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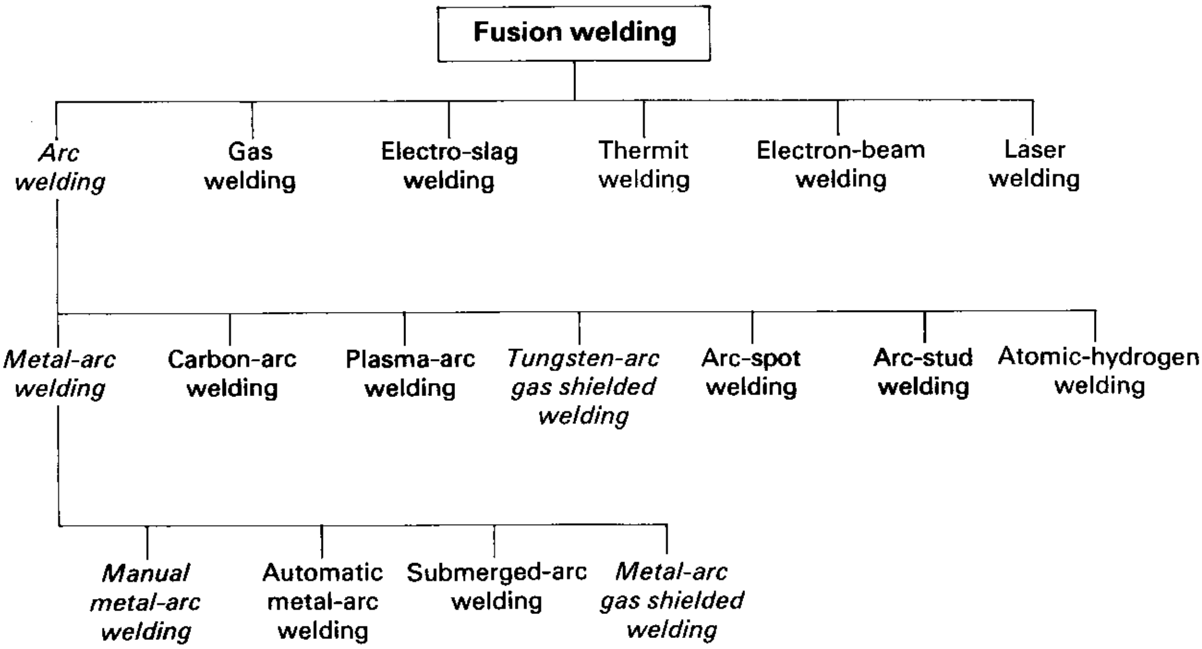
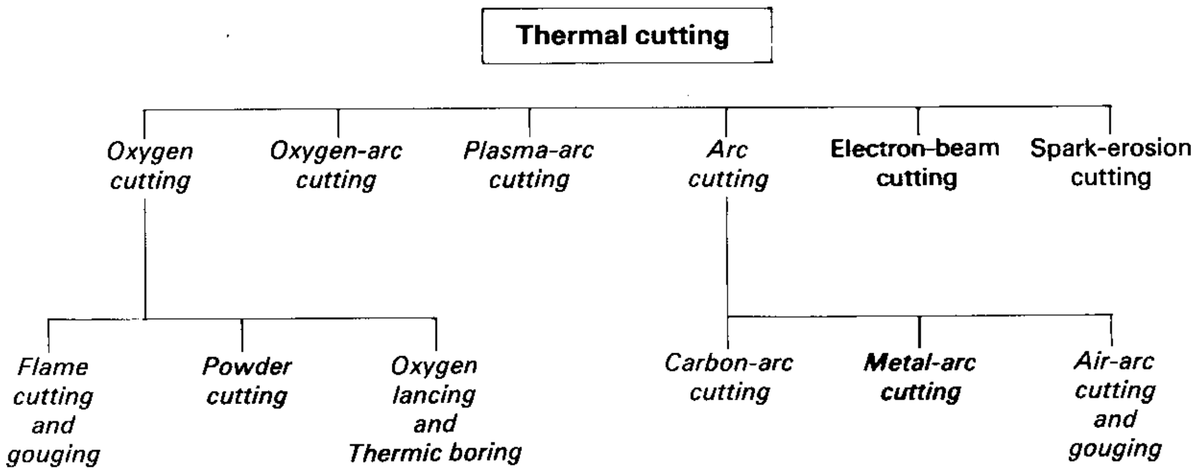
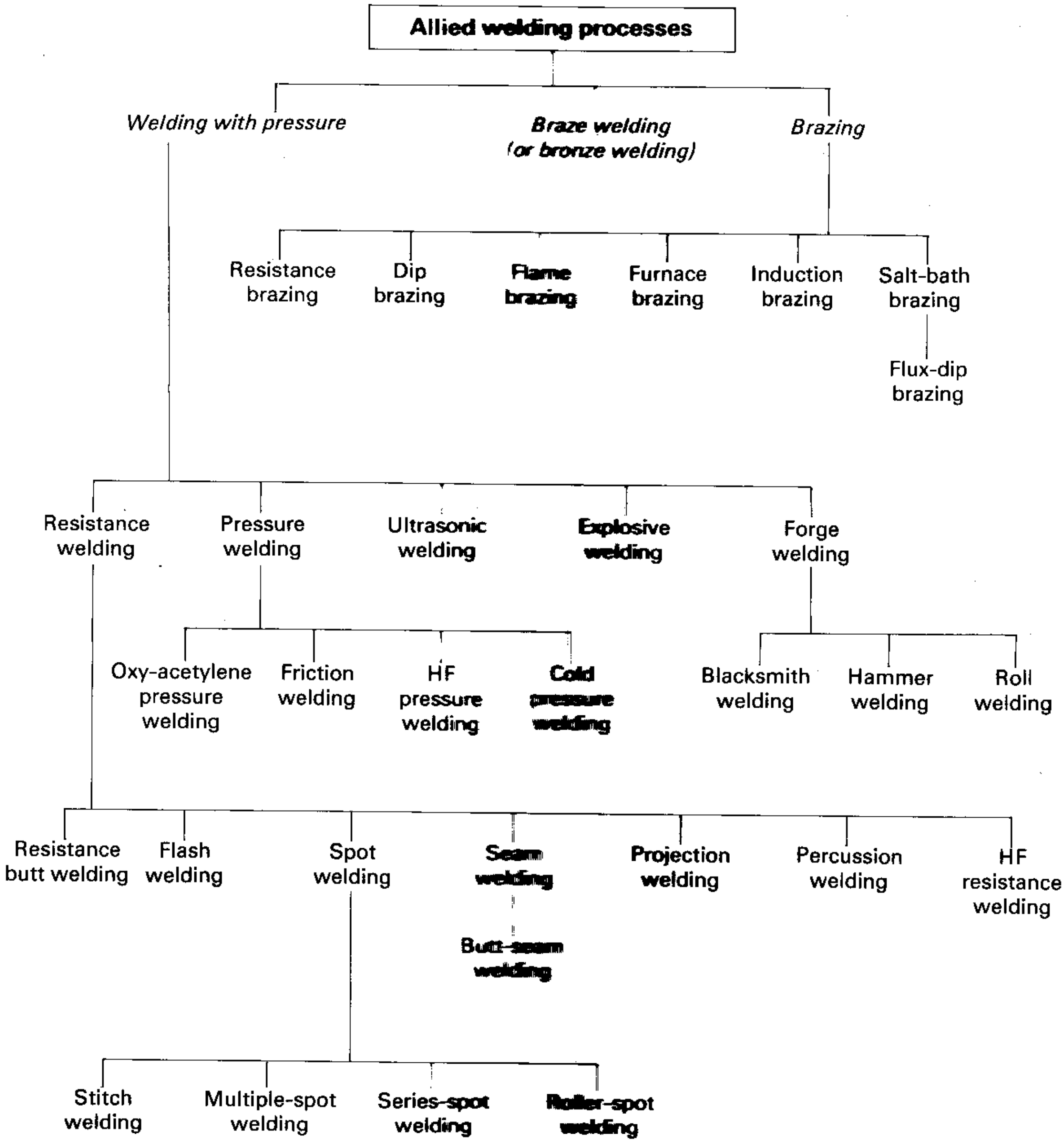
Welding and cutting processes





The fusion welding and thermal cutting processes dealt with in the training for Craftsman Welders are shown in italics

Welding and cutting processes



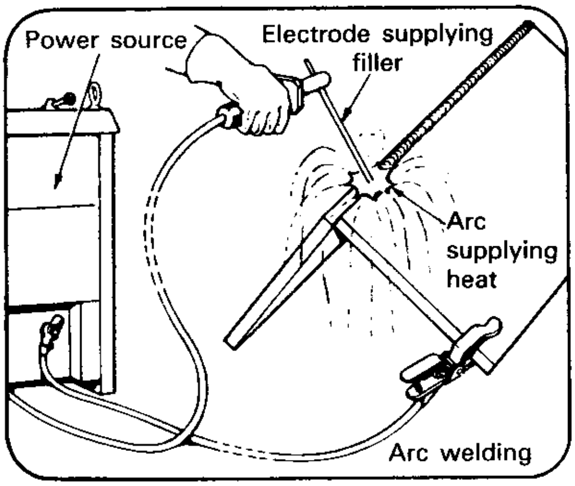
The above chart lists other methods of industrial importance for joining metals. Of these processes, braze welding is the only one dealt with in the training for Craftsman Welders.

Other joining methods of industrial importance include soldering, usually with lead-tin alloy solders, and adhesive bonding using a synthetic resin which solidifies by polymerization.

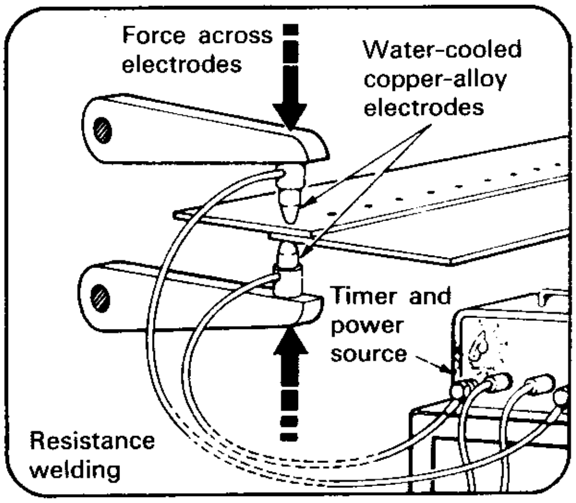
Welding and cutting processes

Methods of joining materials

Methods of joining other than by mechanical means or adhesive bonding, fall into four categories:

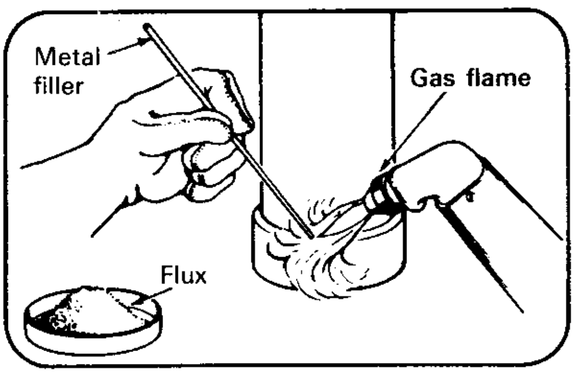


1. Fusion welding
The edges or surfaces of the parts to be joined are fused, with or without the addition of molten filler metal and without the application of pressure.
eg. arc welding, gas welding.



2. Resistance welding
The edges or surfaces of the parts to be joined are fused locally, usually under pressure but without the addition of filler metal.
eg. spot welding, flash welding.

3. Forge or pressure welding
The edges or surfaces of the parts are joined together by force or pressure, usually with the application of heat but without any melting of the metal being joined.
eg. blacksmith welding, friction welding.

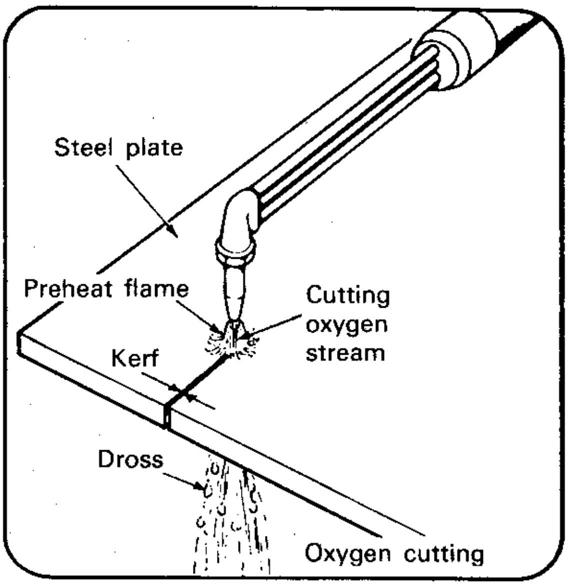


4. Soldering and brazing
The edges or surfaces of the parts to be joined are brought into contact, heated but not melted, and molten filler metal added. The filler metal fills the space between the adjacent parts.

