TIG Welding

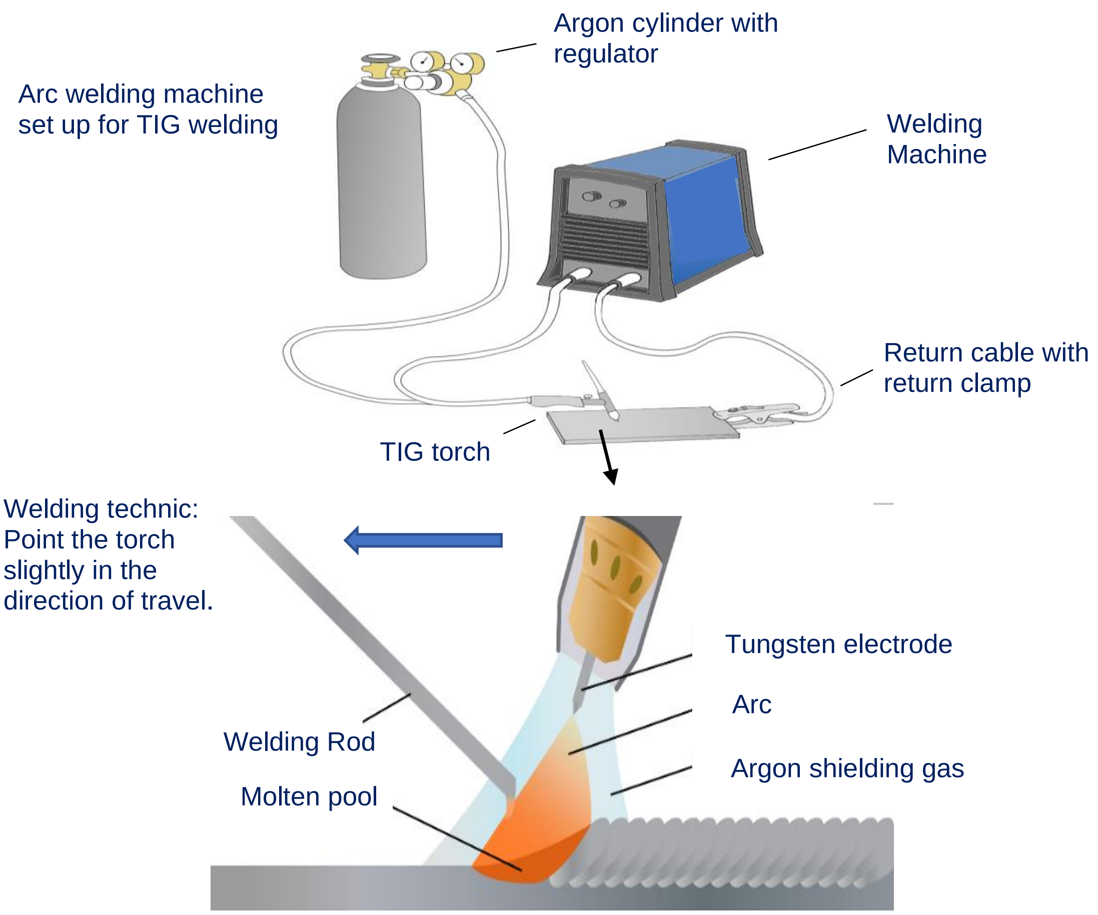
By Leif Andersen, TE Andersen Consulting.

This article will provide the basics for TIG welding and its consumables including advantages and disadvantages, where this process can be used, and how to properly set up a welding power source for TIG welding.

Most vessels will have an electric arc welding machine onboard that can perform Manual Metal Arc Welding (MMAW), also referred to as stick electrode welding. It is quite common that these machines will also be fitted with a mode nob that can switch the machine over to perform Tungsten Inert Gas (TIG) welding.

