TIG Welding in the Product Realization Lab

An Instructional Guide

OVERVIEW

In the TIG (tungsten inert gas) welding process, an essentially non-consumable tungsten electrode is used to provide an electric arc for welding. A sheath of inert gas surrounds the electrode, the arc, and the area to be welded. This gas shielding process prevents any oxidization of the weld and allows for the production of neat, clean welds.

TIG welding differs from MIG (metal inert gas) welding in that the electrode is not consumed in the weld. In the MIG welding process the electrode is continuously melted and is added into the weld. In TIG welding, no metal is added unless a separate filler rod is used.

TIG welding can be performed with a large variety of metals. The two most commonly TIG welded metals in the PRL are steel and aluminum. Steel is relatively easy to TIG weld and it is possible to produce very tight, neat welds. Aluminum takes a little more skill, and one should have at least a little bit of experience in welding steel before making the transition to aluminum. However, the basic technique is essentially the same and most people can make the jump to aluminum fairly easily.

TIG welding is an extremely powerful tool. With a little practice, it is possible to make beautiful welds much more quickly and easily than with oxy-acetylene welding. It also the only option currently available in the shop for welding aluminum. Put in a little time, and you will be rewarded in spades.

WELDING EQUIPMENT IN THE PRL

The Welding Machines

The PRL currently owns two TIG machines: a Miller Syncrowave 300 and a new Miller Syncrowave 250 DX. The 300 is stationary, and the 250 DX is mobile. The interfaces on the two machines are substantially different, but they operate in a similar manner.

Frequently Used Controls on the 300

1. Power Switch- Turns the Machine on or off

2. Range Switch- This toggles between the low range of current values on the current control dial (0 - 75 Amperes) and the high range (15 - 375 Amperes)

3. Current Control Dial- This allows one to dial in the amount of current that will flow between the torch and the workpiece when welding. NOTE: If the foot controller is to be used, the current dial setting will be the level of current flowing when the foot controller is fully pressed down.

4. AC/DC Switch- This switch selects whether the welding current will alternating (AC) or direct (DC).

5. Polarity Switch- This selects the polarity of the electrode during DC welding and thereby the direction in which current will flow. This switch has no effect when the AC/DC switch is in the AC position. The STRAIGHT position causes the electrode to be negative and allows for current to flow from the torch to the grounded workpiece. The REVERSE position causes the electrode to be positive and allows for current to flow from the workpiece back to the torch. (See the overview section about the advantages and disadvantages of each as well as for AC)

6. High Frequency Switch- This controls the superposition of a high frequency AC start voltage on top of the normal voltage between the torch and the workpiece. This is useful because a high frequency current can easily bridge the gap between the torch electrode and the workpiece in order to establish and/or maintain an arc. If the High Frequency Switch is in the OFF position, no high frequency voltage will be present. If the High Frequency Switch is in the START position, the high frequency will be present until an arc is established between the torch and the workpiece. After the arc is established, the high frequency shuts off. This position is usually used for DC welding so that one can start the arc without having to strike the workpiece with the electrode to start the arc. If the High Frequency Switch is in the CONTINUOUS position, the high frequency will be present before starting the arc and also once the arc had been established. This position is usually used for AC welding, where it helps establish the arc and also maintain it each time the voltage passes through zero.

Infrequently Used Controls on the 300

7. Contactor Switch- This toggles between remote control of the voltage between the torch and the workpiece and standard control. If the switch is in the REMOTE position, a voltage will be present only when the foot controller is depressed. If the switch is in the standard position, a voltage will be present whenever the machine is turned on. In the PRL the switch is essentially always left in the remote position. WARNING: Do not put the contactor switch in the standard position unless you really know what you are doing and you have consulted a TA, since the chance of electric shock is high should someone accidentally touch the electrode and ground when there is a voltage between the two. If you do use the machine with the contactor switch in the standard position, be sure to switch it back to REMOTE when you are done.

8. Start Current Switch and Start Current Control Dial- These allow one to select a different current level than that selected on the Current Control Dial for about the first second of welding, after which the current will slope either up or down to the setting of the Current Control Dial. In the PRL, the Start Current Switch is generally left in the OFF position and the start current circuitry is not used.

9. Post Flow Time Dial- This controls the length of time that cooling water and shielding gas will flow after the arc has been extinguished. The scale is calibrated in seconds and the dial is usually set to about 10.

10. Crater Fill Switch- The crater fill circuitry provides a gradual taper of the weld current as the arc is extinguished from the level on the Current Control Dial to a lower level. This gradual taper helps provide better weld puddle solidification at the end of the weld. In general, leave this switch in the OUT position.