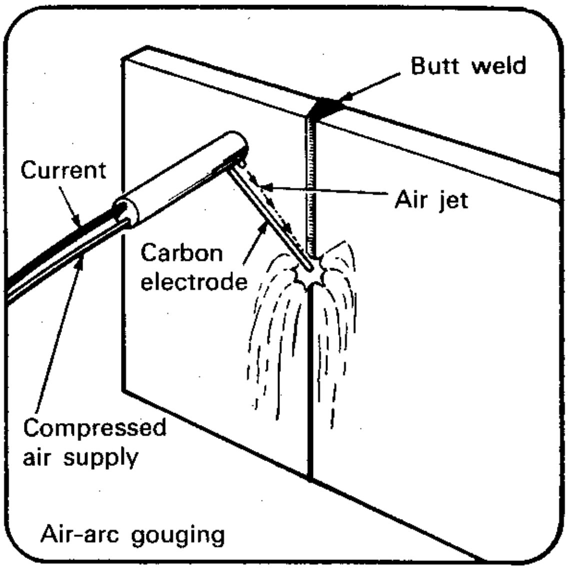
Welding and cutting processes

Cutting and gouging

The following processes are used for cutting and gouging material to size and shape and for the preparation of edges for welding.

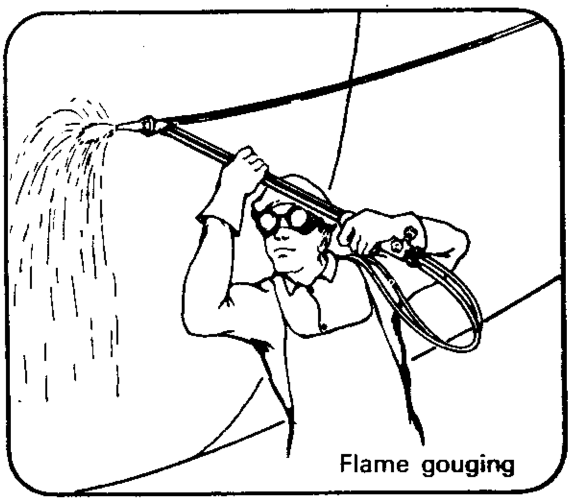


1. (a) Oxygen cutting
The material is cut by a jet of oxygen after it has been raised to ignition temperature by heat from a gas flame, eg. oxygen with acetylene or propane.



(b) Powder cutting
A suitable powder is injected into the cutting (oxygen) stream to assist the cutting action.

2. Arc cutting
The material is cut by melting, using the heat of an arc.

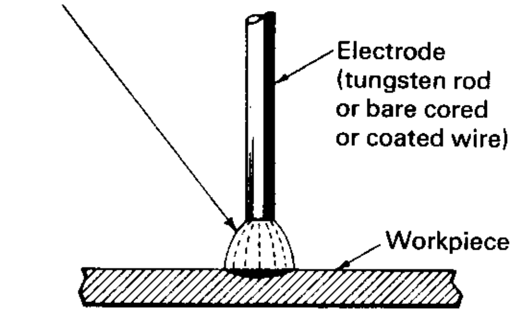


3. Gouging
This is the forming of a groove in metal by means of thermal cutting. Used for the back grooving of welds and removing defective metal.

Welding and cutting processes

Heat sources

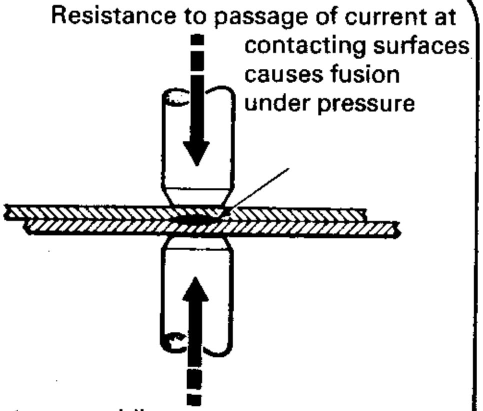
Four sources of heat area used in welding and cutting processes—electrical, high energy beam, chemical and mechanical (eg. frictional).



Electric-arc welding

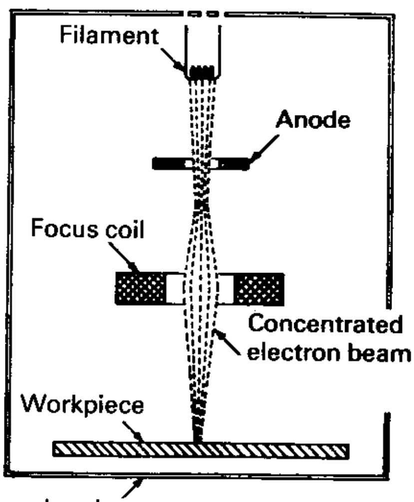
1. Electrical
The electric arc is a source of concentrated heat.

The temperature of the arc depends upon the nature of the electrodes and the arc current.



Resistance welding

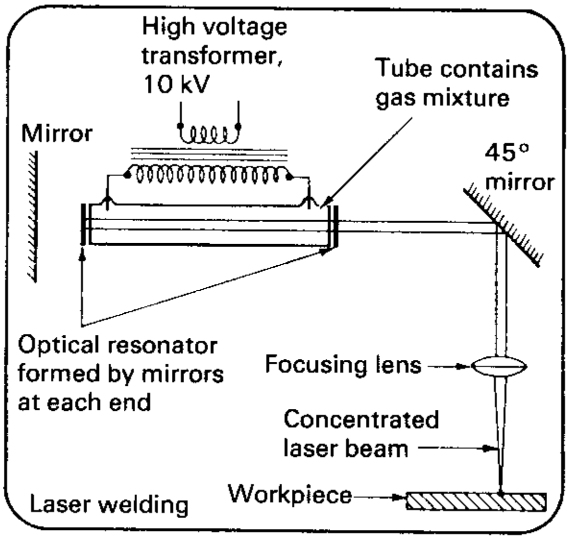
In resistance welding processes, heat is produced by the electrical resistance at the contacting surfaces of the material.



Electron-beam welding

2. (a) High energy beam
In electron-beam welding and cutting, heat is produced by a beam of electrons.

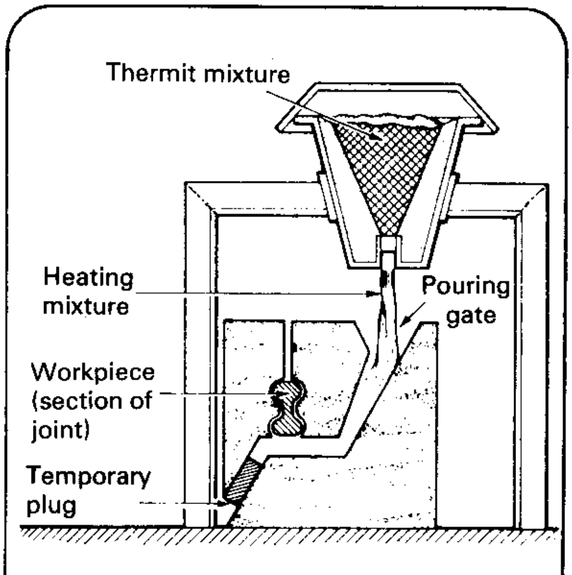
The focussing of the electron beam on to the workpiece is done within a vacuum chamber.



Laser welding

(b) Light radiation

In Laser welding the energy of light is concentrated to become a heat source.



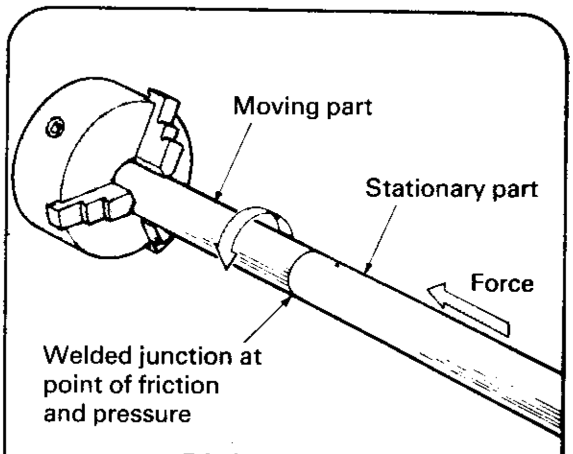
Thermit welding

3. Chemical

Flame welding and cutting processes use fuel gases to burn with oxygen.

Most commonly used fuel gases are acetylene for welding and cutting and propane for pre-heating and cutting.

In Thermit welding, chemical reaction occurs between aluminium powder and iron oxide powder to produce heat.



Friction welding

4. Mechanical

In the friction welding process two rubbing surfaces are pressed together by a force.

Friction creates heat energy until the welding temperature is reached.

In ultrasonic welding, mechanical vibrations of the contacting parts clamped together cause a weld to be made.

In explosive welding, an explosive charge is used to force two parts together with sufficient impact to cause heating and bonding of the surfaces.

Safe operation of equipment

Gas supply

(a) High pressure gas supply
In modern practice it is normal to use a high-pressure supply in the form of dissolved acetylene from cylinders.

(b) Medium and low pressure gas supplies
Acetylene may be produced on site by the action of water and calcium carbide.

Acetylene generating plants
Strict safety precautions are necessary when operating acetylene generating plants. Fully comply with the manufacturer's instructions. The storage and use of calcium carbide must be strictly controlled, in accordance with Local Authority requirements.

Particular attention must be paid to the following safety aspects:

1. Handle and store gas cylinders with care.
(a) Ensure that there are no gas leaks.

(b) Do not allow any flame near cylinder walls.

(c) Avoid oil or grease in contact with cylinder valves or fittings.

(d) Close cylinder valves when not in use.

(e) Ensure that you are fully conversant with the method of valve operation for all types of cylinders in use.

Fire precaution
Keep fuel gas cylinder valve key readily available so that gas supply can be turned off immediately. (Ensure you know the direction in which to turn the cylinder key.) Fireproof gauntlet gloves should be available at all times.

2. Avoid welding hazards.
(a) Wear appropriate goggles fitted with correct filter glass.

(b) Wear suitable clothing (buttoned to the neck), together with a leather apron, and cover the arms.

(c) Protect the hands and where practicable wear suitable gloves or gauntlets.

(d) Protect other persons from glare, using appropriate screening.

3. Avoid operational hazards.
(a) Place material in a safe position where it cannot fall, cause burning or injury to other persons.

(b) Wear goggles when removing scale or flux residue. Ensure adequate protection of persons in the vicinity.

(c) Wherever possible, a helmet or similar form of head protector should be worn as a safeguard against hazards from protruding or falling objects.

4. Avoid lifting and handling hazards.
(a) Seek assistance before lifting heavy objects. Use appropriate lifting equipment and ensure that correct lifting practice is followed.

(b) Use trolleys of sound construction and adequate capacity to move components.

(c) Secure loads, when transporting on trolleys.

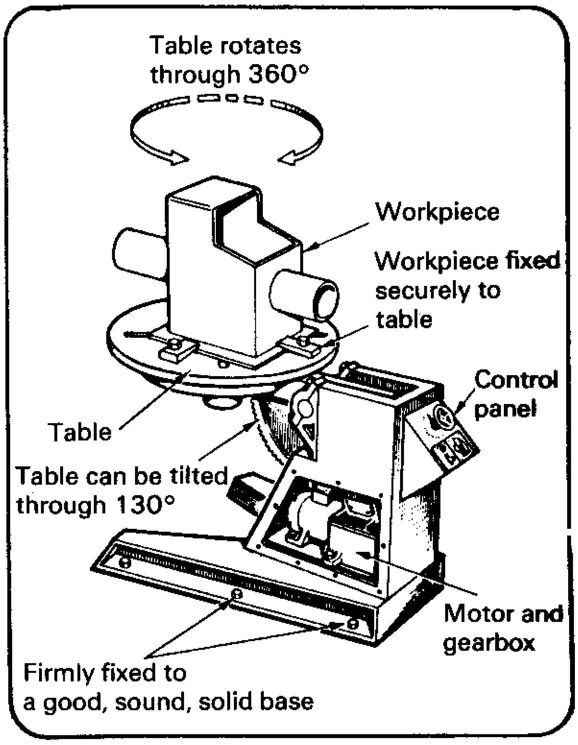
(d) Ensure that only competent persons operate lifting equipment. Consider possible danger to persons in the vicinity.

