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TIG welding requires more skill than many other welding forms, but is extremely versatile, capable of joining a huge range of metals in varying thicknesses. TIG welding is neat and precise, and can produce a beautifully finished weld bead.

TIG welding suits tricky specialist welds

At a glance:

- Tungsten inert gas (TIG) welding employs principles similar to both MIG and oxyacetylene welding.
- As the name suggests, the TIG process uses a tungsten electrode and shielding gas but the filler metal is provided by a welding rod.
- TIG welding is used for specialist metals such as aluminium and stainless steel and creates neat, slag-free welds.
- The main disadvantage of TIG welders is their high cost, and increased skill requirement

TIG welding is a versatile process, capable of handling all sorts of different metal, and can be used to join very thin sections.

Tungsten inert gas (TIG) welding involves principles common to both MIG and oxyacetylene welding.

The gas shielding used in MIG welding is also used in TIG welding with a compressed gas cylinder attached to the unit.

As with the MIG welding process, the use of an inert gas as an oxidation shield ensures the weld is free from atmospheric contamination. As a benefit, there is no welding slag to remove.

But rather than feeding the filler wire through the handpiece, the TIG process uses a bare welding rod to add filler metal to the weld pool, similar to oxyacetylene welding.

For this reason, it is recommended that aspiring TIG welder operators are proficient in oxyacetylene welding first.

Brush up on fusion welding

Oxyacetylene welding uses pressurised, flammable gas to generate a weld pool of molten metal. This produces considerable heat but applying it with precision can be a problem. It can be difficult to avoid distortion in thin metal due to excessive heat.

The heat for TIG welding comes from an electric arc formed between a tungsten electrode and the work. This provides an increased concentration of heat and ▶

allows for high-precision welding, without undue distortion.

Because TIG welding delivers highly concentrated heat, it is ideal for welding aluminium, as the metal will conduct heat away from the weld area. This also makes it most suitable for thinner metals as it can weld them effectively with greater control, and without burning a hole through the work.

But don't be fooled into thinking TIG welders are for thin metal only. TIG welders are capable of welding metals from less than one-millimetre thick to more than 30mm using several passes.

Not all TIGs created equal

The types of metal to be welded will determine the type of TIG welder required. For standard metals such as mild and low-alloy steel, stainless steel, copper, nickel alloys or titanium, a straight polarity (DC) unit will be sufficient. To weld aluminium or its alloys, or magnesium, a TIG unit with alternating current (AC) power and high-frequency current will be required.

Prices range from about $400 for a basic DC TIG inverter welder to thousands of dollars for a high-frequency AC unit, but a multipurpose AC/DC pulse TIG can be purchased for just over $1000.

TIG components

The most obvious difference between a TIG unit and an AC/DC stick welder is the handpiece which is fitted with a non-consumable tungsten electrode. This is held firmly in a collet, which also conducts the welding current.

The shielding gas is directed around the weld by a ceramic nozzle or cup, which is designed to withstand the intense welding heat.

There are different sized cups to suit different jobs. Smaller cups are used for smaller welds and help with access to difficult areas. Larger cups provide improved gas flow and coverage for wider weld beads.

Back shielding: *This stainless steel pipe has been set up or back shielding by using two cover plates at either end.*

Select the largest cup possible without restricting access to the weld. This will depend on the area to be welded. For example, flat section welds may allow sufficient access and permit the use of number 8, 10 or 12 cups. Tight corners might require number 4 or 6 cups.

The back cap covers the opposite end of the electrode and prevents it from arcing against the work during welding (see Figure 1). The cap screws tight against the collet, helping clamp the electrode in position.

Smaller back caps are available for difficult-to-access joins but a short length electrode will also need to be used.

TIG welding units often use a foot pedal to control the welding current, allowing adjustments during welding.

Types of electrodes

There are several types of tungsten electrodes, each with a slightly different chemical composition to suit the welding application (see table 2).