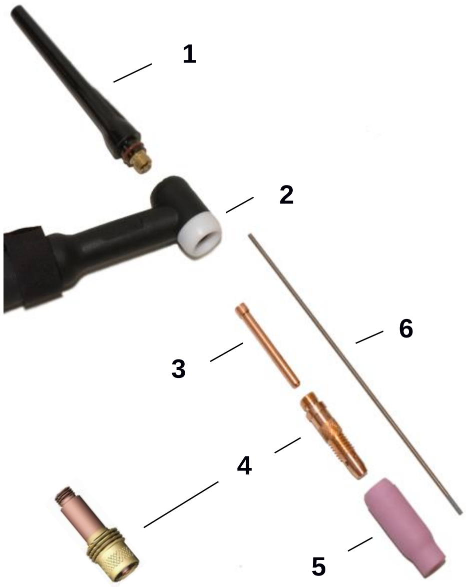
TIG Welding

Tungsten Inert Gas (TIG) welding (also referred to as Gas Tungsten Arc Welding GTAW) is a process where heat is produced by an electric arc that is struck between a Tungsten (Wolfram) electrode and the work piece. The arc and the electrode are shielded by an inert gas (usually Argon) that also surrounds the weld pool and prevents oxidation. TIG welding can be performed using Direct Current (DC) or Alternating Current (AC) welding current.



The TIG Torch

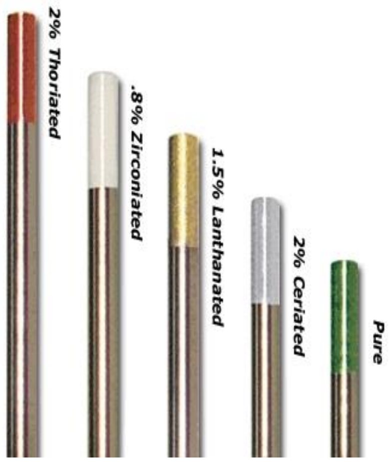
The TIG torch consist of the following parts:



1 Long back-cap
2 Heat shield
3 Collet 1,6mm - 2,4mm – 3,0mm
4 Collet body 1.6mm - 2,4mm – 3,0mm
Alternative: Gas Diffuser 1,6mm - 2,4mm - 3,0mm
5 Alumina nozzle 6, 7, 8
6 Tungsten electrode 1.6 mm - 2,4mm – 3,0mm

When changing Tungsten electrode from 1,6mm to 2,4mm or 3mm it is also necessary to change Collet and Collet body to 2,4mm or 3mm and vice versa.

The reason for using Tungsten is that it has a very high melting point of 3000 ^{O}C (5432^{O}F). They are normally in two different diameter sizes, 1,6mm (1/16″) and 2,4mm (3/32″). For aluminum a 3,0mm (1/8″) tungsten electrode will be useful. During TIG welding the tungsten electrode will not melt despite very high temperatures, but it will gradually be consumed during ignition and to some extent during actual work. This is referred to as the burn-off rate. In time, it will be necessary to regrind the electrode. In order to extend their capacity and performance the manufacturers alloy in any of the following elements: Cerium (Ce), Lanthanum (La), Zirconium (Zr), Yttrium (Y) or Thorium (Th).



ISO Class	ISO Color	AWS Class	AWS Color	Alloy [1]
WP	Green	EWP	Green	None
WC20	Gray	EWCe-2	Orange	~2% CeO_2
WL10	Black	EWLa-1	Black	~1% La_2O_3
WL15	Gold	EWLa-1.5	Gold	~1.5% La_2O_3
WL20	Sky-blue	EWLa-2	Blue	~2% La_2O_3
WT10	Yellow	EWTh-1	Yellow	~1% ThO_2
WT20	Red	EWTh-2	Red	~2% ThO_2
WT30	Violet			~3% ThO_2
WT40	Orange			~4% ThO_2
WY20	Blue			~2% Y_2O_3
WZ3	Brown	EWZr-1	Brown	~0.3% ZrO_2
WZ8	White			~0.8% ZrO_2

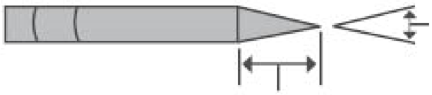
1) Alloying elements in the form of oxides

NB. Thoriated TIG welding electrodes with 2% thorium oxide (color code red) are currently the most widely used electrodes worldwide. Thorium is however a radioactive element and as such represents a potential danger to health and environment. Thorium is a so-called “a-emitter,” but when enclosed in a tungsten matrix, the “a” radiation emitted externally is negligible. The danger to the welder arises when thorium oxide gets into the respiratory canals. This problem can occur during welding (vapors) as well as when grinding the electrode tip (grinding dust).

