



Guide To TIG Welding





This guide is designed to provide helpful information relating to the electric arc welding and cutting process.

The guide is split into specific areas of welding and cutting and designed to give an understanding of these areas.

The guide is not designed to be a comprehensive text book and the concept is to convey knowledge and techniques by theory and practical methods.

It should be understood that methods may not be the “only way to do it” but represent many current practices and systems.

The guides are constantly reviewed to incorporate any changes in procedures, technologies and equipment.

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Tailored courses using the latest equipment and technology, modules include:

Health & Safety • Electrical Principles in Arc Welding
MIG • TIG • MMA • Plasma Cutting • Resistance Welding

Read these instructions carefully before commencing welding



What Is Welding?

Welding is the process of joining together two or more pieces using heat and/or pressure to form a high strength joint. There are many ways to perform a weld and these require different skill levels and can utilise many levels of technology in the equipment used.

To carry out a weld a heat source is required. This can be thermo chemical energy which is produced using a combination of gases such as oxygen and acetylene to produce a flame. This process was widely used but requires a high level of manual skill and dexterity.

Another source is electrical energy, this is where an arc is established between the electrical source or Arc welding power source and the work piece. This process is referred to as Arc welding or Arc cutting and can produce heat at temperatures from 3000°C to 20,000°C. Arc welding can be used on a wide range of different metals, alloys and materials. Dependent on the process and welding result required Arc welding requires different skill and dexterity levels. Arc welding uses a wide range of power source types from basic transformers to equipment which utilises high levels of technology.

The applications which utilise Arc welding are extensive, from DIY to nuclear, structural fabrication to aerospace, vehicle repair to vehicle assembly, robot automation to offshore, the list is endless. Welding can be carried out pretty much anywhere...



The Arc welding and cutting processes covered:

- Manual metal arc
- MIG (Metal inert gas) process
- MAG (Metal active gas) process
- FCW (Flux cored welding) process
- TIG (Tungsten inert gas) process
- Plasma arc cutting process
- Resistance welding

The individual process information will be given in the related units. In addition to the above processes there are others such as laser, submerged arc, ultrasound and friction welding.



The Materials Welded?

The most commonly welded materials are aluminium, mild steel, stainless steel and their alloys. Also in today's rapidly changing world many plastics can also be welded.

Which Process?

The welding process used is chosen based on the materials to be welded and the material thickness. Also to be taken into consideration is the production rate and visual aesthetics of the weld which may be on show.

Manual Arc (MMA)

This is one of the oldest processes and is still in common use. It is well suited to use when welding outdoors and in repair work. It is a slow process however and requires a high skill level but can be used on a wide range of materials. It can also be used in confined areas as the electrodes can be bent into shape for access. Equipment costs are lower than the other processes.

Metal Inert/Active Gas (MIG/MAG)

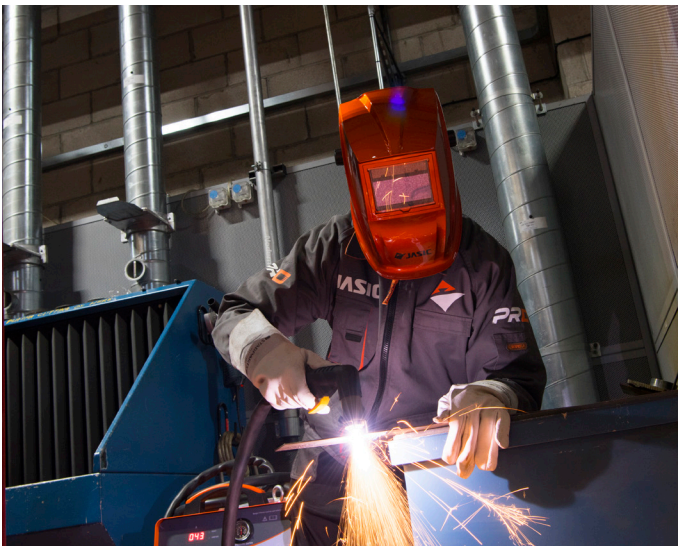
The process is a common, versatile welding process. It provides high deposition rates and is suited to a wide range of material thicknesses, thin to thick. Compared with Manual Arc welding the process provides a weld with minimal weld finishing as there is minimal spatter and no electrode slag. It requires a low - medium skill level and has less problems to achieve good quality compared to TIG/ MMA it has a narrow heat affected area. Its disadvantage is the torch as it is subject to a number of wear components such as contact tips, nozzles, liners etc. It is often a process that is automated to provide even higher production rates.

Flux Cored Welding (FCW)

Flux cored welding is a type of MIG/MAG welding using a standard MIG/MAG power source but uses a consumable which may contain a core of constituents which allow the process to self-shield itself therefore requiring no additional gas shield supply. This makes it suitable for welding in areas where there may be draughts e.g. outdoors. In addition, consumables may contain elements to provide high deposition rates and hence productivity. The flux core however produces a slag coating which needs to be cleaned after welding.

Tungsten Inert Gas (TIG)

TIG welding, is an arc welding process that uses a non-consumable tungsten electrode to produce the weld. The weld area and electrode is protected from oxidation or other atmospheric contamination by an inert shielding gas (argon or helium) and a filler metal is normally used, though some welds known as autogenous welds, do not require it. A constant-current welding power supply produces the electrical energy which is conducted across the arc through a column of highly ionized gas. TIG offers a high quality weld although generally a slower process compared to the others which requires a higher skill level.



Plasma Cutting

The basic principle is that the arc formed between the electrode and the work piece is constricted by a fine bore nozzle. This constriction increases the temperature and velocity of the plasma emanating from the nozzle. The temperature of the plasma arc is in excess of 20,000°C and the velocity can approach the speed of sound. When used for cutting, the plasma gas flow is high and creates a deeply penetrating high temperature plasma jet thereby cutting through the material. The force of the arc blows away any molten material in the form of dross. The plasma process operates by using the high temperature arc to melt the metal. The plasma process can therefore be used to cut metals including cutting metals which form refractory oxides such as stainless steel, aluminium, cast iron and non-ferrous alloys. The cut quality is dependent on many parameters but the system is easy to use and often is the only practical or cost effective solution.

Resistance Welding (Spot)

Resistance welding (Spot) is also one of the oldest of the electric welding processes in use in the welding industry today. The weld is made by a combination of heat, pressure and time. It is the resistance of the material to be welded to current flow that creates a localised heating in the material to be welded and hence the name resistance welding. The resistance of different materials will create different levels of heat for the same current passing through it. The pressure exerted by the electrode arms and electrode tips through which the current flows, holds the parts to be welded in intimate contact before, during and after the welding current time cycle. The required amount of time current flows in the joint is determined by material thickness and type, the amount of current flowing and the cross-sectional area of the welding tip contact surfaces.



Industry Examples That Use Welding And Cutting Processes:



Process Comparison:

	TIG Welding	MMA Welding	MIG Welding
Skill level required	High	High - Especially for high quality and non ferrous material	Low - Medium
Quality	Requires high skills for good quality	Requires high skills for good quality	Less problems to achieve good quality compared to TIG/MMA
Distortion/heat input	High	High	Low - Narrow heat affected area
Ease of mechanisation	Some difficult positions	Difficult	Simple
Equipment maintenance	Needs training	Needs basic training	Needs training
Consumable parts	Negligible	Negligible	Torch components such as contact tips, nozzles, liners etc.

Equipment must only be used for the purpose it was designed for. Using it in any other way could result in damage or injury and in breach of the safety rules. Only suitably trained and competent persons should use the equipment. Operators should respect the safety of other persons. **PPE and workplace safety equipment must be compatible for the application of work involved.**

General Safety Instructions

Use Of Personal Protective Equipment (PPE)

Welding arc rays from all the welding processes produce intense, visible and invisible (ultraviolet and infrared) rays that can burn eyes and skin.

- Wear an approved welding helmet fitted with an appropriate shade of filter lens to protect your face and eyes when welding or watching.
- Wear approved safety glasses with side shields under your helmet.
- Never use broken or faulty welding helmets.
- Always ensure there are adequate protective screens or barriers to protect others from flash, glare and sparks from the welding area.

- Ensure that there are adequate warnings that welding or cutting is taking place.
- Wear suitable protective flame resistant clothing, gloves and footwear.
- Check and be sure the area is safe and clear of inflammable material before carrying out any welding.

Some welding and cutting operations may produce noise. Wear safety ear protection to protect your hearing if the ambient noise level exceeds the allowable limit (e.g: 85 dB).

Current	MMA Electrodes	MIG Light Alloys	MIG Heavy Metals	MAG	TIG On All Metals	Plasma Cutting	Plasma Welding	Gouging ARC/AIR		
10	8	10	10	10	9	11	10	10		
15										
20										
30	9				11		10		11	11
40										
60										
80	10						11			12
100										
125										
150	11	11	12	12		13				
175										
200		12	12		13		14	11		
225										
250										
275	13		14	12		12				
300										
350										
400	13			14	13	14	14	14		
450										
500		14	15						14	15

Safety Against Fumes And Welding Gases

The HSE have identified welders as being an 'at risk' group for occupational diseases arising from exposure to dusts, gases, vapours and welding fumes. The main identified health effects are pneumonia, asthma, chronic obstructive pulmonary disease (COPD), lung and Kidney cancer, metal fume fever (MFF) and lung function changes.

During welding and hot cutting 'hot work' operations, fumes are produced which are collectively known as welding fume. Depending upon the type of welding process being performed, the resultant fume generated is a complex and highly variable mixture of gases and particulates.

Regardless of the length of welding being carried out, all welding fume, including mild steel welding requires suitable engineering controls to be in place which is usually Local Exhaust Ventilation (LEV) extraction to reduce the exposure to welding fume indoors and where LEV does not adequately control exposure it should also be enhanced by using suitable respiratory protective equipment (RPE) to assist with protecting against residual fume. When welding outdoors appropriate RPE should be used.