TABLE 1 Basic TIG welder settings - DCEN welding

Plate thickness (mm)	Electrode size (mm)	Current Amps	Consumable size (mm)	Gas flow l/min
1.0	1.0	30 - 60	1	3 - 4
1.5	1.6	70 - 100	1.5	3 - 4
2.0	1.6	90 - 110	1.5 - 2.0	4
3.0	1.6 - 2.4	120 - 150	2.0 - 3.0	4 - 5
5.0	2.4 - 3.2	190 - 250	3.0 - 4.0	4 - 6
6.0	3.2 - 4.0	220 - 340	4.0 - 6.0	5 - 6
8.0	4.0	300 - 360	4.0 - 6.0	5 - 6
12.0	4.8 - 6.4	350 - 450	4.0 - 6.0	5 - 7

Source: BOC

Advantages of using TIG

- TIG welders produce a neat weld with no slag due to the use of an inert gas as an oxidation shield.
- TIG welds are more precise compared with most other forms of welding.
- TIG welding is particularly useful for welding thin or specialist metals due to the concentration of heat into a small area. There is a smaller heat-affected zone due to the concentration of the heat applied, which reduces distortion and residual stresses caused by the weld process.
- TIG welding is clean.
- The units can be versatile in changing metals — a simple change of the polarity settings if required and the use of a different filler rod is all that may be needed.

Disadvantages of TIG welding

- High cost. The investment in a TIG unit generally cannot be warranted unless there is a significant amount of work to be carried out or contractor work can be sourced.
- TIG welding is slow compared with other welding methods. As a result, the time cost of welding using a TIG is comparatively high.
- The concentration of the heat-affected zone means that constant delivery of the shield gas is critical in maintaining weld quality. As such, TIG welding is better suited to indoor use, where breezes or windy conditions cannot affect the weld shield.
- Because TIG welding requires the operator to use one hand to operate the handpiece, the other hand to dab the bare welding rod, and possibly a footpedal to control current, a great deal of coordination is required.

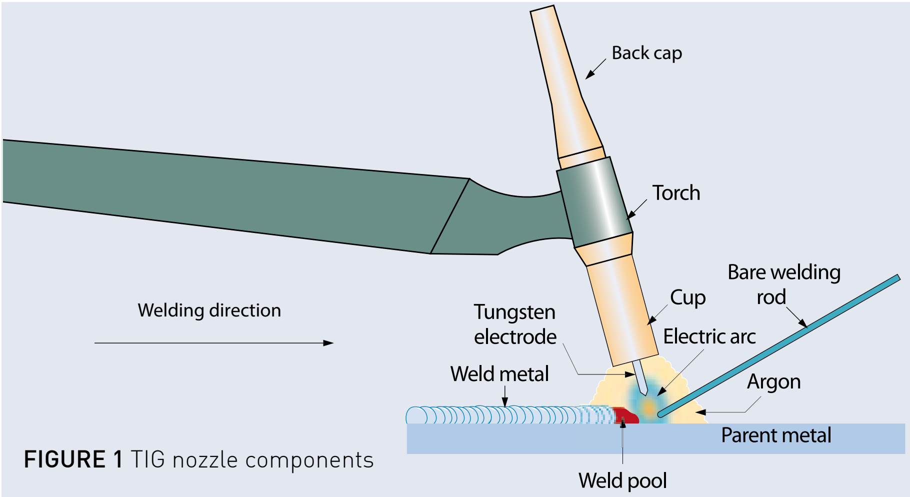


FIGURE 1 TIG nozzle components

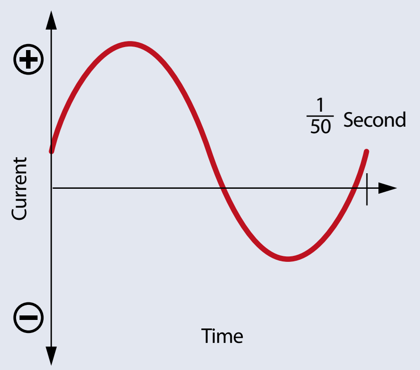


FIGURE 2 Greater cleaning action

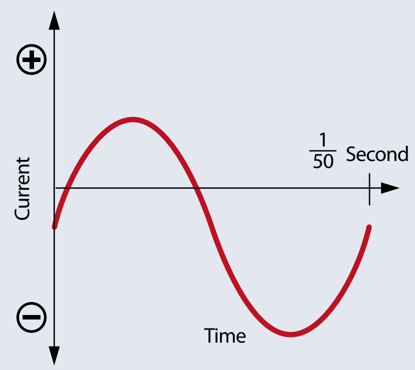


FIGURE 3 Greater weld penetration

Pure tungsten electrodes contain more than 99.5 per cent tungsten and are the cheapest available electrodes. On the downside, they have a low AC carrying ability and can become contaminated from the parent metal during welding.