Tungsten electrode preparation

For Direct Current (DC) Electrode pointed

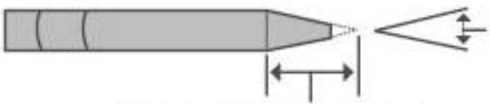
Radial grinding direction result in a wandering arc with possible tungsten fragment braking of causing tungsten inclusions in the weld deposit. Make sure to do lengthwise grinding. The marks do not restrict the current flow and improves performance. Use a dedicated grinding disk for tungsten grinding only.



15^{O} to 30^{O}

1-4 times electrode diameter.

For Alternating Current (AC) Electrode rounded (ball shape)



15^{O} to 30^{O}

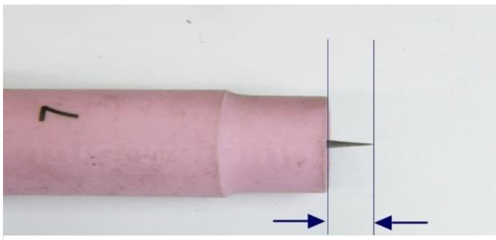
1-4 times electrode diameter

First grind the electrode in similar manner as for DC preparation. Then break the point. Place the electrode in the TIG torch and ignite the torch towards a copper plate. The AC arc will after short time melt the tungsten electrode into ball shape.
There are special grinding machines for tungsten electrodes available.

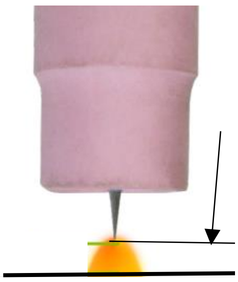
Meltback point

The ball should be equal to or slightly larger than the electrode diameter at the meltback point.

Adjust the tungsten to project from the alumina nozzle a distance of roughly 3-6mm.



3-6mm

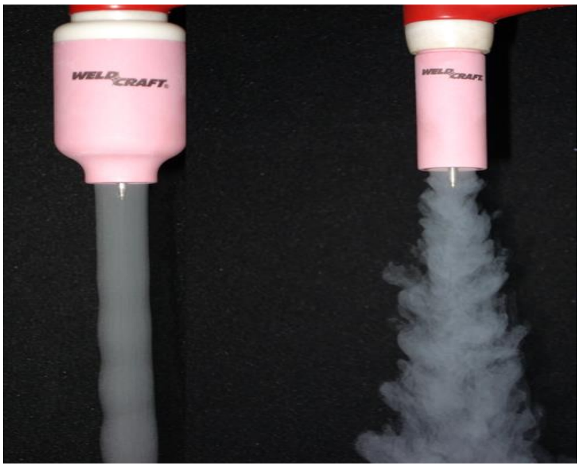


1-3mm

The arc length should be roughly equal to the diameter of the tungsten being used.

Amperage setting

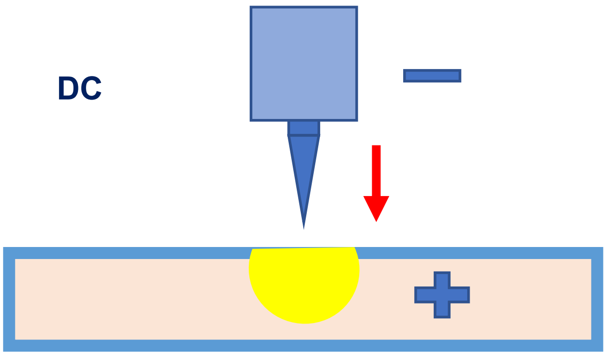
Use a 1,6mm (1/16″) tungsten electrode from 30 to 80 amps. Alumina nozzle size 6.
Use a 2,4mm (3/32″) tungsten electrode from 80 to 180 amps. Alumina nozzle size 7.
Use a 3,0mm (1/8″) tungsten electrode for anything above 180 amps. Alumina nozzle size 8.



The TIG torch should preferably be fitted with a gas lens diffuser. A typical gas lens is composed of a copper and or brass body with layered mesh screens of steel or stainless steel that helps evenly distribute the shielding gas around the tungsten and along the weld puddle and arc. Gas lenses can be used with all shielding gases and are available for both air- and water-cooled TIG torches. The most durable gas lenses-feature a porous metal filter that greatly improves laminar flow compared to mesh screen designs.