Prior to undertaking any welding tasks an appropriate risk assessment should be carried out to ensure expected control measures are in place.

- Locate the equipment in a well-ventilated position and keep your head out of the welding fume.
- Do not breathe the welding fume.

- Ensure the welding zone is well-ventilated and provision should be made for suitable local fume extraction system to be in place.
- If ventilation is poor, wear an approved airfed welding helmet or respirator.
- Read and understand the Material Safety Data Sheets (MSDS's) and the manufacturer's instructions for metals, consumable, coatings, cleaners and de-greasers.
- Do not weld in locations near any de-greasing, cleaning or spraying operations.
- Be aware that heat and rays of the arc can react with vapours to form highly toxic and irritating gases.

For further information please refer to the HSE website www.hse.gov.uk for related documentation.



An example of personal fume protection

Precautions Against Fire And Explosion

- Avoid causing fires due to sparks and hot waste or molten metal.
- Ensure that appropriate fire safety devices are available near the cutting/welding area.
- Remove all flammable and combustible materials from the cutting/welding zone and surrounding areas.
- Do not cut/weld fuel and lubricant containers, even if empty. These must be carefully cleaned before they can be cut/welded.
- Always allow the cut/welded material to cool before touching it or placing it in contact with combustible or flammable material.
- Do not work in atmospheres with high concentrations of combustible fumes, flammable gases and dust.
- Always check the work area half an hour after cutting to make sure that no fires have begun.
- Take care to avoid accidental contact of electrode to metal objects. This could cause arcs, explosion, overheating or fire.



General Operating Safety

- Never carry the equipment or suspend it by the carrying strap or handles during welding.
- Never pull or lift the machine by the welding torch or other cables. Always use the correct lift points or handles. Always use the transport under gear as recommended by the manufacturer.
- Never lift a machine with the gas cylinder mounted on it.
- If the operating environment is classified as dangerous, only use S-marked welding equipment with a safe idle voltage level. Such environments may be for example: humid, hot or restricted accessibility spaces.

Working Environment

- Ensure the machine is mounted in a safe and stable position allowing for cooling air circulation.
- Do not operate equipment in an environment outside the laid down operating parameters.
The welding power source is not suitable for use in rain or snow.
- Always store the machine in a clean, dry space.
- Ensure the equipment is kept clean from dust build up.
- Always use the machine in an upright position.

Protection From Moving Parts

- When the machine is in operation keep away from moving parts such as motors and fans. Moving parts, such as the fan, may cut fingers and hands and snag garments.
- Protections and coverings may be removed for maintenance and controls only by qualified personnel after first disconnecting the power supply cable.
- Replace the coverings and protections and close all doors when the intervention is finished and before starting the equipment.
- Take care to avoid getting fingers trapped when loading and feeding wire during set up and operation.
- When feeding wire be careful to avoid pointing it at other people or towards your body.
- Always ensure machine covers and protective devices are in operation.

Handling Of Compressed Gas Cylinders and Regulators

- Always check the gas cylinder is the correct type for the welding to be carried out.
- All cylinders and pressure regulators used in welding operations should be handled with care.
- Never allow the electrode, electrode holder or any other electrically "hot" parts to touch a cylinder.
- Keep your head and face away from the cylinder valve outlet when opening the cylinder valve.
- Always secure the cylinder safely and never move with regulator and hoses connected.
- Always check for leaks.

Never deface or alter any cylinder

Risks Due To Magnetic Fields

- The magnetic fields created by high currents may affect the operation of pacemakers or electronically controlled medical equipment.
- Wearers of vital electronic equipment should consult their physician before beginning any arc welding, cutting, gouging or spot welding operations.
- Do not go near welding equipment with any sensitive electronic equipment as the magnetic fields may cause damage.
- Keep the torch cable and work return cable as close to each other as possible throughout their length. This can help minimise your exposure to harmful magnetic fields.
- Do not wrap the cables around the body.

Materials And Their Disposal

- Welding equipment is manufactured with BSI published standards meeting CE requirements materials which do not contain any toxic or poisonous materials dangerous to the operator.
- Do not dispose of the equipment with normal waste. The European Directive 2012/19/EU on Waste Electrical and Electronic Equipment states the electrical equipment that has reached its end of life must be collected separately and returned to an environmentally compatible recycling facility for disposal.

For more detailed information please refer to the [HSE website www.hse.gov.uk](http://www.hse.gov.uk)

Always carry out a risk assessment before undertaking any welding or cutting activity

General Electrical Safety

- The equipment should be installed by a qualified person and in accordance with current standards in operation. It is the users responsibility to ensure that the equipment is connected to a suitable power supply. Consult with your utility supplier if required.
- Do not use the equipment with the covers removed.
- Do not touch live electrical parts or parts which are electrically charged.
- Turn off all equipment when not in use.
- In the case of abnormal behavior of the equipment, the equipment should be checked by a suitably qualified service engineer.
- If earth bonding of the work piece is required, bond it directly with a separate cable with a current carrying capacity capable of carrying the maximum capacity of the machine current.
- Cables (both primary supply and welding) should be regularly checked for damage and overheating. Never use worn, damaged, under sized or poorly jointed cables.
- Insulate yourself from work and earth using dry insulating mats or covers big enough to prevent any physical contact.
- Never touch the electrode if you are in contact with the work piece return.
- Do not wrap cables over your body.
- Ensure that you take additional safety precautions when you are welding in electrically hazardous conditions such as damp environments, wearing wet clothing and metal structures.
- Try to avoid welding in cramped or restricted positions.
- Ensure that the equipment is well maintained. Repair or replace damaged or defective parts immediately.
- Carry out any regular maintenance in accordance with the manufacturers instructions.
- The EMC classification of this product is class A in accordance with electromagnetic compatibility standards CISPR 11 and IEC 60974-10 and therefore the product is designed to be used in industrial environment only.

WARNING: This class A equipment is not intended for use in residential locations where the electrical power is provided by a public low-voltage supply system. In those locations it may be difficult to ensure the electromagnetic compatibility due to conducted and radiated disturbances.



What Is The TIG Process?

A number of terms are used for the process such as:

- **TIG Tungsten Inert Gas**
- **GTAW Gas Tungsten Arc Welding**

The idea of welding in an inert gas atmosphere was developed in 1890, but even in the early 1900's, welding non-ferrous materials like aluminum and magnesium remained difficult because these metals reacted rapidly with the air, resulting in porous and dross filled welds. In the early 1930's to solve the problem, bottled inert gases were used. A few years later, a direct gas-shielded welding process emerged in the aircraft industry for welding magnesium.

This process was perfected in 1941 and became known as heliarc or tungsten inert gas welding because it utilised a tungsten electrode and helium as a shielding gas.

Finally, the development of alternating current units made it possible to stabilize the arc and produce high quality aluminum and magnesium welds.

Process Description

The TIG process consists of an electric arc to provide heat created between a non consumable electrode and the work piece to be welded. The molten pool created by this arc is shielded by a gas which is used to exclude the surrounding atmosphere from the weld area. The most common gases used are inert such as helium or argon as they have no reaction with the weld pool and being transparent provide the welder with good visibility of the arc. Sometimes a reactive gas can be added such as hydrogen which can increase the heat of the arc and speed of welding.



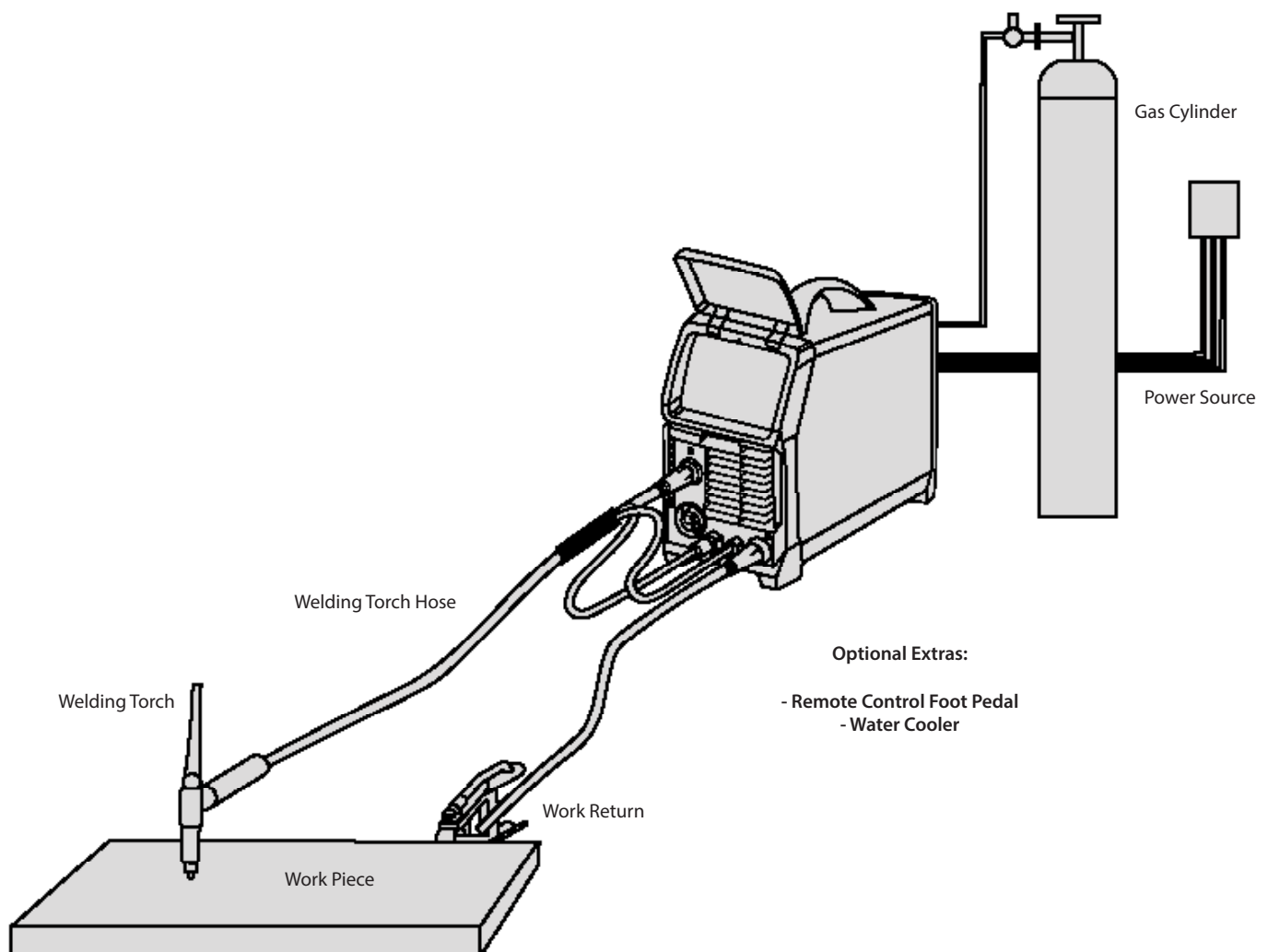
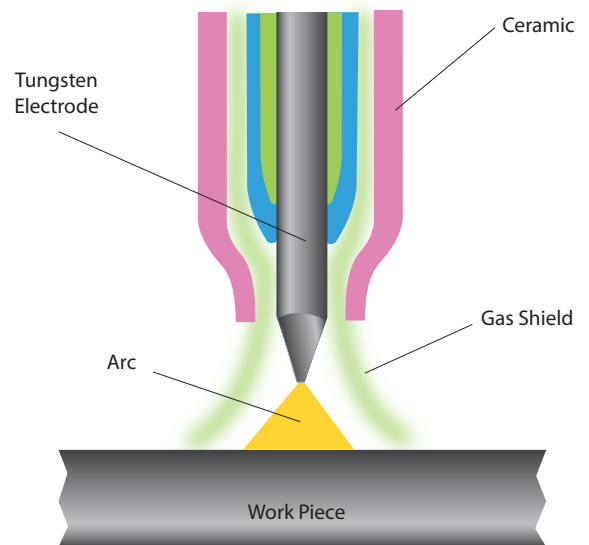
The TIG process produces very high temperatures of up to 19000°C. The TIG arc only produces a source of heat and if additional material is required to complete a weld then this is added either manually or automatically in the form of a consumable filler wire.