11. AC Balance Control Dial- This dial allows one to bias the current used in AC welding so that it is more often going in the straight direction than in the reverse direction, or visa-versa. This can allow one to get more of the benefits of either straight or reverse polarity welding without sacrificing all of the benefits of the other. However, unless you are a really skilled welder, it would be best to leave this in the balanced position.

The Torch

The PRL currently uses a Weldcraft "WP" water-cooled TIG torch for all of its TIG welding operations. The torch is attached by a sheathed bundle of hoses to the TIG welding machine and can normally be found coiled on its hanger to the left of the machine. If one opens up the sheath that protects the hoses connected to the torch, one will note that there are three individual hoses running between the torch and the welding machine. One of the hoses is the shielding gas hose. When the gas flow has been activated, the shielding gas flows up through this hose and out the tip of the torch, thereby enveloping the electrode and the molten portion of the workpiece in a protective cloud of gas. Another hose is the water send line. This hose brings water up to the torch head so that it can circulate around the head and thereby cool the torch when welding. The third hose is actually two hoses in one. It is a combination of the current-carrying cable and the water return line. The current-carrying cable, which brings the welding current up to the electrode, is surrounded by a larger hose through which the cooling water returns. This jacket of water ensures that the cable does not become extraordinarily hot. Proper flow through these hoses is crucial for proper operation of the torch. Be sure that nothing is resting on top of them (it is common to accidentally set one's chair leg upon the hoses) as this can impede flow to or from the torch and thereby cause considerable damage to the equipment.

Electrodes

The electrodes can be found either in the small set of drawers near the welding machine (if they have already been used) or in the red packets sitting next to the drawers (if they are brand new). It is best to try to find an appropriate previously used electrode if possible, since that will usually save you the trouble of having to prepare the tip yourself. The electrodes are made of tungsten so that they can withstand the heat of the arc without melting. The electrodes come in many sizes ranging from .040" to 1/8". Larger electrodes are needed for welding thicker pieces of metal, and reverse polarity welding requires a larger electrode than straight polarity welding. The 1/16" and 3/32" electrodes are the most commonly used, but consult this document's Appendix (Suggested Settings for TIG Welding) or the guidelines posted on the machine in order to find the appropriate electrode for the task at hand.

In order to produce proper welds, the electrode must be shaped correctly. Generally, a pointed tip is used for DC welding and a rounded tip for AC welding.

Collets

The tungsten electrode is held rigidly in place within the torch by means of a collet into which it slides. The PRL has a variety of collet sizes in order to accommodate different size electrodes. The collets can be found in the small set of drawers near the 300.

Gas Lenses

The gas lens helps eliminate turbulence in the gas stream which can pull air into the welding area and contaminate the weld. A lens is essentially a barrier of fine mesh stainless-steel screens through which the shielding gas flows through. The lens screws into the front of the head of the torch and has a orifice in it for the electrode to stick out of. The various lenses owned by the shop have different size orifices to accommodate different size electrodes. The lenses are kept in the bottom drawer of the set of drawers near the welding machine.

Cups

Gas cups are threaded onto the front of the torch head (over the lens) in order to provide distributional control of the shielding gas. The gas cups come in many different sizes to accommodate the various flow rates used for different size electrodes. They can be found in the set of drawers near the welding machine.

Shielding Gas

The shielding gas used in TIG welding can be argon, helium or a mixture of the two. Although the shop keeps a tank of the each next to the welding machine, the helium is almost never used except for special applications. Argon is usually a better choice because it is heavier than air and therefore tends to provide a better blanket over the weld. The flow from the argon tank is controlled by the regulator/flow meter which is screwed onto the top of the tank. The double-seating main valve controls whether the argon will flow at all and the smaller valve at the bottom of the flow meter allows one to adjust the flow rate. Select a flow rate from this document's Appendix or from the guidelines posted on the TIG machine.

Filler Rod

Filler Rod is sometimes required when TIG welding either heavy gage metal or a joint that needs to be reinforced. The filler rod that one uses must be the same composition as the base metal. The shop stocks filler rod for TIG welding both steel and aluminum. The steel rod can be found in the tubes either on top of the welding machine or leaning against the MIG welder. The shop generally only stocks 1/16" steel rod for TIG welding. Be sure not to use the steel rod designed for oxy-acetylene welding, as it is not pure enough for use in TIG welding and can contaminate the tungsten electrode. The shop does have several thicknesses of filler rod for use in aluminum TIG welding; they can be found to the right of the TIG welding machine, leaning against the MIG welder. Consult the Appendix for specific information on selecting the proper size filler rod.

