BOC Guidelines for Welding and Cutting

BOC
A Member of The Linde Group

Welcome to a better way of cutting, welding, brazing and heating with BOC Gas Equipment.

Contents

1.0 Recommended Safety Precautions

1.1 Health Hazard Information

The oxy-fuel process utilizes a flame to generate heat for cutting, welding and brazing. Care must be taken to avoid the contact of the flame with any combustible substances. A firebrick top workbench is recommended for cutting on.

Ensure that you have adequate ventilation to dissipate fumes in work locations.

Refer to the Australian standards AS 4839 "Recommended practice for the use of portable oxy-fuel cutting and welding equipment" for a comprehensive list of safety requirements.

Further information can be obtained in the Welding Institute Technical note 7 "Safety in welding and cutting".

1.2 Clothing

Clothing with long sleeves and a snug fit at wrists, long pants and leather boots should be worn. Woollen clothing is preferred to cotton because it does not readily ignite. Nylon and synthetic clothing and open shoes should not be worn. Leather gloves, an apron, spats and a welder's cap will help protect from sparks and spatter.

Eye Protection

The oxy-acetylene flame produces an intense bright light that causes discomfort and possible injury to the eyes.

In order to comfortably and safely see the flame when welding or cutting, welding goggles must be worn.

Different lenses are recommended for the various processes:

Shade 4

- Oxy-cutting and gouging.
- Flame cleaning.
- Braze welding of light copper and steel.
- Silver brazing.

Shade 5

- Fusion welding of steel, cast iron, nickel and copper.
- Braze welding of heavy steel and cast iron.
- Hard facing.

Shade 6

- Fusion and braze welding of cast iron and steel castings.

1.3 Fire Protection and Cylinder Safety

- Do not work near oil and grease containers, flammable vapours or combustible dust.
- Move all combustibles at least 10 metres away from the work site. Otherwise, protect with flame-proofed covers.
- Have a fire extinguisher or water and sand available.
- After welding/cutting is completed, carefully inspect for sparks and smouldering material before leaving the area.

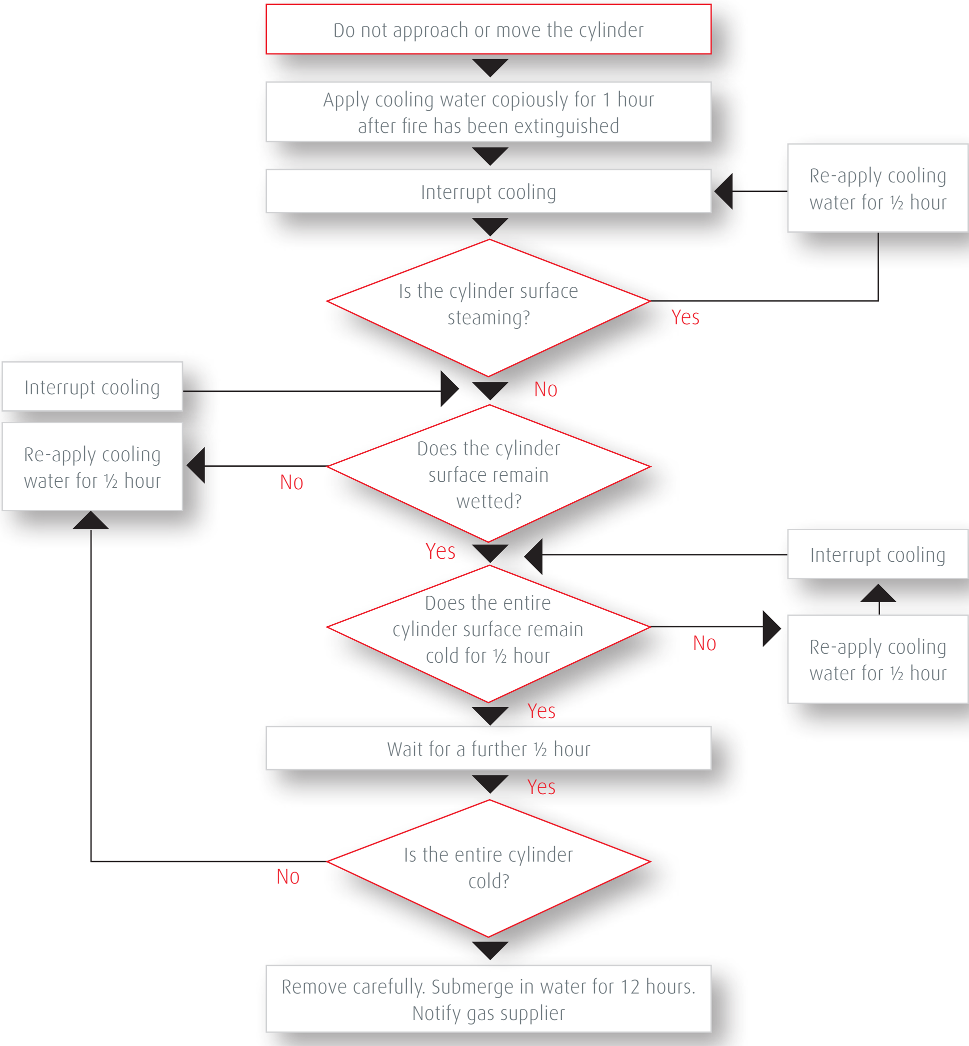
If something goes wrong

Actions to be taken when fire is discovered

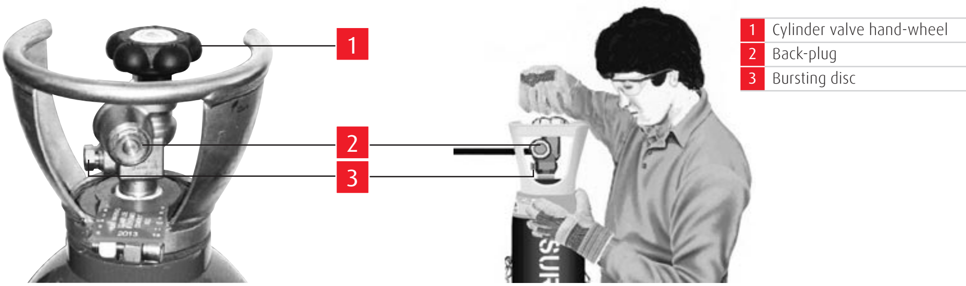
Gas cylinders in a fire may explode. If cylinders are in a fire, the key actions to be taken are

- Evacuate the area (minimum 100 m)

- Call the fire brigade
- Advise persons between 100 and 300 m to take cover
- If you attempt to fight the fire, do so from a protected position using copious quantities of water
- When the fire brigade arrives, inform them of the location and number of gas cylinders and the names of the gases that they contain
- Cylinders which are not directly involved in the fire and which have not become heated should be moved as quickly as possible to safe place provided this can be done without undue risk.



The above has been drawn up in conjunction with the British Compressed Gases Association and the Home Office from the best information available.



Backview of typical cylinder valve

Operator wearing personal protection equipment (PPE) in safe position

Cylinder Safety

Ten Steps to 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. Do not 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.

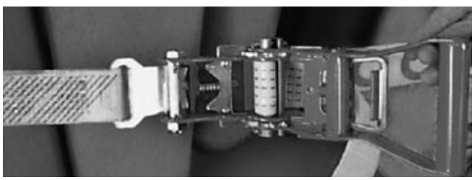
When moving cylinders, ensure that the valve is not accidentally opened in transit.

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-plus 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.

1.4 AS 4839 Safe Use of Portable Oxy-fuel Gas Systems

- Specifies assembly, operation & maintenance of portable & mobile oxy-fuel gas equipment
- Requires use & regular testing of flashback arrestors
- Hose must be maximum of 15 m & single length
- Cylinder storage and handling
- Gas equipment specifications
- Assembly and operation including flow rates
- Leak testing and maintenance
- Safety and emergency procedures
- Recommends the use of a flashback arrestor on each line both fuel and oxygen, at least on end
- For optimum protection it recommends flashback arrestors to be fitted to both ends
- The Western Australian Commission for Safety and Health, states as follows:
  - Regulation 3.98(1) of the Occupational Safety and Health Regulations 1996 says employers, main contractors and self employed persons at workplaces where welding, heating and cutting or an allied process is done must ensure that a flashback arrestor is fitted to the operators side of each regulator connection or gas discharge of a manifold cylinder pack, and to the blowpipe.

2.0 Gases

2.1 The Gases Used

Oxygen (black cylinder) is compressed to 17500 kPa. The pressure in the cylinder is directly related to the quantity of gas stored. If pressure falls to half, then half the contents remain.

If cylinder pressure rises as a result of fire a bursting disc safety device will fracture before the increased cylinder pressure can rupture the cylinder.

Oxygen under pressure accelerates combustion.

Oil, grease and rust will ignite violently in oxygen and must not be permitted to contaminate oxygen connections or equipment.

Acetylene (maroon cylinder) is a highly flammable gas in both air and oxygen. The cylinder is filled with a porous mass and acetone. The acetylene gas is dissolved in the acetone hence the name dissolved acetylene or 'DA'. This allows acetylene to be stored safely up to 1800 kPa.

Acetylene reacts with copper to form unstable copper acetylides, so pure copper must not be used with acetylene under pressure. Copper welding tips and nozzles are OK because the oxy-acetylene mixture is downstream of the mixer.

- DA cylinders have fusible plugs in the neck ring, these will melt in the event of a fire.
- Acetylene is lighter than air so leaked acetylene will dissipate.
- The oxy-acetylene flame at 3100°C is the hottest flame available for welding mild steel.
- High pressure acetylene gas is unstable. The maximum pressure outside the cylinder is restricted to 150 kPa.

Tips and nozzles for acetylene are stamped 'A'.

LPG (Handigas silver cylinder) Liquefied Petroleum Gas is a flammable gas stored as liquid in the cylinder. The pressure is less than 1000 kPa.

- LPG cylinders have a spring loaded safety device that releases gas in the event of the cylinder being overheated or overfilled.
- Heavier than air so LPG leaks flow into low-lying recesses and will remain for a considerable time.
- Accumulated gas can ignite and explode. An odorant is added to give an unpleasant smell as a warning to check for leaks and avoid sources of ignition.
- The oxy-LPG flame is not suitable for welding steel, but is for heating, brazing and cutting of steel.
- Mixer, tips and nozzles for use with LPG are stamped 'P' (Propane) and must not be used with acetylene.

2.2 Storage of Cylinders

All cylinders should be considered and treated as full, regardless of their content.

This means:

1. Keep cylinders away from artificial heat sources (eg. Flames or heaters)
2. Do not store cylinders near combustible materials or flammable liquids
3. Keep cylinders in well drained areas away from water pools or ponds
4. The storage area should be kept well ventilated and clean at all times. Ideally do not store in confined spaces
5. Avoid below ground storage, where possible. Where impractical, consider enclosed space risks
6. Storage area should be designed to prevent unauthorised entry, to protect untrained people from the hazards and guard cylinders from theft
7. Different types of gases should be stored separately, in accordance with State Dangerous Goods legislation. Also refer to AS 4332 (The storage and Handling of Gases in Cylinders)
8. Stores must clearly show signage in accordance with the State Dangerous Goods regulations. This includes Class Diamonds; HAZCHEM: no smoking and naked flame warning signs
9. Full and empty cylinders should be kept separate
10. Liquefied flammable cylinders must be stored upright on a firm, level floor (ideally concrete)
11. Store cylinders away from heavy traffic and emergency exits.

2.3 Handling of Cylinders

When handling gas cylinders, and in line with current manual handling regulations, it is advisable that the following precautions are followed:

1. Larger cylinders are heavy. Manual handling risk assessments and training should be undertaken
2. Safety shoes and gloves should be worn when handling cylinders
3. Cylinders should be handled with care and not knocked violently or allowed to fall
4. Cylinders should be moved with the appropriate size and type of trolley
5. Cylinder valves must be closed when moving cylinders and equipment detached
6. Never roll cylinders along the ground as this may cause the valve to open accidentally.