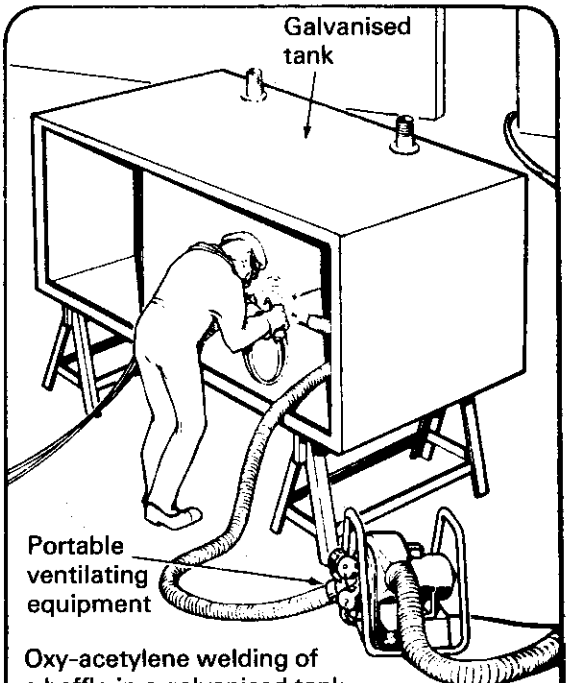
(e) Know the safe working load (SWL) of lifting equipment in use. NEVER EXCEED IT.

(f) Protect both the lifting equipment (slings) and the load to be lifted from damage.

Lifting appliances must be operated by competent persons.

Safe operation of equipment





Oxy-acetylene welding of a baffle in a galvanised tank

Safety

Before commencing welding in any areas where fumes are likely to constitute a hazard, refer to your Safety Officer.

5. Avoid manipulation hazards.

(a) Ensure components, placed in or on a fixture, positioner or welding manipulator are adequately secured.

(b) Secure manipulators firmly on a solid foundation.

(c) Securely fix components or fixtures on the manipulator table.

(d) Ensure the safe working load (SWL) of a manipulator is never exceeded, and that the fixture or component is located to maintain an even balance.

Safety

Manipulators vary in methods of construction, capacity and operation. Always refer to maker's instruction book.

6. Avoid hazards from fumes.

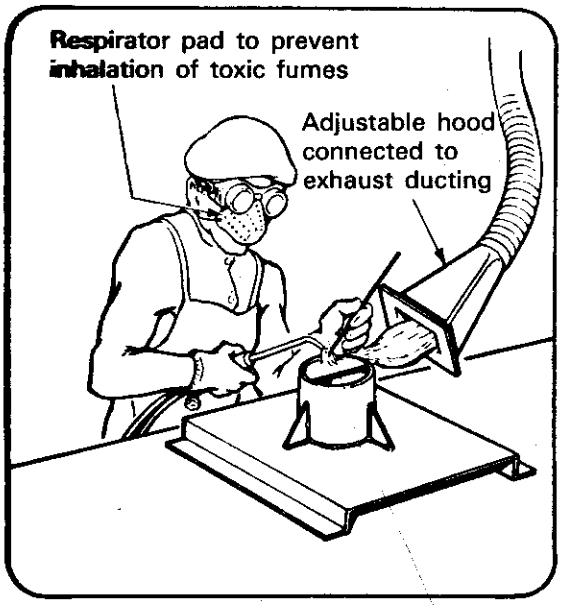
(These include poisoning and asphyxiation.)

(a) Ensure adequate ventilation in areas where welding is carried out. At all times take particular care especially when:

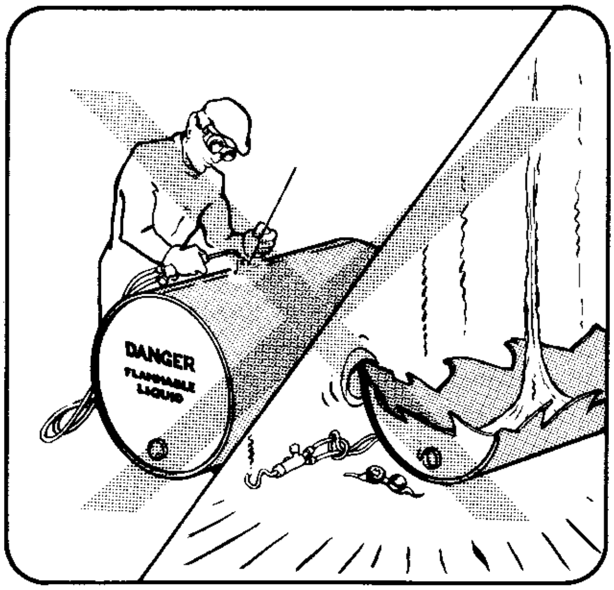
(i) welding in a confined space, especially in tubes, boilers and containers.

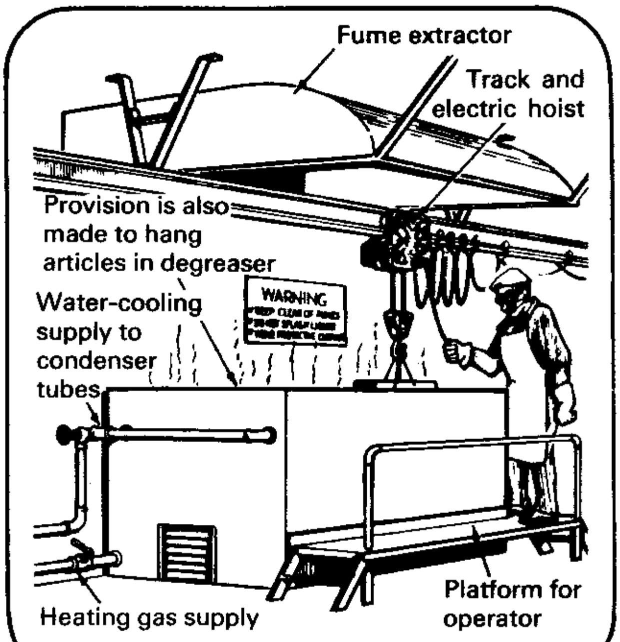
(ii) welding galvanized material or when welding materials which give rise to toxic fumes.

(b) Wear a face respirator where toxic fumes may be present.



Safety
Never use an oxygen supply as a substitute for compressed air or as normal ventilation.
When using compressed air for ventilation, never direct on to the skin or clothes or inhale it. Do not use compressed air in the vicinity of oxygen otherwise oil in the line will create an explosive hazard.





Trichlorethylene degreaser

(c) Ensure that all motors and drive shafts and fan blades on ventilation equipment are fully guarded. Inlet ducting must be constructed with mesh guards at the inlet points and discharge must be arranged to avoid hazard to other people.
(d) Use filters in ventilation systems and ensure that these are cleaned out at regular intervals.
(e) Ensure that compressed air equipment is regularly inspected by competent persons, use only approved hose, free from defects, and ensure that there are no leaks—compressed air is expensive.
Always purge the system of all oil and water in airlines at least daily.

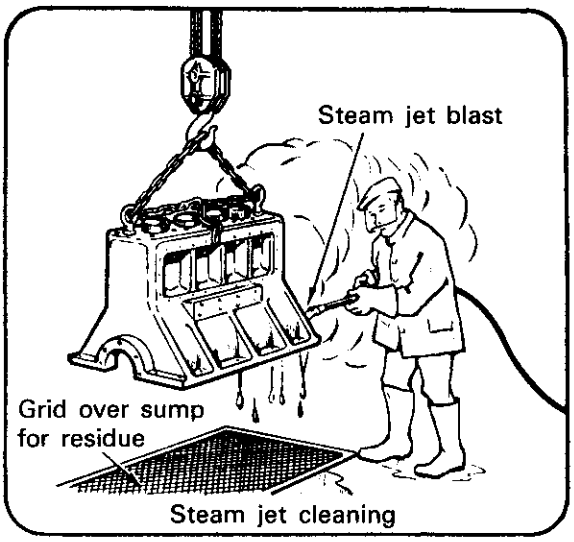
Safety
Never weld a vessel or drum that has contained flammable or toxic substance until it has been thoroughly cleaned and made safe by an appropriate process.

7. Avoid hazards when degreasing components.
Degreasing processes in regular use include:
(a) Chemical process using solvents.
(b) Steam process.
(c) Use of a cleaning solution.

Chemical solvent process
It is normal to use either carbon tetrachloride or trichlorethylene both of which release toxic gases when heated.

Safety
Observe great care when using this process.
(i) Do not inhale fumes. Do not smoke.
(ii) Protect the eyes and skin. Use a barrier-cream and wear protective gloves.
(iii) Observe the supplier's instructions.
(iv) Ensure adequate ventilation.
(v) Do not use in the vicinity of welding operations.

Safe operation of equipment



Steam process
Oil and grease are removed as a result of the component being heated by low-pressure steam.

> **Safety**
>
> (i) Wear suitable protective clothing.
> (ii) Avoid contact with the steam jet.
> (iii) Ensure adequate drainage in the area of operation.
> (iv) Ensure persons in the area are warned of the hazard.
> (v) Ensure the use of a low-pressure steam jet.

Use of cleansing solutions
These include paraffin, thinners, turpentine, petrol to break down the oil or grease barrier, alkaline or detergent solution.

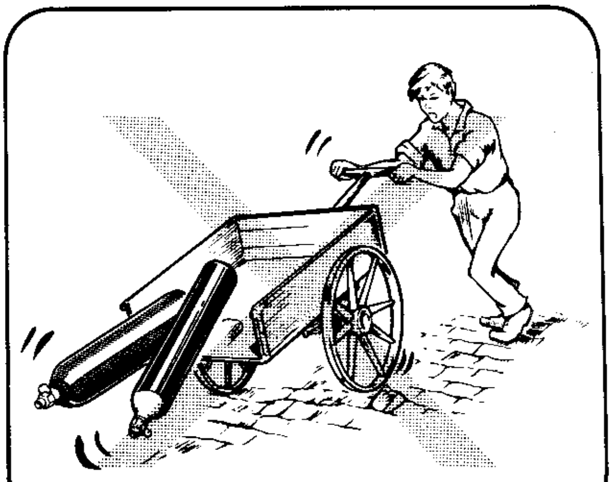
> **Safety**
>
> When using cleansing solutions take great care.
> (i) Do not use in the presence of naked light.
> (ii) ALWAYS ensure adequate ventilation. Wash both hands and components (to remove all residue) by immersing, washing or spraying with water.
> (iii) Do not permit caustic soda to come in contact with trichlorethylene.
> Avoid danger of fumes from pre-heating appliances, ensure adequate ventilation.
> Ensure that suitable fire extinguishing equipment is readily available. Make yourself familiar with the equipment and know when and how to use it, especially on electrical equipment.

8. Avoid hazards in the use of pre-heating appliances.
(a) Do not use a pre-heating appliance in a confined space or in an area where there is any fire risk unless special precautions have been taken.
(b) Do not leave heating appliances unattended as the flame may be extinguished whilst gas escapes.
(c) Before lighting any heating appliance, make sure that the atmosphere is free from escaping and flammable gases.
(d) Always display a prominent notice that:
(i) An appliance is in use.
(ii) Components are hot and dangerous to touch.

General note
Reference should be made to the relevant chapters of the following Safety, Health and Welfare Booklets published by the Health and Safety Executive:
1. New Series No. 32—Repair of drums and tanks: Explosion and Fire Risk.
2. SHW. 1704—Safety measures required in the use of acetylene gas and in oxy-acetylene processes in factories.
3. New Series No. 38—Electric arc welding.

> **Important**
>
> Attention is drawn to the colour coding for Electrical Wiring. Brown is connected to the Live supply, Blue to the Neutral, and **Green/Yellow to the Earth connection** of an electrical circuit.

Safety—Oxy-acetylene welding and cutting

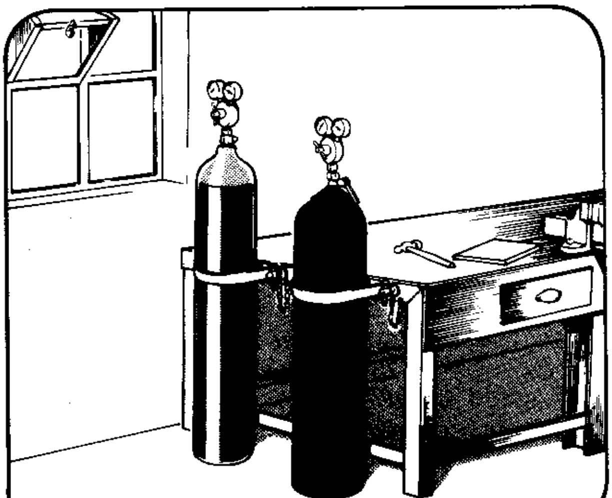


Handle cylinders carefully!

Gas cylinders

Gas cylinders are recognized by a colour code.
1. Oxygen: Black 2. Acetylene: Maroon.
Store oxygen and fuel gas cylinders apart.
Handle cylinders carefully. Take care that they are not dropped or allowed to fall from a height. Cylinders should be used in an upright position and fastened to prevent them falling or being knocked over.