When first developed the process used helium gas as shield gas and was often referred to as the Heliarc process.

How The Process Works

The process works by creating a high temperature arc between the electrode and work piece within a gas shielded area. There are various methods of arc starting (see page 27). This then creates a molten pool which is used to either fuse the material to be welded without the addition of any filler material (an autogenous weld) or filler material can be added. The process can be used in either direct current (DC) or alternating current (AC) modes.

The concentrated arc of the TIG process allows precise control of the heat input and thus enables a narrow heat affected zone. This concentrated arc and heat input makes the process well suited to welding materials with high heat conductivity such as aluminium.



The Power Source

The power source can be either single or three phase input and have either DC or AC/DC output (AC only output machines are now rare in the marketplace). The DC systems are used in the welding of materials such as stainless steel, steel, copper etc whereas the AC systems will be used to weld materials such as aluminium which have a refractory oxide coating. The power source will generally have an output open circuit voltage of between 60 and 90V but always check with the manufacturer's data. The power source will provide a constant current type output and the current varies little with arc length changes although the longer the arc is, the wider it becomes and is harder to control. The power source will normally contain all the process controls, power supply unit, arc starting unit, gas valves and optional controls for additional cooling. Power sources can vary from simple electro mechanical types to sophisticated micro computer controlled inverters and many offer an MMA welding function in addition to the TIG function.



The Gas Cylinder

The gas cylinder contains gas stored under pressure usually 230 or 300 Bar and should be handled carefully. This gas shields the weld area from contaminants and enhances the welding process.

The Regulator / Flow Meter

This regulates the cylinder pressure to a usable shielding gas pressure and controls the flow of gas. Regulators are usually a fixed outlet pressure and an independent flow meter is used for flow control. They are normally a single stage configuration and have a single gauge.



Remote Controls

In certain application it may not be possible for the operator to access the machine controls from the welding area. The operator may need to control various parameters locally such as current, slope control etc. The majority of welding machines designed for TIG welding provide remote control capability. The remote control offers usually current control as a minimum. In addition many remote systems can almost duplicate all the major parameters. The remote controls come in several variants, i.e. hand held, torch mounted, bench mounted and most commonly foot control.



Under Gear

When using the TIG process it is always best practice to keep the torch length as short as possible. Therefore to have the power source mobile is a definite advantage. Many machines are fitted with or have optional under gear kits that transport the machine and ancillaries along with the gas cylinder easily.



The TIG Welding Torch

The welding torch is a critical part of the TIG process. It is the point at which the arc is created and whilst the majority of heat goes into the arc the TIG welding torch is subjected to high heat levels. As the torch is held by the operator it must remain cool whilst still being easily manoeuvrable and compact in size. This heat is removed from the torch by either air/gas cooling or water cooling.

Where torches are required for high production or use high amperage then these would normally be water cooled and where lower amperage or lighter duty is required these would normally be air cooled.

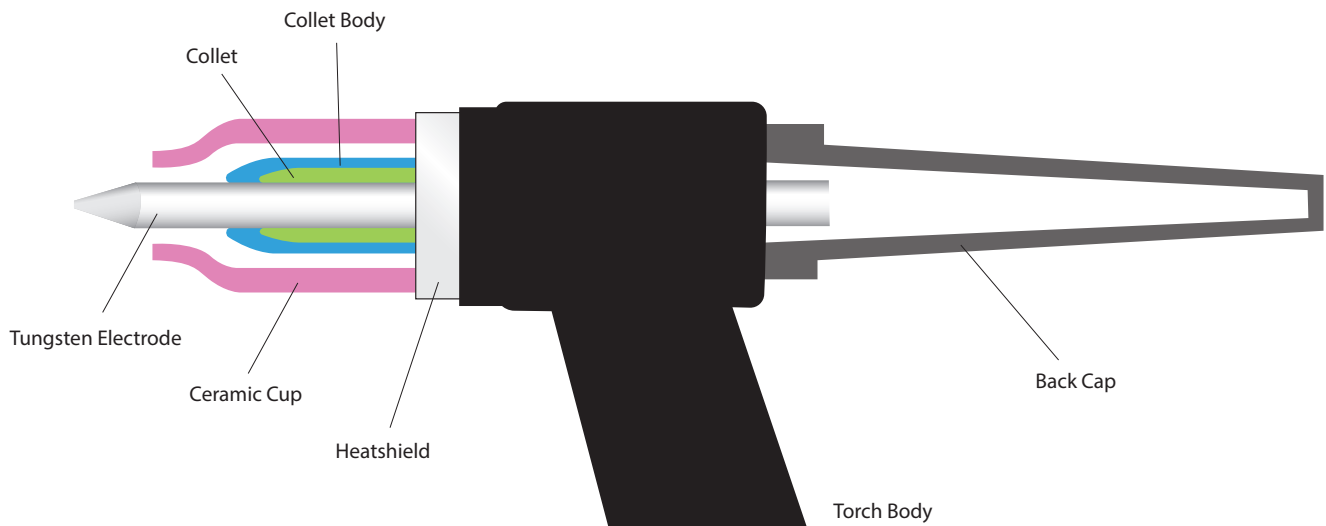
Air/Gas cooled torches require no additional cooling other than the surrounding air and gas flow. Higher current air cooled torches are often larger and less flexible to use than water-cooled torches. The cable carrying the welding current

must be heavier than the cable in water-cooled torches. Water-cooled torches are designed so that water is circulated through the torch cooling it and the power cable. The power cable is contained inside a hose and the water returning from the torch flows around the power cable providing the necessary cooling. This method of cooling means the power cable can be relatively small, making the entire cable assembly light and easily manipulated. Care must be taken when using a water cooled torch that a lack of coolant or no coolant at all will cause the polyethylene or braided rubber sheath to melt or possibly the power cable will melt. Always check the flow rate required to cool the torch.

TIG Torch Components

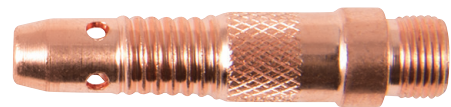
Torch Body

The torch body is usually covered by a rigid phenolic material or a rubberised covering. They can be rigid or flexible variants, with or without valves.



Collet Body

The collet body screws into the torch body. It is replaceable and is changed to accommodate different size tungstens and their respective collets.



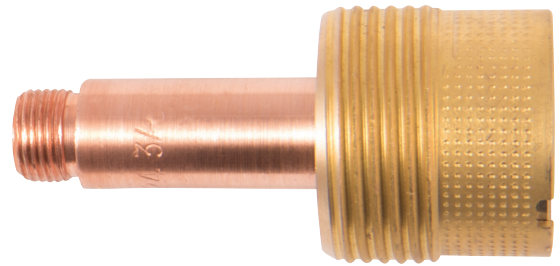
Collets

The welding electrode is held in the torch by the collet. The collet is usually made of copper or a copper alloy. The collet's grip on the electrode is secured when the torch back cap is tightened in place. Good electrical contact between the collet and tungsten electrode is essential for good current transfer.



Gas Lens Body

A gas lens is a device that can be used in place of the normal collet body. It screws into the torch body and is used to reduce turbulence in the flow of shield gas and produce a stiff column of undisturbed flow of shielding gas. A gas lens will allow the welder to move the nozzle further away from the joint allowing increased visibility of the arc. A much larger diameter nozzle can be used which will produce a large blanket of shielding gas. This can be very useful in welding material like titanium. The gas lens will also enable the welder to reach joints with limited access such as inside corners.