Please read and understand the BOC Publication “Guideline for Gas Cylinder Safety” before you use your gas cylinders.

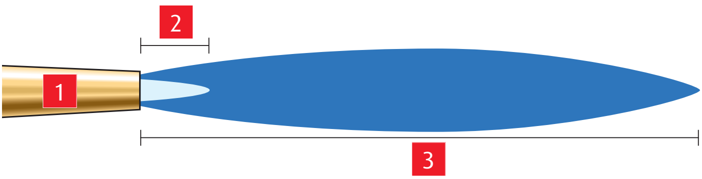
3.0 Fuel Gases Processes

3.1 Fuel Gas Flame Properties

A range of fuel gases is commonly used in the fabrication industry. These include acetylene, hydrogen and LPG.

Each fuel gas has a different ratio of carbon atoms to hydrogen atoms, which means that different amounts of oxygen are needed to burn the fuel gas efficiently. This ratio of fuel to oxidant effects the temperature of the flame, flammability and explosive limits.

- Acetylene is lighter than air and gives the highest flame temperature of all the fuel gases. It also uses the least amount of oxygen to give complete combustion.
- Hydrogen is lighter than air and burns with an invisible flame. It is also the only fuel gas that doesn't contain any carbon atoms.
- LPG (Liquid Petroleum Gas) is a by-product of crude oil refinement. It is made up of several fuel gases such as methane, butane and propane. The ratios of these gases vary by supplier, and because of this, flame properties can also differ.



1	Nozzle
2	Primary flame (or inner cone)
3	Secondary flame (or outer cone)

	Acetylene C_2H_2	Propane C_3H_8
Ratio of Fuel to Oxygen	1:1.1	1:3.75
Maximum Flame Temperature	3,160 °C	2,828 °C
Heat Distribution in Primary Flame (kJ/m^3)	18,890	10,433
Heat Distribution in Secondary Flame (kJ/m^3)	35,882	85,325

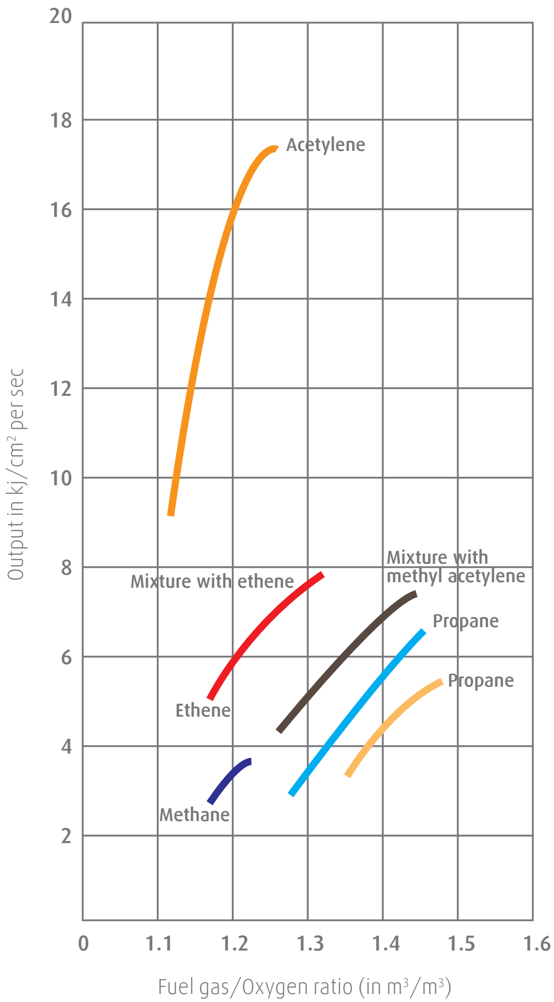
3.2 Fuel Gases Application Table

Process	Acetylene	LPG	Comments
Cutting	Yes	Yes	Dependent on the thickness of the material to be cut, the equipment being used and the operator preference.
Brazing*	Yes	Yes	The recommended fuel gas for brazing is Acetylene because of its higher heat in the primary flame.
Heating*	Yes	Yes	Dependent on the thickness of the material to be cut, the equipment being used and the operator preference. However, it is predominantly LPG due to the higher heat in the secondary flame.
Welding	Yes	No	The low flame temperature and high water combustion process makes LPG unsuitable for gas welding.
Flame gouging	Yes	Yes	The preferred fuel gas for flame gouging is Acetylene because of its high flame temperature and higher heat in the primary flame.
Straightening / bending	Yes	Yes	Dependent on the thickness of the material to be cut, the equipment being used and the operator preference. However, it is predominantly LPG due to the higher heat in the secondary flame.
Cleaning	Yes	Yes	Dependent on the thickness of the material to be cut, the equipment being used and the operator preference. However, it is predominantly Acetylene as it provides sufficient local heat to clean the surface of the steel.
Spot heating	Yes	Yes	The recommended fuel gas for spot heating is Acetylene due to the higher heat in the primary flame.
Thermal spraying materials	Yes	Yes	The recommended fuel gas for thermal spraying materials is Acetylene due to the higher flame temperature.
Case hardening	Yes	Yes	The recommended fuel gas for case hardening is Acetylene, as LPG does not give the benefit of adding carbon into the surface of the material.

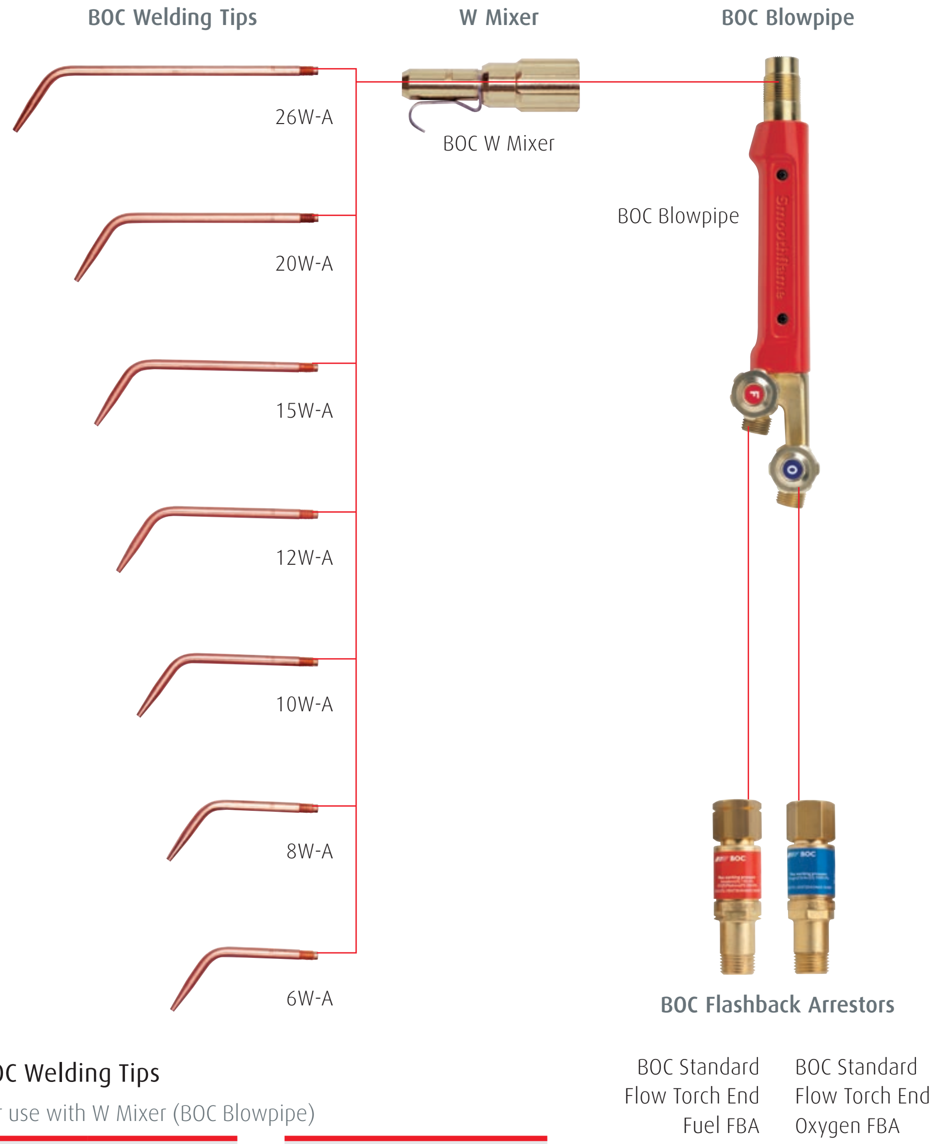
** Fuel gas can be used with air or oxygen*

3.3 Primary Flame Output

The oxygen – acetylene flame has the highest flame temperature when mixed at a ratio of 1,1/1,0 oxygen ratio. Increasing the oxygen ratio decreases the flame temperature and increases the oxidation caused by the gas mixture. Propane flame temperatures can reach temperatures of 2840 degress but with a higher fuel gas to oxygen ratio 1,42/1,0.



4.0 Gas Welding



BOC Welding Tips

For use with W Mixer (BOC Blowpipe)

Tip	Plate (mm)
6W-A	0.5–0.8
8W-A	0.8–1.0
10W-A	1.0–1.5
12W-A	1.6–2.4
15W-A	2.5–3.5
20W-A	4.0–6.5
26W-A	6.5–8.0

5.0 Oxy-Acetylene Welding Procedures

The following section provides a guide to the correct procedures for setting up and closing down an Oxy-acetylene welding plant.

5.1 Setting Up

Before starting, inspect all equipment for damage and ensure no oil or other contamination is present on fittings, hoses and blowpipe. Pay particular attention to all connections. Stand the cylinders in a position out of traffic areas and away from overhead dangers. Cylinders should be mounted on cylinder trolleys or secured to prevent falling.

5.1.1

Crack open and close the cylinder valves carefully with the cylinder key provided to remove any contamination which might harm seats or cause ignition.

5.1.2

Attach the regulator to their respective cylinders and tighten sufficiently to prevent leaks with the spanner provided. Do not use lubricants or gaskets.

NOTE: The fuel gas fittings are left hand threads indicated by notches on the nuts.

5.1.3

Attach the blue oxygen hose to the oxygen regulator end FBA and the red acetylene hose to the acetylene regulator end FBA. Open the cylinder valves slowly.

5.1.4

Slightly screw in the adjusting knobs of both regulators to clear regulators and hoses of any dirt and dust. Back off adjusting knobs and close cylinder valves.

Don't perform any part of the setting up procedure near a source of ignition or while smoking.

5.1.5

Attach the other ends of the hose to the correct oxygen (RH thread) and acetylene (LH thread) FBA on the welding blowpipe.
The valves are stamped "O" for oxygen and "F" for fuel gas.

5.1.6

Select the correct welding tip for the job (see section 19) and screw into mixer.

5.1.7

Unscrew the sleeve on the mixer to rotate the welding tip to the required position, retighten sleeve.

5.1.8

Checking for leaks.

Close the blowpipe valves, slowly open the oxygen cylinder valve and set the regulator to show approx 100 kPa on the delivery gauge. Close the oxygen cylinder valve. If there are no leaks the pressure registered by the gauge will not change.

Repeat for the acetylene.

If a leak is noted in either case, locate the leak by applying **leak testing solution** with a brush or applicator to joints.

Never use flames to locate leaks.

5.2 Lighting Up

Before lighting up visually inspect all equipment for damage or wear.

5.2.1

Back off the adjusting knob before opening the cylinder valve. Open cylinder valve as in 5.1.3.

5.2.2

Open the blowpipe oxygen valve and adjust the oxygen regulator until the correct pressure is obtained. Let the gas flow for a short time to purge the system of air. Close valve. Repeat for the acetylene using a pressure chart as a guide to the correct pressure for the job.

