Smootharc

MMA171 VRD
Operating manual

BOC
A Member of The Linde Group

Welcome to a better way of welding

Congratulations on purchasing a Smootharc MMA171 VRD welding machine. The products in BOC's manual metal arc range perform with reliability and have the backing of BOC's national service network.

This operating manual provides the basic knowledge required for MMA and DC TIG welding, as well as highlighting important areas of how to operate the Smootharc MMA171 VRD welding machine.

With normal use and by following these recommended steps, your Smootharc MMA171 VRD welding machine can provide you with years of trouble free service. BOC equipment and technical support is available through our national BOC Customer Engagement Centre or contact your local Gas & Gear outlet.

Please Note: This machine is to be used only by appropriately trained operators in industrial applications.

Contents

1.0 Recommended safety precautions

1.1 Health hazard information

The actual process of welding is one that can cause a variety of hazards. All appropriate safety equipment should be worn at all times, i.e. headwear, respiratory, hand and body protection. Electrical equipment should be used in accordance with the manufacturer's recommendations.

Eyes

The process produces ultra violet rays that can injure and cause permanent damage. Fumes can cause irritation.

Skin

Arc rays are dangerous to uncovered skin.

Inhalation

Welding fumes and gases are dangerous to the health of the operator and to those in close proximity. The aggravation of pre-existing respiratory or allergic conditions may occur in some workers. Excessive exposure may cause conditions such as nausea, dizziness, dryness and irritation of eyes, nose and throat.

1.2 Personal protection

Respiratory

Confined space welding should be carried out with the aid of a fume respirator or air supplied respirator as per AS/NZS 1715 and AS/NZS 1716 Standards.

- → You must always have enough ventilation in confined spaces. Be alert to this at all times
- → Keep your head out of the fumes rising from the arc
- → Fumes from the welding of some metals could have an adverse effect on your health. Don't breathe them in. If you are welding on material such as stainless steel, nickel, nickel alloys or galvanised steel, further precautions are necessary
- → Wear a respirator when natural or forced ventilation is not good enough

Eye protection

A welding helmet with the appropriate welding filter lens for the operation must be worn at all times in the work environment. The welding arc and the reflecting arc flash gives out ultraviolet and infrared rays. Protective welding screen and goggles should be provided for others working in the same area.

Clothing

Suitable clothing must be worn to prevent excessive exposure to UV radiation and sparks. An adjustable helmet, flameproof loose fitting cotton clothing buttoned to the neck, protective leather gloves, spats, apron and steel capped safety boots are highly recommended.

Recommended filter shades for arc welding

Less than 150 amps	Shade 10*
150 to 250 amps	Shade 11*
250 to 300 amps	Shade 12
300 to 350 amps	Shade 13
Over 350 amps	Shade 14

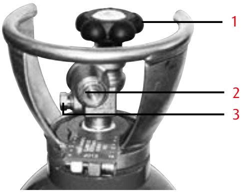
*Use one shade darker for aluminium.

Cylinder safety diagram

1 Cylinder valve hand-wheel

2 Back-plug

3 Bursting disc



Back view of typical cylinder valve.

Operator wearing personal protective equipment (PPE) in safe position.

Ten points about cylinder safety

1	Read labels and Material Safety Data Sheet (MSDS) before use
2	Store upright and use in well ventilated, secure areas away from pedestrian or vehicle thoroughfare
3	Guard cylinders against being knocked violently or being allowed to fall
4	Wear safety shoes, glasses and gloves when handling and connecting cylinders
5	Always move cylinders securely with an appropriate trolley. Take care not to turn the valve on when moving a cylinder
6	Keep in a cool, well ventilated area, away from heat sources, sources of ignition and combustible materials, especially flammable gases
7	Keep full and empty cylinders separate
8	Keep ammonia-based leak detection solutions, oil and grease away from cylinders and valves
9	Never use force when opening or closing valves
10	Don’t repaint or disguise markings and damage. If damaged, return cylinders to BOC immediately

Cylinder valve safety

When working with cylinders or operating cylinder valves, ensure that you wear appropriate protective clothing – gloves, boots and safety glasses.

When moving cylinders, ensure that the valve is not accidentally opened in transit.

Before operating a cylinder valve

Ensure that the system you are connecting the cylinder into is suitable for the gas and pressure involved.

Ensure that any accessories (such as hoses attached to the cylinder valve, or the system being connected to) are securely connected. A hose, for example, can potentially flail around dangerously if it is accidentally pressurised when not restrained at both ends.

Stand to the side of the cylinder so that neither you nor anyone else is in line with the back of the cylinder valve. This is in case a back-plug is loose or a bursting disc vents. The correct stance is shown in the diagram above.

When operating the cylinder valve

Open it by hand by turning the valve hand-wheel anti-clockwise. Use only reasonable force.

Ensure that no gas is leaking from the cylinder valve connection or the system to which the cylinder is connected. DO NOT use ammonia-based leak detection fluid as this can damage the valve. Approved leak detection fluid, can be obtained from a BOC Gas & Gear centre.

When finished with the cylinder, close the cylinder valve by hand by turning the valve hand-wheel in a clockwise direction. Use only reasonable force.

Remember NEVER tamper with the valve.

If you suspect the valve is damaged, DO NOT use it. Report the issue to BOC and arrange for the cylinder to be returned to BOC.

1.3 Electrical shock

- Never touch 'live' electrical parts
- Always repair or replace worn or damaged parts
- Disconnect power source before performing any maintenance or service
- Earth all work materials
- Never work in moist or damp areas

Avoid electric shock by:

- Wearing dry insulated boots
- Wearing dry leather gloves
- Never changing electrodes with bare hands or wet gloves
- Never cooling electrode holders in water
- Working on a dry insulated floor where possible
- Never hold the electrode and holder under your arm

1.4 User responsibility

- Read the Operating Manual prior to installation of this machine
- Unauthorised repairs to this equipment may endanger the technician and operator and will void your warranty. Only qualified personnel approved by BOC should perform repairs
- Always disconnect mains power before investigating equipment malfunctions
- Parts that are broken, damaged, missing or worn should be replaced immediately
- Equipment should be cleaned periodically

BOC stock a huge range of personal protective equipment. This combined with BOC's extensive Gas and Gear network ensures fast, reliable service throughout the South Pacific.

STOP

PLEASE NOTE that under no circumstances should any equipment or parts be altered or changed in any way from the standard specification without written permission given by BOC. To do so will void the Equipment Warranty.

Further information can be obtained from Welding Institute of Australia (WTIA) Technical Note No.7.

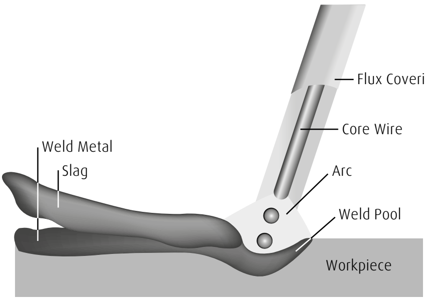
Health and Safety Welding
Published by WTIA,
PO Box 6165 Silverwater NSW 2128

Phone (02) 9748 4443

2.0 Manual metal arc welding process (MMAW)

2.1 Process

Manual Metal Arc welding is the process of joining metals where an electric arc is struck between the metal to be welded (parent metal) and a flux-coated filler wire (the electrode). The heat of the arc melts the parent metal and the electrode which mix together to form, on cooling, a continuous solid mass.