Ceramic Cups

Gas cups are made of various types of heat resistant materials in different shapes, diameters and lengths. The cups are either screwed onto the collet body or gas lens body or in some cases pushed in place. Cups can be made of ceramic, metal, metal-jacketed ceramic, glass or other materials. Ceramic is the most popular but can be easily broken.

Nozzles used for automatic applications and high current situations often use a water-cooled metal design. Gas cups must be large enough to provide adequate shielding gas coverage to the weld pool and surrounding area.

A cup of a given size will allow only a given amount of gas to flow before the gas flow becomes disturbed due to the speed of flow. Should this condition exist the size of cup should be increased to allow the flow speed to reduce and once again establish an effective regular shield.



TIG Welding Electrodes

TIG welding electrodes are a 'non consumable' as it is not melted into the weld pool and great care should be taken not to let the electrode contact the welding pool to avoid weld contamination. This would be referred to as tungsten inclusion and may result in weld failure. Electrodes will often contain small quantities of metallic oxides which can offer the following benefits:

- Assist in arc starting
- Improve current carrying capacity of the electrode
- Reduce the risk of weld contamination
- Increase electrode life
- Increase arc stability

Oxides used are primarily zirconium, thorium, lanthanum or cerium. These are added usually 1% - 4%.

The types of tungsten electrode used are:

Pure Tungsten (Green)

AWS A5.12 EWP, ISO 6848 WP

These electrodes are unalloyed, 'pure' tungsten with a 99.5% tungsten minimum and are relatively low cost. They provide good arc stability when using AC current, with either balanced wave or unbalanced wave and continuous high-frequency stabilization. Pure tungsten electrodes are preferred for AC sine wave welding of aluminium and magnesium because they provide good arc stability with both argon and helium shielding gas. The pure tungsten electrode easily forms a balled end but has a tendency to spit at higher currents and this should be considered when making critical welds.

Ceriated (2% Ceriated, Grey)

AWS A5.12 EWCe-2, ISO 6848 WC20

These electrodes are alloyed with about 2% ceria, a non-radioactive material and the most abundant of the rare earth elements. The addition of this small percentage of cerium oxide increases the electron emission qualities of the electrode which gives them a better starting characteristic and a higher current carrying capacity with no spitting. These are all-purpose electrodes that will operate successfully with AC or DC electrode negative. Compared with pure tungsten, the ceriated tungsten electrodes provide for greater arc stability. They have excellent arc starting properties at low current. If used on higher current applications the cerium oxide may be concentrated to the excessively hot tip of the electrode. This condition and oxide change will remove the benefits of the cerium. The non radioactive cerium oxide has slightly different electrical properties as compared to the thoriated tungsten electrodes. The cerium electrodes work well with the Advanced Squarewave power sources and should be ground to a modified point.

Lanthanated (1% Lanthanum, Black), (1.5% Lanthanum, Gold), (2% Lanthanum, Blue) AWS A5.12 EWL^a-^{}, ISO 6848 WL^{**} eg Lanthanated 1.5% spec is AWS A5.12 EWL^a-1.5, ISO 6848 WL15**

These electrodes are alloyed with non radioactive lanthanum oxide, often referred to as lanthana, another of the rare earth elements. These electrodes have excellent arc starting, low erosion rate, arc stability and excellent re-ignition characteristics.

The addition of 1 – 2% lanthana increases the maximum current carrying capacity by approximately 50% for a given size electrode using alternating current compared to pure tungsten. The higher the percentage of lanthana, the more expensive the electrode. Since lanthana electrodes can operate at slightly different arc voltages than thoriated or ceriated tungsten electrodes these slight changes may require welding parameters and procedures to be adjusted. The 1.5% content appears to

most closely match the conductivity properties of 2% thoriated tungsten. Compared to cerium and thorium the lanthana electrodes had less tip wear at given current levels. Lanthanum electrodes generally have longer life and provide greater resistance to tungsten contamination of the weld.

The lanthana is dispersed evenly throughout the entire length of the electrode and it maintains a sharpened point well, which is an advantage for welding steel and stainless steel on DC or the AC from Advanced Squarewave power sources. Thus the lanthana electrodes work well on AC or DC electrode negative with a pointed end or they can be balled for use with AC sine wave power sources.

Thoriated (2% Thorium, Red) AWS A5.12 EWTh-2, ISO 6848 WT20

Thoriated electrodes both 1 and 2% are very commonly used electrodes since they were the first to show better arc performance over pure tungsten for DC welding. However, thoria is a low-level radioactive material, thus vapours, grinding dust and disposal of thorium raises health, safety and environmental concerns. The relatively small amount present has not been found to represent a health hazard. But if welding will be done in confined spaces for prolonged periods of time, or if electrode grinding dust might be ingested, special precautions should be taken concerning proper ventilation. The welder should consult informed safety personnel and take the appropriate steps to avoid the thoria. The thoriated electrode does not ball as does the pure tungsten, cerium or lanthana electrodes. Instead, it forms several small projections across the face of the electrode

when used on alternating current. When used on AC sine wave machines, the arc wanders between the multiple projections and is often undesirable for proper welding. Should it be absolutely necessary to weld with these type machines, the higher content lanthana or thoria electrodes should be used. The thoriated electrodes work well with the Advanced Squarewave power sources and should be ground to a modified point. These electrodes are usually preferred for direct current applications. In many DC applications, the electrode is ground to a taper or pointed. The thorium electrode will retain the desired shape in those applications where the pure tungsten would melt back and form the ball end. The thoria content in the electrode is responsible for increasing the life of this type over the pure tungsten.

Zirconiated (1% Zirconium, White)

AWS A5.12 NONE, ISO 6848 WZ8

This tungsten is alloyed with zirconium oxide (zirconia) and is preferred for AC welding when the highest quality work is necessary and where even the smallest amounts of weld pool contamination cannot be tolerated. This is accomplished because the zirconium alloyed tungsten produces an extremely stable arc which resists tungsten spitting in the arc. The current carrying capability is equal to or slightly greater than an equal sized cerium, lanthana or thorium alloyed electrode. Zirconium electrodes are

typically used only for AC welding with a balled end. The tungsten electrodes come in a variety of diameters and you would select the appropriate diameter for the current to be used and type for the process mode. To physically identify the tungsten type the end is dipped with a colour. Take care to grind the non coloured end for welding.

Electrode Colour Chart

Welding Mode	Tungsten Type	Colour
AC	Pure Tungsten	Green
DC or AC/DC	Ceriated 2%	Grey
DC or AC/DC	Lanthanated 1%	Black
DC or AC/DC	Lanthanated 1.5%	Gold
DC or AC/DC	Lanthanated 2%	Blue
DC	Thoriated 1%	Yellow
DC	Thoriated 2%	Red
AC	Zirconiated 1%	White

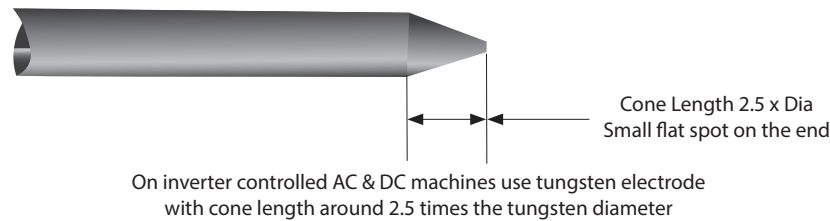
Recommended Electrode Current Guide

Tungsten Size	DC-Electrode Negative	AC Symmetrical Wave	AC Un-symmetrical Wave
1.0 mm	15-80A	10-80A	20-60A
1.6mm	70-150A	70-150A	60-120A
2.4mm	150-250A	140-225A	100-180A
3.2mm	250-400A	225-325A	160-250A
4.0mm	400-500A	300-400A	200-320A
6.0mm	750-1000A	500-630A	340-525A

Tungsten Preparation

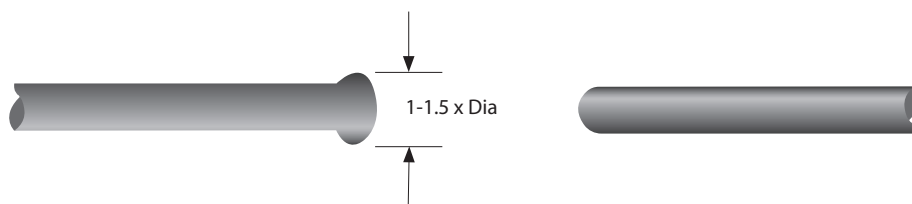
DC Welding (and for AC welding with some modern inverter controlled machines)

When welding at low current the electrode can be ground to a point. At higher current a small flat on the end of the electrode is preferable as this helps with arc stability.



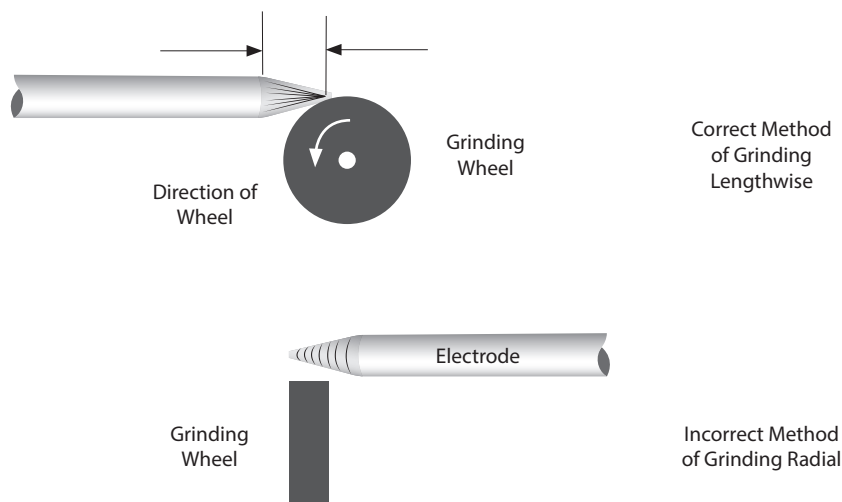
AC Welding

(Standard AC Power Sources and Sinusoidal Operations)



Electrode Grinding

It is important when grinding the electrode to take all necessary precautions such as wearing eye protection and ensuring adequate protection against breathing in any grinding dust. Tungsten electrodes should always be ground lengthwise and not in a radial operation. Electrodes ground in a radial operation tend to contribute to arc wander due to the arc transfer from the grinding pattern. Always use a grinder solely for grinding electrodes to avoid contamination.