JOINT TYPES

The following are the most common types of joints designed for TIG welding[1]:

Butt Joint

For light materials the square-edge butt joint is the easiest to prepare and can be welded without filler rod. It consists of "butting" two pieces of metal up against one another (no overlapping) and then welding along the seam between them. If the weld is to be made without filler rod, extreme care must be taken to avoid burning through the metal.

The single-V butt joint is preferable on material ranging in thickness from 3/8" to 1/2" in order to secure complete penetration. It is prepared like a regular butt joint except that the top edge of each piece is chamfered in order to reduced the area of contact between the two. The included angle of the V formed by the chamfering should be approximately 60° with a depth of about 1/8" to 1/4".

The double-V butt joint is needed when the metal exceeds 1/2" thickness and the design is such that the weld can be made on both sides. This is like a single-V joint except that both the top and the bottom edges of the pieces are chamfered, and welding is performed on both sides. With a double V there is greater assurance that penetration will be complete.

Lap Joint

A lap joint is made by overlapping two pieces of metal and then welding the edge of the top piece to the bottom piece. The only special requirement for making a good lap weld is to have the pieces in close contact along the entire length of the joint. On metal 1/4" or less in thickness, the weld can be made with or without filler rod. As a rule, the lap joint is not recommended for material exceeding 1/4" in thickness.

Corner Joint

A corner joint consists of welding one piece of metal at a right angle to the edge of a second piece, thereby forming a corner. On light material up the 1/8" in thickness, no filler rod is required for a corner joint. With heavier metal the use of a filler rod is advisable. If the metal exceeds 1/4", one of the two pieces of the joint should be beveled as in a single-V joint.

T-joint

A T-joint is prepared by placing a piece of metal perpendicular to another in order to form a "T". Then a weld is made along the seam on either side of the perpendicular piece. Filler rod is necessary to weld T-joints regardless of the thickness of the metal.

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[1]Giachino, Joseph W. and Weeks, William, *Welding Skills and Practices*, (Chicago: American Technical Society), 1976.

WELDING PROCEDURE

Assembling the Torch

Select the proper diameter electrode by consulting this document's Appendix. It is necessary to properly prepare the electrode tip in order to get a good weld. If DC welding is to be performed, the tip must be sharpened much like a pencil. The easiest way to do this is to use the band-sanders in the foundry. Turn on the sander, hold the electrode at about a 20° angle to the sander face, and rotate the electrode until a sharp point is formed. If AC welding is to be performed, a rounded, conical tip is necessary. In order to properly shape an electrode for AC welding, first sharpen it as one would for DC welding. The second half of the AC electrode preparation will be discussed later, after the rest of the equipment is up and running.

Select a collet that is the same size as your electrode. The collets are often not in their proper bins, so double-check to see that it slides snugly around the electrode. Pick a cup with an appropriate orifice diameter to match the electrode (see Appendix). Screw the lens into the back of the torch, and then the cup over the lens from the front. Slide the collet around the electrode and slip the electrode through the lens and out the front of the torch. Then screw the electrode cap onto the back of the torch, thereby, covering the back of the electrode and locking it into place. The electrode should protrude between 1/8 and 1/4 of an inch out of the front of the torch. If it sticks too far out, loosen the cap and adjust it until it is in the appropriate position.

Grounding the Workpiece

One must make sure that electricity can properly flow out of the workpiece to ground. First, securely clamp the grounding cable to the welding table. Second, fixture the workpiece in a manner so that there is direct contact between the workpiece and the table.

Turning on the Equipment

First of all, check to see that the cooling water valve to the right of the welding machine is fully open (it should always be left open for safety's sake). Then flip the main switch on the front of the welding machine to the ON position. Next, open the regulator valve on the top of the argon tank. It is a "double seating" valve which must opened all the way in order to properly seal.

It is usually a good idea to check that both the argon and the water are flowing properly. In order to do this, hold the torch in one hand so that it is not in contact with any metal and press down on the foot controller. This should start both the argon and the water flow. On the 300, you can look out the window behind the machine to see that the water is exiting the machine through the disposal tube. Check the flow meter on the argon regulator to see that the argon is flowing at the proper level. (See Appendix for suggested flow rates) Adjust the flow meter if necessary.

Joint Preparation

Proper cleaning of the metal can be essential in producing a solid joint. This is especially true with aluminum, where the pieces to be welded should always be scrubbed clean of all corrosion and dirt. Steel can usually be left as is, unless the pieces are extremely corroded.

Fixture the pieces to be welded in a fashion that allows for proper current flow between the workpiece and the table. Pieces usually do not have to be clamped together, but they should be well supported.