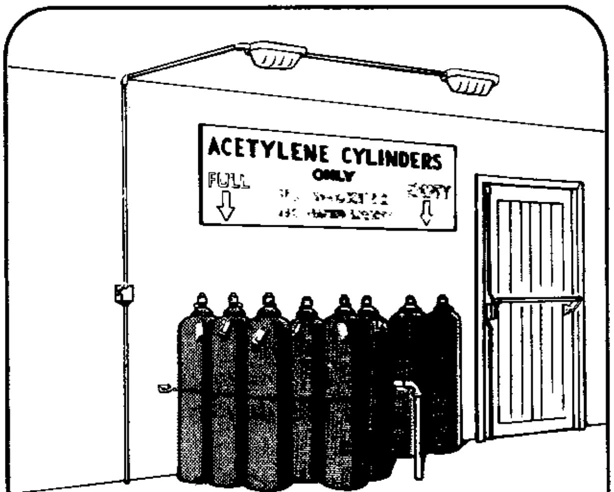
Accidental 'arcing' on cylinders may create a serious hazard.
Do not allow any flame near cylinder walls.
Do not allow any electric arc welding to be undertaken in the immediate vicinity.



Make sure cylinders are secure

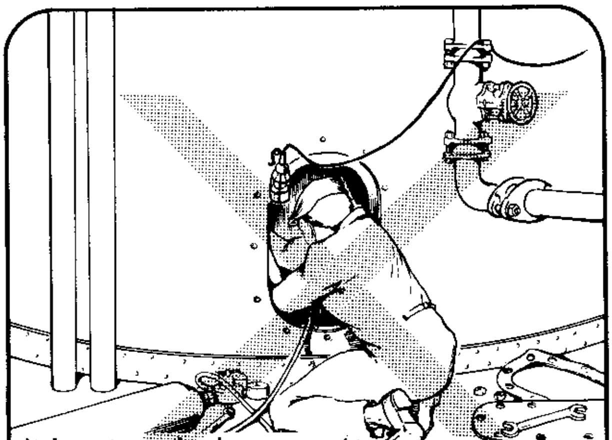
> If fire breaks out try to remove all gas cylinders to a safe place.

Fuel gas cylinders
Close cylinder valve when not in use.
If gas leaks when valve is closed:
1. Move the cylinder into the open, and away from electric motors and sources of sparks or heat.
2. Forbid smoking or naked lights.
3. Ensure suppliers are advised immediately.



Store acetylene cylinders in a cool dry place away from heat and direct sunlight.
Do not mix with oxygen cylinders.
Switches and lamps must be flameproof.

> Acetylene and other fuel gases are highly flammable and form explosive mixtures with air and oxygen. **Fuel gas leaks are a source of fire risk.**



It is extremely dangerous to ventilate an enclosed space with oxygen, or to inhale it directly from the cylinder

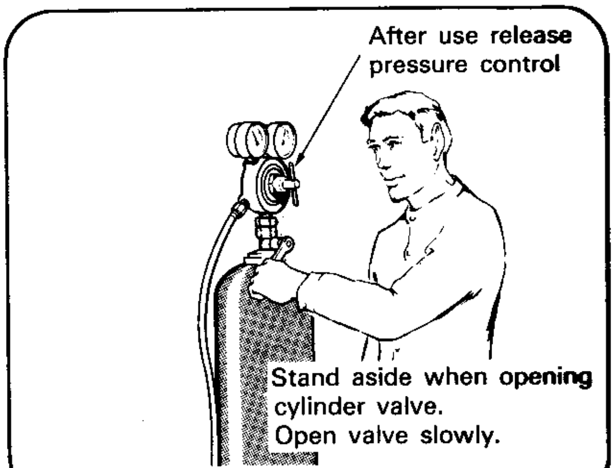
Oxygen cylinders

1. Do not inhale oxygen from the cylinder.
2. Do not use it as a method of ventilation.
3. Do not allow it to leak.
4. Do not use oxygen as a substitute for compressed air.

In an oxygen-enriched atmosphere, clothing and any combustible material can be ignited easily by a spark and will burn fiercely.

Never weld a vessel or drum that has contained flammable or toxic substance until it has been thoroughly cleaned and made safe by an appropriate process (See H.M. Factory Inspectorate Form 814).
When using compressed air for ventilation never direct on to the skin or clothes or inhale it. Do not use compressed air in the vicinity of oxygen because oil in the line may create an explosive hazard.

Never allow oil or grease to be on cylinder valves or cylinder fittings. **Oxygen reacts explosively with oil or grease.**

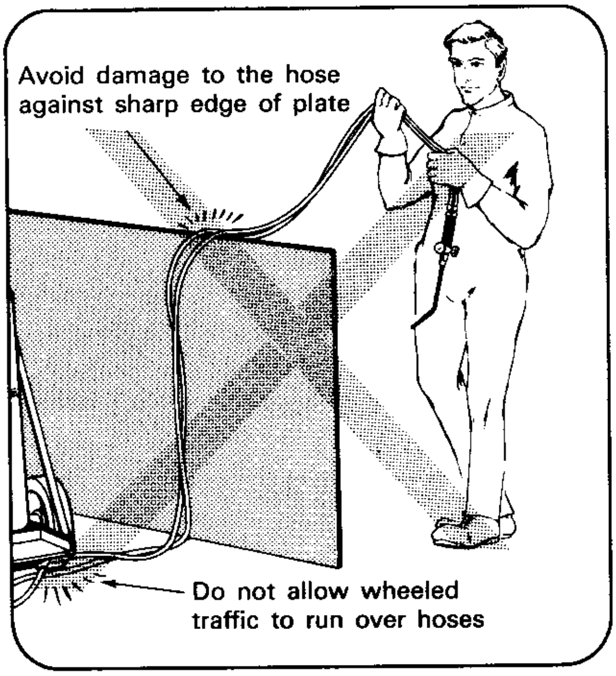


Use sound regulators and gauges

Regulators

Do not use regulators with broken gauges.
Do not stand in front of gauge faces when opening cylinder valve.

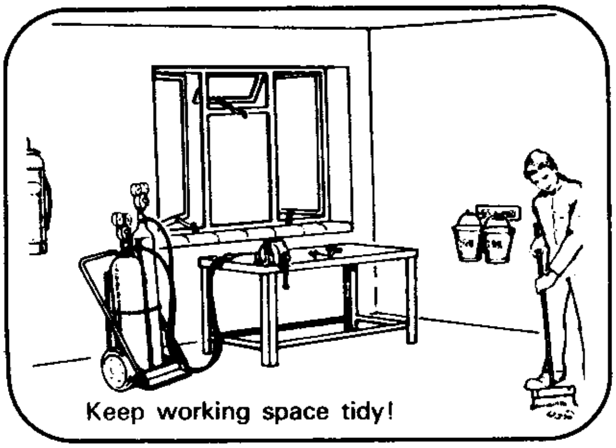
Select the correct regulator for the gas being used.
Do not use:
(a) Low-pressure regulator on dissolved acetylene cylinders.
(b) Dissolved acetylene regulator on hydrogen cylinders.
(c) Compressed air regulator on oxygen cylinder.



Hoses

Use only pressure type rubber canvas hose in good condition and fitted with the correct type of connections.
Do not allow hoses to 'kink' or tangle and thus obstruct the gas flow.
Keep hoses clear of abrasive surfaces, sharp edges, and hot metal.
Do not allow traffic to pass over them.

> Do not pass oxygen through hose previously used with compressed air. Use the correct fittings to join lengths of hose or when repairing damaged hose. Never use copper pipe on acetylene hose connections.



Working area

Welding and cutting should be performed in areas free from fire risk.
Wooden floors should be covered with non-combustible material and kept clean and free from litter within 10 m of welding and cutting operations.

Lighting blowpipes
Spark lighters are recommended. Do not use methods involving fire risk.

Ventilation
Ensure there is thorough natural ventilation during welding and cutting operations.
Do not allow fuel gases to leak into the atmosphere.

Cutting
Dross must be caught in a metal receptacle.
Ensure material being cut is adequately supported and that the discard cannot fall and cause personal injury.

Safety—Oxy-acetylene welding and cutting

> Ensure that suitable fire extinguishing equipment, including buckets of dry sand, is readily available and maintained in good condition.

Flashbacks and gas cylinder fires

If 'backfire' is arrested at the blowpipe mixer or injector no damage will occur, provided the blowpipe valves are closed promptly.

Outward signs of a severe flashback include:

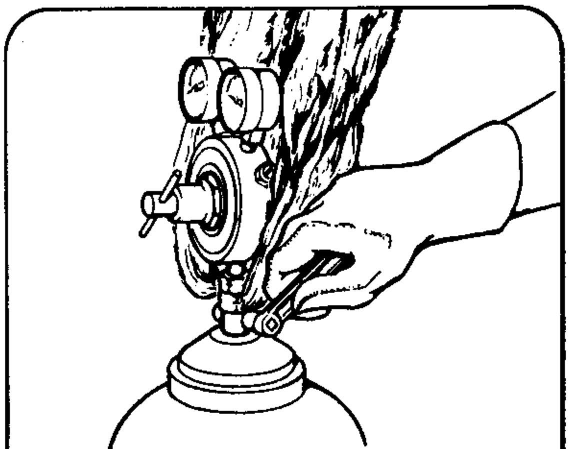
A squealing or hissing noise; heavy black smoke; sparks coming out of nozzle; blowpipe handle overheating.

In such cases:

1. Turn off cylinder valves.
2. Detach regulators and equipment from cylinders.
3. Check hoses and blowpipe for damage before re-use.

When gas from the cylinder catches fire at the valve or regulator because of leakage at the connection:

1. Close the cylinder valve. Wear asbestos gauntlet gloves for this operation.
2. Make the leaky joint gas-tight before further use.

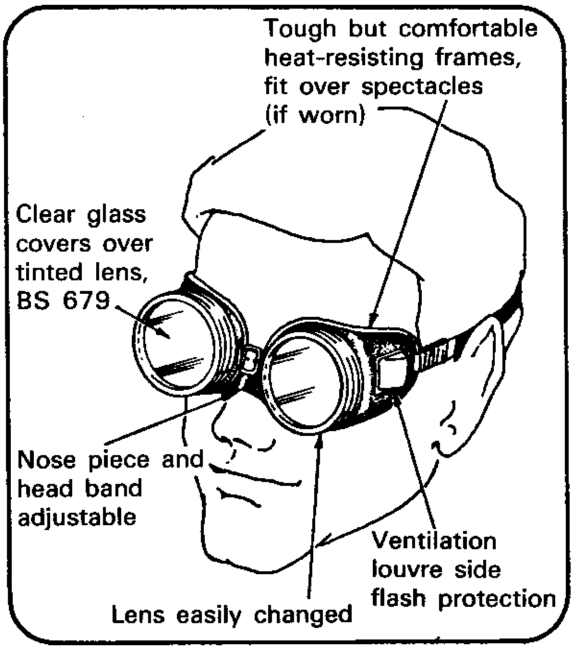


Fuel gas leaks are dangerous

If cylinder becomes overheated or if fire prevents immediate closing of valve:

1. Extinguish the flame by using a Carbon Dioxide fire extinguisher or by smothering with an asbestos blanket.
2. Remove the cylinder to open space; forbid smoking or naked lights in the vicinity.
3. Cool cylinder by spraying it with water.
4. Advise the suppliers immediately.

> **Fire precaution**
>
> Keep fuel gas cylinder valve key readily available so that gas supply can be turned off immediately.
>
> Fireproof gauntlet gloves should be available at all times.



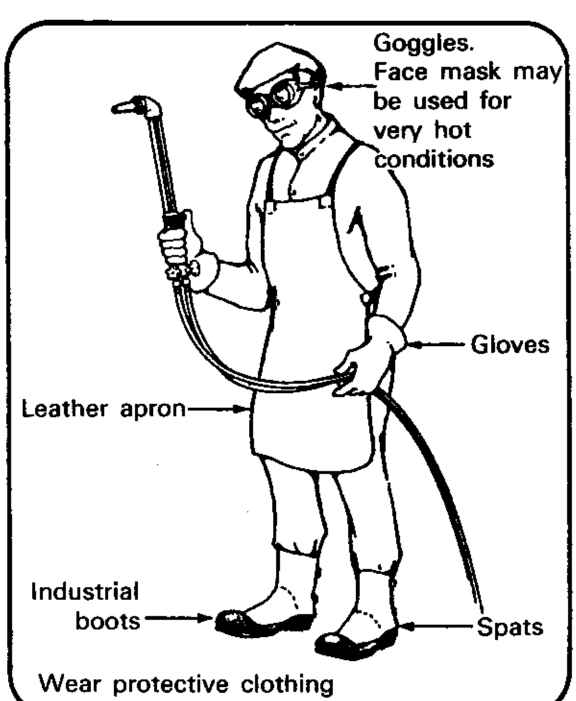
Protective equipment

The eyes must be protected from heat and glare, and from particles of hot metal or scale.

Goggles

These should be fitted with an approved lens.
Use:
Shade 4 G.W. for light work
Shade 6 G.W. for heavier work.

Lens supplied for gas welding and cutting operations must not be used for arc welding and cutting.



Protective clothing

Normal dress

The outer clothing should be free from oil, grease or flammable substances. Cuffs on overalls, and turn-ups on trousers, are possible lodging places for sparks or globules of hot metal.