Welding using Direct Current

TIG welding using DC current is relatively straightforward. The TIG torch needs a Lanthanum alloyed tungsten electrode (color code gold) that is pointed and DC current with the torch connected to minus polarity. With DC we can weld all metals including seawater resistant alloys like Cunifer and York Albro. Only exception is aluminium and aluminium alloys.

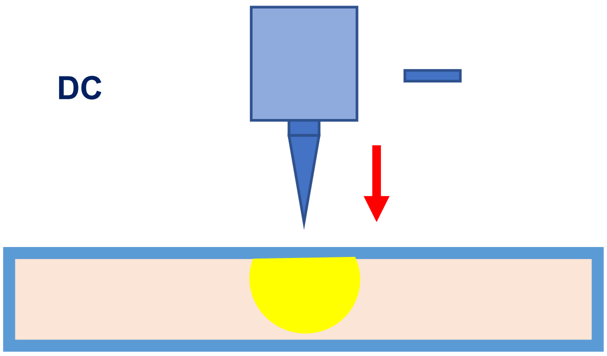


TIG welding using Direct Current (DC) minus polarity the electrons bombard the base material and melt it.

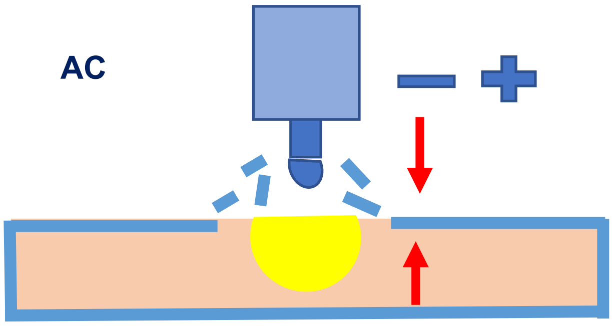
Welding using Alternating Current

Aluminium melts at 658 ^{O}C, the aluminium oxides melts at 2000 ^{O}C. If we use direct current – polarity we are able to melt the aluminium but unable to break the oxide layer.

To better understand why, consider the following:



TIG welding using Direct Current (DC) minus polarity the electrons bombard the aluminium melting it, but are unable to break the oxides.



TIG welding using Alternating Current (AC) the polarity changes from minus to plus. During minus the electrons melts the aluminium, during plus the electrons breaks up the oxides.

With AC, during the half cycle when the electrode is positive and the workpiece is negative, the electrons coming out from the base material break up the oxide layer: this action is known as **cathodic cleaning** and is essential for successful welding of aluminium. So, it is necessary to use alternating current or preferably square wave when welding aluminum.

The Tungsten electrode must have a round shape.

Fit the TIG torch with a pure tungsten (color code green) or with Lanthanum (color code gold) electrode for aluminum welding if you have a non-square wave welding machine.

Fit the TIG torch with a Lanthanum (color code gold) tungsten electrode for aluminum welding if you have a square wave welding machine.

The TIG torch should preferably be fitted with a gas diffuser (sintered metal) in order to avoid turbulence in the shielding gas as it comes out of the TIG torch.

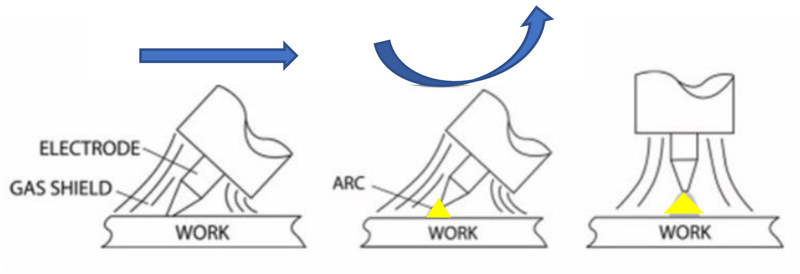
The TIG torch alumina nozzle must be size 8. This because the aluminum molten pool needs better protection towards oxidation than steel or stainless steel.

Use Argon as shielding gas. Set the flow rate on the regulator to 6 to 9 L/min. TIG welding is sensitive to draft. If welding location is not sufficiently screened of the shielding gas can be insufficient and create weld porosity.