Before arc welding can be carried out, a suitable power source is required. Two types of power sources may be used for arc welding, direct current (DC) or alternating current (AC).

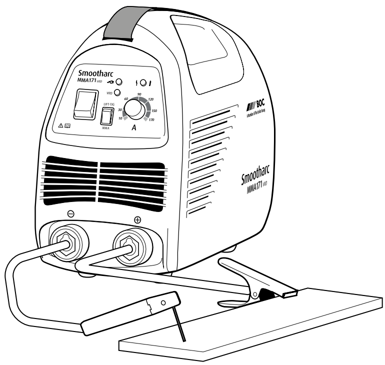
The essential difference between these two power sources is that, in the case of DC, the current remains constant in magnitude and flows in the same direction. Similarly, the voltage in the circuit remains constant in magnitude and polarity (i.e. positive or negative).

In the case of AC however, the current flows first in one direction and then the other. Similarly, the voltage in the circuit changes from positive to negative with changes in direction of current flow. This complete reversal is called a 'half cycle' and repeats as long as the current flows. The rate of change of direction of current flow is known as the 'frequency' of the supply and is measured by the number of cycles completed per second. The standard frequency of the AC supply in Australia is 50 Hz (Hertz).

2.2 Welding machine

The most important consideration when contemplating the use of arc welding for the first time is the purchase of a suitable welding machine.

BOC supplies a popular range of arc welding machines. Machines range from small portable welders that operate from standard 240 Volt powerpoint to heavy-duty welders used by the largest steel fabricators.



Basic welding machine and cables

The choice of welding machine is based mostly on the following factors:

- primary voltage, e.g. 240 Volt or 380 Volt
- output amperage required, e.g. 140 amps
- output required, e.g. AC or DC +/-
- duty cycle required, e.g. 35% @ 140 amps
- method of cooling, e.g. air-cooled or oil-cooled method of output amperage control, e.g. tapped secondary lugs
- or infinitely variable control.

For example, the Smootharc 171 connects to 240 Volt supply (15 amps Input), has an output of 170 amps DC @ 50% duty cycle.

Having decided on a welding machine, appropriate accessories are required. These are items such as welding cables, clamps, electrode holder, chipping hammer, helmet, shaded and clear lenses, scull cap, gloves and other personal protective equipment.

BOC stocks a huge range of personal protective equipment. This combined with BOC's extensive network ensures fast reliable service throughout the South Pacific.

2.3 Welding technique

Successful welding depends on the following factors:

- selection of the correct electrode
- selection of the correct size of the electrode for the job
- correct welding current
- correct arc length
- correct angle of electrode to work
- correct travel speed
- correct preparation of work to be welded.

2.4 Electrode selection

As a general rule the selection of an electrode is straight forward, in that it is only a matter of selecting an electrode of similar composition to the parent metal. It will be found, however, that for some metals there is a choice of several electrodes, each of which has particular properties to suit specific classes of work. Often, one electrode in the group will be more suitable for general applications due to its all round qualities.

The table below shows just a few of the wide range of electrodes available from BOC with their typical areas of application.

For example, the average welder will carry out most fabrication using mild steel and for this material has a choice of various standard BOC electrodes, each of which will have qualities suited to particular tasks. For general mild steel work, however, BOC Smootharc 13 electrodes will handle virtually all applications. BOC Smootharc 13 is suitable for welding mild steel in all positions using AC or DC power sources. Its easy-striking characteristics and the tolerance it has for work where fit-up and plate surfaces are not considered good, make it the most attractive electrode of its class. Continuous development and improvement of BOC Smootharc 13 has provided in-built operating qualities which appeals to the beginner and experienced operator alike. For further recommendations on the selection of electrodes for specific applications, see table page 9.

Electrodes and typical applications

Name	AWS class.	Application
BOC Smootharc 13	E6013	A premium quality electrode for general structural and sheet metal work in all positions including vertical down using low carbon steels
BOC Smootharc 24	E7024	An iron powder electrode for high speed welding for H-V fillets and flat butt joints. Medium to heavy structural applications in low carbon steels
BOC Smootharc 18	E7018-1	A premium quality all positional hydrogen controlled electrode for carbon steels in pressure vessel applications and where high integrity welding is required and for free-machining steels containing sulphur
BOC Smootharc S 308L	E308L	Rutile basic coated low carbon electrodes for welding austenitic stainless steel and difficult to weld material
BOC Smootharc S 316L	E316L	
BOC Smootharc S 309L	E309L	Rutile basic coated low carbon electrode for welding mild steel to stainless steel and difficult to weld material

Electrode size

The size of the electrode is generally dependent on the thickness of the section being welded, and the larger the section the larger the electrode required. In the case of light sheet the electrode size used is generally slightly larger than the work being welded. This means that if 1.5 mm sheet is being welded, 2.0 mm diameter electrode is the recommended size. The following table gives the recommended maximum size of electrodes that may be used for various thicknesses of section.

Recommended electrode sizes

Average thickness of plate or section	Maximum recommended electrode diameter
≤1.5 mm	2.0 mm
1.5–2.0 mm	2.5 mm
2.0–5.0 mm	3.15 mm
5.0–8.0 mm	4.0 mm

Welding current

Correct current selection for a particular job is an important factor in arc welding. With the current set too low, difficulty is experienced in striking and maintaining a stable arc. The electrode tends to stick to the work, penetration is poor and beads with a distinct rounded profile will be deposited.

Excessive current is accompanied by overheating of the electrode. It will cause undercut, burning through of the material, and give excessive spatter. Normal current for a particular job may be considered as the maximum which can be used without burning through the work, over-heating the electrode or producing a rough spattered surface, i.e. the current in the middle of the range specified on the electrode package is considered to be the optimum.

In the case of welding machines with separate terminals for different size electrodes, ensure that the welding lead is connected to the correct terminal for the size electrode being used. When using machines with adjustable current, set on the current range specified. The limits of this range should not normally be exceeded.

The following table shows the current ranges generally recommended for BOC Smootharc 13.

Generally recommended current range for BOC Smootharc 13

Electrode size	Current range (Amp)
2.5 mm	60–95
3.2 mm	110–130
4.0 mm	140–165
5.0 mm	170–260

Arc length

To start the arc, the electrode should be gently scraped on the work until the arc is established. There is a simple rule for the proper arc length; it should be the shortest arc that gives a good surface to the weld. An arc too long reduces penetration, produces spatter and gives a rough surface finish to the weld. An excessively short arc will cause sticking of the electrode and rough deposits that are associated with slag inclusions.

For downhand welding, it will be found that an arc length not greater than the diameter of the core wire will be most satisfactory. Overhead welding requires a very short arc, so that a minimum of metal will be lost. Certain BOC electrodes have been specially designed for ‘touch’ welding. These electrodes may be dragged along the work and a perfectly sound weld is produced.

Electrode angle

The angle which the electrode makes with the work is important to ensure a smooth, even transfer of metal. The recommended angles for use in the various welding positions are covered later.