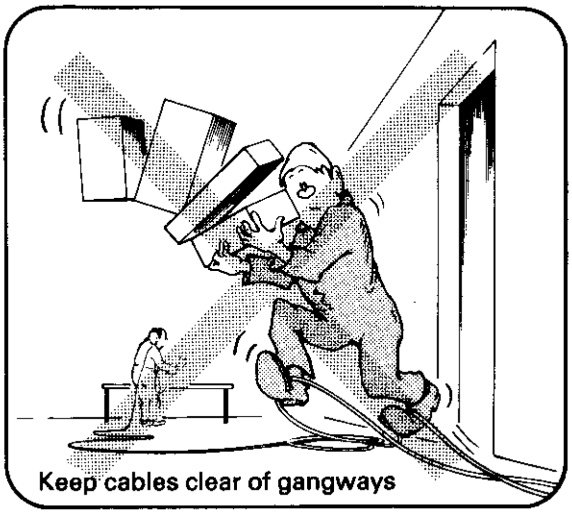
Special protection

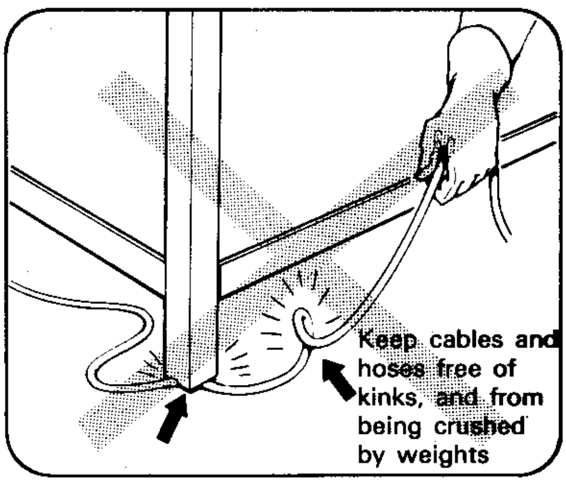
The protective clothing worn depends upon the nature of the work. Safety boots and protective spats should be worn when doing cutting work.

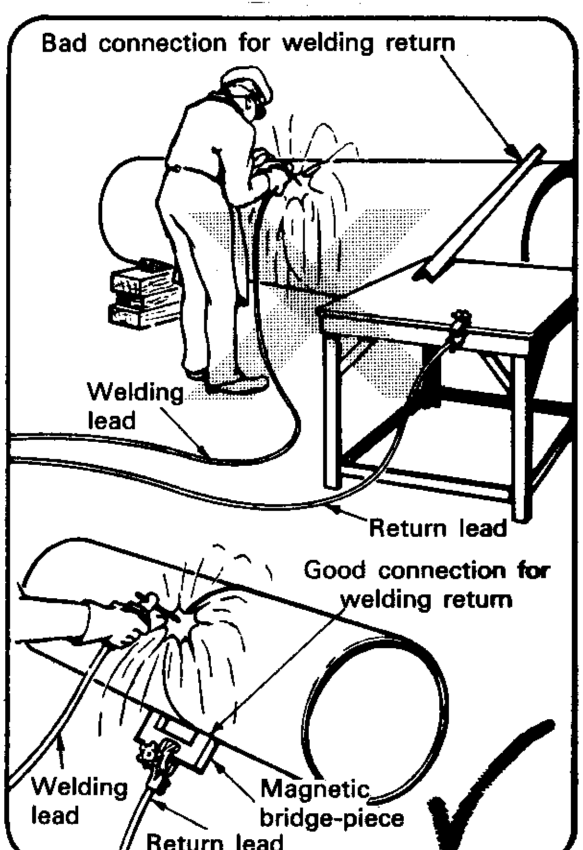
Leather gloves should be worn for all cutting operations involving the handling of hot metal.

Gauntlet gloves and leather apron should be worn when welding, especially when working in the vertical and overhead positions.

Safety—Arc welding and cutting







Power sources

Make sure that they are correctly connected to the appropriate mains supply and adequately earthed. Seek the advice and assistance of competent persons.
Switch off mains supply to power source when work is finished.

Cables

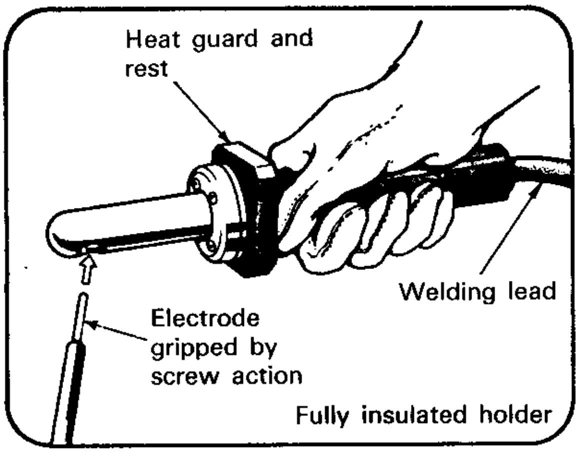
Keep cables clear of ladders, gangways, and doors.
Do not allow traffic to pass over cables.
Disconnect from power source before joining any cables. Never use damaged cables.

Hoses

Keep hoses clear of ladders, gangways, and doors.
Do not allow traffic to pass over hoses.
Ensure hoses do not become tangled, keep them clear of abrasive surfaces, sharp edges, and hot metal.
Ensure hoses and connections are leak-proof especially when water cooling is used near electrical circuits.
Makeshift repairs to damaged hoses, using rubber patches or self-adhesive tape, are a source of danger.

Leads

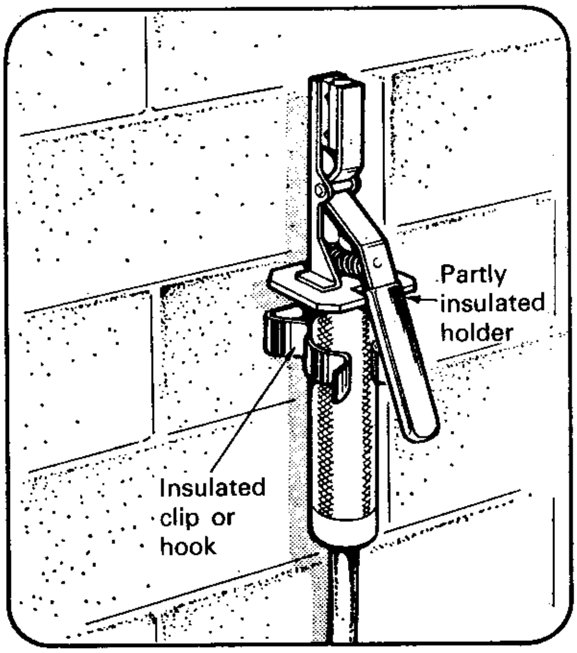
Avoid hazards due to inefficient earthing of electrical equipment and the welding circuit.
(a) Ensure that only competent persons connect the power source to the appropriate mains supply.
(b) All welding return leads must be securely connected by bolting or clamping to prevent contact resistance or arcing.
(c) Welding return leads must have ample current carrying capacity and always be kept as short as possible.
(d) Do not wrap welding return leads around components, work table, scaffolding, or other metallic objects.
(e) Do not attach welding return leads to manipulators or fixtures unless these are specially designed for this purpose. Always attach the welding return lead to the components to be welded.



Fully insulated holder

Electrode holders

Use a fully insulated holder when:
(a) welding in a confined space
(b) there is difficulty of access to the weld because of the proximity of metal parts
(c) welding a steel which may be hardened by accidental 'arcing'.



When using a partly insulated holder avoid contact with metal parts causing 'stray flashes'. When the holder (torch or gun) is not being used place it securely on an insulated hook. Do not dip hot electrode holders in water.

> When equipment requires to be paralleled to increase the current available it is essential to use the correct procedure for inter-connecting the power sources.

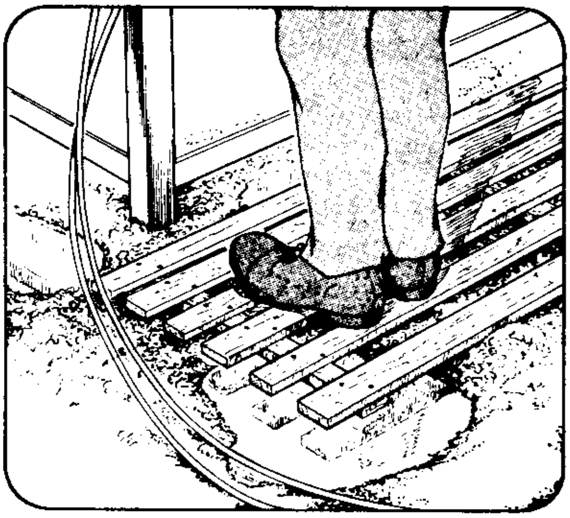
General safety precautions and fire prevention measures

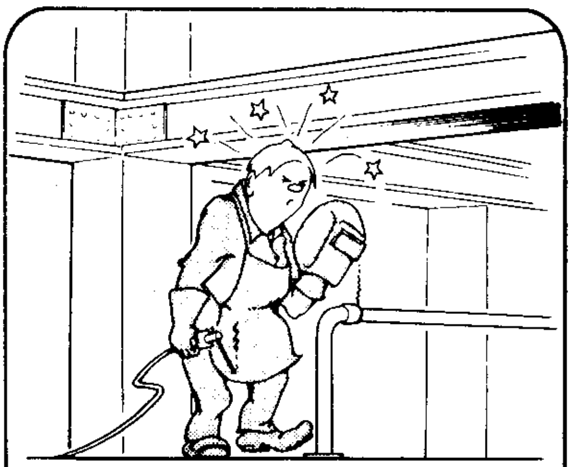
Gas cylinders
Do not allow them to be in contact with cables and keep cylinders away from arc welding and cutting operations whenever possible.

Note: See additional precautions as detailed on pages 20 to 23.

Working area
Keep the working area tidy and free from flammable material.
When cutting material make sure that the detached portion cannot fall and cause personal injury.
Beware of the danger from beads of hot metal when arc cutting.

> Ensure suitable fire extinguishing equipment is readily available and maintained in good condition.





Beware of obstructions

Site conditions

Stand on a dry wooden floor or duck board and/or wear rubber boots.

Take care when working in congested conditions or on staging. Beware of slippery and unsound surfaces.

Ventilation

Ventilation means the removal of dangerous fumes and/or gases and replacing them with FRESH AIR.

Dangerous fumes are:

(1) Those evolving from fluxes and/or the metal being worked upon.

(2) The product of the combustion of fuel gases in the flame processes.

Gases used in confined spaces can become hazardous and include:

(1) Shielding gases used in TAGS, MAGS and Automatic Welding.

(2) Nitrogen.

The above are dangerous because they replace the normal atmosphere and in a confined space they may cause asphyxiation. They may also be toxic.

(3) Common Fuel Gases:

Acetylene, Liquid Petroleum Gases, Hydrogen, Town Gas, Natural Gas.

These are dangerous when combined with air because they can cause explosions or fires in addition to replacing the atmosphere and causing asphyxiation and may be toxic.

Oxygen

Increases the rate of burning of combustibles to a very violent rate.

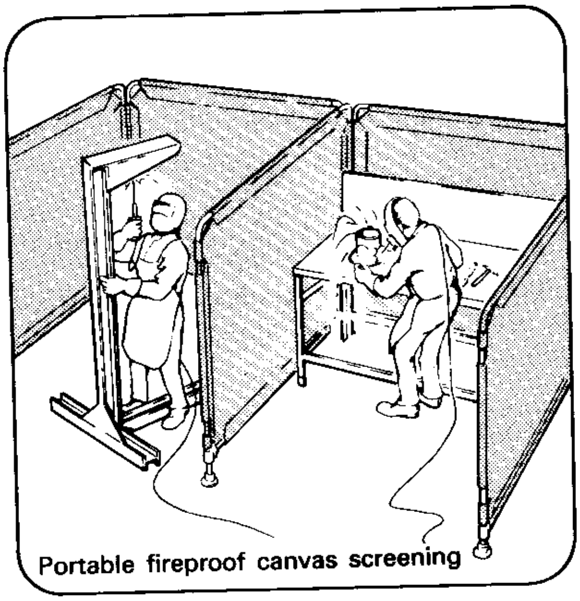
An increase of only 5% to 10% above normal is sufficient to make clothing burn fiercely.

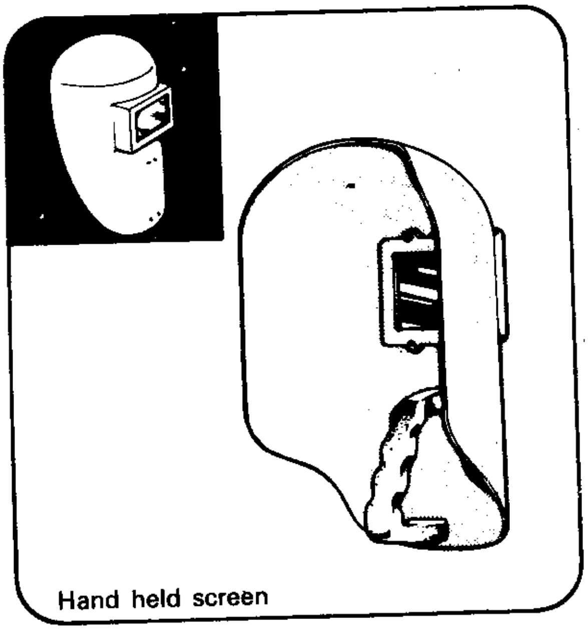
Always ventilate with fresh air. Supplement natural air movement with fans if necessary.