Welding Machine requirements

There are 3 different ways of initiating the TIG torch, Scratch start, Lift Arc or High Frequency.

Scratch start is a very basic and simple process, usually found on low cost DC welding machines that have been essentially designed for Manual Metal Arc Welding (MMAW) Stick electrode welding. The TIG tungsten electrode is scratched on the workpiece to initiate the arc, and must be quickly lifted off the workpiece to try prevent it sticking, but not lifted too far to avoid extinguishing the arc. Not a very user-friendly process as the tungsten gets hot almost instantly as the arc is struck. Small bits and pieces of the tungsten break off the electrode and get stuck in the weld deposit. This can cause structural problems later.

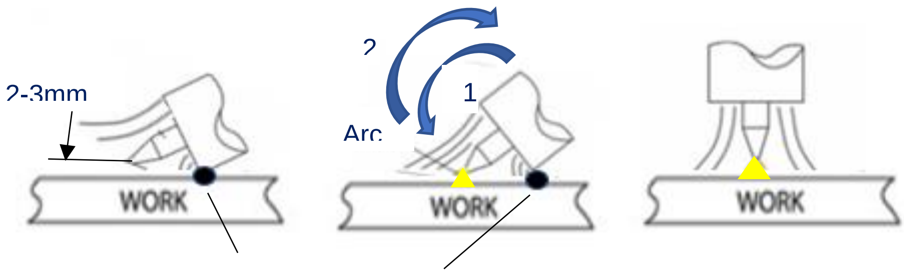


With **Lift-Arc** Ignition feature, to start the arc the tungsten electrode is touched on the workpiece and lifted off. The start-up current is very low and therefore the tungsten barely sticks to the workpiece and the sharpened point is not damaged. Place and rest the alumina nozzle in a tilted angle on the ignition location so that there is a gap of 2-3 mm between the tungsten electrode tip and the workpiece. Gradually tilt up the welding torch until the tungsten electrode tip touches the workpiece. This will trigger the lift arc function. Raise the torch and lift it into the normal position- the arc ignites and increase in intensity to the set amperage. The machine senses that the contact is broken and begins supplying full welding current. This creates little contamination and preserves the point on the tungsten. It is still not 100% clean. The tungsten still can get contaminated. Lift start is a much better option than scratch starting, for steel and stainless. But it is not a good option for aluminium because of the affinity aluminium and tungsten have for each other.

Place and rest the alumina nozzle in a tilted angle on the work piece.

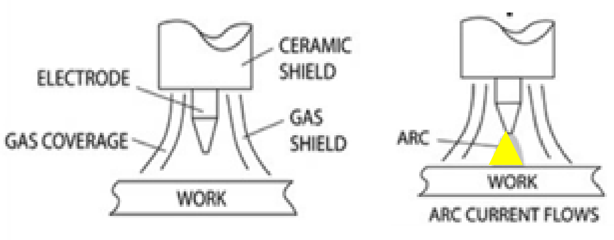
1) Tilt up the welding torch until the tungsten electrode tip touches the work piece. 2) Tilt the torch back igniting the arc.

Raise the torch and lift it into the normal position.



Rest the alumina nozzle on the work piece.

High Frequency (HF) ignition allows the operator to position the tungsten electrode near to the starting point, and simply press the torch trigger to start the arc. The High Frequency start is a touch-less method and creates almost no contamination unless the tungsten is over sharpened or the amperage is turned too high at the start. It is the only acceptable choice for welding aluminium. Unless you need to weld Aluminium, you don't have to really have High Frequency start, but it is nice to have for weld AC or DC if you have the option. HF is typically found on professional or dedicated TIG welding machines, such as AC/DC TIG welders or higher end DC TIG machines. On these machines, often the controls will allow the operator to choose between Lift-Arc or HF start. NB. Please be aware that High Frequency can disturb radio communication on-board and also influence on other electronic equipment.



Should the tungsten electrode be contaminated by the pool or by the consumable rod during welding it will be necessary to regrind it. If only slightly contaminated, keep a copperplate at the worksite. Ignite the electrode towards the copperplate and let it burn for some time. The electrode will gradually clean itself toward the copper.