Tungsten electrodes with up to 2% thoria will carry higher currents and are more resistant to contamination.

The arc is easier to start and the electrodes tend to maintain their sharpened points longer.

Thoria is an oxide of the radioactive element thorium, which may present a small danger to operators if the dust is inhaled while grinding the tip.

Tungsten electrodes containing zirconia carry higher currents than pure tungsten electrodes but not as high as thoriated electrodes.

Zirconia electrodes are ideal for welding aluminium as the electrode tip will form a round shape during welding and will not become contaminated with aluminium oxides.

Electrode sizes

The size of the electrode used will depend on the material being welded, its thickness and the joint type.

Electrodes are available in sizes from 0.3 to 6.4 millimetres, with the larger electrode sizes more suited to AC and electrode positive welding. As a guide, tungsten diameter will be about half the thickness of the base metal.

The electrodes are also available in different lengths, with the longer length electrodes allowing more tip reshaping before requiring replacement.

Some handpieces might not accommodate overly long electrodes, especially if a short back cap is used. The electrodes can be cut to length if desired.

Electrode shape

The shape of the electrode tip is crucial to obtain the best results. The current type (AC or DC, electrode positive or electrode negative) and type of metal welded will affect shape.

Electrode tips require sharpening on a grinding wheel periodically to produce a sharp point for welding steel, stainless steel and tungsten. The finer the taper ground on the tip, the higher the weld penetration.

A sharp tip used to weld aluminium will melt and contaminate the weld and will provide too much heat concentration.

The ideal shape for an aluminium welding tip is a balled or crayon-like end. But grinding tips to this shape is not worthwhile as a rounded shape usually forms after a few seconds of welding. Simply grind a blunt, coarse tapered shape for aluminium.

Always grind tips lengthwise, otherwise any circumferential grind marks will lead to poor arc stability. The electrode tip needs to project past the end of the cup by about 3–6mm.

Operating modes

TIG welding has three operating modes: electrode positive, electrode negative and alternating current (AC).

Most metals are welded using electrode negative, which produces the highest amount of heat, creating deep, penetrating welds. Electrode positive retains heat in the electrode, producing a shallow ▶

TABLE 2 Selction guide for TIG tungstens

Tungsten type	Welding materials	Welding current	Tungsten tip colour
2% Thoriated tungsten	Steels, low alloys, stainless steels, copper, titanium and nickel alloy	DCEN	Red
2% Ceriated tungsten	Steels, low alloys, stainless steels, copper, titanium and nickel alloy	DCEN	Grey
0.8% Zirconiated tungsten	Aluminium and magnesium and associated alloys	AC	White
2% Zirconiated tungsten	Aluminium and magnesium and associated alloys	AC	White
2% Lanthianated tungsten	Steels, low alloys, stainless steels, copper, titanium and nickel alloy, aluminium and magnesium and associated alloys	DCEN and AC	Gold
Pure tungsten	Steels, low alloys, stainless steels, copper, titanium and nickel alloy	DCEN - lower currents	Green
Source: BOC Note: DCEN = Direct current electrode negative. AC = Alternating current.			

There are several basic inverter TIG welders on the market which can be purchased for a few hundred dollars. These machines are little more than a stick welder attached to some TIG components, and are DC only, meaning welding aluminium is not possible. They are severely limited, with no pulse function, and must be 'scratch started' to initiate the arc.

weld but has a surface cleaning action due to gas ions.

AC welding combines the best of both positive and negative electrode features, with a medium penetrating weld and surface cleaning action.