Correct travel speed

The electrode should be moved along in the direction of the joint being welded at a speed that will give the size of run required. At the same time the electrode is fed downwards to keep the correct arc length at all times. As a guide for general applications the table below gives recommended run lengths for the downhand position.

Correct travel speed for normal welding applications varies between approximately 125–375 mm per minute, depending on electrode size, size of run required and the amperage used.

Excessive travel speeds lead to poor fusion, lack of penetration, etc. Whilst too slow a rate of travel will frequently lead to arc instability, slag inclusions and poor mechanical properties.

Run length per electrode – BOC Smootharc 13

Electrode size	Electrode length	Run length Minimum	Maximum
4.0 mm	350 mm	175 mm	300 mm
3.2 mm	350 mm	125 mm	225 mm
2.5 mm	350 mm	100 mm	225 mm

Correct work preparation

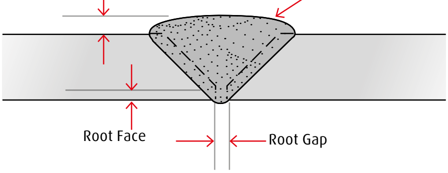
The method of preparation of components to be welded will depend on equipment available and relative costs. Methods may include sawing, punching, shearing, lathe cut-offs, flame cutting and others. In all cases edges should be prepared for the joints that suit the application. The following section describes the various joint types and areas of application.

2.5 Types of joints

Butt welds

A butt weld is a weld made between two plates so as to give continuity of section. Close attention must be paid to detail in a butt weld to ensure that the maximum strength of the weld is developed. Failure to properly prepare the edges may lead to the production of faulty welds, as correct manipulation of the electrode is impeded.

Butt welding



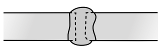
Two terms relating to the preparation of butt welds require explanation at this stage.

They are:

- Root Face: the proportion of the prepared edge that has not been bevelled.
- Root Gap: the separation between root faces of the parts to be joined.

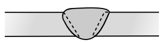
Various types of butt welds are in common use and their suitability for different thickness of steel are described as follows:

Square butt weld



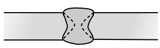
The edges are not prepared but are separated slightly to allow fusion through the full thickness of the steel. Suitable for plate up to 6 mm in thickness.

Single 'V' butt weld



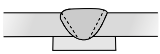
This is commonly used for plate up to 16 mm in thickness and on metal of greater thickness where access is available from only one side.

Double 'V' butt weld



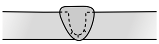
Used on plate of 12 mm and over in thickness when welding can be applied from both sides. It allows faster welding and greater economy of electrodes than a single 'V' preparation on the same thickness of steel and also has less of a tendency to distortion as weld contraction can be equalised.

Butt weld with backing material



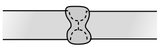
When square butt welds or single 'V' welds cannot be welded from both sides it is desirable to use a backing bar to ensure complete fusion.

Single 'U' butt weld



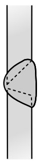
Used on thick plates an alternative to a single 'V' preparation. It has advantages as regards speed of welding. It takes less weld metal than a single 'V', there is less contraction and therefore a lessened tendency to distortion. Preparation is more expensive
than in the case of a 'V', as machining is required. The type of joint is most suitable for material over 40 mm in thickness.

Double 'U' butt weld



For use on thick plate that is accessible for welding from both sides. For a given thickness it is faster, needs less weld metal and causes less distortion than a single 'U' preparation.

Horizontal butt weld



The lower member in this case is bevelled to approximately 15° and the upper member 45°, making an included angle of 60°. This preparation provides a ledge on the lower member, which tends to retain the molten metal.

General notes on butt welds

The first run in a prepared butt weld should be deposited with an electrode not larger than 4.0 mm. The angle of the electrode for the various runs in a butt weld is shown.

It is necessary to maintain the root gap by tacking at intervals or by other means, as it will tend to close during welding.

All single 'V', single 'U' and square butt welds should have a backing run deposited on the underside of the joint; otherwise 50% may be deducted from the permissible working stress of the joint.

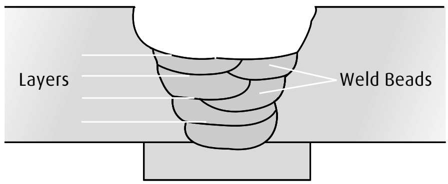
Before proceeding with a run on the underside of a weld it is necessary to remove any surplus metal or under penetration that is evident on that side of the joint.

Butt welds should be overfilled to a certain extent by building up the weld until it is above the surface of the plate. Excessive build-up, however, should be avoided.

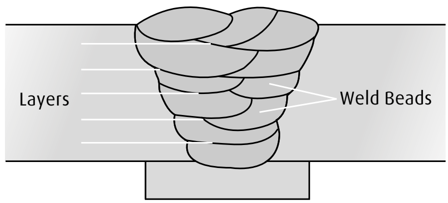
In multi-run butt welds it is necessary to remove all slag, and surplus weld metal before a start is made on additional runs; this is particularly important with the first run, which tends to form sharp corners that cannot be penetrated with subsequent runs. Electrodes larger than 4.0 mm are not generally used for vertical or overhead butt welds.

The diagrams following indicate the correct procedure for welding thick plate when using multiple runs.

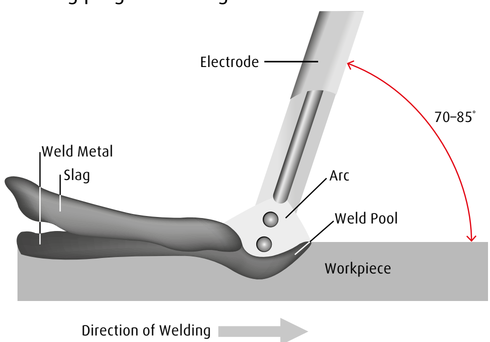
Electrode angle for 1st and 2nd layers



Electrode angle for subsequent layers



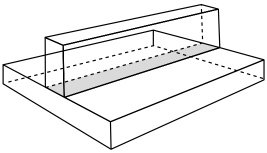
Welding progression angle



2.6 Fillet welds

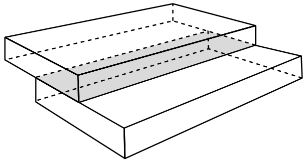
A fillet weld is approximately triangular in section, joining two surfaces not in the same plane and forming a lap joint, tee joint or corner joint. Joints made with fillet welds do not require extensive edge preparation, as is the case with butt welded joints, since the weld does not necessarily penetrate the full thickness of either member. It is important that the parts to be joined be clean, close fitting, and that all the edges on which welding is to be carried out are square. On sheared plate it is advisable to entirely remove any 'false cut' on the edges prior to welding. Fillet welds are used in the following types of joints:

'T' joints



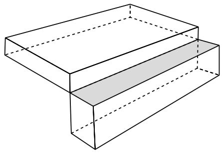
A fillet weld may be placed either on one or both sides, depending on the requirements of the work. The weld metal should fuse into or penetrate the corner formed between the two members. Where possible the joint should be placed in such a position as to form a "Natural 'V' fillet" since this is the easiest and fastest method of fillet welding.