Remote control

After welding has progressed a while, much of this heat has moved ahead of the arc and pre-heated the base metal to a temperature requiring less welding current than the original cold plate. If the weld is continued further on to the end of the two plates where there is nowhere for this heat to go, it can pile up and make welding difficult unless the current is decreased. Because of this the TIG torch should be fitted with a hand amperage control so that the welder can gradually reduce the amperage. It can also be that the joint figuration, edge preparation or welding position is varying, which will also require a change of amperage. It will be an advantage if the TIG torch is fitted with a thumb control amperage setting so that amperage can be increased or decreased during welding.

The remote control can be incorporated into the TIG torch.

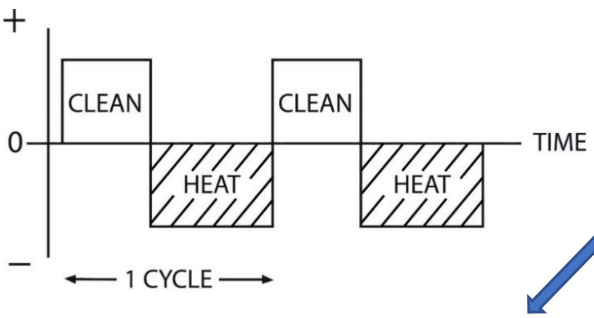
The remote control can also be added to the torch by fastening with Velcro straps.

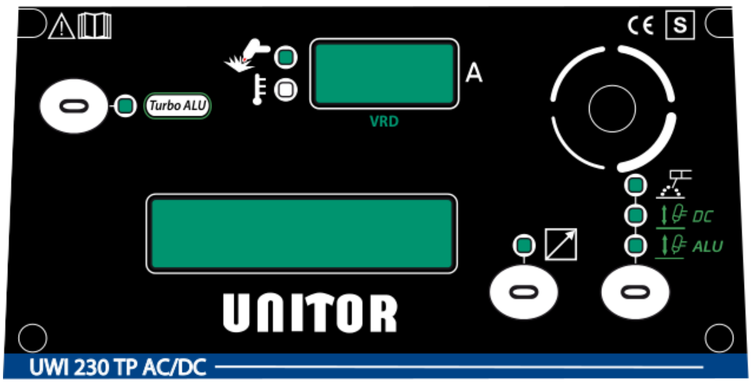
Another feature to consider is if the TIG torch should have a flexible head. This will for some maintenance welding applications be an advantage. For giving better access in difficult working situations the tungsten electrode can also be shortened and the long back-cap exchanged with a short back cap.

Short back cap.

For maintenance welding an air cooled TIG torch will normally be sufficient. If extensive welding considers a water cooled TIG torch.

Modern power sources for TIG welding can also have **square wave** configurations where both the time proportions of electrode positive vs. negative and the relative intensities can be finely adjusted. The effect is a more stable arc (than with simple AC), better penetration, and a more balanced heat distribution between torch and workpiece.





This welding machine have a setting for:
Manual Metal Arc Welding,
TIG DC lift arc,
TIG Square wave lift arc for Aluminium and
Remote control.

The shielding gas

Shielding gas is necessary for the TIG process. Argon and in some cases Helium can be used. This gases which are chemically inactive (inert), has several functions in the TIG process:

- To provide the atmosphere needed for ionization, ensuring a stable arc and suitable heat transfer.
- To protect the hot tungsten electrode against the oxidizing effect of the air.
- To protect the molten pool against contamination and oxidation from the air.
- To protect the hot end of the filler metal rod from oxidation.
- To protect melt pool and electrode during cooling after the arc is broken.

The most commonly used shielding gas for TIG welding is Argon. The degree of purity should be at least 99.95 %.
Common Argon qualities available:

Argon 4.0 Purity >= 99.99%	Steel, Austenitic stainless steel.
Argon 4.8 Purity >= 99.998%	Duplex stainless steel, Nickel alloys (6Mo), Aluminium.

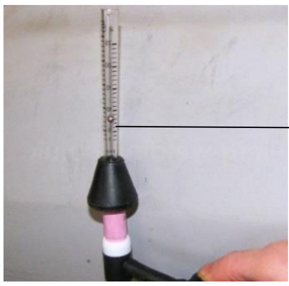
Cylinder gauge informing cylinder pressure in bar. A full 50L argon cylinder will normally have a pressure of 200bar.

Argon cylinders are painted grey.