5.2.3

Open the acetylene valve slightly and light the blowpipe with a flint lighter.

Never use acetylene at a gauge pressure above 100 kPa.

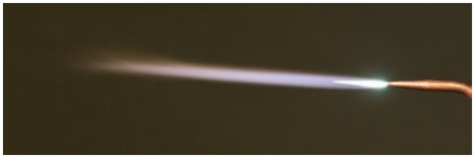
5.2.4

Continue to open the valve until the flame no longer produces soot.

5.2.5

Slowly open the blowpipe oxygen valve until a neutral flame is produced.

Acetylene burning in air



Carburising flame

Neutral flame

Oxidising flame

5.3 Shutting Down

5.3.1

Close down blowpipe acetylene valve.
Then close down oxygen blowpipe valve.

5.3.2

Close both cylinder valves.

5.3.3

Open oxygen blowpipe valve and allow gas to drain out. When both oxygen regulator gauges have fallen to zero, close blowpipe valve.

5.3.4

Release oxygen regulator knob.

5.3.5

Repeat steps 6.3.3 and 6.3.4 for acetylene.

6.0 Welding Techniques

6.1 Backfires

For most welding applications a neutral flame is desired. An oxidising flame is used for welding brass and bronze. Occasionally the blowpipe may backfire (pop). This is a small explosion at the blowpipe tip which is caused by one or more of the following:

1. The gas flow is insufficient for the size of tip.
2. The tip is too hot, caused by welding too close to the metal or for extended periods. This situation can also lead to flashbacks and is to be avoided. Simply cool the tip.
3. Particles of carbon or metal stuck inside the tip. Clean tip with correct size tip cleaning drill or universal tip cleaners.

6.2 Blowpipe Position and Movements

Forehand welding is the most common welding procedure. The blowpipe is held at an angle of 60–75 degrees to the work and the blowpipe is moved in the direction the tip is pointing (figure 1). The flame spreads over the work ahead of the weld, preheating it.

The angle may vary depending on the tip size used, metal thickness and other welding conditions. Angles of between 30 to 45 degrees are sometimes required for metals other than mild steel.

An oscillating or circular blowpipe motion is commonly used. In either case the cone of the flame should never go outside the weld puddle. The tip of the inner flame cone should be about 2–3 mm above the metal.

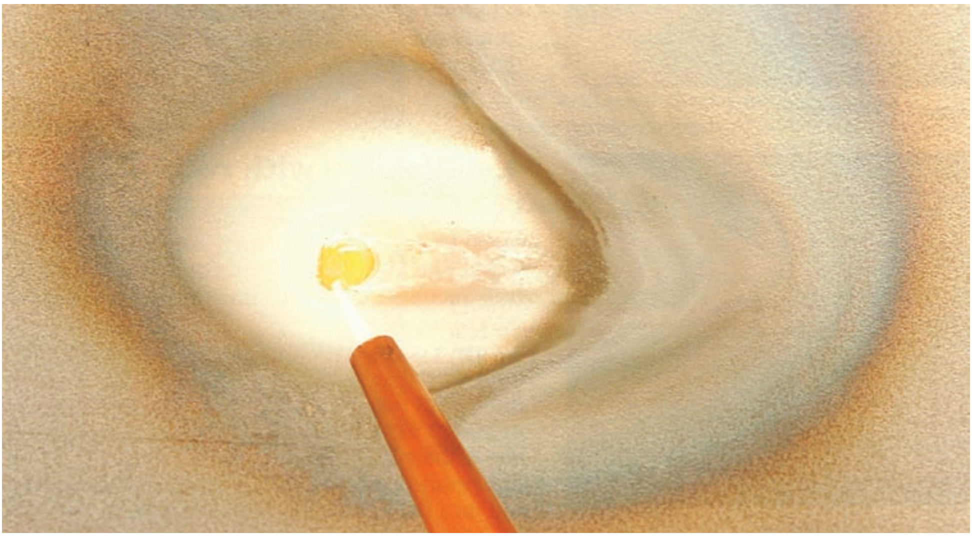


Figure 1. Blowpipe angle, flame direction and distance from plate for forehand welding.

6.3 Puddling

Puddling is the creation and control of a molten puddle of metal which is carried along the seam of the metal to be welded. The weld puddle will tell the welder:

1. The weld penetration, the greater the diameter of the puddle the greater the penetration.
2. The speed to move the blowpipe.
3. The blowpipe adjustment; a neutral flame will produce a smooth and glossy appearance, a carburising one will cause it to become dirty and dull, and an oxidising flame will cause the puddle to bubble and spark.
4. When and if to use a filler rod.

The learner welder should become practiced at forming and controlling weld puddles without a filler metal.

6.4 Welding without Rods

The outside corner joint can be welded without the use of a filler metal and makes an excellent practice weld for the learner (figure 2). Points to watch are:

1. None of the weld should run on the flat surfaces.
2. Good penetration is required, but the weld should not have excess or uneven penetration on the inside.

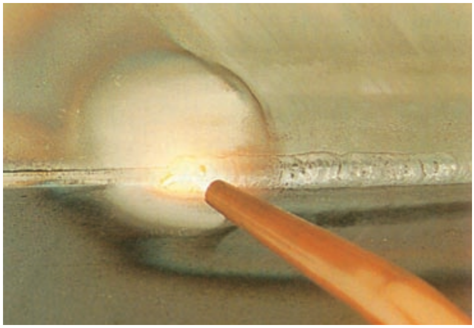


Figure 2. Outside corner weld without filler rod.

6.5 Welding with Rods

Most oxy-acetylene welding calls for a filler metal to increase the strength and shape of the weld. The filler metal is provided by a filler rod (see Section 8 for selecting the correct rod).

To use a rod, create a puddle at the part of the joint where the weld is to start. At the same time, with the other hand, bring the rod to within 10 mm of the blowpipe flame and 2–3 mm above the surface of the puddle (figure 3). In this position the welder can dip the preheated rod into the puddle whenever the additional weld metal is required.

A good weld is produced when the welder has mastered the handling of blowpipe and filler rod together.

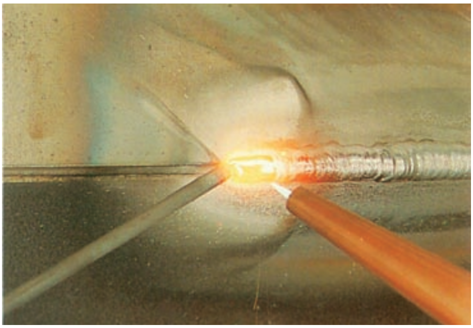


Figure 3. Welding using a filler rod.

6.6 Types of Welding Joints

The following is an overview of the common welding joints made by an oxy-acetylene welding.

6.6.1 Butt joint welding

Two pieces of metal are butted together for welding. To avoid distortion during welding it is advisable to tack weld every 50 mm along the entire length of the join before commencing. Clamping can also be used to avoid distortion of the two pieces of metal.

The finished weld should have consistent width with the edges forming two parallel lines (figure 4). The weld bead should also be slightly convex for reinforcement.

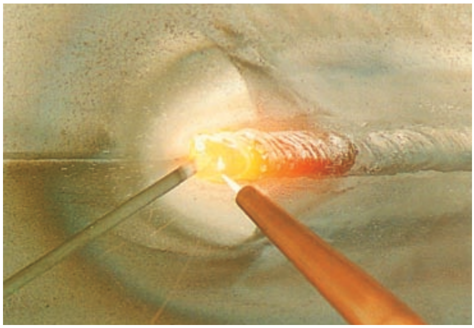


Figure 4. Butt weld joint appearance.

6.6.2 Lap joint welding

The laps joint consists of one piece of metal lying over the top of another. To produce a satisfactory lap joint weld (figure 5), the welder should concentrate the blowpipe flame on the lower surface of the joint, and sufficient rod must be used to produce a convex bead right up to the top edge of the upper piece of metal.

The finished weld should have consistent width with the edges forming two parallel lines (figure 5). The weld bead should also be slightly convex for reinforcement.

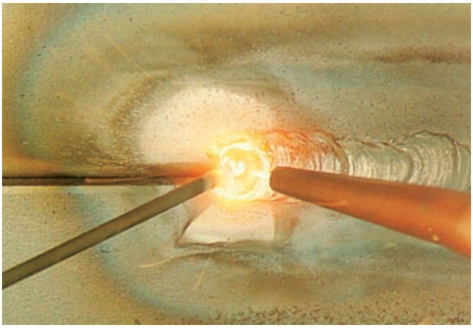


Figure 5. Lap joint appearance.

6.6.3 Outside corner welding

As discussed above this weld can be made without a filler rod, with the metals overlapping. However, the weld can be made without overlap and using a filler rod to produce the weld bead (figure 6).

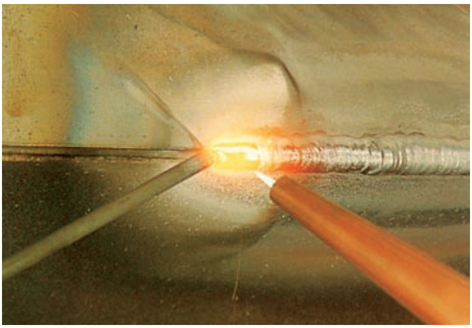


Figure 6. Outside corner joint appearance.

6.6.4 Inside corner and T-joint (fillet weld)

The is a relatively easy weld to perform (figure 7), providing sufficient penetration can be obtained. The technique of handling the blowpipe and rod will be almost the same as for the lap weld.

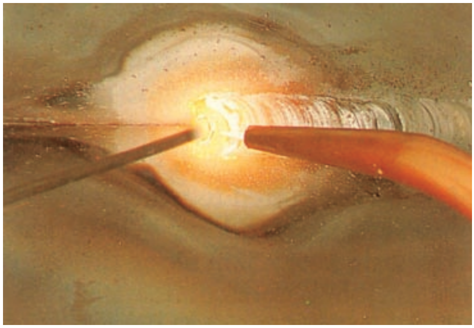


Figure 7. Fillet joint appearance.

6.7 Backhand Welding

Backhand welding is when the flame is directed back over the welded area (figure 8). It is often used when welding heavy sections or cast iron to relieve the stresses created by the welding process.

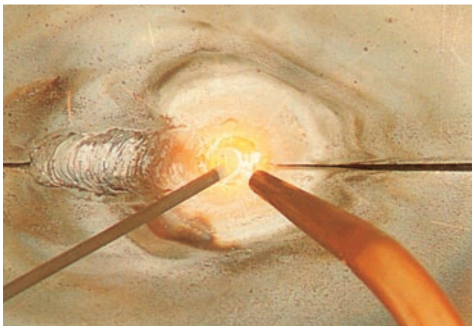


Figure 8. Backhand welding technique.