Lap joints



In this case, a fillet weld may be placed either on one or both sides of the joint, depending on accessibility and the requirements of the joint. However, lap joints, where only one weld is accessible, should be avoided where possible and must never constitute the joints of tanks or other fabrications where corrosion is likely to occur behind the lapped plates. In applying fillet welds to lapped joints it is important that the amount of overlap of the plates be not less than five times the thickness of the thinner part. Where it is required to preserve the outside face or contour of a structure, one plate may be joggled.

Corner joints



The members are fitted as shown, leaving a 'V'-shaped groove in which a fillet weld is deposited. Fusion should be complete for the full thickness of the metal. In practice it is generally necessary to have a gap or a slight overlap on the corner. The use of a 1.0–2.5 mm gap has the advantage of assisting penetration at the root, although setting up is a problem. The provision of an overlap largely overcomes the problem of setting up, but prevents complete penetration at the root and should therefore be kept to a minimum, i.e. 1.0–2.5 mm.

The following terms and definitions are important in specifying and describing fillet welds.

Leg length

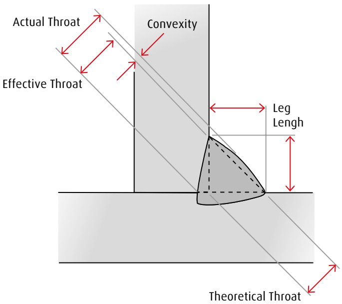
A fusion face of a fillet weld, as shown below. All specifications for fillet weld sizes are based on leg length.

Throat thickness

A measurement taken through the centre of a weld from the root to the face, along the line that bisects the angle formed by the members to be joined.

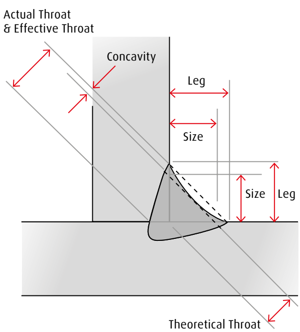
Effective throat thickness is a measurement on which the strength of a weld is calculated. The effective throat thickness is based on a mitre fillet (concave Fillet Weld), which has a throat thickness equal to 70% of the leg length. For example, in the case of a 20 mm fillet, the effective throat thickness will be 14 mm.

Convex fillet weld



A fillet weld in which the contour of the weld metal lies outside a straight line joining the toes of the weld. A convex fillet weld of specified leg length has a throat thickness in excess of the effective measurement.

Concave fillet weld



A fillet in which the contour of the weld is below a straight line joining the toes of the weld. It should be noted that a concave fillet weld of a specified leg length has a throat thickness less than the effective throat thickness for that size fillet. This means that when a concave fillet weld is used, the throat thickness must not be less than the effective measurement. This entails an increase in leg length beyond the specified measurement.

The size of a fillet weld is affected by the electrode size, welding speed or run length, welding current and electrode angle. Welding speed and run length have an important effect on the size and shape of the fillet, and on the tendency to undercut.

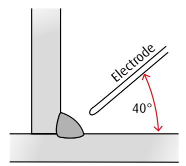
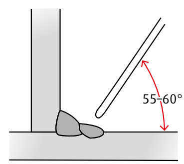
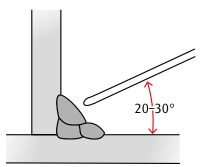
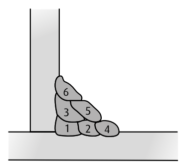
Insufficient speed causes the molten metal to pile up behind the arc and eventually to collapse. Conversely, excessive speed will produce a narrow irregular run having poor penetration, and where larger electrodes and high currents are used, undercut is likely to occur.

Fillet weld data

Nominal fillet size	Minimum throat thickness	Plate thickness	Electrode size
5.0 mm	3.5 mm	5.0–6.3 mm	3.2 mm
6.3 mm	4.5 mm	6.3–12 mm	4.0 mm
8.0 mm	5.5 mm	8.0–12 mm & over	4.0 mm
10.0 mm	7.0 mm	10 mm & over	4.0 mm

Selection of welding current is important. If it is too high the weld surface will be flattened, and undercut accompanied by excessive spatter is likely to occur. Alternatively, a current which is too low will produce a rounded narrow bead with poor penetration at the root. The first run in the corner of a joint requires a suitably high current to achieve maximum penetration at the root. A short arc length is recommended for fillet welding. The maximum size fillet which should be attempted with one pass of a large electrode is 8.0 mm. Efforts to obtain larger leg lengths usually result in collapse of the metal at the vertical plate and serious undercutting. For large leg lengths multiple run fillets are necessary. These are built up as shown below. The angle of the electrode for various runs in a downhand fillet weld is shown on next page.

Recommended electrode angles for fillet welds

1st run	2nd run
	
3rd run	Multi-run fillet
	

Multi-run horizontal fillets have each run made using the same run lengths (run length per electrode table). Each run is made in the same direction, and care should be taken with the shape of each, so that it has equal leg lengths and the contour of the completed fillet weld is slightly convex with no hollows in the face.

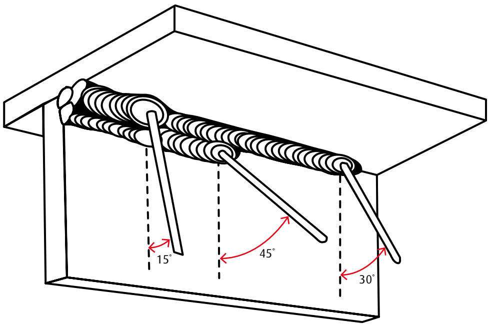
Vertical fillet welds can be carried out using the upwards or downwards technique. The characteristics of each are: upwards – current used is low, penetration is good, surface is slightly convex and irregular. For multiple run fillets large single pass weaving runs can be used. Downwards – current used is medium, penetration is poor, each run is small, concave and smooth (only BOC Smootharc 13 is suitable for this position).

The downwards method should be used for making welds on thin material only. Electrodes larger than 4.0 mm are not recommended for vertical down welding. All strength joints in vertical plates 10.0 mm thick or more should be welded using the upward technique. This method is used because of its good penetration and weld metal quality. The first run of a vertical up fillet weld should be a straight sealing run made with 3.15 mm or 4.0 mm diameter electrode. Subsequent runs for large fillets may be either numerous straight runs or several wide weaving runs.

Correct selection of electrodes is important for vertical welding.

In overhead fillet welds, careful attention to technique is necessary to obtain a sound weld of good profile. Medium current is required for best results. High current will cause undercutting and bad shape of the weld, while low current will cause slag inclusions. To produce a weld having good penetration and of good profile, a short arc length is necessary. Angle of electrode for overhead fillets is illustrated above.

Recommended angles for overhead fillet welds

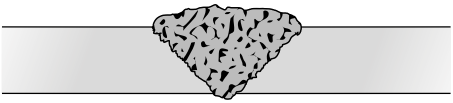


2.7 Typical defects due to faulty technique

Shielded metal arc welding, like other welding processes, has welding procedure problems that may develop which can cause defects in the weld. Some defects are caused by problems with the materials. Other welding problems may not be foreseeable and may require immediate corrective action. A poor welding technique and improper choice of welding parameters can cause weld defects. Defects that can occur when using the shielded metal arc welding process are slag inclusions, wagon tracks, porosity, wormhole porosity, undercutting, lack of fusion, overlapping, burn through, arc strikes, craters, and excessive weld spatter. Many of these welding technique problems weaken the weld and can cause cracking. Other problems that can occur which can reduce the quality of the weld are arc blow, finger nailing, and improper electrode coating moisture contents.