AC welding is especially suited to aluminium due to the cleaning action. The surface oxide layer on aluminium melts at several times the temperature of the parent metal. If it were to be melted by welding current, it would be difficult to avoid overheating the parent metal. But each positive half of the AC cycle (see page 2) will clean the surface, with most of the welding heat being developed on the negative half.

Other metals such as steel that form an oxide layer do not require the cleaning action of AC because the oxides melt readily under arc temperatures.

Although it might seem possible to weld aluminium with a positive electrode due to its cleaning action, the current would have to be far higher to achieve welding temperatures due to the concentration of heat in the electrode. Aluminium usually requires a high current due to its ability to conduct heat away from the weld quickly.

Advanced AC TIG welders have the capacity to bias the AC cycle to favour the positive or negative side.

For improved cleaning, the positive side is increased, so that the welding current spends longer as a positive charge. The AC cycle is simply shifted up from the zero axis.

When more heat is required, the cycle is biased toward the negative side and the waveform is shifted down (see Figure 3).

TIG welding in practice

Being proficient in oxyacetylene welding will help when learning to TIG weld.

The two processes are similar, except the heat for TIG welding is created using an electric arc instead of a gas flame. Both use the same welding method where heat is applied and a rod is fed in to provide weld filler metal.

To operate, place the TIG torch in the dominant hand and hold the welding rod in the other.

A forehand welding direction is best, meaning the nozzle is moved forward along the joint with the filler rod applied (see Figure 1). Depress the TIG torch handle lever and create an arc, using the foot pedal (if fitted) to increase the current gradually until the weld pool forms.

Dip the filler rod into the weld pool and gradually move in the direction of travel. Use an 'in-out' filler rod action (similar to oxyacetylene welding) with the rod held at a 15–30-degree angle to the work piece and the nozzle at 70°.

If welding a 90° fillet, position the hand piece at 60° up from the bottom section and angle the torch at 80°, using a 60° filler rod angle.

Keep the filler rod close to the nozzle to protect it by the shielding gas.

Most welding rods are supplied in long lengths, which are easier to handle if cut to a manageable size.

Tips for better welding:

- Operators need to ensure they are comfortable and can see the task clearly. TIG welding takes time, so comfort is a factor. In workshops where a considerable amount of welding is carried out, the welder is seated at a table. TIG welding does not create any sparks, which may otherwise burn the operator if seated. Ensure the welding table is well lit.
- Ensure the base metal is clean, as TIG welding does not have flux to float the impurities off.
- Wear the required safety equipment such as gloves, apron and a welding helmet with number 10 to 12 shaded lens (see page 18). TIG welding emits a duller light than regular welding but the ultra-violet light radiation is more intense, which can pose a danger for operators and other people in the area. Ensure the light from the arc is well shielded.
- Tack the work piece before welding. Place tacks at regular intervals and at the ends of the piece.
- Set the shielding gas pressure at a flow rate of about 10 litres per minute.
- Angle the torch in the direction of travel. If a hole burns through the metal, reduce the current in the weld using the foot pedal or break the arc. Allow the weld to cool before resuming work.
- When running the final bead, ensure there is no breeze that might cool the weld pool quickly. This will cause cracking of the bead due to the concentration of heat from the TIG process.

Back shielding

Back shielding or purging is needed to prevent oxidisation of the reverse side of stainless steel TIG welds.

When welding stainless steel, oxidisation causes the opposite side of the root weld run to turn a black colour. The molten stainless steel on the back of the weld will also crystallise if exposed to air, leading to a weak join. A solution is to grind back the area and re-weld.

Access to the back of the weld can be impossible, particularly when welding pipes. In this situation, back shielding is needed.