Flow meter gauge Informing flow rate in L/min. Flow rate should be from 6-9 L/min.

Regulating knob for setting flow rate.

Argon has proven to be the most suitable gas for shielding. It is a colourless and odourless inert gas, heavier than air, non-toxic and nonflammable. It is obtained from air which contains approximately 1% argon. For the TIG process, a quality 4.0 is commonly used. Duplex, Nickel alloys and aluminium will requier quality 4.8. It is necessary to adjust the gas flow and a regulator with flow-meter is therefore needed. Onboard a ship it is necessary to have a flow-meter that functions correctly also when positioned out of vertical.



The argon flow will lift the steel ball. Read correct value from underneath the steel ball.

Use an additional flow meter to check that there is correct gas flow out of the torch. Do not trust the flow meter on the cylinder regulator. There will normally be a drop in a long shielding gas hose.

Surface preparation

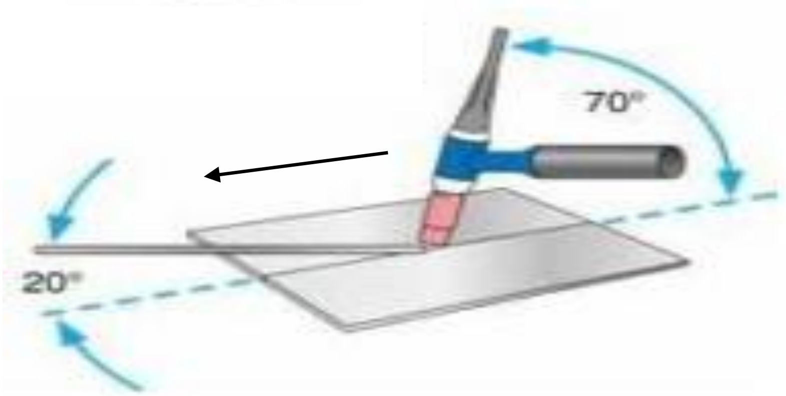
Always remember that cleanliness of the work piece is a priority for first class TIG welding results. Remove any oil, paint or other residue from the joint area. Then remove any oxide layer on the base material. The surface must be metallically clean.

Welding procedure

Before welding starts, if a DC welding machine, check that the torch is connected to the negative (-) polarity, and that sufficient gas is available from the gas supply. Open the argon cylinder valve and the torch valve. If necessary, purge the gas system before setting correct gas flow on the regulator.

Check that the electrode is properly prepared (pointed if DC or rounded if AC) and protrudes 3-6mm from the nozzle. If current remote control is available, adjust to low or minimum current. Start procedure depend on the welding machines features: Scratch start, Lift arc or HF.

TIG welding can be carried out in all welding positions and the procedure is largely similar to the gas welding forehand welding technique. Vertical welding is normally done upwards. Keep an arc length of approximately 1-3mm. Note that a longer arc will increase the heat input and a shorter arc will reduce it. If welding current remote control is used, the heat input may be adjusted through the whole process by adjusting the current. Hold the torch at an angle of approximately 70° to the workpiece. The arc may be used just to melt the edges of the joint together, or additional welding rod may be used.



Introduce the rod to the molten pool, but in such a way that it does not touch the electrode or enter the arc between electrode tip and workpiece. The rod may be added continuously or in a slightly dipping motion. The hot end of the rod shall be kept close to the melt pool and protected by the argon gas to avoid oxidation, which will contaminate the weld. Hold the rod at an angle of approximately 20° to the workpiece.

Finishing the bead by removing the welding rod from the pool. Adjust welding current to minimum and extinguish the arc but keep the torch in place for 15 to 20 seconds with the gas flowing. This in order to protect the molten pool and the electrode during the cooling-off period.

The tungsten electrode may be contaminated through contact with the molten pool or the welding rod. It will also be contaminated (by oxidation) if the shielding gas supply is not opened before the arc is struck, or if the gas is shut off before the electrode has cooled down to below red glowing temperature. If there is little contamination the electrode may be cleaned by striking an arc against a copper plate and letting it burn for a few seconds. Remember gas supply. If the electrode is heavily contaminated the welding current supply must be disconnected, the electrode removed and the contaminated part broken off. The electrode must be reground to the correct shape and replaced in the torch.