7.0 Welding Information

7.1 Filler Rod and Flux Selection Chart

Metal	Flame	Filler Rod	Flux
Iron			
Wrought iron	Neutral	BOC mild steel	None
Low carbon iron	Neutral	BOC mild steel	None
Carbon steels			
Low carbon (M, S)	Normal	COMWELD high test	None
Medium carbon	Slightly carburising	COMWELD super steel	None
Cast steel			
Plain carbon	Neutral	COMWELD high test	None
Low alloy	Neutral	COMWELD super steel	None
Cast irons			
Grey cast irons	Normal	COMWELD cast iron	COMWELD cast iron
Low alloy high tensile steels			
General	Neutral	COMWELD super steel	None
Carbon and chrome-Molybdenum steels (0.5 moly type)	Neutral	COMWELD CrMo1	None
		COMWELD super steel	
Manganese alloy steels	Neutral		None
Stainless steels			
Stainless iron (12% to 28% Cr.)	Strictly neutral	ProFill 347 stainless steel	None
Stainless steel (18% Cr. To 8% Ni).	Strictly neutral	ProFill 347 stainless steel	None
Molybdenum bearing	Strictly neutral	ProFill 316L stainless steel	None
Copper and copper alloys			
Commercial bronze and low brass	Slightly oxidizing	ProFill TOBIN bronze	Flux Tenacity 20
Spring, admiralty and yellow brass	Slightly oxidizing	ProFill TOBIN bronze	Flux Tenacity 20
Muntz metal, tobin bronze, Navel brass	Slightly oxidizing	ProFill TOBIN bronze	Flux Tenacity 20
Nickel silver	Neutral	ProFill nickel bronze	Flux Tenacity 20
Phosphor bronze	Slightly oxidizing	ProFill TOBIN bronze	Flux Tenacity 20
Aluminium and aluminium alloys			
Pure	Neutral	Aluminium 1080	COMWELD aluminium
Aluminium manganese	Neutral	Aluminium 1080	COMWELD aluminium
Aluminium silicon Magnesium	Neutral	Aluminium 4043	COMWELD aluminium
Aluminium magnesium	Neutral	Aluminium 5356	COMWELD aluminium

7.2 How to Improve Weld Quality

Metal	Flux
CAUSE	**CORRECTIVE ACTION**
A. Distortion	
1 Shrinkage of deposited metal pulls welded parts together and changes their relative positions.	1 Properly clamp or track parts to resist shrinkage. Separate or preform parts sufficiently to allow for shrinkage of welds. Peen the deposited metal while still hot.
2 Non-uniform heating of parts during welding causes them to distort or buckle before welding is finished. Final welding of parts in distorted position prevents control of desired dimensions.	2 Support parts of structure to be welded to prevent buckling in heated sections, due to weight of parts themselves. Preheating is desirable in some heavy structures. Removal of rolling or forming strains before welding is sometimes helpful.
3 Improper welding sequences.	3 Study the structure and develop a definite sequence of welding. Distribute welding to prevent excessive local heating.
B. Welding stresses	
1 Joints too rigid.	1 Slight movement of parts during welding will reduce welding stress. Develop welding procedure that permits all parts to be free to move as long as possible.
2 Incorrect welding procedure.	2 Make weld in as few passes as practicable. Use special intermittent or alternating welding sequence and step-back or skip procedure. Properly clamp parts adjacent to the joint. Use back-up cool parts rapidly.
3 Inherent in all welds, especially in heavy parts.	3 Peen each deposit of weld metal. Stress-relief finished product.
C. Warping (thin plates)	
1 Shrinkage of deposited weld metal.	1 Distribute heat input more evenly over full length of the seam.
2 Excessive local heating at the joint.	2 Weld rapidly with a minimum input to prevent excessive local heating of the plates adjacent to the weld.
3 Incorrect preparation of joint.	3 Do not have excessive space between the parts to be welded. Prepare thin plate edges with flanged joints, making off-set approximately equal to the thickness of the plates. No filler rod is necessary for this type of joint. Make a U-shaped corrugation in the plates parallel to an approximately 13.0 mm (1/2 in) away from the seam. This will serve as an expansion joint to take up movement during and after the welding operation.
4 Improper welding procedure.	4 Use special welding sequence and step-back or skip procedure.
5 Improper clamping of parts.	5 Properly clamp parts adjacent to the joint. Use back-up to cool parts rapidly.

Metal	Flux
CAUSE	CORRECTIVE ACTION
D. Poor weld appearance	
1 Poor welding technique: Improper flame adjustment or welding rod manipulation.	1 Use the proper welding techniques for the welding rod used. Do not use excessive heat. Use a uniform weave and welding speed at all times.
2 Inherent characteristics of welding rod used.	2 Use a welding rod designed for the type of weld.
3 Improper joint preparation.	3 Prepare all joints properly.
E. Cracked welds	
1 Joint too rigid.	1 Design the structure and develop a welding procedure to eliminate rigid joints.
2 Welds too small for size of parts joined.	2 Do no use too small a weld between heavy plates. Increase the size of welds by adding more filler metal.
3 Improper welding procedure.	3 Do not make welds in stringer beads. Make welds full-size in short sections 200 mm (8 in) to 250 mm (10 in) long. Welding sequence should be such as to leave ends free to move as long as possible. Preheating parts to be welded sometimes helps to reduce high contraction stresses caused by localised high temperatures.
4 Poor welds.	4 Make sure welds are sound and the fusion is good.
5 Improper preparation of joints.	5 Prepare joints with a uniform and proper gap. In some cases a gap is essential. In other cases, a shrink or press fit may be required.
F. Undercut	
1 Excessive weaving of the blowpipe, improper tip size, and insufficient welding rod added to molten puddle.	1 Modify welding procedure to balance weave of bead and rate of welding rod deposition, using proper tip size. Do not use too small a welding rod.
2 Improper manipulation of welding rod.	2 Avoid excessive and non-uniform weaving. A uniform weave with unvarying heat input will aid greatly in preventing undercut in butt welds.
3 Poor welding technique: Improper welding rod deposition with non-uniform heating.	3 Do not hold welding rod too low near the lower edge of the plate in the vertical plane when making a horizontal filler weld as undercut on the vertical plate will result.

7.2 How to Improve Weld Quality continued

Metal	Flux
CAUSE	CORRECTIVE ACTION
G. Incomplete penetration	
1 Improper preparation of joint.	1 Be sure to allow the proper gap at the bottom of the weld. Deposit a layer of weld metal on the back side of the joint where accessible, to ensure complete fusion in lower "V".
2 Use of too large a welding rod.	2 Select proper-sized welding rod to obtain a balance in the heat requirements for melting rod, breaking down side-walls, and maintaining the puddle of molten metal at the desired size. Use small-diameter welding rods in a narrow welding groove.
3 Welding tip too small – insufficient heat input.	3 Use sufficient heat input to obtain proper penetration for the plate thickness being welded.
4 Too fast a welding speed.	4 Welding speed should be slow enough to allow welding heat to penetrate to the bottom of the joint.
H. Porous welds	
1 Inherent properties of the particular type of welding rod.	1 Use welding rod of proper chemical analysis.
2 Improper welding procedure and flame adjustment.	2 Avoid overheating of molten puddle of weld metal. Use the proper flame adjustment and flux (if necessary) to ensure sound welds.
3 Insufficient puddling time to allow entrapped gas, oxides, and slag inclusions to escape to the surface.	3 Use the multi-layer welding technique to avoid carrying too large a molten puddle of weld metal molten puddling keeps the weld longer and often ensures sounder welds.
4 Poor base metal.	4 Modify the normal welding procedures to weld poor base metals of a given type.
I. Brittle welds	
1 Unsatisfactory welding rod producing air-hardening weld metal.	1 Avoid welding rods producing air-hardening weld metal where ductility is desired. High-tensile low-allow steel rods are air-hardening and require proper base metal preheating, post-heating or both, to avoid cracking due to brittleness.
2 Excessive heat input with over-sized welding tip, causing coarse-grained and burnt metal.	2 Do not use excessive heat input, as this may cause course grain structure and oxide inclusions in weld metal deposits.
3 High-carbon or alloy base metal which has not been taken into consideration.	3 A single-pass weld may be more brittle than a multi-layer weld, because it has not been refined by successive layers of weld metal. Welds may absorb alloy elements from the parent metal and become hard. Do not weld a steel unless the analysis and characteristics are known.
4 Improper flame adjustment and welding procedure.	4 Adjust the flame so that molten metal does not boil, foam or spark.

Metal	Flux
CAUSE	CORRECTIVE ACTION
J. Poor fusion	
1 Improper size of welding rod.	1 When welding in narrow V's, use a welding rod small enough to reach the bottom.
2 Improper size of tip and heat input.	2 Use sufficient heat to melt welding rod and to break down side walls of plate edges.
3 Improper welding technique.	3 Be sure the weave is wide enough to melt the sides of a joint thoroughly.
4 Improper preparation of joint.	4 The depositied metal should completely fuse with the side walls of plate to form a consolidated joint of base and weld metal.
K. Brittle joints	
1 Air-hardening base metal.	1 In welding on medium carbon steel or certain alloy steels, the fusion zone may be hard as the result of rapid cooling. Preheating at 150°C to 260°C (300°F to 500°F) should be resorted to before welding.
2 Improper welding procedure.	2 Multi-layering welds will tend to anneal hard zones. Stress-relieving at 600°C to 675°C (1,100°F to 1,250°F) after welding will generally reduce hard areas formed during welding.
3 Unsatisfactory welding rod.	3 The use of austenitic welding rods will often be satisfactory on special steels, but the fusion zone will generally contain an alloy which is hard.
L. Corrosion	
1 Type of welding rod used.	1 Select welding rods with the proper corrosion-resisting properties, which are not changed by the welding process.
2 Improper weld deposit for the corrosive fluid or atmosphere.	2 Use the proper flux on both parent metal and welding rod to produce welds with the desired corrosion resistance. Do not expect more from the weld than you do from the parent metal. On stainless steels, use welding rods that are equal to or better than the base metal. For the best corrosion resistance use a filler whose composition is the same as that of the base metal.
3 Metallurgical effect of welding.	3 When welding 18/8 austenitic stainless steel, be sure the analysis of the steel and the welding procedure are correct, so that welding does not cause carbide precipitations. This condition can be corrected by annealing at 1,040°C to 1,150°C.
4 Improper cleaning of weld.	4 Certain materials such as aluminium require careful cleaning of all slag to prevent corrosion.

8.0 Joining Processes

8.1 Welding

Welding is using a flame to melt the plate and add filler.

Welding (fusion welding) takes place when a flame is used to heat the edges of the joint melting temperature. When the metal is in a molten state, the edges flow together. The addition of the welding rod may be required, depending on the type of joint being welded.

8.2 Braze Welding

Brazing and braze welding take place at temperatures above 450°C, but below the melting point of the base metal.

Braze welding happens when the edges of the joint to be welded are heated sufficiently to melt the braze welding rod, which then flows onto the joint edges, producing a fillet in the joint. The parent metal does not melt. The process is one of adhesion.

An advantage of braze welding is reduced distortion because of the lower temperatures.

The filler material is an alloy of copper and zinc and may also contain other elements such as silicon, nickel or manganese.

A flux, either coated on or contained within the rod, must chemically clean the surface of the parent metal during heating.

Comparisons

Advantages of braze welding:

- Less distortion because of lower heat input
- Faster welding speeds because of lower heat input

Disadvantages:

- Weakness of joint at high temperatures
- Mismatch of colour between parent metal and the bronze welded deposit

Braze welded joints

- Fillet joints
- Lap joint
- Butt joint
- No fusion of the joint edges
- Pronounced build up of the filler metal

8.3 Brazing

Brazing is the adhesion of one plate to another without melting at temperatures above 450°C but below the melting point of the base metal. The filler material to form the union is non-ferrous.

Features of Brazing

- Filler metal forms a thin film (0.0254–0.0085 mm) between two or more tightly fitted pieces of base metal
- Often referred to as silver brazing or silver soldering
- Fast metal joining is achieved because:
  - Brazing rod has the lowest achievable melting point, which can lead to capillary action
  - Whole joint is raised to the correct temperature (in contrast with localised heat applied in welding)
  - Brazing rod flows by capillary action along joint edges and through to the reverse side of the joint

Braze joints

- Fillet joints
- Lap joints
- Butt joints – not suitable for brazing

Fluxes in brazing

Fluxes clean the metal surface.

When fluxes which are used to clean the surface chemically, the parent metal does not melt. The cleaning permits a good bond between the parent metal and the brazing welding rod when brazing:

- Mild steel
- Stainless steel
- Cast iron
- Copper

Removal of fluxes

Removal of fluxes after brazing is important when using aluminium, as the flux residues are very corrosive to aluminium.

Flux not needed

When using the copper phosphor brazing rod to braze with copper, a flux is not needed.

8.4 Soldering

Soldering is also adhesion at a lower temperature. Filler metal or solder alloy with a melting temperature of less than 450°C is used. The filler metal wets the parent metal, spreads, makes contact with the joint opening and is drawn into the joint by capillary action.