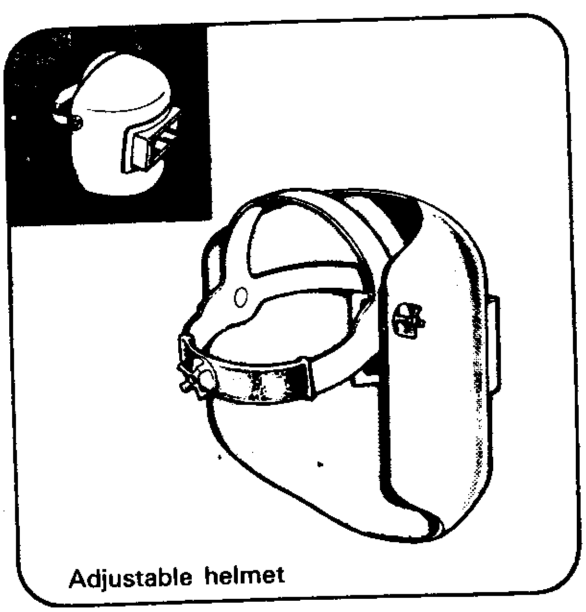
> **Never** use oxygen in place of air for power tools or ventilation.

> Never weld a vessel or drum that has contained flammable or toxic substance until it has been thoroughly cleaned and made safe by an appropriate process (See H.M. Factory Inspectorate Form 814).
>
> Never use an oxygen supply as a substitute for compressed air or as normal ventilation.
>
> When using compressed air for ventilation never direct on to the skin or clothes or inhale it. Do not use compressed air in the vicinity of oxygen because oil in the line may create an explosive hazard.

Safety—Arc welding and cutting


Portable fireproof canvas screening


Hand held screen


Adjustable helmet

Protective equipment
Avoid exposure of yourself and others to the heat and light radiations of the welding arc.

Note: Radiation includes invisible ultra-violet and infra-red rays.

Screening—General
Screen arc-welding and cutting operations so that persons who work in the vicinity are protected from 'flashes'.

Arc eye
It is not unusual for irritation and watering of the eyes to start some hours after exposure to arc rays.
When symptoms occur:
1. Use an eye bath to wash the eyes with an approved eye lotion.
2. Repeat at about four-hourly intervals.
3. In the meantime, cold compresses, made by soaking cotton wool in cold water (which has been boiled previously), may be applied.
4. If going into bright light, dark glasses should be worn.
5. Report to the first aid room as soon as possible.

> If recovery from 'Arc eye' is not complete in 36 to 48 hours, medical advice must be sought.

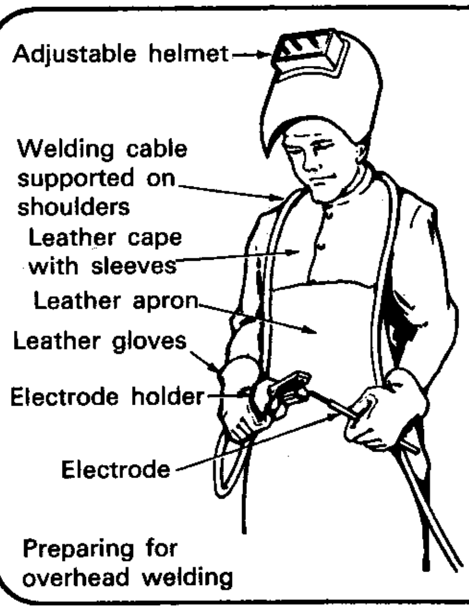
Screening—Personal
For most operations a hand held screen made of lightweight, insulating, and non reflecting material can be used. It must have an approved 'filter glass'.
Goggles alone do not give adequate protection for arc-welding and cutting operations.
Make sure that the screen is of a size and shape to shield the face, throat, wrist, and hand.
Where it is necessary to protect the head or to have both hands free a helmet type screen fitted with an approved filter should be used.

Protective filters
Filter glasses are expensive. Protect them from damage when not in use.

Recommended filters for electric welding

BS 679 Shade	Tungsten-arc gas shielded welding	Metal-arc gas shielded welding	Manual metal-arc welding
8EW			Up to 100 amps
9EW	15– 75 amps		Up to 100 amps
10EW	75–100 amps	Up to 200 amps	100–300 amps
11EW	100–200 amps	Up to 200 amps	100–300 amps
12EW	200–250 amps	Over 200 amps	Over 300 amps
13EW	250–300 amps	Over 200 amps	Over 300 amps
14EW	250–300 amps	Over 200 amps	Over 300 amps

Where two or more shade numbers are recommended for a particular process and current range, the higher shade numbers should be used for welding in dark surroundings and the lower shade numbers for welding in bright daylight out of doors.



Preparing for overhead welding

Protective clothing
Normal dress
Outer clothing should be free from oil, grease or flammable substances. Protect the forearms from exposure to arc rays; do not roll up sleeves.
Cuffs on overalls, turn-ups on trousers, exposed long hair and low-cut shoes are likely lodging places for sparks or globules of hot metal and slag.

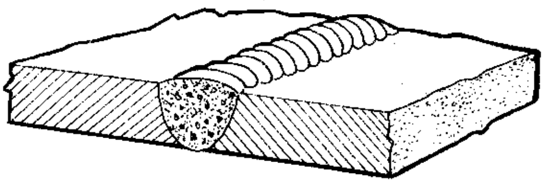
Special protection
Protect the front of the body from the throat to the knees with suitable leather cape and apron. If only an apron is worn this must provide full protection.
Wear suitable leather gloves to protect the wrists and hands.

Terminology

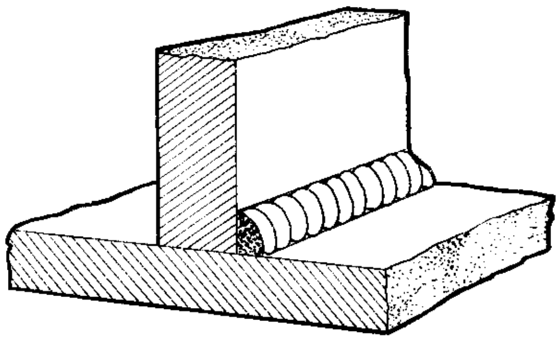
Welds and joints

Frequently the terms 'weld' and 'joint' are used incorrectly. Exact definitions are given in BSS 499–'Welding Terms and Symbols'. Examples are given below.

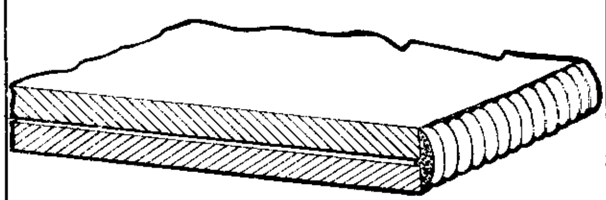
Types of weld



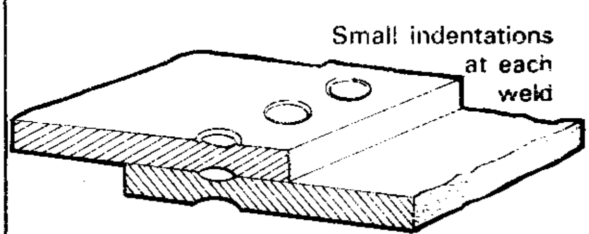
Butt weld



Fillet weld



Edge weld



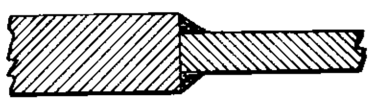
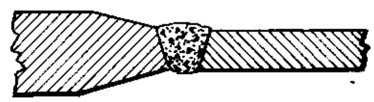
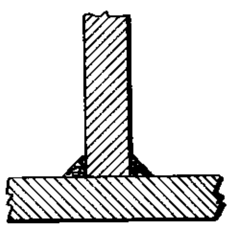
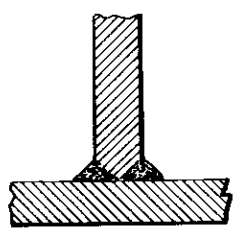
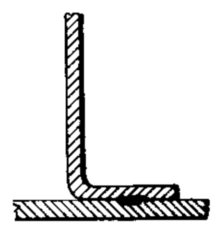
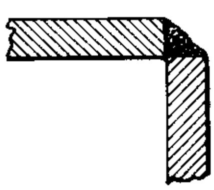
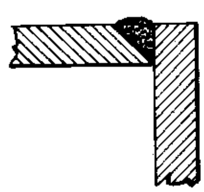
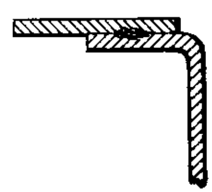
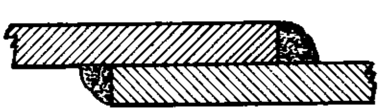
Section through resistance spot weld

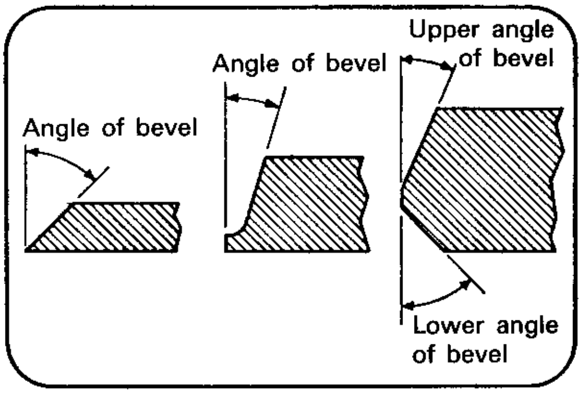
Spot weld

Illustration depicts resistance welded sheets. Arc spot welds can be made with metal-arc gas shielded welding (MAGS) or tungsten-arc gas shielded welding (TAGS).

Types of joint

The four basic welds can be used to produce various types of joint. The following are some typical joints:

Examples	Type of joint
  With backing strip  Unequal thickness—fillet welded  Unequal thickness—butt welded	**Butt**
 Fillet welded  Butt welded  Resistance welded	**Tee**
 Fillet welded  Butt welded  Resistance welded	**Corner**
 Fillet welded  Resistance welded	**Lap**

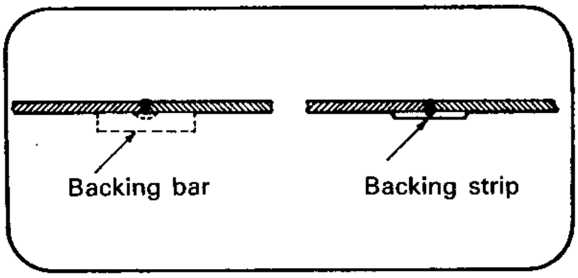


Terms used in welding and cutting

For precise definitions of the following terms use BS 499 Part 1. The explanations given here have been simplified.

Angle of bevel
The angle at which an edge or end is cut or chamfered.

Arc length
The distance between the end of an electrode and the surface of the weld pool.



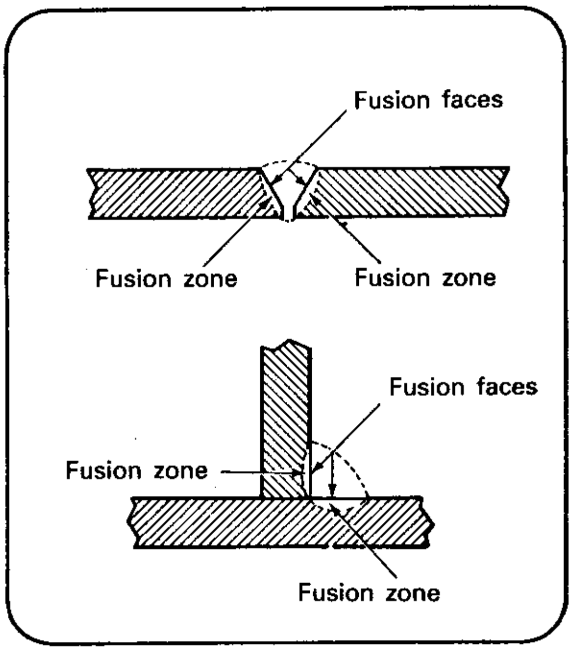
Backing bar (Back up bar)
A piece of metal or other material placed behind a butt or corner joint to help the welding operation but not intended to become part of the weld.

Backing strip
A piece of metal placed at the root of the joint and becoming part of the welded joint.

Deposited metal
The metal produced by the melting of the filler metal or electrode and which becomes part of the weld.

Drag lines
Serrations left on the face of a cut made by thermal cutting.

Edge preparation
Squaring, grooving, chamfering or levelling an edge in preparation for welding (See weld symbol diagrams on pages 51 to 55).