Protection

The arc produced in TIG welding gives off very dangerous UV radiation. Even if one is to catch only a slight glimpse of the arc with the naked eye, one can expect to have a headache the next day. It is the responsibility of the welder to look after his/her own safety and the safety of others.

First, always set up the orange screens around the two edges of the welding table that face the rest of the room. These are crucial in protecting others. Next be sure that there is no exposed skin on the body of the welder. Wear the TIG welding gloves to protect one's hands and be sure that one is wearing only natural fabrics, since synthetics could melt if exposed to sparks from the welding. It is also a good idea to wear either a turtle neck or a shirt with the neck buttoned in order to be sure that one's neck is not exposed. Any unprotected skin can receive a nasty sunburn from overexposure.

Next, put on an arc-welding helmet. Keep it in the upright position on your head until you actually weld. The one with the large smoked glass plate in the front provides a better field of vision than the others with smaller plates. The darkness of the glass is rated from 1 to 15. Be sure that the glass in your helmet is 11 or over.

Preparing to Weld

Sit at the welding table with your properly fixtured workpiece in front of you. Place the foot controller in front of your chair so that you can comfortably control it with your foot. Hold the properly assembled torch in the hand that you write with. Grasp it about half way along the shaft that connects to the hoses in the same manner as you would grip a pencil. Hold a piece of filler rod in your other hand if you intend to use it.

Starting the Arc

Since the welding machine features a high frequency start current, it is not necessary to make contact with the workpiece in order to start the arc. So place the torch at the point where you wish to begin the weld about with the tip of the electrode about 1/8” off the workpiece. Then lower the visor on the welding helmet. You will not be able to see anything until the arc has started. Call out “welding” so that everyone else in the room knows to avoid looking at the arc. Press down nearly all the way on the foot switch and the arc should start. If it does not start (because you are too far away) slowly bring the electrode tip closer to the workpiece until the arc forms. Do not make contact with the workpiece as this can melt the electrode! The light of the arc should illuminate as small area around the torch so that you can see.

A common problem is to have the torch stray away from the intended starting position when the visor is lowered. A good trick in avoiding this is to actually touch the electrode to the intended starting point on the workpiece before lowering the visor. This will usually anchor the electrode enough so that it will not move when the visor is lowered. Then, bring the electrode slightly off the workpiece but keep it within 1/8” so that the arc will still start. Then press down on the foot controller to start the arc.

Making the weld

BUTT JOINT

One the arc has been formed, the next step is to form a puddle. Hold the torch perpendicular to the face of the work piece and heat the starting point of the weld by moving the torch in a tight circular motion. Once the puddle has become bright and fluid you are ready to move along the weld.

Angle the torch back slightly so that it points along the weld to be formed and makes about a 75° angle with the workpiece face. Move the torch slowly forward and push the puddle along the weld seam. Remember that the puddle makes the weld, not the torch! If you let the torch get ahead of the puddle, you will not form a complete weld. The puddle must move along the entire length of the seam in order to properly fuse the two pieces together. A circular motion is often not necessary when moving the puddle. Some people prefer to use a slight circular or crescent shaped motion in order to ensure that the puddle bridges the weld seam, but this usually also results in a wider weld.

If filler rod is to be used, hold the rod with your other hand and bring it in ahead of the torch at about a 15° angle to the workpiece. The key to properly using filler rod is to alternately add filler and move the puddle forward. As the puddle becomes fluid, move the arc to the rear of the puddle and add the rod by dipping it in the front of the puddle. Then remove the rod and bring the arc back to the leading edge of the puddle. Repeat this for the entire length of the seam.

LAP OR T-JOINT

In welding a lap joint or T joint with or without filler rod, the procedure is similar to that for a butt joint except that the puddle should be started on the bottom piece. Once the puddle has been formed, shorten the arc to about 1/16” and rotate the torch directly over the joint until the pieces are joined. After this has been done, no further rotation is necessary, simply push the puddle down the seam to continue the weld.

CORNER JOINT

A corner joint rarely requires any filler rod and is very similar to a butt weld. Simply start the puddle at the beginning edge and push it down the seam. If the molten metal tends to roll off the edge, your speed is too slow. If the weld is rough and uneven, your speed is to fast.

Extinguishing the Arc

Once you have moved the puddle all the way along the seam to be welded, back off on the foot controller until the arc goes out. Leave the torch in the same position for a few seconds after the arc is extinguished to ensure that the metal at the end of the weld has a chance to cool down before being exposed to the oxygen in the atmosphere. Otherwise, a glassy bubble may form at the end of the weld.