Filler metals in soldering

- Soldering is another type of adhesion process.
- Filler metal or solder alloy with a melting temperature of <450°C is used.
- Binary-tin-lead alloys are most commonly used.
- Some tin-lead filler metals contain a little antimony (up to 3%) to improve the mechanical properties of the soldered joints.

Fluxes in soldering

- Fluxes consist of either:
  - Various forms of inorganic weak acid solutions and salts
  - Resins dissolved in organic solvents
- Acid and salt fluxes are corrosive and residues must be removed after soldering
- Resin fluxes are not corrosive

Function of fluxes in soldering

The function of the flux is:

- To prevent
- To dissolve
- To remove

oxide films and other contaminants.

It is NOT a function of the flux to clean dirt from the base metal. Pre-cleaning of the joint faces must be done.

Types of joints

The lap joint is best used because it offers maximum strength. The solder alloy must completely fill the gap to prevent moisture getting in and causing corrosion.

Only the correct clearance between the joint faces will enable the solder to enter the joint by capillary action. The filler alloy must be selected for joint gap, as those with a narrow melting range tend to rise higher than those with a wide melting range.

Suitability of Various Metals for Soldering

Metal	Solder	Flux
Stainless steel	965 solder	965 flux
Copper, copper alloys and brass	Lead-tin alloys	Moderately active flux
Aluminium and aluminium alloys	Alloys of zinc, cadmium, tin and aluminium	Active flux or aluminium zinc rub on fluxless alloys
Cast iron	Parent metal must be pre-tinned with pure tin. This allows wetting of the joint, despite the presence of free carbon.	965 flux
Tin-plated and galvanised steel	Soldering is widely used for thin sheet metal, galvanised or tin-plated. A wide variety of solders can be used.	Highly active flux to protect cut faces and joints
Plated materials		
Chrome plating	Very difficult to solder	
Silver plating	Easily soldered	
Anodised aluminium	Soldering destroys anodised finish	

Name	Composition	Melting Range, (°C)	Recommended Joint Gap (mm)	Remarks
ProSilver 56T SilverCoat 56T	56% Ag:Cu:Zn:Sn	620–650	0.05–0.15	These two alloys have similar low melting temperatures and quick flowing characteristics. ProSilver 45T is the popular choice.
ProSilver 45T SilverCoat 45T	45% Ag:Cu:Zn:Sn	640–680	0.05–0.15	ProSilver 56T is used where maximum ductility and smoother joint fillets are required. Both alloys need well-fitted joints with small gaps for their best performance.
ProSilver 39T	39% Ag:Cu:Zn:Sn	650–705	0.075–0.2	This series of three alloys of silver, copper, zinc and tin gives a range of fillet-forming materials designed for use where wide joint gaps may arise or where pronounced fillets may be required. They are not suitable for applications where slow heating may produce liquation.
ProSilver 34T	34% Ag:Cu:Zn:Sn	630–730	0.075–0.2	
ProSilver 30T	30% Ag:Cu:Zn:Sn	665–755	0.075–0.2	
ProSilver 15	15% Ag:Cu:P	645–800	0.05–0.15	Designed primarily for brazing copper without flux, these alloys can be used with flux on copper alloys, but should not be used on ferrous or nickel-base metals. As the silver content of these alloys decreases, so does joint ductility. Where service conditions are severe, ProSilver 15 should be the alloy chosen.
ProSilver 5	5% Ag:Cu:P	645–810	0.05–0.15	
ProSilver 2	2% Ag:Cu:P	645–800	0.05–0.15	
PhosCopper	7% P:Cu	705–820	0.075–0.2	A free flowing, self-fluxing alloy for use on unstressed copper to copper joints. Higher melting temperature than the silver containing alloys.
ProSilver 494	49% Ag:Cu:Zn:Ni:Mn	680–705	0.1–0.25	ProSilver 494 and ProSilver 402 are specialised alloys designed for brazing of tungsten carbide.
ProSilver 402	40% Ag:Cu:Zn:Ni	660–780	0.1–0.25	

9.0 Silver Brazing

9.1 Choice of Filler Metal

Listed on page 30 are details of BOC ProSilver brazing alloys commonly used in all general purpose joining operations.

An alloy is normally selected for its melting and flow characteristics.

The easiest to use filler materials are the high silver, free flowing alloys, because of their low melting temperatures and narrow melting ranges. The higher the brazing temperature and the wider the melting range of the alloy, the more difficult the brazing operation will be.

9.2 Pre-Cleaning

It is important that the mating surfaces of the components to be brazed are free from oil, grease and any surface oxide layer prior to joining. Most engineering components require nothing more than degreasing before assembly.

Oxide removal can be accomplished either chemically or mechanically. Mechanical removal is preferable, because the surface is roughened and excellent bonding is obtained. A medium emery cloth provides about the right amount of surface roughness.

Oil and grease removal is best carried out by using a solvent degreasing agent, but hot, soapy water is better than nothing at all.

9.3 Fluxing

The choice of the correct flux is just as important as the choice of filler material.

There are three desirable properties of a flux:

1. The flux must melt and become active below the melting point of the brazing alloy. Borax or borax based fluxes are not sufficiently molten at the low temperatures at which silver brazing alloys are used. A low temperature fluoride based flux such as Easyflo needs to be employed.
2. The flux must be capable of removing the oxides found on the parent materials. Easyflo flux will remove the oxides found on most common engineering materials such as mild steel, brass and copper. Special fluxes may be required on certain types of highly alloyed steel and tungsten carbide tool tips. It is also necessary to use a specially formulated flux on aluminium bronze or aluminium brasses containing more than 2% aluminium.
3. The flux must remain active at the brazing temperature for long enough to allow the brazing operation to be carried out. Fluxes are chemical compounds which dissolve oxides formed in heating. Like most chemical compounds, a flux eventually reaches the point where it is saturated and becomes unable to dissolve any more oxide. If the flux residues appear blackened and glassy, the flux has most likely been exhausted during heating, and a flux with higher time / temperature stability should be used.

For most engineering requirements, there are two fluxes that will take care of most needs. These are Easyflo flux paste and Tenacity No. 4A flux paste.

Easyflo Flux

This is the accepted general-purpose flux for use with all low-temperature silver brazing alloys that have brazing temperatures not exceeding 800°C. It will successfully flux all the common engineering materials, and its residues are soluble in hot water.

Where difficulty is encountered when removing residues, immersion in 10% caustic soda is suggested.

Tenacity No. 4A

This is a higher temperature flux, suitable for use with alloys with brazing temperatures not exceeding 900°C or where long heating times are involved. In common with Easyflo flux, it will deal with all common engineering materials and may be used on stainless steels. Tenacity No. 4A residues cannot be removed in hot water, and are best removed mechanically or by the use of 10% sulphuric acid.

Flux Application

The best way to apply a flux is to paint it onto the joint as a paste before assembly. It is common to see operators heating the rod end and dipping it into the flux, and then applying both to the joint. This 'hot rodding' technique has the disadvantages that the flux does not protect the joint during the heating cycle and that the limited amount of flux applied does not allow alloy penetration into the capillary gap.

If a flux powder is used, it should be mixed to a double cream consistency with water and a few drops of detergent. It should also be applied to the joint by means of a paint brush. Too much flux will rarely result in a bad joint, but too little flux will invariably give joints of poor quality.

9.4 Heating the Joint and Applying the Alloy

When heating a joint for brazing, it is essential that it is slowly and evenly heated to the brazing temperature.

The type and size of flame used will depend on the parent materials and the mass of the components. Oxy / Acetylene, Air / Acetylene and Air / Propane or MAPP are commonly used, but care should be taken with the first due to the high flame intensity, which may melt the parent materials.

If the mass of metal is very large, more than one torch should be used to raise the components to temperature before the flux becomes exhausted.

As a temperature guide, either the colour of the metals or the condition of the flux may be used. The flux on a joint that has reached the correct temperature for brazing should be clear, fluid and flow over the joint area like water.

When the brazing temperature is reached, the filler metal is applied by touching the joint gap with the rod and applying some indirect or splash heat from the torch to the parent material. The molten filler metal will follow the heat from the flame as it is directed along the joint. The brazing alloy should be applied according to its flow characteristics; an alloy with free flowing characteristics such as ProSilver 56T should be touched at one point on the joint, from where it will flow into and around the joint by capillary action. A less-free flowing alloy, such as ProSilver 39T, should be applied along or around the entire joint, building up a fillet of alloy.

If phosphorus bearing filler rods are used, such as ProSilver 5, the colour of the metal should be a dull cherry red before the rod is applied to the joint gap.

Once brazing has been completed the heating should be discontinued, as excess heating may cause metallurgical problems with the parent materials and porosity in the filler materials.

When the alloy has solidified, the joint can be quenched in water to help remove flux residues.

Quenching should only be carried out when it will not damage the properties of the parent metals, or cause cracking because of stresses caused by the thermal shock (e.g. in the case of tungsten carbide pieces).

9.5 Removal of Flux Residues

The method of residue removal depends on the type of flux that has been used. Easyflo flux residues can be quite simply removed by soaking in hot water, provided they are not in a burnt and blackened condition. Complete flux residue removal is usually possible within 10–15 minutes of soaking in water with a temperature of 60°C or above. After soaking, the joints should be scrubbed under running water to ensure complete cleanliness.

Tenacity No.4A flux residues are not water soluble and are best removed by some mechanical means (e.g. shot blasting).

Acid pickling is not effective in removing flux unless the residues are in a burnt and blackened condition. If pickling is necessary, it should be carried out after the flux residue removal operation.

9.6 Health and Safety

Brazing alloys and fluxes contain elements which, if overheated, produce fumes that may be harmful or dangerous to health. Brazing should be carried out in a well ventilated area with operators positioned so that any fume generated will not be inhaled. Adequate ventilation to prevent an accumulation of fumes and gases should be used. Where fume levels cannot be controlled below the recognised exposure limits, use a local exhaust to reduce fumes and gases. In confined spaces without adequate ventilation, an air-fed breathing system should be used. When outdoors, a respirator may be required. Precautions for working in confined spaces should be observed.

Apart from fume hazards, flux can be irritating to the skin and prolonged contact should be avoided.

Before use, read all the manufacturer's instructions and refer to the warning labels on the packaging. And ask your employer for the Materials Safety Data Sheet. You can obtain the MSDS by referring to our website at www.boc.com.au or www.boc.co.nz or by calling 131 262 in Australia or 0800 111 333 in New Zealand.

9.7 Joint Design

The best brazed joints are those which have a capillary joint gap into which the molten filler metal can flow. A comparison of the different joint designs used in welding and brazing is shown below.

10.0 Typical Designs

10.1 Comparisons between Joint Design

The most common type of joint used for brazing is the lap joint, or the sleeve joint in the case of tubular components. To design a good lap joint, two criteria should be considered:

1 The joint gap

2 The degree of overlap

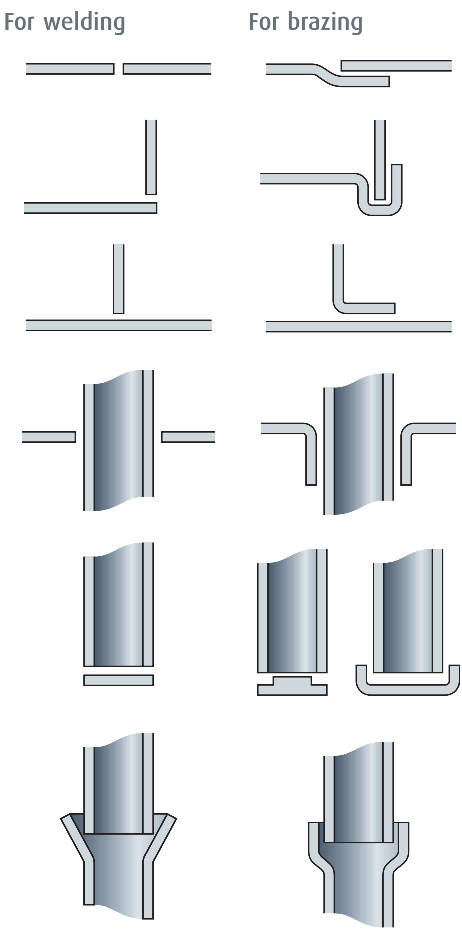
It is these two parameters that determine the ultimate joint strength, rather than the properties of the filler metal.