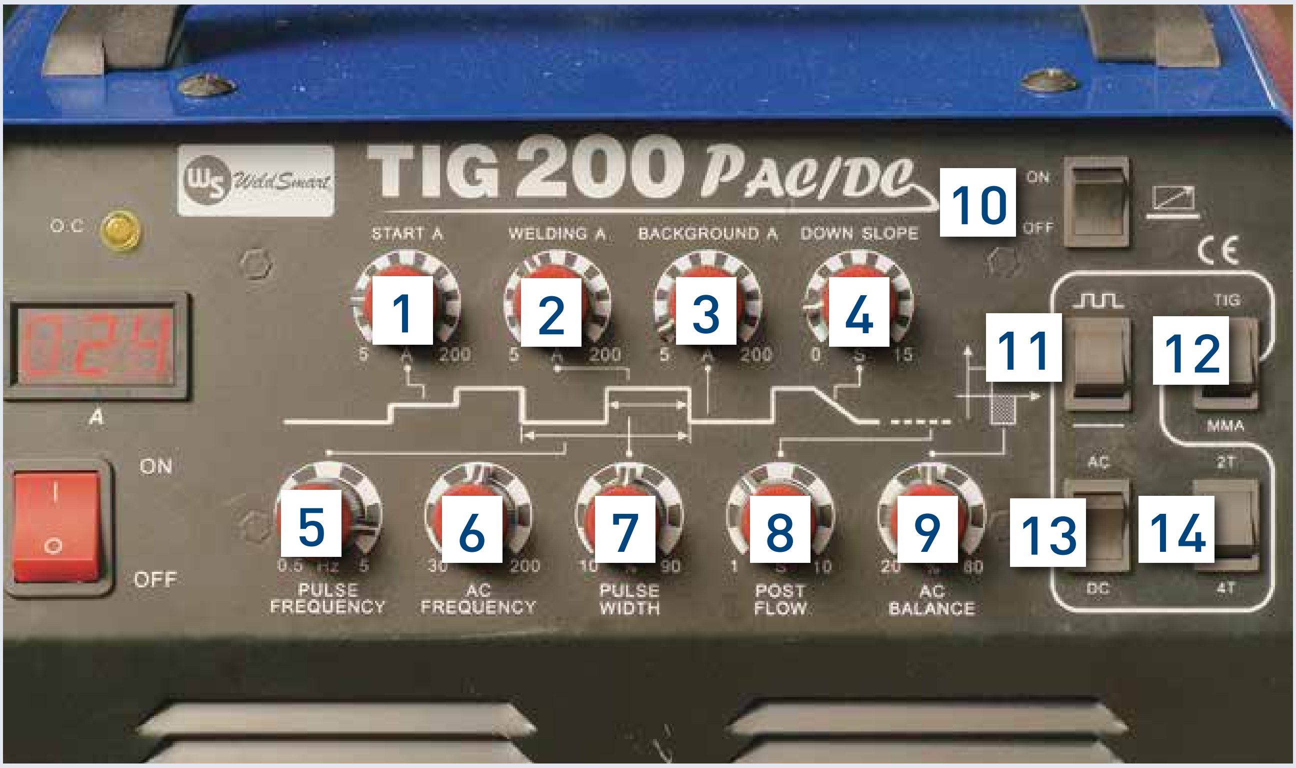
Back shielding involves supplying the back of the weld with shielding gas. In pipework, this is as simple as blocking the ends of pipe and plumbing in the shielding gas. A small breather hole is required at the opposite end to allow the gas to flow, with a flow rate of about 4L/minute.

Other options include constructing a cardboard baffle, which is taped to the reverse side of the weld and supplied with gas.

Back shielding is essential for critical welds and those used in food-handling situations such as in a dairy or processing plant.

A more convenient method may be to grind down the back of the weld, if accessible, and run another bead in place.

Typical functions of an AC/DC pulse TIG.