Defects caused by welding technique

Slag inclusions



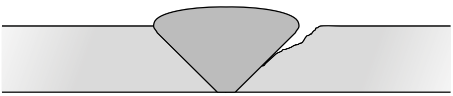
Slag inclusions occur when slag particles are trapped inside the weld metal which produces a weaker weld. These can be caused by:

- erratic travel speed
- too wide a weaving motion
- slag left on the previous weld pass
- too large an electrode being used
- letting slag run ahead of the arc.

This defect can be prevented by:

- a uniform travel speed
- a tighter weaving motion
- complete slag removal before welding
- using a smaller electrode
- keeping the slag behind the arc which is done by shortening the arc, increasing the travel speed, or changing the electrode angle.

Undercutting



Undercutting is a groove melted in the base metal next to the toe or root of a weld that is not filled by the weld metal. Undercutting causes a weaker joint and it can cause cracking.

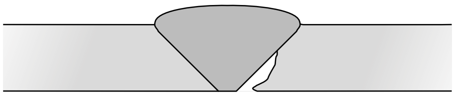
This defect is caused by:

- excessive welding current
- too long an arc length
- excessive weaving speed
- excessive travel speed.

On vertical and horizontal welds, it can also be caused by too large an electrode size and incorrect electrode angles. This defect can be prevented by:

- choosing the proper welding current for the type and size of electrode and the welding position
- holding the arc as short as possible
- pausing at each side of the weld bead when a weaving technique is used
- using a travel speed slow enough so that the weld metal can completely fill all of the melted out areas of the base metal.

Lack of fusion



Lack of fusion is when the weld metal is not fused to the base metal. This can occur between the weld metal and the base metal or between passes in a multiple pass weld. Causes of this defect can be:

- excessive travel speed
- electrode size too large
- welding current too low
- poor joint preparation
- letting the weld metal get ahead of the arc.

Lack of fusion can usually be prevented by:

- reducing the travel speed
- using a smaller diameter electrode
- increasing the welding current
- better joint preparation
- using a proper electrode angle.

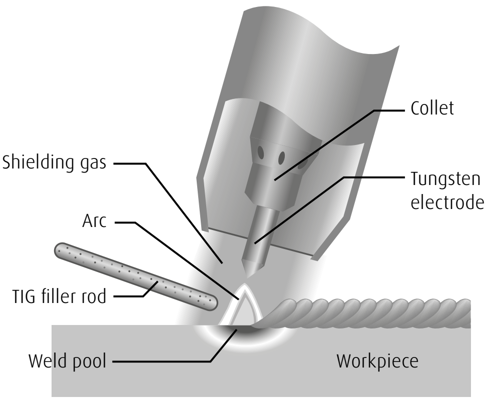
3.0 Gas tungsten arc welding (GTAW/TIG)

3.1 Introduction

The Tungsten Inert Gas, or TIG process, uses the heat generated by an electric arc struck between a non-consumable tungsten electrode and the workpiece to fuse metal in the joint area and produce a molten weld pool. The arc area is shrouded in an inert or reducing gas shield to protect the weld pool and the non-consumable electrode. The process may be operated autogenously, that is, without filler, or filler may be added by feeding a consumable wire or rod into the established weld pool.

3.2 Process

Schematic of the TIG welding process



Direct or alternating current power sources with constant current output characteristics are normally employed to supply the welding current. For DC operation the tungsten may be connected to either output terminal, but is most often connected to the negative pole. The output characteristics of the power source can have an effect on the quality of the welds produced.

Shielding gas is directed into the arc area by the welding torch and a gas lens within the torch distributes the shielding gas evenly over the weld area. In the torch the welding current is transferred to the tungsten electrode from the copper conductor. The arc is then initiated by one of several methods between the tungsten and the workpiece.

During TIG welding, the arc can be initiate by several means:

Scratch start

With this method, the tungsten electrode is physically scratched on the surface of the workpiece and the arc is initiated at the full amperage set by the operator. The incidence of the tungsten melting at the high initiation amperage is high and tungsten inclusions in the weld metal are quite common.

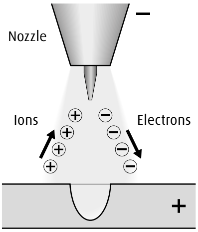
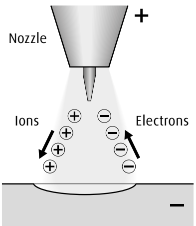
High frequency start

During High Frequency start, the arc will 'jump' towards the workpiece if a critical distance is reached. With this method, there is no incidence of tungsten inclusions happening. High Frequency is only available on certain types of machines and it can affect nearby electronic equipment.

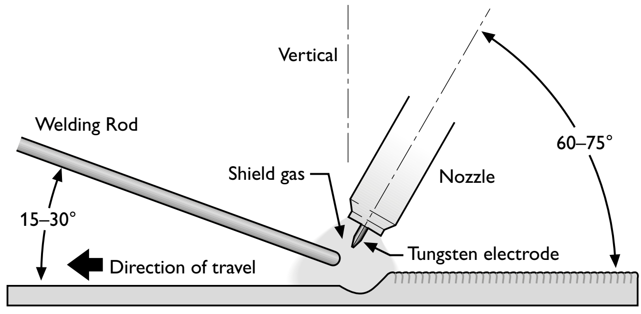
Lift Arc™

During this method of arc initiation, the tungsten is actually touching the workpiece. This occurs at very low amperage that is only sufficient to pre-heat, not melt the tungsten. As the tungsten is moved off the plate, the arc is established. With this method, there is little chance of tungsten inclusion occurring.

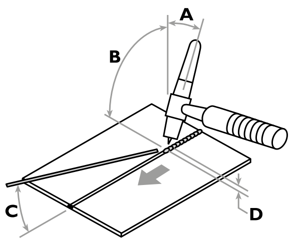
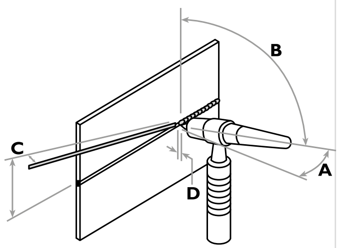
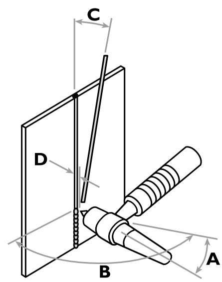
3.3 Process variables

Process variable	Explanation	Usage
DCEN Narrow bead, deep penetration 	When direct-current electrode-negative (straight polarity) is used: → Electrons strike the part being welded at a high speed → Intense heat on the base metal is produced → The base metal melts very quickly → Ions from the inert gas are directed towards the negative electrode at a relatively slow rate → Direct current with straight polarity does not require post-weld cleaning to remove metal oxides	For a given diameter of tungsten electrode, higher amperage can be used with straight polarity. Straight polarity is used mainly for welding: → Carbon steels → Stainless steels → Copper alloys The increased amperage provides: → Deeper penetration → Increased welding speed → A narrower, deeper, weld bead
DCEP Wide bead, shallow penetration 	The DCEP (reverse polarity) are different from the DCEN in following ways: → High heat is produced on the electrode rather on the base metal → The heat melts the tungsten electrode tip → The base metal remains relatively cool compared to sing straight polarity → Relatively shallow penetration is obtained → An electrode whose diameter is too large will reduce visibility and increase arc instability	→ Intense heat means a larger diameter of electrode must be used with DCEP → Maximum welding amperage should be relatively low (approximately six times lower than with DCEN)

3.4 Welding techniques

Welding techniques	
	The suggested electrode and welding rod angles for welding a bead on plate. The same angles are used when making a butt weld. The torch is held 60–75° from the metal surface. This is the same as holding the torch 15–30° from the vertical. Take special note that the rod is in the shielding gas during the welding process.