A correctly designed brazed joint will often be stronger than the parent materials from which it is constructed.

The best degree of overlap for a brazed joint is 3–4 t where t is the thickness of the thinnest parent metal part that makes up the joint.

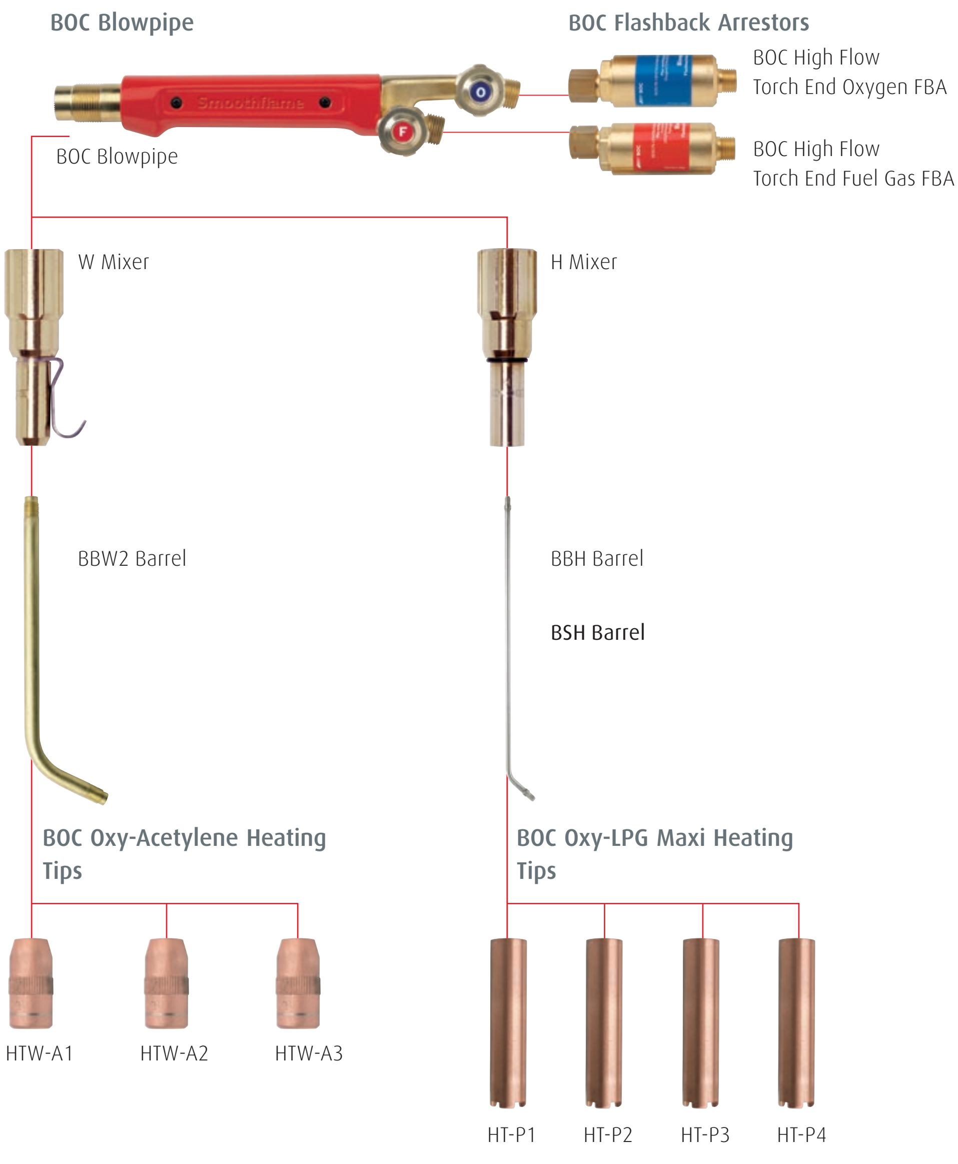
The general rule for tubular parts is that the overlap should be one pipe diameter for sizes up to 25 mm diameter tube.

The most suitable joint gap depends mainly on the flow characteristics of the filler metal. The joint gaps for the various alloys listed in the following section have been indicated. The gaps quoted are those that should be present at the brazing temperature, the cold clearances being adjusted as necessary to account for any difference in the expansion properties of the parent materials.



11.0 Flame Heating

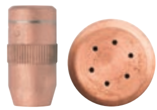
11.1 Heating Assembly



11.2 Heating Tips

BOC multi-flame heating tips are designed to provide large volumes of heat for applications such as bending, straightening, preheating, brazing, shrinking, forming and many others. They can be used to braze or silver-solder large pipes, or can be used for heating castings. Smaller sizes are often used for brazing or for applying hard-facing metal to large areas.

Heating tips deliver significant cost-savings by providing great amounts of quick, concentrated heat. They help to do the job faster and cut labour time to a minimum.



BOC Oxy-Acetylene Heating Tips

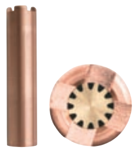
For use with W Mixer and BBW2 Barrel

Description	DA (kPa)	Oxy (kPa)	DA (L/min)	Oxy (L/min)	Heat Output (kJ/hr)
HTW-A1	100	100	11	12	36,000
HTW-A2	100	150	24	27	80,000
HTW-A3	100	350	59	64	192,000

BOC Oxy-Acetylene Maxi-Heating Tips

For use with H Mixer and BBH or BSH Barrel

Description	DA (kPa)	Oxy (kPa)	DA (kPa)	Oxy (kPa)	Heat Output (kJ/hr)
HT-A1	100	150	56	62	185,000
HT-A2	100	200	67	74	220,000



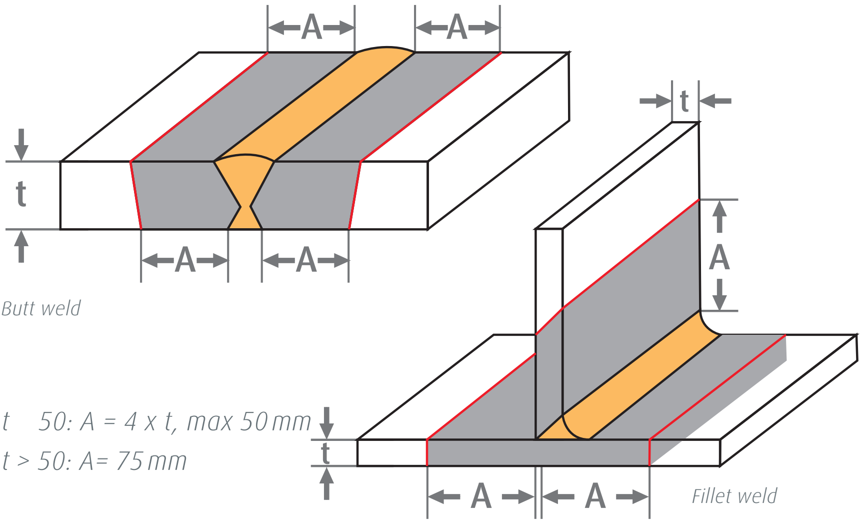
BOC Oxy-LPG Maxi-Heating Tips

Description	LPG (kPa)	Oxy (kPa)	LPG (L/min)	Oxy (kPa)	Heat Output (kJ/hr)
For use with H Mixer and BBH or BSH Barrel					
HT-P1	150	300	54	203	302,000
HT-P2	175	480	81	304	453,000
For use with M Mixer and BBH or BSH Barrel					
HTP-P3	180	570	85	310	500,000
HTP-P4	200	800	116	466	652,000

11.3 Preheating Area and Point of Measurement

Using the oxyfuel gas flame for preheating is a most customary procedure. It is usually performed by the welder onsite, immediately prior to welding.

The preheating temperature must completely penetrate the workpiece. The preheat temperature shall be measured on the face opposite to that being heated.



t   50: A = 4 x t, max 50 mm

t > 50: A = 75 mm

Distance between the points of measurment

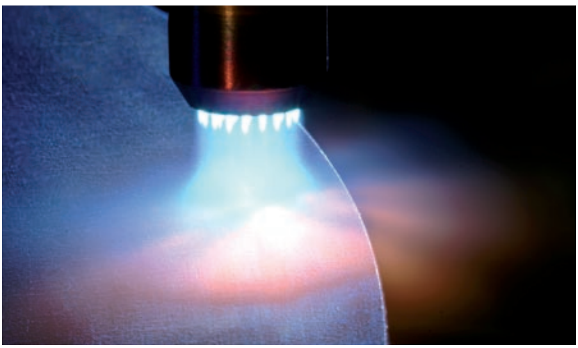
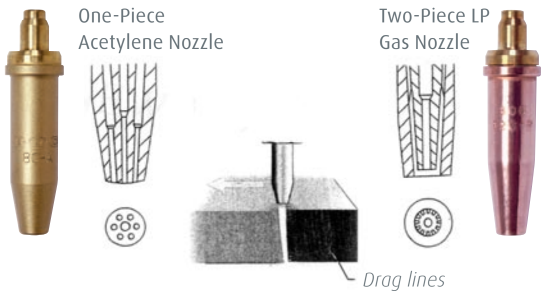


Figure 9. The application of preheat gases.

12.0 Gas Cutting



Acetylene	Thickness		LPG
	300mm		
32C-A	200mm		32C-P
24C-A	125mm		24C-P
20C-A	80mm		20C-P
15C-A	40mm		15C-P
15C-A	20mm		15C-P
12C-A	10mm		12C-P
8C-A	5mm	6mm	8C-P
6C-A			6C-P

Not to scale

BOC Cutting Nozzles

BOC cutting nozzles are precision-machined and hand-finished to give a positive seat. The orifices are swaged to minimise gas turbulence and slag accumulation, while the nozzle design provides excellent gas-mixing for fast preheating. The smoother nozzle surface reflects heat and reduces spatter accumulation. Every nozzle is inspected and flame-tested at the point of manufacture.

BOC Flashback Arrestors

BOC Standard Flow Torch End Fuel FBA

BOC Standard Flow Torch End Oxygen FBA

BOC Cutting Attachment

The BOC Cutting Attachment provides a flip-back cutting lever that allows easy attachment of the blowpipe and replacement of cutting valve components. The rugged head design maintains stability when involved in harsh applications and the enhanced design reduces the potential of flashbacks.

Features

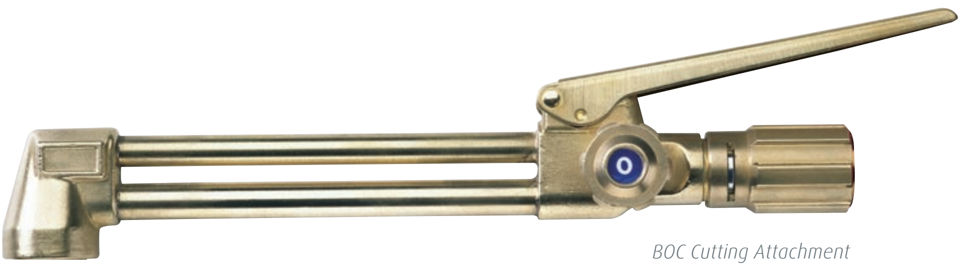
- Flip-back cutting lever that allows easy attachment of the blowpipe and replacement of cutting valve components
- Enhanced design that reduces the potential of flashbacks
- Rugged head design to maintain stability when involved in harsh applications

Cutting Nozzles

BOC 2 Seat Acetylene Cutting Nozzle

BOC 2 Seat LPG Cutting Nozzle

Size	Size
6C-A	6C-P
8C-A	8C-P
12C-A	12C-P
15C-A	15C-P
20C-A	20C-P
24C-A	24C-P
32C-A	32C-P



BOC Cutting Attachment

13.0 Oxy-fuel Cutting Procedures

Figure 10. Cutting attachment assembly.