Coolers And Coolants

Many modern welding machines designed for high duty work will either have a cooler fitted or available as an option. The use of mains water is now seldom used due to a number of factors;

- Waste of water constantly flowing into the drain system.
- Mains water has inherent mineral content, which can build up over a period of time and clog the small cooling orifices in the torch head.
- As high frequency is being used in the torch the water should be de-ionized to prevent HF being bled to the water before getting to the arc.

The conservation of water now also dictates use of less wasteful methods. Many machines are available with recirculation coolers which either fit in the chassis or can be stand alone. These consist generally of a pump, motor, tank and cooling radiator with a fan.

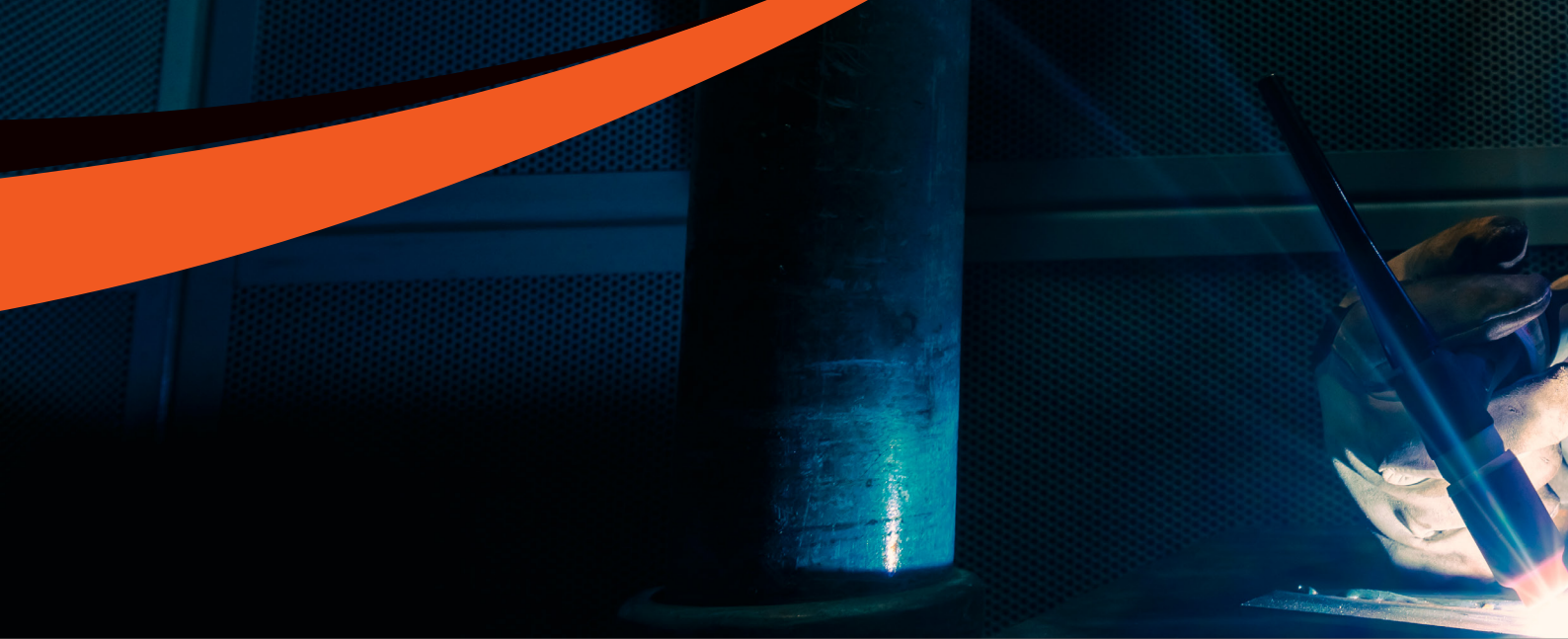
The coolant used in these systems often contain an algae inhibitor to reduce algae growth, a lubricant for the pump and an additive for use if the ambient temperature can drop below freezing to stop the coolant freezing. DO NOT USE antifreeze as it contains ingredients which can cause damage or safety risks. Always consult with the manual of the recirculation / cooler unit to obtain the correct coolant additive and mix strengths. De-ionized water can be used.

All coolants must be clean and it is advisable to use a filter to extract any contaminant from entering the coolant system. This will help to reduce any blocked passages which may cause overheating and damage the equipment or torch.

The coolant flow rate through the system and torch is important. If the rate of flow is too low it may decrease cooling efficiency. If the coolant flow is too high then damage to the torch and hoses within the system may occur.

The direction the coolant flows through the torch is also critical. It should flow from the cold output of the cooler directly through the water hose to the torch head. The torch head is the hottest spot in the coolant system and should be cooled first with the coolant at its most efficient thermal transfer temperature. This coolant upon leaving the torch head will flow over the power cable on its return to the re-circulating system.





The Consumables

The consumables of the process are filler wires and shield gas.

Filler Wires

Filler wires come in many different material types and usually as cut lengths, unless some automated feeding is required where it will be in reel form. Always consult the manufacturer's data and welding requirements.

Argon

Argon is obtained as a by product in the manufacturing of oxygen. Argon may be obtained in the gaseous state in cylinders or as a liquid in specially constructed cylinders or in bulk tanks. When choosing a shielding gas, a fact that must be considered is the ionization potential of the gas. Ionization potential is measured in volts and is the point where the welding arc will be established between the electrode and the work piece through the shielding gas. In other words, it is the voltage necessary to electrically charge the gas so that it will conduct electricity. The ionization potential of argon is 15.7 volts. So this is the minimum voltage that must be maintained in the welding circuit to establish the arc or to weld with argon.

Gases

Gases normally used in the TIG welding process are:

The ionization potential is different for every gas and has a major effect on the arc and weld bead. The ionization potential for helium is 24.5 volts. Comparing two welding circuits, each being equal except for shielding gas, the arc voltage produced with argon would be lower than that produced by helium. Argon has low thermal conductivity which means it is not a good conductor of heat. This results in a more compact, higher density arc. Arc density refers to the concentration of energy in the arc. With argon this energy is confined to a narrow or more 'pinpointed' area. Argon provides excellent arc stability and cleaning action even at low amperages.



Helium

Unlike argon, helium has high thermal conductivity. Due to this higher thermal conductivity, the arc column expands, reducing current density in the arc. The arc column will become wider and more flared out than the arc column with argon shielding gas. The more flared out the arc column, the more work surface area is being heated. The heat at the centre of the arc can move more readily downward towards the colder metal at the bottom of the work piece. This results in a deeper penetrating arc.

It was mentioned previously that with an equivalent arc length, helium will produce a higher arc voltage than will argon. Since the total power is a product of voltage and amperage, it is apparent that more heat energy is available with helium. Helium or argon-helium mixtures are desirable on thick material and where high travel speeds are desired. The use of 2:1 helium to argon gas mixture has also been shown to yield lower porosity welds in production situations

by allowing wider variation in welding parameters. With helium shielding, any slight variation of arc length can have quite an affect on arc voltage and consequently total arc power. For this reason, helium is not as desirable as argon for manual welding applications.

Because of its higher ionization potential, it is more difficult to start an arc with helium shielding gas, especially at lower amperages. Argon is used almost exclusively when welding at 150 amps and lower. As helium is a light gas, flow rates are usually two or three times higher than argon for equivalent shielding. The cost of helium is considerably more than argon and with the increased flow rate, total cost of shielding goes up sharply. The cost must be weighed against increased penetration on thick material and the increased travel speed attainable.

Hydrogen

Just as helium is mixed with argon to take advantage of the best features of both gases, hydrogen is mixed with argon to further constrict the arc and produce a cleaner weld with a greater depth to width ratio (penetration). This mix is used primarily for welding austenitic stainless steel and some nickel alloys. The addition of hydrogen to argon also increases travel speed. It should be noted that an argon hydrogen mix will introduce the risk of hydrogen cracking and metal porosity particularly in multi pass welds.

Nitrogen

Nitrogen when mixed with argon provides the capability of producing more energy to the work than with argon alone. This can be particularly beneficial when welding materials of high conductivity such as copper. However, a nitrogen mix cannot be used on ferrous metals such as steel and stainless steel because nitrogen pick up in the weld pool causes a significant reduction in strength and a weaker, more porous bead.

Flow Rates

The correct flow rate is an adequate amount to shield the molten weld pool and protect the tungsten electrode. More than this amount is wasted. The correct flow rate in litres per min (or cubic feet per hour) is influenced by many variables that must be considered on each application. Generally speaking, when the welding current, cup diameter or electrode stick out is increased, the flow rate should be increased. When welding in the AC mode the current reversals have a disturbing affect on the shielding gas and

flow should be increased by 25% and of course, when welding in a draft situation, flow rate should be doubled. When welding in difficult areas excessive flow rates can cause turbulence and air entrapment. In this situation, the effectiveness of the shielding gas can be improved by reducing the gas flow by about 25%.

As a guide the flow rate is normally around 8-12 l/m for argon but can be double that for helium.