1. Welding start current. This adjusts the initial lower starting current used to help arc ignition, before welding current kicks in.
2. Welding current. Welding or main current is used for creating heat and fusion during welding. If pulse setting is used, this is sometimes called peak current.
3. Background current. If pulse welding is used, this is used to set the low current pulse value. This helps cool the weld puddle between high pulses, allowing welding of thinner material. Set to 20-30% of welding current for stainless or mild steel.
4. Downslope time. This sets the amount of time in seconds the welding current will decay to the final current when finishing a weld. This helps to avoid weld craters at the end of beads by tapering off the current.
5. Pulse frequency. For pulse welding, this sets the number of times the current cycles per second between welding current (2) and background current (3).
6. AC Frequency control. In AC mode, increasing the AC frequency narrows the weld bead, focuses the arc and increases penetration.
7. Pulse width. In pulse mode, this adjusts the duration of the cycle spent at welding current (2), before dropping back to background current (3).
8. Post flow gas control. Controls the length of time shielding gas continues to run after the arc has been extinguished. Post flow protects to cooling weld and helps prevent oxidisation of the tungsten.
9. AC balance. Adjusts the time spent in the positive cycle for increased cleaning effect of aluminium. Adjusting this up increases heat concentration in the electrode, and decreases penetration in the work.
10. Foot pedal on/off. Turn this on when the foot pedal is connected
11. Pulse on/off. Selects pulse or no pulse welding.
12. TIG/stick welding selector. Some TIG welders can be used as a stick welder.
13. AC/DC selector. Us AC for aluminium, DC for most other metals.
14. Two touch/four touch selector. Controls the operation of the handpiece trigger. For most units, hold the trigger down to weld in 2T mode, and release to extinguish the arc. Starting current and downslope are disabled. In 4T mode, press and hold the trigger to initiate the starting current, release to trigger welding current. Press and hold a second time to initiate downslope, and then release to extinguish the arc and commence post flow gas.

The TIG welding handpiece consists of several components and must be treated gently to avoid damage. Standard handpieces are air cooled, but units fitted to high output welders may be water-cooled.

Gas nozzles or cups are usually made of ceramic, but are also available in glass for improved weld visibility. They are available in a range of sizes to suit different sized welds, or where welding in tight positions, such as fillet welding.

Collets are used to clamp the tungsten in the handpiece, and conduct the welding current into the electrode. They are available in a range of sizes to suit different sized electrodes, such as 1.6, 2.4 and 3.2mm.

Shown above are a tungsten electrode, secured in a collet which is held by the collet body. Note the coarse threads on the collet body which are used to secure the gas nozzle.

Tungsten electrodes are not consumed in the welding process, but will require re-sharpening periodically. Shown above are several different sizes and tungsten types, as designated by the tip colour. Make sure you only sharpen the opposite uncoloured end, so you can still identify the tungsten type.

Back caps screw to the rear of the torch and provide a clamping force to the collet, locking it in place. They also seal the rear of the torch body against shielding gas leaks, and prevent arcing between the rear of the tungsten if it touches the work. Short back caps are available, shown fitted to the torch, for working in restricted spaces

Sharpen tungstens to a point as shown for welding most steels. Note how the sharpening lines run down the point, parallel to the tungsten.

This tungsten has been sharpened incorrectly, with the lines running around the tip.

Note how the tungsten is sharpened on the bench grinder. It is gently rolled between the fingers to produce the point.

This tungsten has been sharpened with a more blunt point for welding aluminium. It will form a balled, crayon-like end during welding. Sharp points contaminate the weld.

Adjust the tungsten so that it protrudes past the end of the cup by about 3-6mm. Longer stickout will help visibility, but will adversely affect the shielding of the weld.

Almost all DC TIG welding is performed with DCEN (negative electrode). You will quickly burn the electrode if you connect it to the positive supply.

Adjust the gas flow regulator to between 5 to 12 litres per minute, depending on welding current, cup size, and wind conditions.

If you are learning to TIG weld, first practice forming a pool and running a bead without using a filler rod. This will help you gain coordination with the use of the torch and the correct angle of the electrode.

Spend a fair amount of time experimenting with the settings on the welder, and note their influence of the weld bead. Better still, have a friend adjust an individual setting as you weld, which will help you to experience the effect on the bead.

When you feel you have become proficient at running a weld pool, experiment with adding in filler in a dabbing motion, similar to oxyacetylene welding.

TIG welding rods are quite long and unwieldy, so it pays to cut them in half to help steady your hand.

Before long you should be able to join some scrap, both with and without filler. The weld above has been performed without a filler rod. Experiment with the welder settings, in particular the pulse function, to help eliminate distortion on thin sections.