Torch and filler metal manual control guidelines

Flat position (1G)	Horizontal position (2G)	Vertical position (3G) Upwards progression
		

A = Torch travel angle – forehand technique
– push angle 10–20° (to the vertical)

B = Work angle: 90°

C = Filler metal feed angle: 10–20°

D = Arc length: 1–1.5 x electrode diameter

3.5 Shielding gas selection

Material	Shielding gas	Benefits
Brass	Argon	Stable arc Low fume
Cobalt-based alloys	Argon	Stable and easy to control arc
Copper-nickel (Monel)	Argon	Stable and easy to control arc Can be used for copper-nickel to steel
Deoxised copper	Helium	Increased heat input Stable arc Good penetration
	Helium(75%)/ Argon(25%)	Stable arc Lower penetration
Nickel alloys (Inconel)	Argon	Stable arc Manual operation
	Helium	High speed automated welding
Steel	Argon	Stable arc Good penetration
	Helium	High speed automatic welding Deeper penetration Small concentrated HAZ
Magnesium alloys	Argon	Used with continuous high frequency AC Good arc stability Good cleaning action
Stainless steel	Argon	Good penetration Good arc stability
	Helium	Deeper penetration
Titanium	Argon	Stable arc
	Helium	High speed welding

3.6 Welding wire selection

The following table includes the recommended welding consumable for the most commonly welded materials.

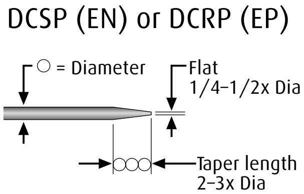
Base material	BOC consumable
C-Mn and low carbon steels	BOC Mild steel TIG wire
Low Alloy steels	
1.25Cr/0.5Mo	Comweld CrMo1
2.5Cr/1Mo	Comweld CrMo2
Stainless Steel	
304/304L	Profill 308
316/316L	Profill 316
309/309-C-Mn	Profill 309
321/Stabilised grades	Profill 347

Filler rod diameter	Thickness of metal
2 mm	0.5 – 2 mm
3 mm	2 – 5 mm
4 mm	5 – 8 mm
4 or 5 mm	8 – 12 mm
5 or 6 mm	12 mm or more

3.7 Tungsten electrode selection

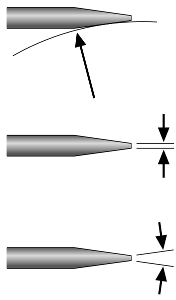
Base metal type	Thickness range	Desired results	Welding current	Electrode type	Shielding gas	Tungsten performance characteristics
Copper alloys, Cu-Ni alloys and Nickel alloys	All	General purpose	DCSP	2% Thoriated (EW-Th2)	75% Argon/ 25% Helium	Best stability at medium currents. Good arc starts Medium tendency to spit Medium erosion rate
				2% Ceriated (EW-Ce2)	75% Argon/ 25% Helium	Low erosion rate. Wide current range. AC or DC. No spitting. Consistent arc starts Good stability
	Only thick sections	Increase penetration or travel speed	DCSP	2% Ceriated (EW-Ce2)	75% Argon/ 25% Helium	Low erosion rate. Wide current range. AC or DC. No spitting. Consistent arc starts Good stability
Mild Steels, Carbon Steels, Alloy Steels, Stainless Steels and Titanium alloys	All	General purpose	DCSP	2% Thoriated (EW-Th2)	75% Argon/ 25% Helium	Best stability at medium currents. Good arc starts Medium tendency to spit Medium erosion rate
				2% Ceriated (EW-Ce2)	75% Argon/ 25% Helium	Low erosion rate. Wide current range. AC or DC. No spitting Consistent arc starts Good stability
				2% Lanthanated (EWG-La2)	75% Argon/ 25% Helium	Lowest erosion rate. Widest current range on DC. No spitting. Best DC arc starts and stability
	Only thick sections	Increase penetration or travel speed	DCSP	2% Ceriated (EW-Ce2)	75% Argon/ 25% Helium	Low erosion rate. Wide current range. No spitting. Consistent arc starts. Good stability
				2% Lanthanated (EWG-La2)	Helium	Lowest erosion rate. Highest current range. No spitting. Best DC arc starts and stability

Tungsten tip preparation

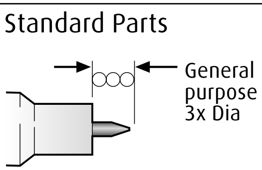


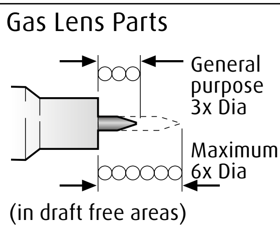
Tungsten grinding

Shape by grinding longitudinally (never radially). Remove the sharp point to leave a truncated point with a flat spot. Diameter of flat spot determines amperage capacity (See below). The included angle determines weld bead shape and size. Generally, as the included angle increases, penetration increases and bead width decreases. Use a medium (60 grit or finer) aluminium oxide wheel.



Tungsten extension





Tungsten electrode tip shapes and current ranges

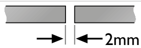
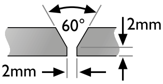
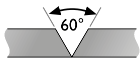
Thoriated, ceriated, and lanthanated tungsten electrodes do not ball as readily as pure or zirconiated tungsten electrodes, and as such are typically used for DCSP welding. These electrodes maintain a ground tip shape much better than the pure tungsten electrodes. If used on AC, thoriated and lanthanated electrodes often spit. Regardless of the electrode tip geometry selected, it is important that a consistent tip configuration be used once a welding procedure is established. Changes in electrode geometry can have a significant influence not only on the weld bead width, depth of penetration, and resultant quality, but also on the electrical characteristics of the arc. Below is a guide for electrode tip preparation for a range of sizes with recommended current ranges.