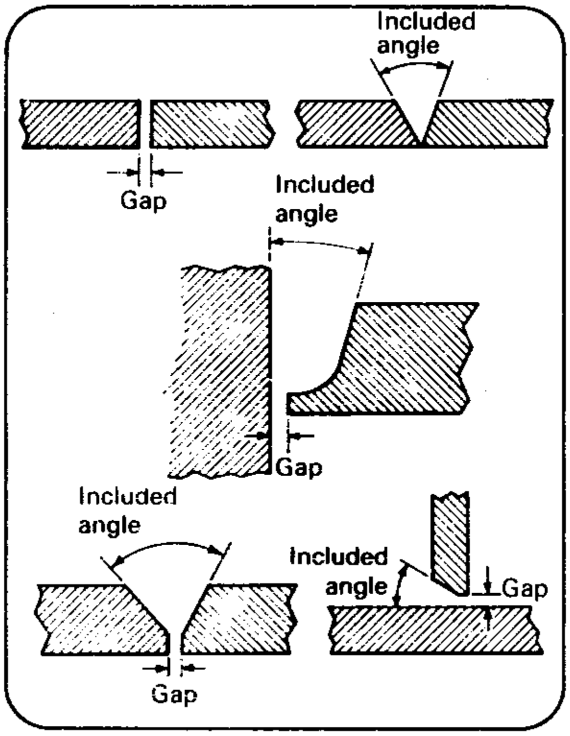
Filler rod
Filler metal in the form of a rod.

Filler wire
Filler metal in the form of a continuous wire.

Fusion face
The portion of a surface, or of an edge, which is to be fused on making the weld.

Fusion zone
The depth to which the parent metal has been fused.

Terminology

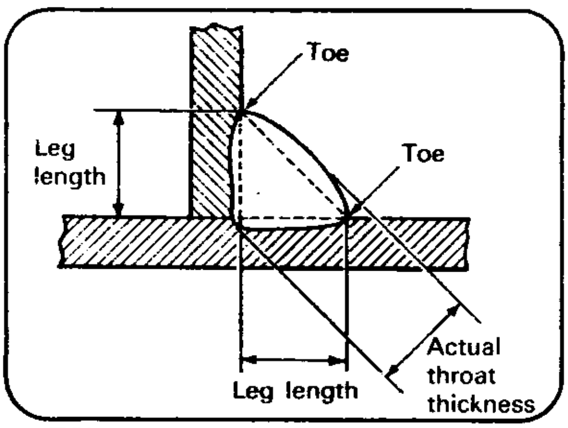


Gap
The distance between the parts to be joined.

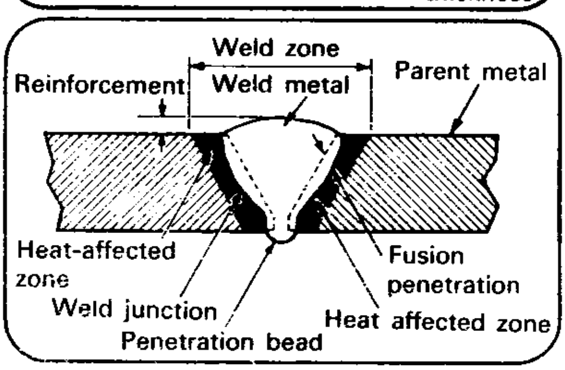
Heat-affected zone
The part of the parent metal where the metallurgical properties have been changed by the heat of welding or cutting but not melted.

Included angle
The angle between the fusion faces (not the root faces) when the parts to be joined are placed in position for welding.

Kerf
The gap or void left after metal has been removed by thermal cutting.

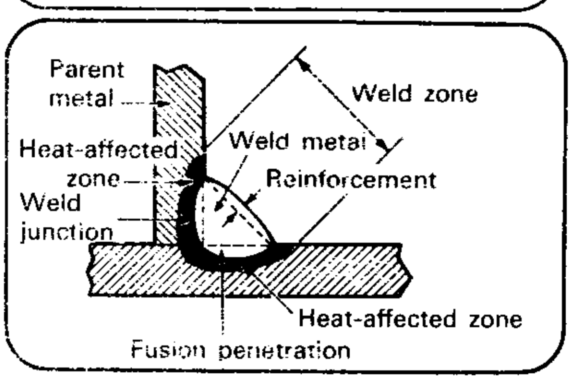


Leg length
The size of a fillet weld can be specified by leg length, being the distance from the apex of the angle formed by the two fusion faces, to the line where the weld face joins the parent metal.



Parent metal
The material or the part to be welded.

Penetration
The depth of the fusion zone in the parent metal or the distance that fusion goes beyond the root of the joint.



Excess weld metal (Reinforcement)
Metal deposited on the surface of parent metal,

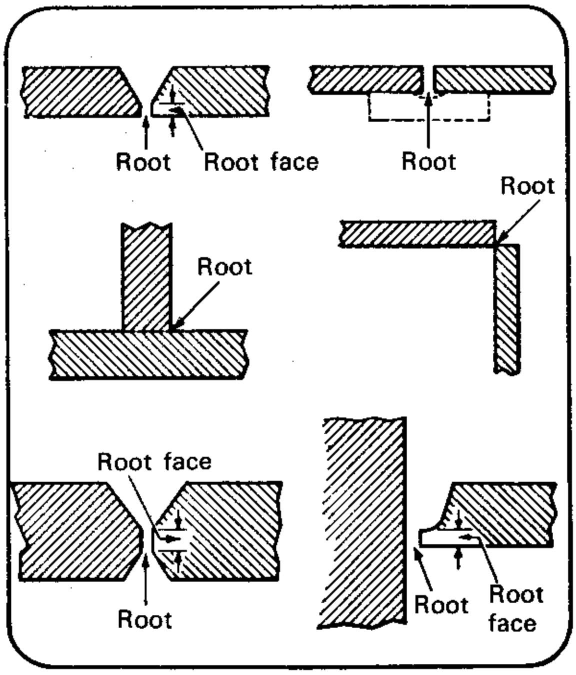
or

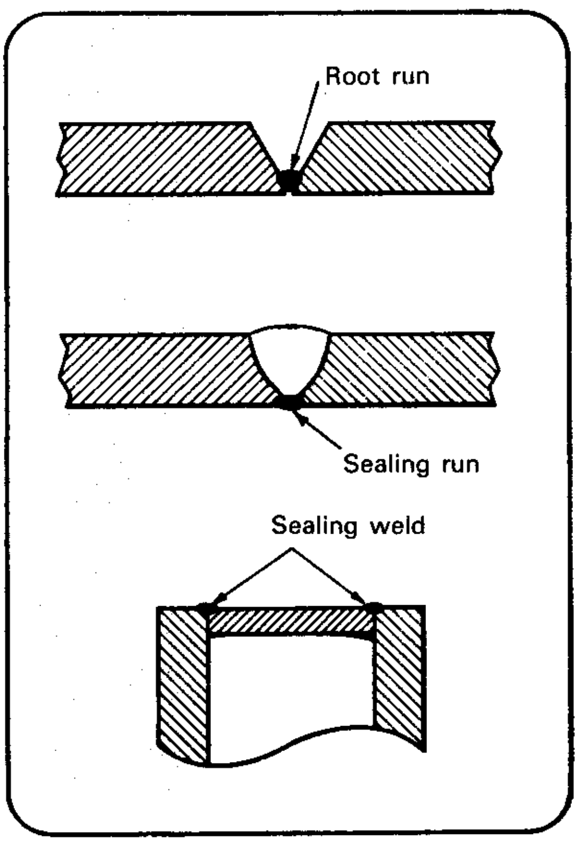
the metal deposited, when making a butt weld, which is surplus to that required to make a flush joint,

or

the metal deposited when making a fillet weld, which is surplus to that required to give a mitre weld profile.

Terminology





Root
The position in a prepared butt joint where the parts to be joined are nearest together,

or

in a square butt joint, the edges of the fusion faces which are furthest from the faces of the intended weld,

or

in a fillet weld, the apex of the angle formed by the two fusion faces.

Root face
The surface formed by the 'squaring-off' of the root edge of the fusion face to avoid a sharp edge at the root of the preparation.

Root run
The first run deposited in the root of a joint if there is to be more than one run.

Run
The metal melted or deposited during one passage of the electrode or blowpipe.

Sealing run
A small weld deposited on the root side of a butt or corner joint, after completion of the main weld.

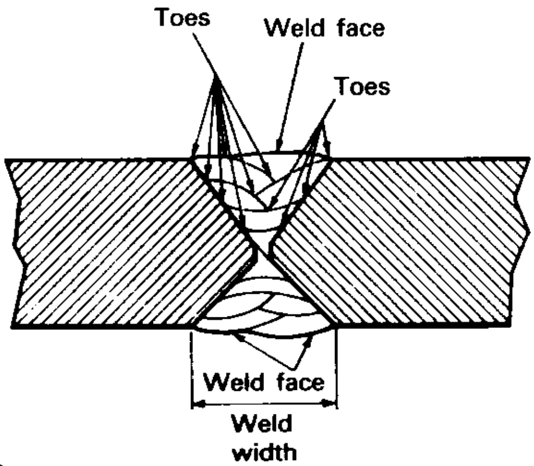
Sealing weld
A weld not being a strength weld, used to make a fluid-tight joint.

Spatter
Globules of metal thrown out during welding.

Throat thickness
The shortest distance from the root of the weld to the weld face of a fillet weld,

or

the thickness of weld metal in a butt weld measured at its centre line.



Toe of weld
The line where the weld face joins the parent metal,

or

the line where the weld face joins the weld face of a previously deposited run.

Weld face
The surface of a weld seen from the side from which the weld was made.

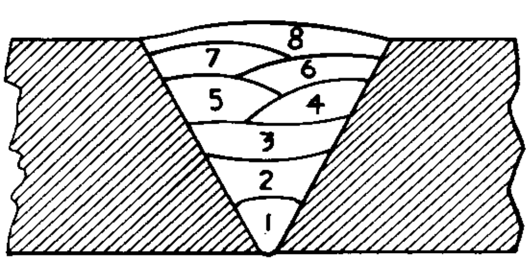
Weld junction
The boundary between the fusion zone and the heat affected zone. (See diagram page 46).

Weld metal
All the metal melted during the making of a weld and retained in the weld.

Weld pool
The pool of liquid metal formed during fusion welding.

Weld area
The area that includes the weld metal, the fusion zone, and the heat-affected zone.

Welding sequence
The order and direction in which joints, welds, or runs are to be made.



Welding sequence

Tubes and pipes
The terms 'tube' and 'pipe' are interchangeable in use to some extent but in this manual the term 'tube' is intended to signify the use as a structural member and the term 'pipe' is intended to signify the use for conveying gas or liquid, or of solids entrained in a gas or liquid.

Weld symbols

Welds are denoted on drawings by the use of symbols as specified in BS 499 Part 2.

Details relating to edge preparation, gaps, and welding procedure are not covered by BS 499, these details usually appear on Welding Procedure Sheets.

In this manual reference to BS 499 is limited to simple butt and fillet welds.

The basic requirements of BS 499 schedule of symbols for welding comprise:

1. A symbol for the type of welded joint.
2. An arrow and reference line to indicate the position of the weld.
3. The addition of weld details where necessary.
4. Symbols for supplementary instructions.

Symbols indicating weld position

Arrow

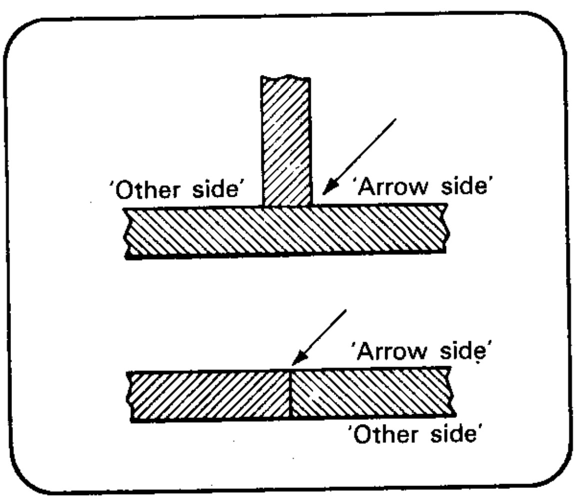
An arrow shows the position of a welded joint. The arrow head is shown on the side from which the joint is to be welded.

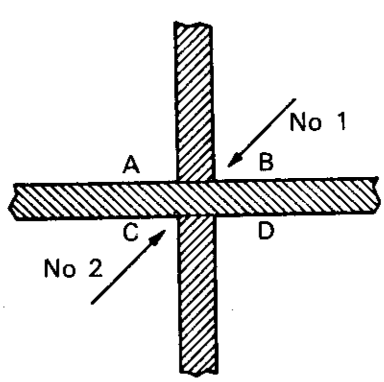
The side of the joint nearer to the arrow head is called the 'arrow side'.

The side of the joint furthest from the arrow head is called the 'other' side.