Welding Fume

Welding fume consists of various airborne substances in the form of fine particles and gases. These elements may increase hazards to health if they are inhaled or swallowed. The degree of hazard to the welder will depend on:

- The time the welder is exposed to the fume
- The composition of the fume
- The concentration of the fume in the air that they are breathing

When the consumable electrodes are at a normal ambient temperature then no fumes or gases are created. However the TIG process when welding can produce fume due to both the molten weld metal and filler materials.

For more detail on welding fume please consult the Health & Safety Executive (HSE) website for more information (WL11 – COSHH essentials for welding, hot work and allied processes).

Occupational Exposure Limits

The recommended limit on the concentration of welding fume in the air breathed by any person is defined by the Health & Safety Executive in a list of Occupational Exposure Limits (guidance note EH40). This guidance note is revised annually and reference should always be made to the most recent edition. A long term exposure limit (8 hr TWA value) for particulate welding fume is included in the current list. It is the responsibility of the welder and employer under the

Health & Safety at Work Act and the Control of Substances Hazardous to Health (COSHH) regulations that limits are not exceeded. The fume analysis provided by the electrode manufacturer cannot be used to assess the concentration of total welding fume to which a welder is exposed. An assessment of the possible exposure of the welder to fume must be carried out by a competent person.

Controls

The main basic controls for the TIG system are as follows.

Current Control

This control is normally a stepless adjustment of the welding current. This can either be via the front panel of the welding power source, via a remote control foot or hand operated control or a combination of both.



Typical front Control Panel

Mode Selection

This selects the welding modes. These can be:

MIG

TIG

AC Mode

DC Mode

Pulse Welding

AC Frequency

The normal mains frequency of equipment is 50Hz. However, modern power sources are able to vary this frequency, for example 50-100Hz. Many welders will often settle on around 70Hz.

Pulse Control

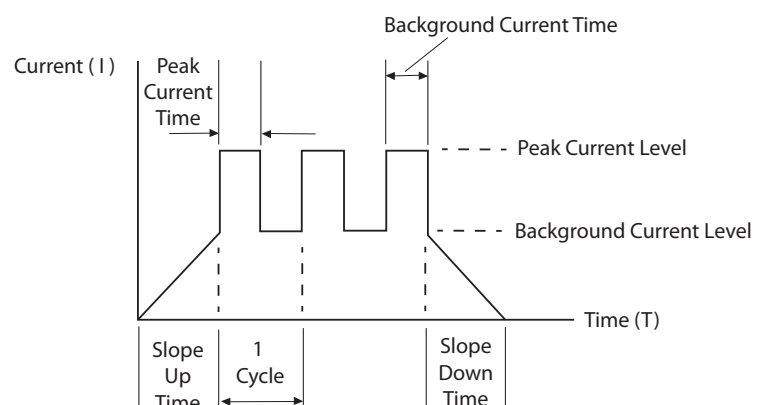
Pulse control is a variation of control of the welding current. The control often consists of a peak welding and background welding current level and also the times of each level. In addition there may be a frequency control. On some machines pulsing may be preset ratios and just high and low frequency selections offered.

Slope Control

The slope control is a time control by which the rise or fall of current from welding level can be set.

Balance Control

This selects the percentage of cleaning between positive and negative cycles in the AC welding mode. Balance zero is normally 50:50 positive and negative. More cleaning is more positive and less negative and more penetration is the opposite, i.e. more negative and less positive. Controls will often show a zero as the balanced state and a +10 -10 indicator range either side of zero. With the correct setting of the frequency and balance controls it is possible to use a smaller size tungsten.



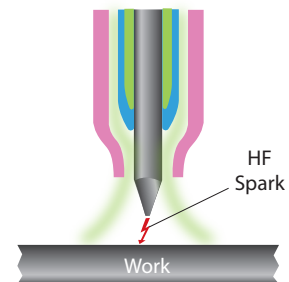
Arc Starting

The process uses both non contact and contact methods to provide arc starting. Options are indicated on a selector switch on the power source. The most common method of arc starting is 'HF' start. This term is often used for a variety of starting methods and covers many different types of start.

Some Methods Of Non Contact 'HF' Start Include:

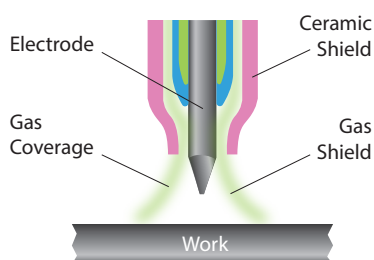
- High Frequency - This is a high voltage / low amperage generated using a spark gap assembly. The frequency varies with the spark gap and can be around 16000 Hz to 1000000 Hz. There can be problems with this method as it can cause electrical interference with nearby electrical equipment such as computers and CNC controls. Also as spark gaps widen, the HF can become erratic.
- Electronic/Solid state – This is a method of start where no spark gap exists and the arc is started by means of high voltage discharge controlled electronically for a very short period.

In general when operating in the DC mode the electrical arc initiation will cease once the main arc is struck. Some of the more modern units with electronic control will also do this in the AC mode thereby reducing any possible electrical interference.

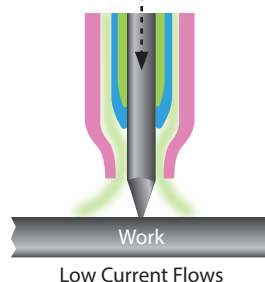


Some Methods Of Contact Start Include:

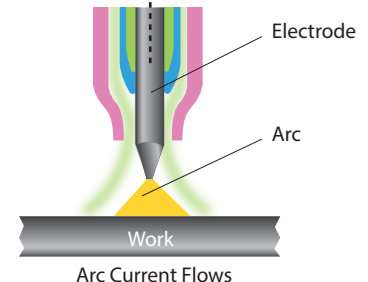
- Lift-arc - This system allows the tungsten to be in direct contact with the work piece but with minimal current so as not to leave a tungsten deposit. The tungsten is lifted and an arc is established.



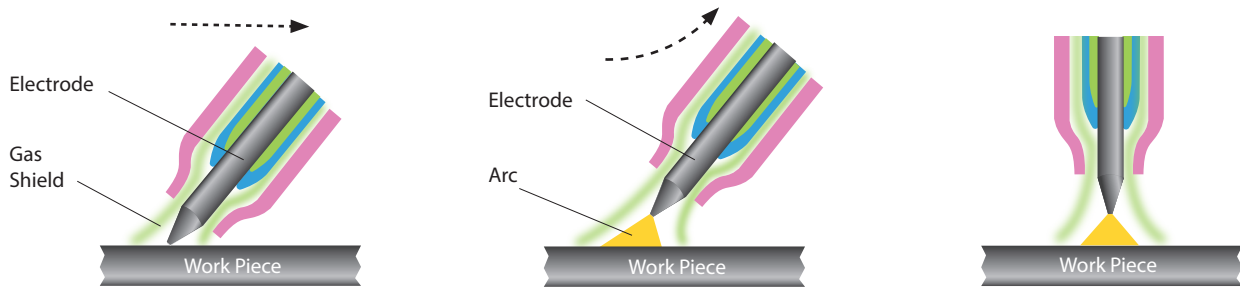
Touch Electrode to work



Lift Electrode



- Scratch start - This system is where the electrode is scratched along the work piece like striking a match. It is not considered suitable for high integrity welding due to the fact that the tungsten can be melted on the work piece thereby contaminating the weld.



Gas Flow Timers

Timers that are used to control the time that shield gas is fed to shield the weld area. Gas flow prior to an arc being struck (pre gas or pre flow) is used to purge the weld zone and the welding torch of any contaminant. It would normally be used when the material to be welded is sensitive to atmospheric contamination. This time setting will have to complete its cycle prior to any other functions starting. Following the

completion of the weld and the weld zone is cooling, a timer controls the time gas flows (post gas or post flow) without any other machine functions in operation to shield the weld zone. In addition, post gas flow protects the cooling tungsten electrode from contamination.

Other Controls

Other common control features are:

Latching or 2T/4T where the welding can either be in 2T mode:-press the torch trigger to weld and release to stop or in 4T mode:- press and release the torch trigger to start, weld without holding the trigger on and stop by pressing and releasing the trigger again. This is particularly useful when welding long weld runs.

- A spot welding timer will allow the time of the weld to be set and after the time has expired the operator will have to release the torch switch to re start the weld. In many of the new technology machines there are many other control features made possible by the use of electronics and micro computers such as synergic control, auto pulse, program storage etc.

The above control features can greatly improve both machine and welder performance and the operator should always read the manufacturer's instructions to gain a full knowledge of all these additional features.

DC Welding

Direct current welding is when the current flows in one direction only. Compared with AC welding the current once flowing will not go to zero until welding has ended. In general TIG machines will be capable of welding either DC or AC/DC welding with very few being AC only.

Direct Current - Electrode Negative (DCEN)

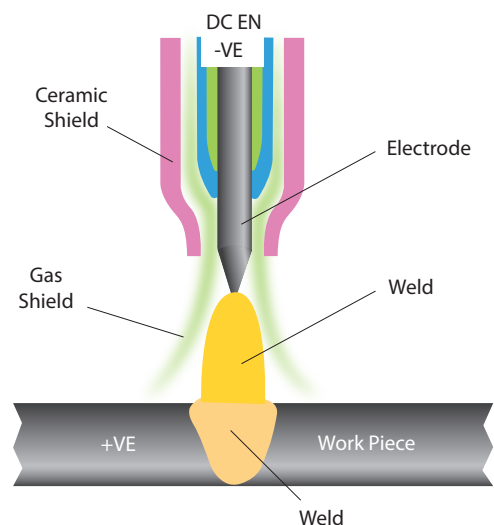
This method of welding can be used for a wide range of materials. The welding torch is connected to the negative output of the machine and the work return cable to the positive output.