Cleaning Up
Once you are done, be sure to shut off the gas flow valve, turn off the welding machine, clean off the welding table, and coil the torch and cable on the stand next to the welding machine. Do not shut off the water valve; it should be left on for safety's sake.

FINAL WORDS

As with any shop instructional document, this packet was designed to grow with time. Any suggestions or comments on how to improve this document would be greatly appreciated. Contact Craig Milroy about any recommendations you may have.

Revision History

Edition	Author	Date
Original Document	Pierre Kaiser	3/15/94
Minor Revisions	Katherine Kuchenbecker	11/01/01

Appendix: Suggested Settings for TIG Welding

Settings for TIG Welding Aluminum						
Stock Thickness (inches)	Type of Joint	AC Current (Amperes)	Electrode Diameter (inches)	Cup Orifice Diameter (inches)	Argon Flow Rate (cfh)	Filler Rod Diameter (inches)
0.0625	Butt	60-80	0.0625	0.25 - 0.375	15	0.0625
	Lap	55-75	0.0625	0.25 - 0.375	15	0.0625
	Corner	60-80	0.0625	0.25 - 0.375	15	0.0625
	T	70-90	0.0625	0.25 - 0.375	15	0.0625
0.125	Butt	125-145	0.09375	0.375 - 0.4375	17	0.125
	Lap	140-160	0.09375	0.375 - 0.4375	17	0.125
	Corner	125-145	0.09375	0.375 - 0.4375	17	0.125
	T	140-160	0.09375	0.375 - 0.4375	17	0.125
0.1875	Butt	190-220	0.125	0.4375 - 0.5	21	0.15625
	Lap	210-240	0.125	0.4375 - 0.5	21	0.15625
	Corner	190-220	0.125	0.4375 - 0.5	21	0.15625
	T	210-240	0.125	0.4375 - 0.5	21	0.15625
0.25	Butt	260-300	0.1875	0.5 - 0.75	25	0.1875
	Lap	290-340	0.1875	0.5 - 0.75	25	0.1875
	Corner	280-320	0.1875	0.5 - 0.75	25	0.1875
	T	280-320	0.1875	0.5 - 0.75	25	0.1875

Settings for TIG Welding Plain Steel						
Stock Thickness (inches)	Type of Joint	DC Straight Current (Amperes)	Electrode Diameter (inches)	Cup Orifice Diameter (inches)	Argon Flow Rate (cfh)	Filler Rod Diameter (inches)
0.035	All	80-100	0.0625	0.25 - 0.375	10	0.0625
0.049	All	100-120	0.0625	0.25 - 0.375	10	0.0625
0.06	All	80-100	0.0625	0.25 - 0.375	10	0.0625
0.089	All	90-110	0.0625	0.25 - 0.375	10	0.0625

Settings for TIG Welding Stainless Steel

Stock Thickness (inches)	Type of Joint	DC Straight Current (Amperes)	Electrode Diameter (inches)	Cup Orifice Diameter (inches)	Argon Flow Rate (cfh)	Filler Rod Diameter (inches)
0.0625	Butt	80-100	0.0625	0.25 - 0.375	11	0.0625
	Lap	100-120	0.0625	0.25 - 0.375	11	0.0625
	Corner	80-100	0.0625	0.25 - 0.375	11	0.0625
	T	90-110	0.0625	0.25 - 0.375	11	0.0625
0.09375	Butt	100-120	0.0625	0.25 - 0.375	11	0.12109
	Lap	110-130	0.0625	0.25 - 0.375	11	0.0625
	Corner	100-120	0.0625	0.25 - 0.375	11	0.0625
	T	110-130	0.0625	0.25 - 0.375	11	0.0625
0.125	Butt	120-140	0.0625	0.25 - 0.375	11	0.09375
	Lap	130-150	0.0625	0.25 - 0.375	11	0.09375
	Corner	120-140	0.0625	0.25 - 0.375	11	0.09375
	T	130-150	0.0625	0.25 - 0.375	11	0.09375
0.1875	Butt	200-250	0.09375	0.375 - 0.4375	13	0.125
	Lap	225-275	0.09375	0.375 - 0.4375	13	0.125
	Corner	200-250	0.09375	0.375 - 0.4375	13	0.125
	T	225-275	0.09375	0.375 - 0.4375	13	0.125
0.25	Butt	275-350	0.125	0.4375 - 0.5	13	0.1875
	Lap	300-375	0.125	0.4375 - 0.5	13	0.1875
	Corner	275-350	0.125	0.4375 - 0.5	13	0.1875
	T	300-375	0.125	0.4375 - 0.5	13	0.1875