13.1 Cutting Attachment Operation

The cutting torch assembly has 3 main parts; blowpipe handle, cutting attachment and cutting nozzle (figure 10). The blowpipe handle is the same as that used for welding with separate valves controlling the flow of acetylene and oxygen into the cutting attachment.

The cutting attachment separates the preheat gas mixture from the cutting oxygen flow. The cutting oxygen is controlled by a lever of the top of the cutting attachment. When this lever is depressed a high pressure flow of oxygen passes down the cutting nozzle onto the heated metal, thus producing the cutting action.

The mixture of oxygen and acetylene for the preheat flame passes down a separate passage to the cutting oxygen (figure 11).

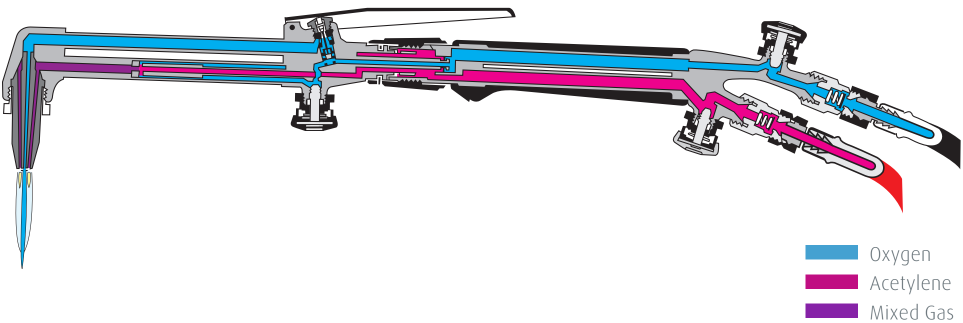


Figure 11. Gas flow through cutting attachment.

13.2 Setting Up

13.2.1

Check that the adjusting knobs are backed off on both regulators and then slowly open the cylinder valve for each gas. Too rapid an opening of the cylinder valve could damage the internal components of the regulator.

13.2.2

Set the working oxygen pressure with:

- the blowpipe oxygen valve fully open
- the heating oxygen control valve on the cutting attachment closed
- the cutting oxygen lever depressed

Release the cutting lever and set the working pressure for acetylene up to a maximum of 100Kpa. Purge each hose prior to lighting torch.

13.3 Lighting Up

13.3.1

Open the blowpipe acetylene valve slowly and ignite the nozzle with a flint lighter. Continue to open the valve until all soot disappears from the flame.

Caution: Do not use LPG cigarette lighters or matches.

13.3.2

Open the heating oxygen control valve on the cutting attachment until a neutral flame is obtained with the cutting lever depressed.

Oxidising flame

Neutral flame

Carburising flame

The cutting assembly is now ready for use. The oxygen valve on the blowpipe handle must be operated in the fully opened position when cutting with cutting attachment.

13.4 Closing Down

Closing down follows the same procedures as with welding.

13.4.1

Close the acetylene valve on the blowpipe first then the oxygen valve.

13.4.2

Close the cylinder valves. Drain the oxygen out of the system by opening the oxygen valve on the blowpipe. Depress the cutting oxygen lever. Then drain the acetylene from the system by opening the acetylene valve on the blowpipe.

13.4.3

Close the blowpipe and cutting attachment valve and back off both regulators fully.

14.0 Oxy-acetylene Cutting Techniques

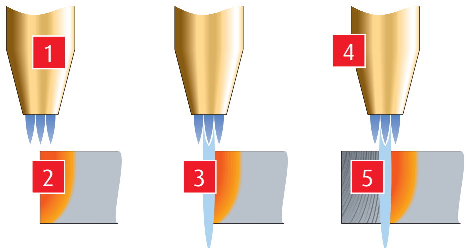
Flame cutting, oxy-fuel cutting, fuel gas cutting and oxygen cutting are terms that are generally used for the same process. Of all the terms used, oxygen cutting best describes how the process operates.

In oxygen cutting, the metal is heated to its ignition temperature and then a jet of pure oxygen is added, which reacts with the metal creating the cut.

14.1 How it Works

The oxygen cutting process can be considered as a combination of two distinct and separate processes. First the material to be cut must have its temperature increased to the point where it will burn in the presence of oxygen. This is called the ignition temperature of the steel. In oxygen cutting of steel, this is achieved by preheating a localised area until the metal reaches a bright cherry red heat at about 870–900°C.

1	Cutting oxygen nozzle
2	Heated steel
3	Cutting oxygen
4	Direction of cut
5	Steel



Schematic of the oxygen cutting process

At this point, a jet of cold oxygen is passed through the centre of the nozzle onto the red-hot steel. This causes a chemical reaction between the steel and the oxygen, generating more heat and melting the steel. This is called an exothermic reaction.

The steel immediately below the oxygen jet is converted to a metal oxide or slag, and is blown away by the jet. If the oxygen stream isn't powerful enough, or if the cutting speed is too quick, the slag will solidify in the cut, and a cut will not be achieved.

As the torch begins to move, more steel is preheated and the oxygen jet burns more of the steel, creating the cut.

Preheat Flame

The preheat flame is formed by the combustion of the preheat oxygen and the fuel gas combined either in the torch or the nozzle. It serves three purposes:

- It raises the metal to its ignition temperature.
- It counters heat losses due to conduction into the bulk metal.
- It shields the cutting oxygen from the effects of entrainment from the surrounding atmosphere.

Although the ignition temperature depends upon the material being cut, the choice of fuel gas has an effect on how quickly the flame will raise the material to the ignition temperature. The higher flame temperature of oxy-acetylene (3,160°C compared to 2,828°C for oxy-propane) will mean that if oxy-acetylene is used, then cutting would commence sooner than for oxy-propane. The thicker the material, the more pronounced this effect becomes.

As cutting begins, it is theoretically possible to turn off the preheat flame as the reaction of the oxygen and steel is exothermic, generating heat. In reality, heat is conducted away from the cut face by the material and the preheat flame is needed to counteract this effect.

The purity of the cutting oxygen stream is very important and the preheat flame acts as a barrier, keeping out the nitrogen in the atmosphere that would react with the cutting oxygen, producing oxides of nitrogen. Should these oxides be produced, they would reduce the cutting speeds and increase oxygen consumption.

15.0 Using the Cutting Assembly

Before attempting to cut, the plate should be cleaned of dirt, paint, grease, oil, mud, mill bloom or scale and rust with a stiff wire brush or by scaping. Mill scale can often be readily removed by running the preheating flame over the line of the cut.

Hold the inner cone of the preheating flame 3–5 mm above the edge of the plate until it is heated to a bright red colour. Start the cut at the edge of the plate, when practicable, or pierce, as required.

When cutting, the nozzle must be held at right angles to the work or inclined slightly forward in the direction of travel. The roller guide will assist the operator to maintain the working distance and angle of the torch.

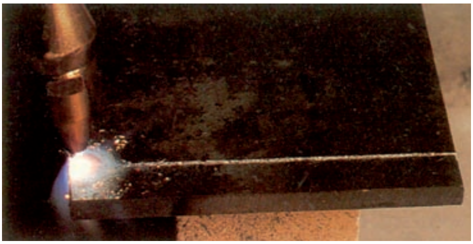


Figure 12. Starting a cut.

Then slowly depress the cutting lever to commence the flow of cutting oxygen. Move the torch forward at the rate indicated by the tables.

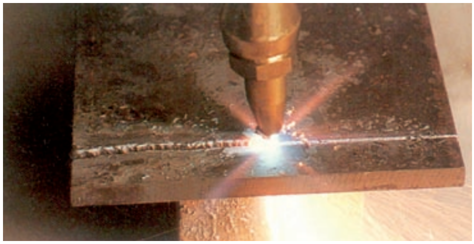


Figure 13. Cutting progression.

16.0 Mild Steel Cutting

The operator when cutting should stand in a comfortable position, with a clear view of the cut as it is being made. This will allow the operator to determine if a satisfactory cut is being made. The cutting assembly should be held with both hands to ensure control.

Cutting faults to look for are:

1 Too much oxygen will result in the cut widening out at the base of the kerf into a bell shape.

2 Too quick a movement will produce incomplete penetration.

3 Too slow a movement will melt and round the top edge, gouge the lower half of the cut and cause excessive slag adhesion on the underside.

4 Tip too high above plate can cause the top edge to undercut.

5 Tip too close to plate surface can melt top edge of cut section.

16.1 Thin Steel

To cut thin steel, 6 mm or less, the smallest standard nozzle available is required or special sheet metal nozzles indicated by "SM" stamped on them are available. The SM nozzle for example is designed to cut sheet metal as thin as 1mm. Holding the cutting torch at a steep angle to the plate will increase the section of the cut, thus assisting to produce a clean acceptable finish.

16.2 Thick Steel

The nozzle must be held at right angles to the metal for thick steel. If the cut can not be started easily at the edge of the metal in the way described above, the operator may try to start by holding the torch at an angle opposite the direction of travel.

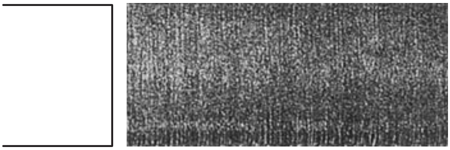
Alternatively a small slot can be cut out of the bottom edge of material. As the corner is cut, the operator moves the torch to a vertical position until the total thickness is cut and then the cut may proceed. When circular flanges, or sections, are to be cut in heavy material drilling a small diameter hole (4 mm) will greatly assist the process.

Nozzle Type	Material thickness mm	Oyxgen pressure kPa	Fuel gas pressure kPa
S/M	Up to 3mm	150	15

17.0 Good and Bad Cuts

17.1 Correct Conditions

The very light dragline should be almost vertical for profile cutting. For straight cutting, a drag of up to 10 percent would be permissible.



Sharp top edges, smooth surface, draglines barely visible. A very light scale of oxide easily removed. Square face. Sharp bottom removed.

17.2 Common Faults

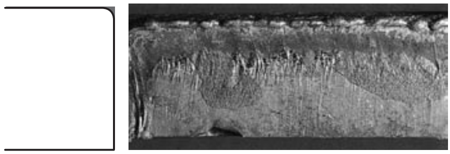
Speed too slow

Bad gouging in the lower half of the cut is caused by molten steel scouring the cut surface, and the hot metal and slag that congeals on the underside is always difficult to remove. Secondary cause of this condition is too low oxygen pressure.

Melted and rounded top edge. Lower part of cut face fluted or gouged very irregularly. Bottom edge rough. Heavy scale on cut face that is difficult to remove.

Nozzle too low

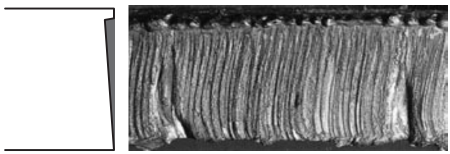
Having the nozzle too low does not usually spoil the cut surface badly, but it does of course badly burn the top corner. Very often it retards the oxidation reaction and makes it appear that the cut has been done too slowly.



Top edge slightly rounded and heavily beaded. Cut face usually square with fairly sharp bottom corner.

Preheat flame too large

This is the easiest and most obvious condition to correct, which (provided other conditions are correct) usually gives a fairly clean, although excessively oxidised cut face, but with a heavy rounding at the top edge.



Rounded top edge with metal falling into kerf. Cut face generally smooth, but tapered from top to bottom. Excessive, tightly adhering slag.