When the arc is established the current flows in the circuit and the heat distribution in the arc is around 33% in the negative side of the arc (the welding torch) and 67% in the positive side of the arc (the work piece). This balance gives deep arc penetration of the arc into the work piece and reduces heat in the electrode.

This reduced heat in the electrode allows more current to be carried by smaller electrodes compared to other polarity connections. This method of connection is often referred to as straight polarity and is the most common connection used in DC welding.

Polarity

The TIG welding process has three options of welding current based upon the type of connection. Each method of connection has both advantages and disadvantages.



Direct Current – Electrode Positive (DCEP)

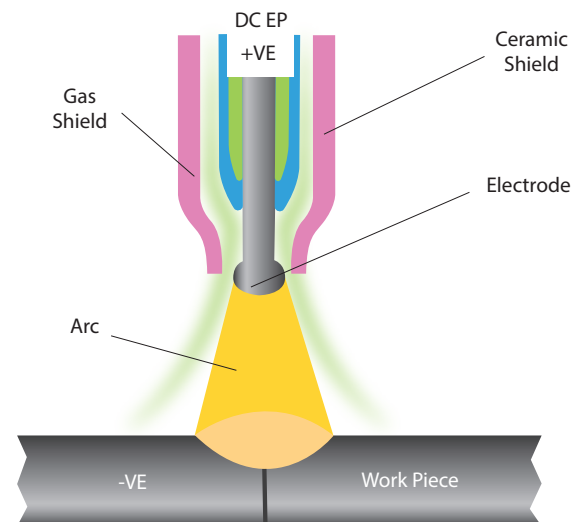
When welding in this mode the welding torch is connected to the positive output of the machine and the work return cable to the negative output. When the arc is established the current flows in the circuit and the heat distribution in the arc is around 33% in the negative side of the arc (the work piece) and 67% in the positive side of the arc (the welding torch). This means the electrode is subjected to the highest heat levels and therefore must be much larger than with DCEN mode even when the current is relatively low to prevent the electrode overheating or melting. The work piece is subjected to the lower heat level so the weld penetration will be shallow. This method of connection is often referred to as reverse polarity.

Also, with this mode the effects of magnetic forces can lead to instability and a phenomenon known as arc blow where the arc can wander between the materials to be welded. This can also happen in the DCEN mode but is more prevalent in the DCEP mode.

It may be questioned what use is this mode when welding. The reason is that some non ferrous materials such as aluminium on normal exposure to atmosphere form an oxide on the surface. This oxide is created due to the reaction of oxygen in the air and the material similar to rust on steel. However this oxide is very hard and has a higher melting point than the actual base material and therefore must be removed before welding can be carried out.

The oxide may be removed by grinding, brushing or some chemical cleaning but as soon as the cleaning process ceases the oxide begins to form again. Therefore, ideally it would be cleaned during welding. This effect happens when the current flows in the DCEP mode when the electron flow will break down and remove the oxide. It could therefore be assumed that DCEP would be the ideal mode for welding these materials with this type of oxide coating. Unfortunately because of the exposure of the electrode to the high heat levels in this mode the electrodes size would have to be large and arc penetration would be low.

The solution for these types of materials would be the deep penetrating arc of DCEN mode plus the cleaning of DCEP mode. To obtain these benefits AC welding mode is used.



Alternating Current (AC) Welding

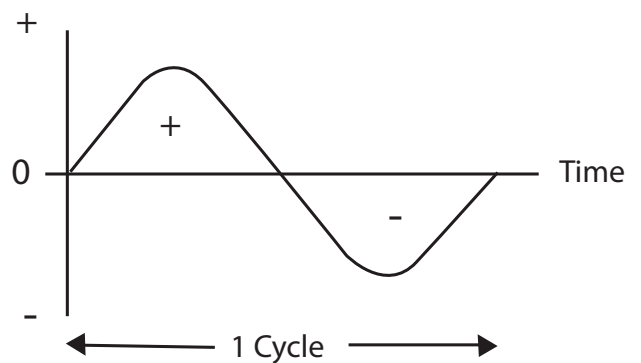
When welding in this mode the current supplied by the machine operates with either positive and negative elements or half cycles. This means current flows one way and then the other at different times so the term alternating current is used. The combination of one positive element and one negative element is termed one cycle.

The number of times a cycle is completed within one second is referred to as the frequency. In the UK the frequency of alternating current supplied by the mains network is 50 cycles per second and is denoted as 50 Hertz (Hz).

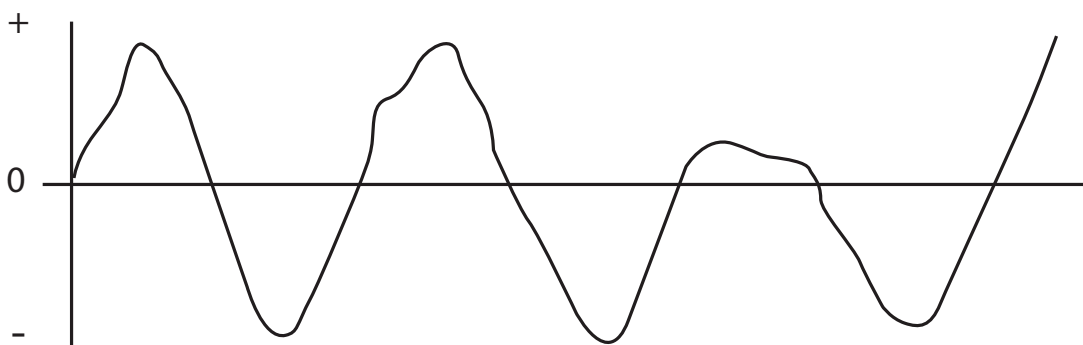
This would mean that the current changes 100 times each second. The number of cycles per second (frequency) in a standard machine is dictated by the mains frequency which in the UK is 50Hz.

It is worth noting that as frequency increases magnetic effects increase and items such as transformers become increasingly more efficient. Also increasing the frequency of the welding current stiffens the arc, improves arc stability and leads to a more controllable welding condition.

However, this is theoretical as when welding in the TIG mode there are other influences on the arc. The AC sine wave can be affected by the oxide coating of some materials which acts as a rectifier restricting the electron flow. This is known as arc rectification and its effect causes the positive half cycle to be clipped off or distorted. The effect for the weld zone is erratic arc conditions, lack of cleaning action and possible tungsten damage.



Arc rectification of the positive half cycle

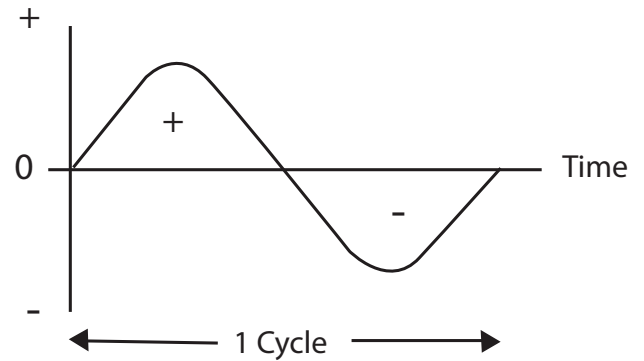


Alternating Current Waveforms

The Sine Wave

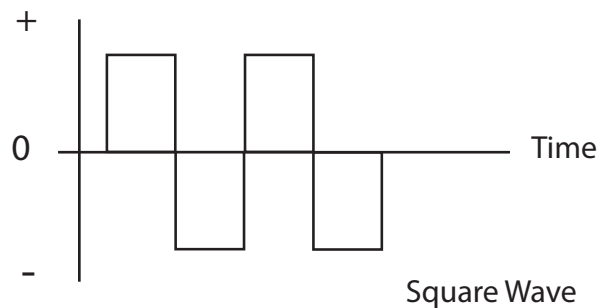
The sinusoidal wave consists of the positive element building up to its maximum from zero before falling back to zero (often referred to as the hill). As it crosses zero and the current changes direction towards its maximum negative value before then rising to zero (often referred to as the valley) one cycle is completed.

Many of the older style welders were only sine wave type machine. With the development of modern power sources with increasingly more sophisticated electronics came development on control and shaping of the AC waveform used for welding.



The Square Wave

With the development of power sources to include more electronics a generation of square wave machines was developed. Due to these electronic controls the cross over from positive to negative and vice versa can be made almost in an instant which leads to more effective current in each half cycle due to a longer period at maximum. The effective use of the magnetic field energy stored creates waveforms which are very near square.

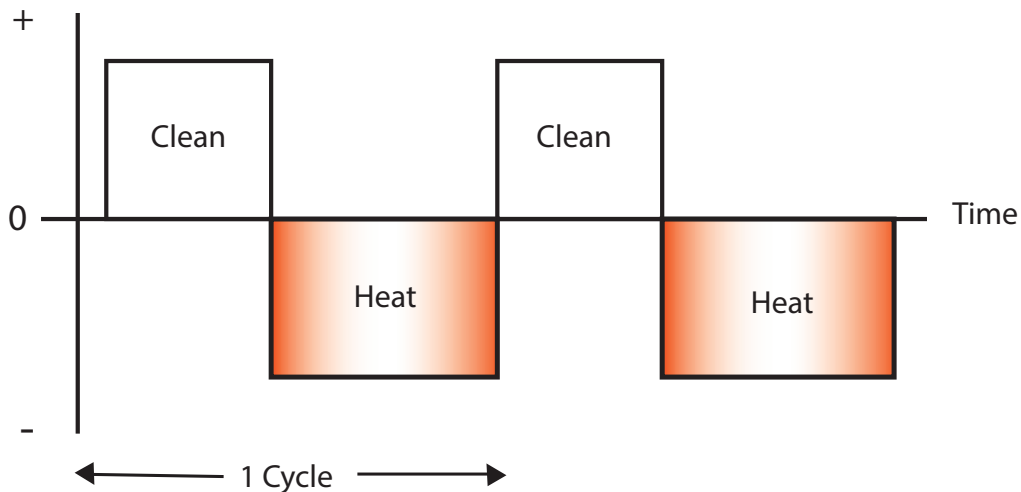
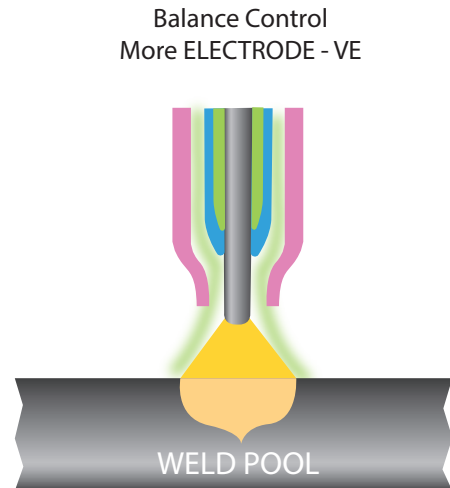


The controls of the first electronic power sources allowed the control of a 'square wave'. The system would allow control of the positive (cleaning) and negative (penetration) half cycles.

