the frequency (inverters only). Decreasing frequency produces a broader arc cone, which widens the weld bead profile and better removes impurities from the surface of the metal. It also transfers the maximum amount of energy to the work piece, which speeds up applications requiring heavy metal deposition (such as building up a worn part or making a fill pass). Increasing frequency produces a tight, focused arc cone; this narrows the weld bead, which helps when welding in corners, on root passes and fillet welds. The operator can direct the arc precisely at the joint and not have the arc dance from plate to plate. Increasing frequency may also increase travel speed dramatically in the right applications, perhaps up to 40 pecent.

A good starting point for general welding would be 80 to 120 Hz. These frequencies will be comfortable to work with, increase control of the arc direction and boost travel speed. For a fillet weld application with full penetration in the weld without putting too much amperage in the metal, increase the frequency to 200 Hz or more. For build-up work, start at 60 Hz and adjust lower from there.

Making a Good GTAW Weld

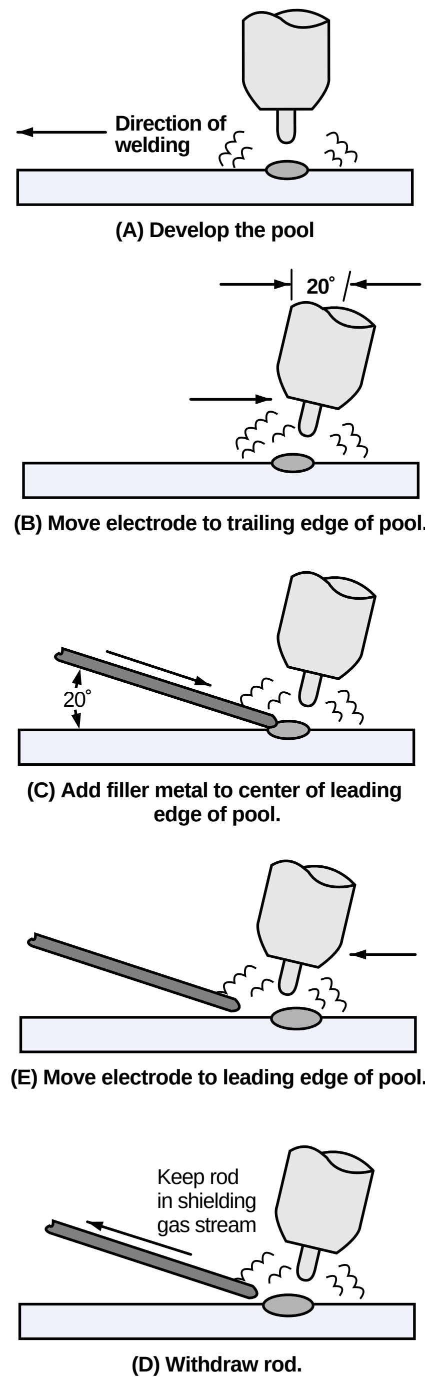
1. Get in a comfortable position and brace yourself. Maneuvering a GTAW torch properly is like trying to write neatly in a small space: brace your arm, move slowly, and focus on the end of the tungsten. In fact, many people grip the torch like a pencil.

2. Hold the torch at the proper angle. When describing the fundamentals of a good weld, keep in mind the direction of travel and the angle of the direction of travel. Travel angle is defined as the angle relative to the torch in a perpendicular position. Normal welding conditions in all positions call for a travel angle of 15 to 20 degrees. Travel angles beyond this lead to less penetration, poor direction of the weld metal, poor shielding gas coverage, and general arc instability.

For travel direction when GTAW welding, always use the push technique, which involves pushing the torch away from (ahead of) the weld puddle. Pushing ensures good gas coverage of the weld puddle, ensures that oxides have been removed, and it offers you a better view of the weld puddle.

3. Practice welding on scrap. Start by welding on a flat piece of metal; don't try to weld on a joint or add filler. Practice identifying the weld pool from the base metal. Play with the amperage control to find the right amount of heat. Learn how to control the size and shape of the weld puddle.

GTAW is like welding with an acetylene torch. If you think



The torch and rod should move progressively so the weld pool, filler and solidifying weld are not exposed to air.

you didn't make a good weld, you can go back over it, remelt it and repair the weld. However, remember that aluminum acts as a heat sink. Don't take a long time to get a molten puddle or you can easily overheat a small part.

4. Starting the arc. To start an arc using high frequency, hold the electrode about 1/8 in. from the work and depress the foot pedal; never touch the electrode to the work during a high frequency start. Many people tilt the torch and rest the gas cup against the work, establish the arc, and then shift the torch into the proper welding position. With Lift-Arc starting, just touch the tungsten to the work piece, lift it off the work piece, and the full welding current begins flowing.

5. Maintain consistent arc length – about one electrode diameter from the work. Varying the arc length produces inconsistencies. One common error beginning GTAW welders commit is picking up the torch, or tilting the torch too much, to get a better view of the electrode and weld puddle. If you need to see better, shift the position of your face – typically down and to the side.

6. Maintain a travel speed consistent with the bead shape you desire. Moving the torch too quickly creates a bead that is too narrow, while moving the torch too slowly produces an excessively wide bead. With GTAW welding, you don't have to move the torch forward until the weld puddle reaches the desired size. However, remember that holding the torch too long in one spot, especially on thin metal, can result in the arc burning through the base metal.

7. Adding filler metal (this is the part that requires a lot of practice). Once the arc is started and you've established a weld puddle of the desired size, you can begin to add filler metal. Hold the filler rod at a 15 to 20 degree angle up from the work piece, creating a 90 degree angle between the filler rod and the tungsten.

Fig. 1 shows the technique for adding filler. Be sure to move the torch and the filler rod progressively so that the weld pool, hot filler rod end and the solidifying weld are not exposed to air. Do not remove the hot end of the filler rod from the protection of the shielding gas.

There's good news and bad news about GTAW welding aluminum. The good news is that it's almost hard to make a bad GTAW weld. If you melt the base metal and get the filler rod into the weld puddle, you're most likely going to make a good weld. The bad news is that learning to make pretty weld beads, as well as coordinating your hands, feet and eyes, takes patience and practice. However, when you become proficient, the results are very satisfying.

Visit our website at **www.MillerWelds.com** or call us at **1-800-4-A-Miller (1-800-426-4553)**. You can also download articles like this one at **www.AppliedWelding.com**