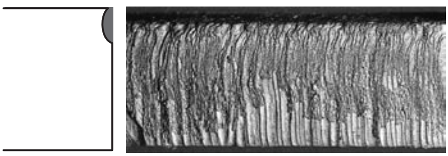
Nozzle too high above work

The melting of the top edge is due to heat spread each side of the cut and the undercutting is caused by the oxygen stream being above the work, so that it spreads and tends to 'bell-out' as it transverses down the kerf.

Excessive melting and rounding of the top edge. Undercut at top of cut face with lower part square and sharp bottom corner.

Pressure of cutting oxygen too high

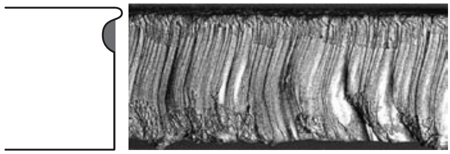
This is probably the most common fault in cutting that causes the rounding of the top part of the cut face. It is caused by the turbulence of the oxygen stream due to the high pressure at which it leaves the nozzle. On thinner material it may cause a taper cut that sometimes leads to the incorrect supposition that the cutter is incorrectly mounted in relation to the plate.



Regular bead along the top edge. Kerf wider at top edge with undercutting of face just below.

Speed too fast

The excessive backward drag of the cut line would result in the cut not being completely severed at the end. The occasional gouging or fluting along the cut indicates that the oxygen pressure is too low for a normal speed. In other words, if the speed was dropped and the oxygen pressure maintained, a perfectly good cut would result.



Top edge not too sharp and may be bearded. Undercutting at top of the cut face. Draglines have excessive backward drag. Slightly rounded bottom edge.

Acetylene and LPG are the most commonly used fuel gases for the cutting of mild steel. Prior to attempting to cut, the material should be cleaned with a stiff wire brush to remove dirt and scale. With correct gas pressures, nozzle size, cutting torch angle and speed, the quality of freehand cutting depends upon the steadiness of the operator.

18.0 Other Cutting Plant Applications

A number of processes are available to the oxy-acetylene cutting operator to suit particular applications.

18.1 Flame Gouging

This process allows the operator to use the oxy-acetylene cutting torch to create U-shaped grooves. The process is particularly useful for removing welds from metal for demolition or rewelding. The process is also used to remove surplus metal.

In order to successfully gouge, gouging nozzles are required and often a high pressure oxygen regulator, capable of delivery up to 650 Kpa (refer to the gouging nozzle, pressure selection chart below). These nozzles are designed so the cutting oxygen has a much lower velocity than with cutting nozzles.

Hence the oxygen orifice is much larger in a gouging nozzle than in a cutting nozzle.

Nozzle size mm	Groove width mm	Oxygen pressure kPa	Acetylene pressure kPa
13	8	400	50
19	11	500	50
25	13	550	55

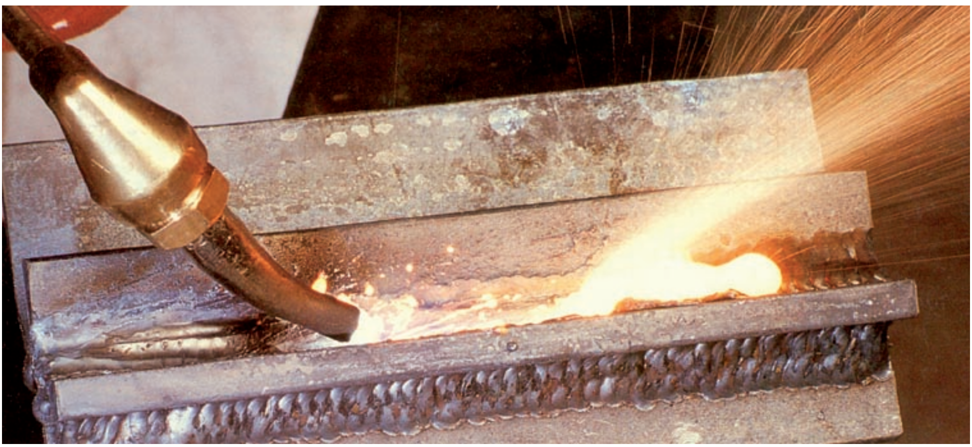


Figure 14. Oxy-acetylene gouging application

18.2 Straight Line and Bevel Cutting

A roller guide is a good way of obtaining a clean cut requiring minimum finishing. With acetylene as the fuel gas a stand off distance of 4-6 mm will give the best results. Generally speaking, some extra preheat will greatly facilitate straight line cutting.

The angle of the nozzle determines the angle of the bevel cut. The thickness of the metal to be cut is greater than if the cut was square. Accordingly the cutting speed needs to be decreased and the oxygen pressure increased or a large nozzle used. Hence the depth of metal cut rather than plate thickness is used to determine the correct nozzle, oxygen, pressure and speed.

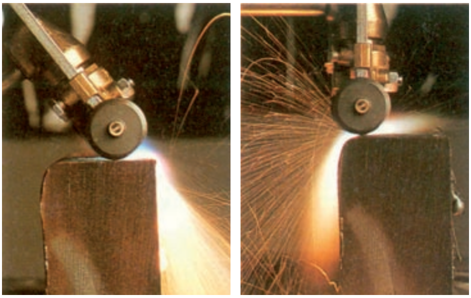


Figure 15. Cutting thick steel using a roller guide.

18.3 Piercing and Cutting Holes

Piercing is used to produce a relatively small hole and to assist in preventing plate distortion whilst cutting. Excellent results can be achieved with oxy-acetylene.

The steel is preheated to a bright cherry red (about 760°C). When this temperature is reached, the oxygen jet may be turned on very slowly. At the same time the nozzle should be raised enough to prevent slag being blown back into the nozzle (about 12 mm) (figure 16). A large centre punch mark will also assist the piercing operation, as the top edges of the mark will readily melt.

The nozzle is held at right angles and about 6 mm from the surface so the inner cones almost touch the surface.

To cut larger holes the circle is first drawn in chalk and then the operator pierces or drills a hole inside this line. The cut is moved from the hole up to the line and then follows the line to produce a clean freehand cut. However for an accurate cut a radius arm attached to the nozzle is recommended (figure 17).

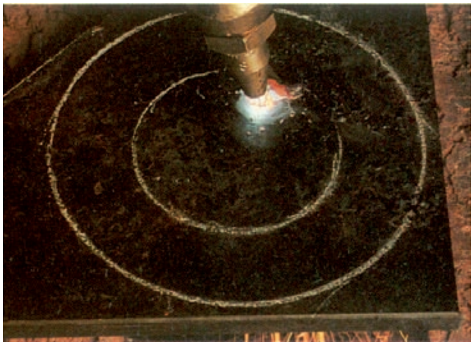


Figure 16. Piercing a hole.

Figure 17. Circle cutting.

19.0 Nozzle Data Section

19.1 BOC Welding Tips

For use with W Mixer (BOC Blowpipe)

Tip	Plate (mm)	DA (kPa)	Oxy (kPa)	DA (L/min)	Oxy (L/min)
6W-A	0.5–0.8	50	50	1.5	1.5
8W-A	0.8–1.0	50	50	2	2
10W-A	1.0–1.5	50	50	3	3
12W-A	1.6–2.4	50	50	4	4
15W-A	2.5–3.5	50	50	7	7
20W-A	4.0–6.5	50	50	12	12
26W-A	6.5–8.0	50	50	22	22

19.2 BOC 2 Seat Oxy-Acetylene Cutting Nozzles

Nozzle	Plate (mm)	DA (kPa)	Oxy (kPa)	Speed (mm/min)	DA (L/min)	Oxy (L/min)
6C-A	1–5	100	180	450	2	11
8C-A	6–10	100	200	400	3	20
12C-A	12–20	100	220	350	4	40
15C-A	25–40	100	250	300	6	60
15C-A	50–80	100	350	220	7	80
20C-A	100–125	100	400	150	10	150
24C-A	150–200	100	500	120	13	260
32C-A	200–300	100	600	100	45	420

19.3 BOC 2 Seat Oxy-LPG Cutting Nozzles

Description	Plate (mm)	LPG (kPa)	Oxy (kPa)	LPG (L/min)	Oxy (L/min)
6C-P	3–6	100	200	2	18
8C-P	6–10	100	200	3.5	30
12C-P	10–20	100	250	4.5	58
15C-P	20–40	100	400	5.5	100
15C-P	40–80	100	400	6	120
20C-P	80–125	100	400	6.5	171
24C-P	125–200	100	500	9	256
32C-P	200–300	100	600	14	450

19.4 BOC 3 Seat Oxy-Acetylene Cutting Nozzles

For use with Universal Cutter

Description	Plate (mm)	DA (kPa)	Oxy (kPa)	DA (L/min)	Oxy (L/min)
ANM 8	4–6	15	150	8	8
ANM 12	6–12	15	200	9	10
ANM 16	12–25	15	250	10	13
ANM 16	25–50	20	300	11	13
ANM 16	50–75	20	350	11	14
ANM 20	75–100	30	300	13	20
ANM 24	100–150	30	300	16	25
ANM 32	150–250	35	450	20	26
ANM 32	250–300	45	550	23	28

19.5 BOC 3 Seat Oxy-LPG Cutting Nozzles

For use with Universal Cutter

Description	Plate (mm)	LPG (kPa)	Oxy (kPa)	LPG (L/min)	Oxy (L/min)
PNM 8	4–6	20	150	5	22
PNM 12	6–12	20	200	5	24
PNM 16	12–25	20	300	10	41
PNM 16	25–50	30	300	12	43
PNM 16	50–75	35	350	15	50
PNM 20	75–100	40	350	17	59
PNM 24	100–150	40	400	17	60
PNM 32	150–250	50	560	18	66
PNM 32	250–300	60	560	19	72

20.1 Equipment Care

As specified in AS 4839-2001 "The Safe use of Portable and Mobile Oxy-Fuel Systems for Welding, Cutting, Heating and Allied Processes".

Equipment	Maintenance		
	Weekly (if in constant use) or before every use (to be performed by the operator)	As nominated (to be carried out by a technically competent person)	Refurbishment or replacement intervals (equipment condition determines whether refurbishment or replacement is required.)
1. Regulators (including their integral protective devices)	According to the manufacturer's instructions including – visual examination to determine suitability for service (eg. gas, pressure rating, damage); condition of threads and sealing surfaces; and oil or grease contamination. Leak test all joints at working pressure.	Six monthly: Functional test to ensure the correct operation of internal components.	Manufacturer or supplier recommendation, but not exceeding five years.*
2. Flashback arrestors and other external devices (including non-return valves)	Visual examination to determine suitability for service (eg. gas, pressure rating, damage); condition of threads and sealing surfaces; and oil or grease contamination. Leak test all joints at working pressure.	Yearly as detailed in AS 4603 or following a flashback: Proper functioning of the non-return valves and flashback arrestors. For pressure-activated valves, check that there is no flow in the normal direction with the valve tripped.	Manufacturer or supplier recommendation, but not exceeding five years.*

Equipment	Maintenance		
	Weekly (if in constant use) or before every use (to be performed by the operator)	As nominated (to be carried out by a technically competent person)	Refurbishment or replacement intervals (equipment condition determines whether refurbishment or replacement is required.)
3. Hose assemblies	Visual examination to determine suitability for service (eg. gas, pressure rating, damage); condition of cover; and threads and sealing surfaces of the end fittings. Leak test all joints at working pressure.	Six monthly: Check for absence of cuts and excessive wear by bending the hose in a tight radius, to ensure reinforcement is not visible.	Determined by the hose assembly condition.
4. Blowpipes, mixers and attachments	Visual examination for damage of the threads and sealing surfaces of the hose connections and the attachment connections. Leak test all joints at working pressure.	Six monthly: Test control valve function. Blank the attachment connections and leak test for internal malfunction.	Manufacturer or supplier recommendation, but not exceeding five years.*

**Regulator elastomers and seals will wear and deteriorate in service and deteriorate out of service. Items stored for one year or over without use should receive inspection as per the annual maintenance inspection.*

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