Electrode diameter (mm)	Diameter arc tip (mm)	Constant included angle, (degrees)	Current range (A)
1.0	0.125	12	2–15
1.0	0.250	20	5–30
1.6	0.500	25	8–50
1.6	0.800	30	10–70
2.3	0.800	35	12–90
2.3	1.100	45	15–150
3.2	1.100	60	20–200
3.2	1.500	90	25–250

3.8 Typical welding joints for gas tungsten arc welding

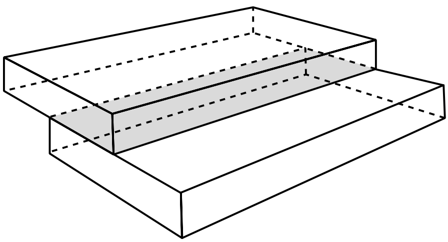
Butt welds

TIG welding is commonly combined with other faster filling processes such as MMA or MIG welding. It is therefore not uncommon to use the same weld preparations as would have been used for the filling process. When welding a butt joint, centre the weld pool on the adjoining edges. When finishing, decrease the heat (amperage) to aid in filling the crater.

3 mm		
6 mm		

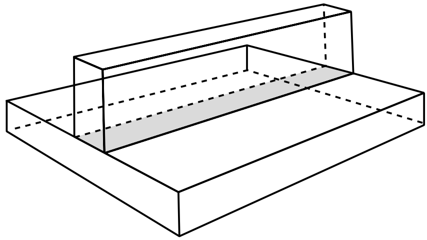
Lap joint

For a lap weld, form the weld pool so that the edge of the overlapping piece and the flat surface of the second piece flow together. Since the edge will melt faster, dip the filler rod next to the edge and make sure you are using enough filler metal to complete the joint.



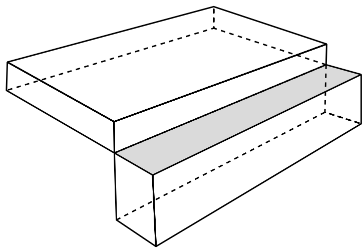
T-joint

When welding a T-joint, the edge and the flat surface are to be joined together, and the edge will melt faster. Angle the torch to direct more heat to the flat surface and extend the electrode beyond the cup to hold a shorter arc. Deposit the filler rod where the edge is melting.



Corner joint

For a corner joint, both edges of the adjoining pieces should be melted and the weld pool should be kept on the joint centre line.
A convex bead is necessary for this joint, so a sufficient amount of filler metal is needed.



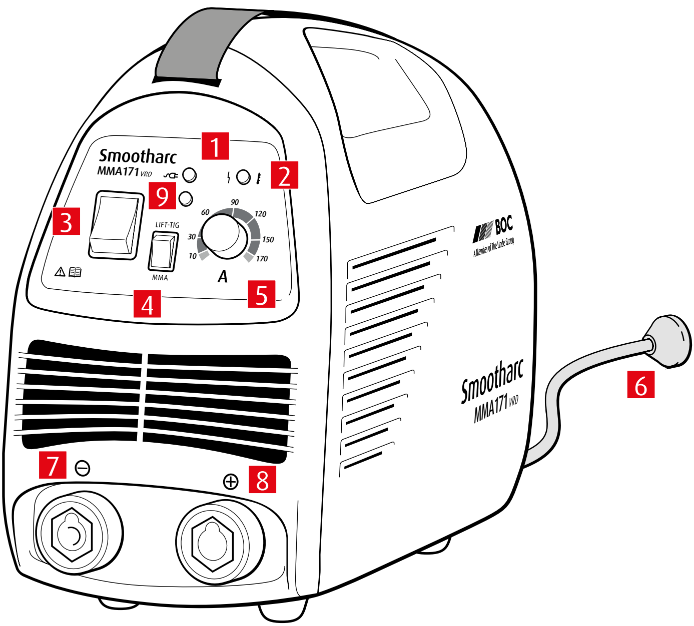
4.0 Troubleshooting guide

Problem	Cause	Solution
Excessive electrode consumption	Inadequate gas flow	Increase gas flow
	Improper size electrode for current required	Use larger electrode
	Operating of reverse polarity	User larger electrode or change polarity
	Electrode contamination	Remove contaminated portion, then prepare again
	Excessive heating inside torch	Replace collet. Try wedge collet or reverse collet
	Electrode oxidising during cooling	Increase downslope
	Shield gas incorrect	Change to Argon (no oxygen or CO_2)
Erratic arc	Incorrect voltage (arc too long)	Maintain short arc length
	Current too low for electrode size	Use smaller electrode or increase current
	Electrode contaminated	Remove contaminated portion, then prepare again
	Joint too narrow	Open joint groove
	Contaminated shield gas. Dark stains on the electrode or weld bead indicate contamination	The most common cause is moisture or aspirated air in gas stream. Use welding grade gas only. Find the source of the contamination and eliminate it promptly
	Base metal is oxidised, dirty or oily	Use appropriate chemical cleaners, wire brush, or abrasives prior to welding
Inclusion of tungsten or oxides in weld	Poor scratch starting technique	Many codes do not allow scratch starts. Use copper strike plate. Use high frequency arc starter
	Excessive current for tungsten size used	Reduce the current or use larger electrode
	Accidental contact of electrode with puddle	Maintain proper arc length
	Accidental contact of electrode to filler rod	Maintain a distance between electrode and filler metal
	Using excessive electrode extension	Reduce the electrode extension to recommended limits
	Inadequate shielding or excessive drafts	Increase gas flow, shield arc from wind, or use gas lens
	Wrong gas	Do not use ArO_2 or $ArCO_2$ GMAW (MIG) gases for TIG welding
	Heavy surface oxides not being removed	Use wire brush and clean the weld joint prior to welding

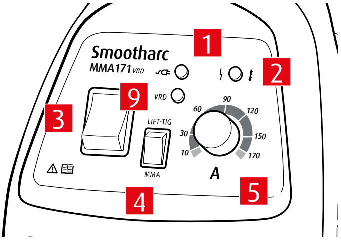
Problem	Cause	Solution
Porosity in weld deposit	Entrapped impurities, hydrogen, air, nitrogen, water vapour	Do not weld on wet material. Remove condensation from line with adequate gas pre-flow time
	Defective gas hose or loose connection	Check hoses and connections for leaks
	Filler material is damp (particularly aluminium)	Dry filler metal in oven prior to welding
	Filler material is oily or dusty	Replace filler metal
	Alloy impurities in the base metal such as sulphur, phosphorous, lead and zinc	Change to a different alloy composition which is weldable. These impurities can cause a tendency to crack when hot
	Excessive travel speed with rapid freezing of weld trapping gases before they escape	Lower the travel speed
	Contaminated shield gas	Replace the shielding gas
Cracking in welds	Hot cracking in heavy section or with metals which are hot shorts	Preheat. Increase weld bead cross-section size. Change weld bead contour. Use metal with fewer alloy impurities
	Crater cracks due to improperly breaking the arc or terminating the weld at the joint edge	Reverse direction and weld back into previous weld at edge. Use Amprak or foot control to manually down slope current
	Post weld cold cracking due to excessive joint restraint, rapid cooling or hydrogen embrittlement	Preheat prior to welding. Use pure or non-contaminated gas. Increase the bead size. Prevent craters or notches. Change the weld joint design
	Centreline cracks in single pass weld	Increase bead size. Decrease root opening. Use preheat. Prevent craters
	Underbead cracking from brittle microstructure	Eliminate sources of hydrogen, joint restraint and use preheat
Inadequate shielding	Gas flow blockage or leak in hoses or torch	Locate and eliminate the blockage or leak
	Excessive travel speed exposes molten weld to atmospheric contamination	Use slower travel speed or carefully increase the flow rate to a safe level below creating excessive turbulence. Use a trailing shield cup
	Wind or drafts	Set up screens around the weld area
	Excessive electrode stickout	Reduce electrode stickout. Use a larger size cup
	Excessive turbulence in gas stream	Change to gas safer parts or gas lens parts
Arc blow	Induced magnetic field from DC weld current	Rearrange the split ground connection
	Arc is unstable due to magnetic influence	Reduce weld current and use arc length as short as possible
Short parts life	Cup shattering or cracking in use	Change cup size or type. Change tungsten position
	Short collet life	Ordinary style is split and twists or jams Change to wedge style
	Short torch head life	Do not operate beyond rated capacity. Use water cooled model. Do not bend rigid torches