The balance condition would be equal positive and negative half cycles giving a stable weld condition. The problems that can be encountered are that once cleaning has occurred in less than the, positive half cycle time then some of the positive half cycle is not productive and can also increase potential damage to the electrode due to overheating. However, this type of machine would also have a balance control which allowed the time of the positive half cycle to varied within the cycle time.

Maximum Penetration

This can be achieved by placing the control to a position which will enable more time to be spent in the negative half cycle with respect to the positive half cycle. This will allow for higher current to be used with smaller electrodes as more of the heat is in the positive (work). The increase in heat also results in deeper penetration when welding at the same travel speed as the balanced condition. A reduced heat affected zone and less distortion due to the narrower arc.



Maximum Cleaning

This can be achieved by placing the control to a position which will enable more time to be spent in the positive half cycle with respect to the negative half cycle. This will allow for very active cleaning current to be used. It should be noted that there is an optimum cleaning time after which more cleaning will not occur and the potential of damage to the electrode is greater. The effect on the arc is to provide a wider clean weld pool with shallow penetration.

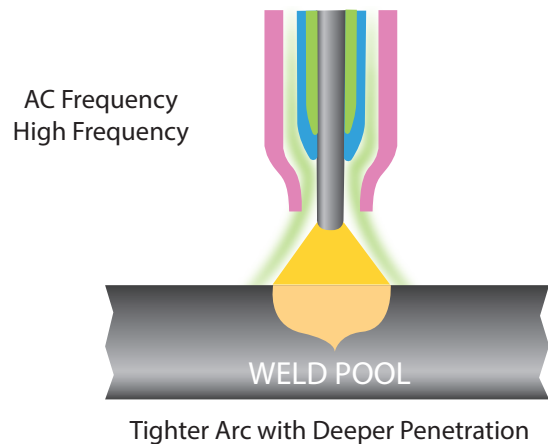
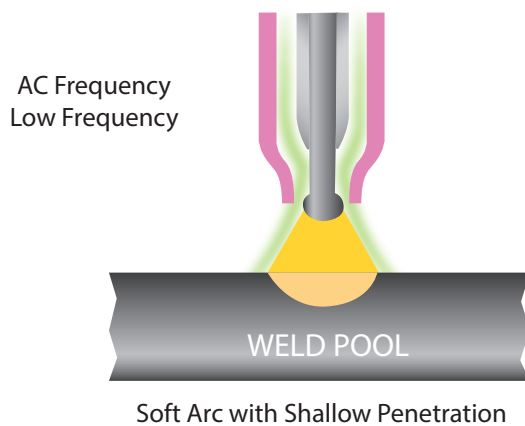


Frequency Control

The alternating current as earlier noted consists of current changing direction constantly. The completion of each complete change is called a cycle. The number of cycles per second is denoted as the frequency. In the UK the mains supply frequency is 50Hz so that would mean 100 current changes per second.

The modern machines can alter the frequency of their output from lower ranges around 20Hz up to higher frequencies of for example 500Hz. The lower frequency would provide a soft and less forceful arc, wider arc with shallow penetration.

Increasing the frequency has the effect of concentrating the arc making it easily directional with deeper penetration.

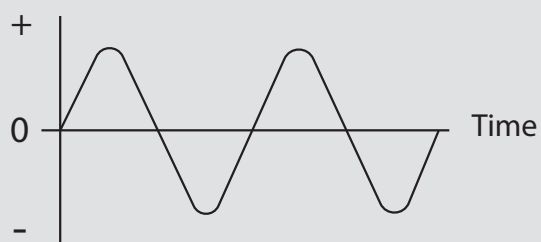


Advanced AC Waveforms

Modern inverter power sources represent in many cases sophisticated controls within the electronics to provide advanced waveforms.

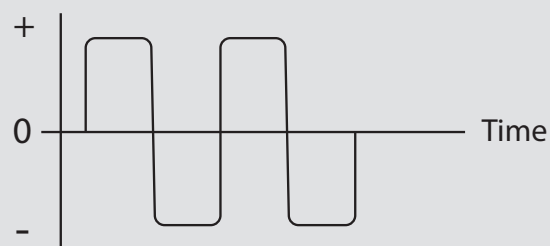
Many of the new design machines have the ability to use different waveform shaping and independent control of the current in positive and negative half cycles, balance and frequency. This level of control allows some extra advantages as cleaning and welding conditions can be optimised resulting in better results in weld integrity, finish and welding speeds. Synergic TIG is now also available where the machine will set parameters based on a few basic inputs from the operator.

Typical Waveforms Are:



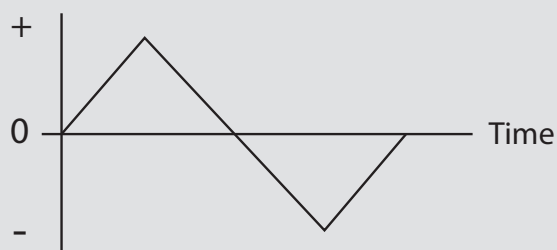
Sine Wave

The sine wave achieves a balance between the cleaning and the penetration values of the bead



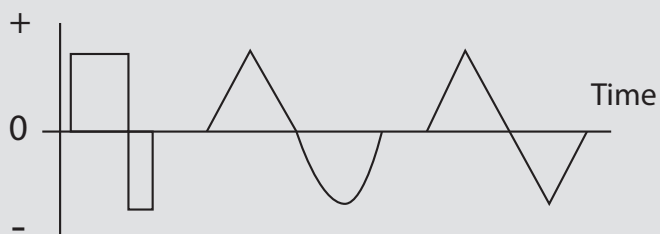
Square Wave

The square wave allows better cleaning of the weld bead

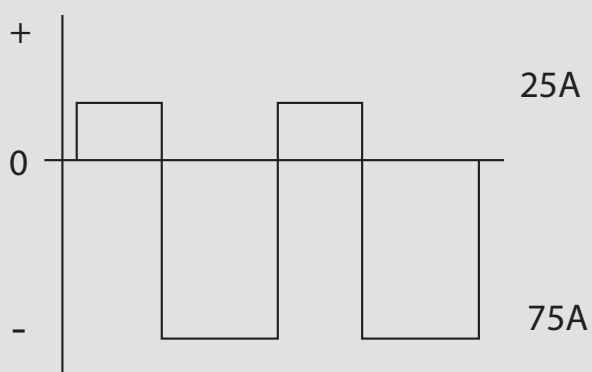


Delta Wave

The delta wave instead increases penetration of the welding bead, reducing the cleaning effect



Modified Waveforms



Process Features And Benefits

The TIG process has a number of features and benefits over other modes especially if the correct method is used:

- High quality and precision welds
- Excellent weld appearance
- No slag or flux required
- No sparks or spatter
- Reduced fumes (only from the materials)
- Capability to weld more metals than any other process

TIG however has some disadvantages in that it is:

- Generally a slow process compared with others
- Requires a high skill level
- Has relatively low deposition rates
- Has higher light emissions (UV) than other processes
- Original equipment costs are usually higher than other processes

TIG Welding Properties

Defect	Possible Cause	Action
Excessive tungsten use	Set up to DCEP	Connect to DCEN
	Insufficient shield gas flow	Check for blockages and correct flow rate. Also check for drafts
	Electrode size too small	Select correct size
	Electrode contamination during cooling time	Extend post flow gas period
	Electrode melting up into shield cup when welding in AC	Balance control may be set to high in cleaning. Electrode type incorrect Electrode size too small
Porosity / Weld Contamination	Loose torch or hose fittings	Check and tighten all fittings
	Inadequate shield gas flow	Adjust flow rate – normally 8-12L/m
	Incorrect shield gas	Use correct shield gas
	Gas hose damaged	Trace and replace damaged component
	Base material contaminated	Base material contaminated
	Incorrect filler material	Check correct filler material grade in use
No operation when the torch switch is operated	Torch switch faulty	Check the torch switch continuity and replace if faulty
	Mains fuse blown	Check fuses and replace if necessary
	Fault inside the equipment	Call a service engineer
Low output current	Loose or defective work clamp	Tighten / replace clamp
	Loose cable plug	Re-fix plug
	Power source faulty	Call a service engineer
High frequency but will not strike an arc	Weld circuit broken	Check all connections and cables continuity - especially torch cables
	No shield gas flowing	Check cylinder contents, regulators and valves. Also could be a power source fault
Unstable arc when welding in AC	Tungsten electrode contaminated	Break off the contaminated end and regrind the electrode
	Arc length incorrect	Arc length should be between 3-6mm
	Material contaminated	Clean all base and filler materials
	Electrode connected to the wrong polarity	Reconnect to correct polarity
Arc is difficult to start	Incorrect electrode type	Refit correct electrode
	Incorrect shield gas	Use Argon shield gas

Notes

[illegible]



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