5.0 Operating controls

1	Power indicator light
2	Overtemperature control indicator
3	On/Off switch
4	Process selector switch MMA/Lift TIG
5	Welding current regulator
6	15A input plug
7	Negative '35' dinse connector
8	Positive '35' dinse connector
9	VRD indicator



6.0 Operating functions



1	Power indicator light
2	Overtemperature control indicator
3	On/Off switch
4	Process selector switch MMA/Lift TIG
5	Welding current regulator
9	VRD indicator

Always switch the machine off at the supply switch. When changing electrode or return leads the machine's on/off switch 3 should be in the off postion. The machine should then also be switched off at the mains supply plug and the plug removed from the supply socket.
The green power light 1 will illuminate when the machine is switched on using the on/off switch 3.

The machine is fitted with a process selector switch 4 that will change the function of the machine from MMA to Lift TIG.

The machine will stop working if the temperature reaches a certain level. (Exceeds the units duty cycle). The overtemperature control indicator light 2 will illuminate.

6.1 Welding selections

Manual metal arc welding (MMA)

→ Select the current as per the recommendations of the consumable manufacturer.

→ Select the polarity of the electrode cable as per the recommendations (+/-)

→ Select the process selector switch to MMA

DC TIG welding (Lift TIG)

→ Select the current as per the recommendations of the consumable manufacturer.

→ Connect the TIG torch to the negative (-) pole of the welding machine.

→ Select the process selector switch to 'Lift TIG'

→ When Lift TIG is selected the tungsten electrode can be touched onto the workpiece. The arc will be initiated as the electrode is moved upwards and the current will revert to the adjusted current.

6.2 Earthing

For the welding process to be most effective it is important to ensure that there is a solid connection between the work return clamp and the workpiece.

Always ensure that the return clamp is as close as practically possible to the area to be welded.

Ensure that the workpiece is clean and free from rust, scale paint or oil and grease before affixing the work return clamp.

7.0 Technical specifications

Specifications		Smootharc MMA171 VRD	
Part No.		MMA171VRD	
Input voltage		Single phase AC240 V ±15%	
Frequency		50/60 Hz	
		MMA	TIG
Maximum rated input current (I_{1max})		32 A	26 A
Maximum effective supply current (I_{1eff})		14.3 A	11.6 A
Output current range		10-170 A	10-200 A
Rated output voltage		26.8 V	18 V
Duty cycle @	20%	170A	200A
	100%	76A	89A
No-load voltage		79 V	
No-load loss		40 W	
Efficiency		80 %	
Power factor		0.73	
Insulation grade		F	
Housing protection grade		IP21	
Weight		5.1 kg	
Dimension (L × W × H)		367 × 169 × 289 mm	
Standards		AS/NZS 60974-1, IEC/EN 60974-10	

8.0 Periodic maintenance

In maintenance of the unit, take into consideration the rate of use and the environment it is used in. When the unit is used properly and serviced regularly, you will avoid unnecessary disturbances in use and production.

8.1 Daily maintenance

Perform the following maintenance daily:

→ Clean electrode holder and TIG torch's gas nozzle. Replace damaged or worn parts.

→ Check TIG torch's electrode. Replace or sharpen, if necessary.

→ Check tightness of welding and earth cable connections.

→ Check condition of mains and welding cables and replace damaged cables.

→ See that there is enough space in front of and back of the unit for ventilation

8.2 Troubleshooting

Main switch signal light is not lit.

Unit does not get electricity.

→ Check mains fuses and replace if necessary.

→ Check mains cable and plug, replace damaged parts.

Unit does not weld well.

Arc is uneven and goes off. Electrode gets stuck in weld pool.

→ Check welding settings and adjust when necessary.

→ Check that earth clamp is properly fixed and that contact surface is clean and the cable is undamaged.

Signal light for overheating is lit.

The unit has overheated. See 5.0 Operating Functions

→ Check that there is ample space in front of and back of the unit for ventilation.

→ Check welding settings. See 5.1 Welding Selections

If problems in use are not solved with above mentioned measures, please contact your local BOC representative.

9.0 Warranty information

9.1 Terms of warranty

BOC provides a warranty for the Smoothharc MMA171 VRD sold by it against defects in manufacture and materials.

- Valid for 18 months from date of purchase.
- An authorised BOC Service Agent must carry out warranty repairs.
- Freight, packaging and insurance costs are to be paid for by the claimant.
- No additional express warranty is given unless in writing signed by an authorised manager of BOC.
- This warranty is in addition to any other legal rights you may have.
- Electrode holders are not covered.

9.2 Limitations on warranty

The following conditions are not covered:

- Non compliance with operating and maintenance instructions such as connection to incorrect faulty voltage supply including voltage surges outside equipment specs, and incorrect overloading.
- Natural wear and tear, and accidental damage.
- Transport or storage damage.

The Warranty is void if:

- Changes are made to the product without the approval of the manufacturer.
- Repairs are carried out using non-approved spare parts.
- A non-authorised agent carries out repairs.

9.3 Warranty repairs

BOC or their Authorised Service Agent must be informed of the warranty defects, and the product returned within the warranty period.

- Before any warranty work is undertaken, the customer must provide proof of purchase and serial number of the equipment in order to validate the warranty.
- The parts replaced under the terms of the warranty remain the property of BOC.

10.0 Recommended safety guidelines

- Repair or replace defective cables immediately.
- Never watch the arc except through lenses of the correct shade.
- In confined spaces, adequate ventilation and constant observation are essential.
- Leads and cables should be kept clear of passageways.
- Keep fire extinguishing equipment at a handy location in the shop.
- Keep primary terminals and live parts effectively covered.
- Never strike an electrode on any gas cylinder.
- Never use oxygen for venting containers.

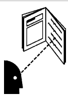
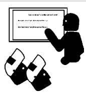
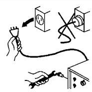
Diagram and safety explanation	
Electrical safety alert	
Welding electrode causing electric shock	
Fumes and gases coming from welding process	
Welding arc rays	
Read instruction manual	
Become trained	

Diagram and safety explanation	
Wear dry, insulated gloves	
Insulate yourself from work and ground	
Disconnect input power before working on equipment	
Keep head out of fumes	
Use forced ventilation or local exhaust to remove fumes	
Use welding helmet with correct shade of filter	

For more information contact the
BOC Customer Engagement Centre
on 171 262 (AU) or 0800 111 333 (NZ)

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