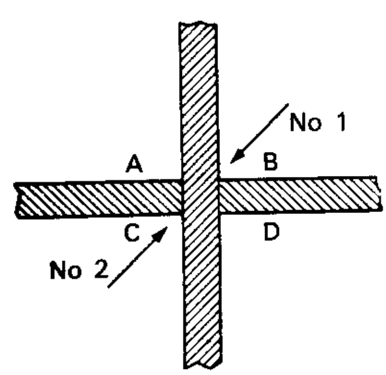
Do not use the terms 'near side' and 'far side'.

In a cruciform joint the relative positions of the parts to be joined determines the 'other side' in relation to the 'arrow side'.

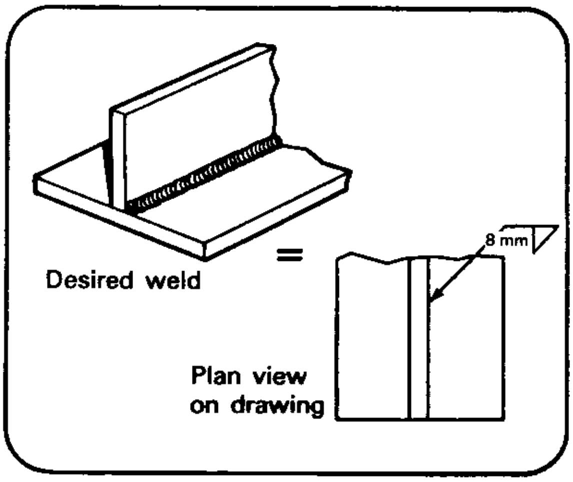




For arrow No 1—'B' is the 'arrow side', and 'A' is the 'other side'
For arrow No 2—'C' is the 'arrow side', and 'D' is the 'other side'

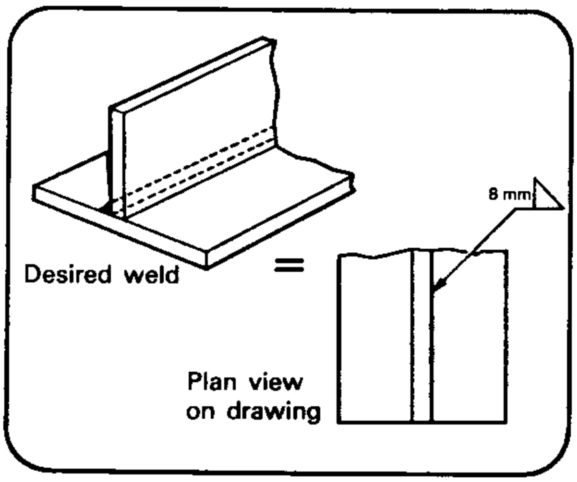


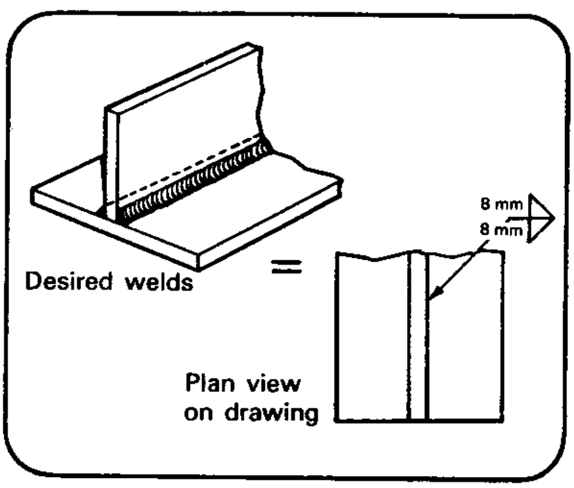
For arrow No 1—'B' is the 'arrow side', and 'D' is the 'other side'
For arrow No 2—'C' is the 'arrow side', and 'A' is the 'other side'

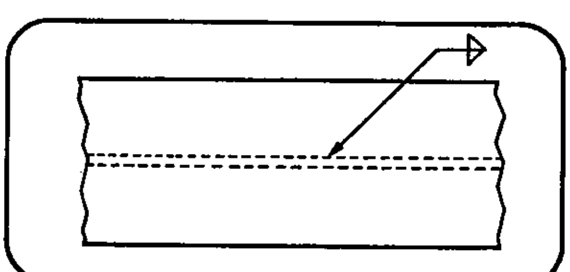


Reference line

The required position of a weld is shown by an arrowed reference line and appropriate welding symbols as in the diagrams.



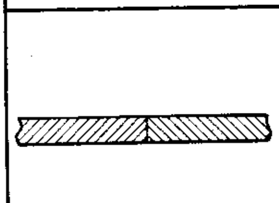
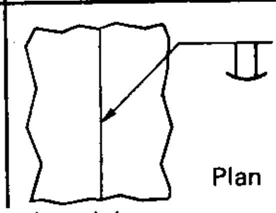
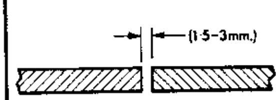
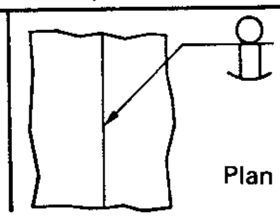
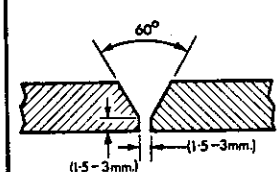
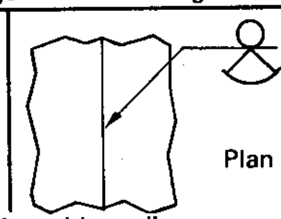
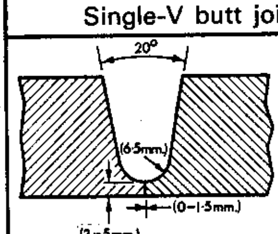
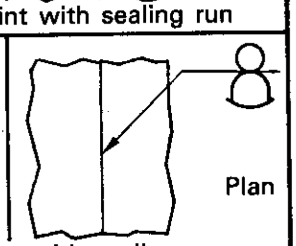
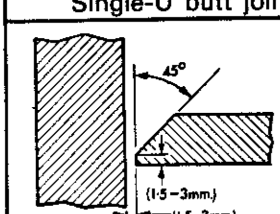
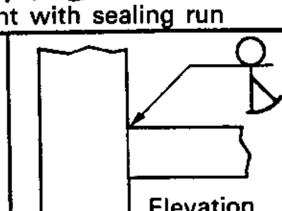
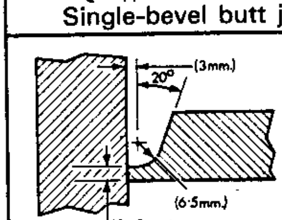
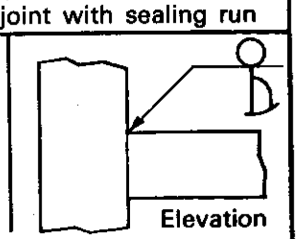


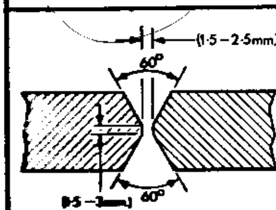
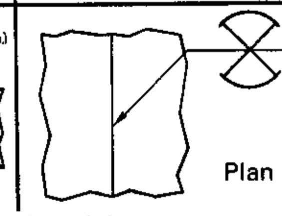
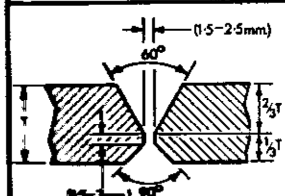
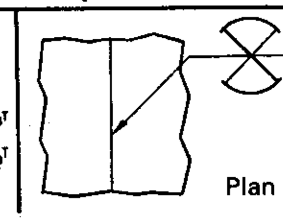
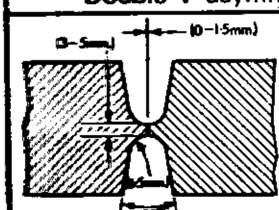
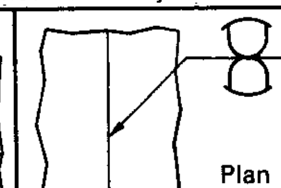
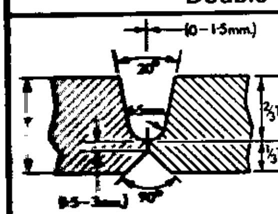
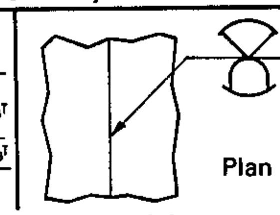
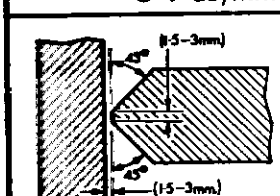
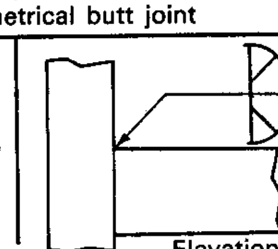
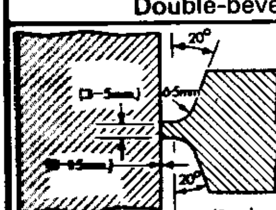
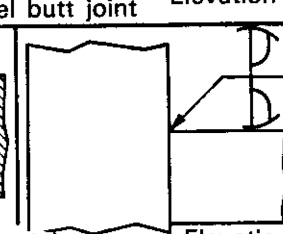


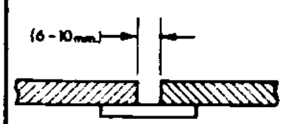
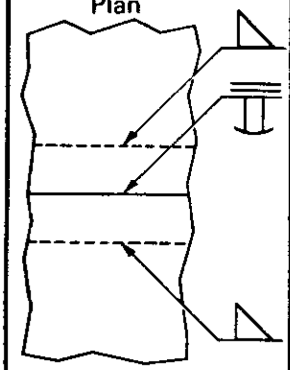
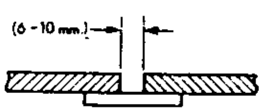
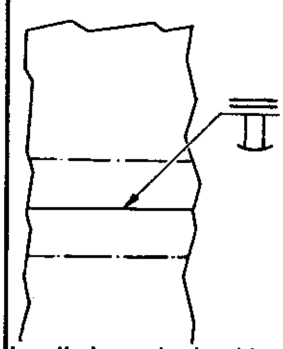
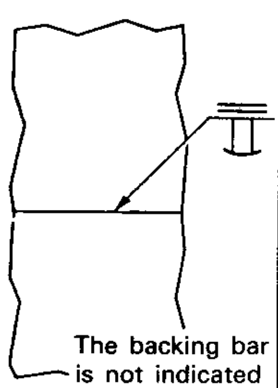
In a hidden view:

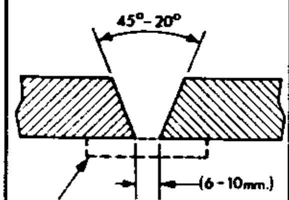
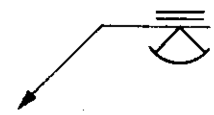
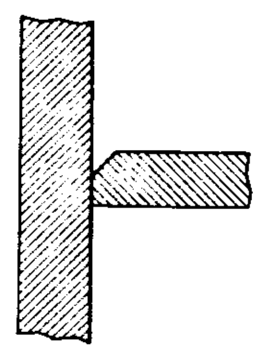
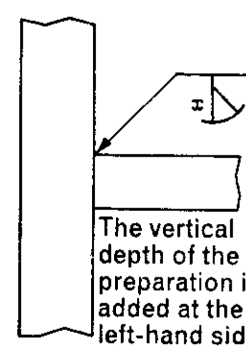
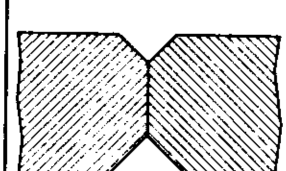
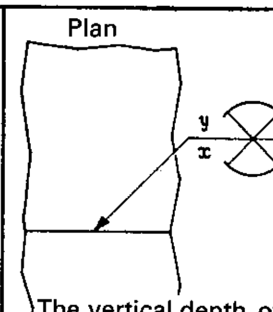
The arrow points to the hidden weld and the size and position of the weld is indicated on the reference line.

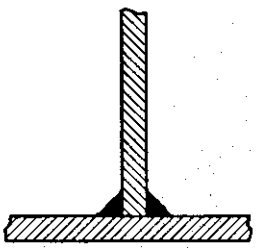
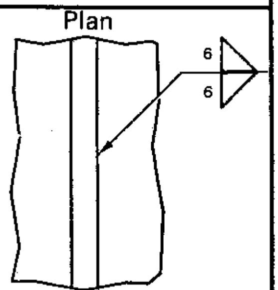
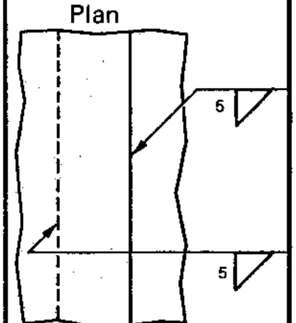
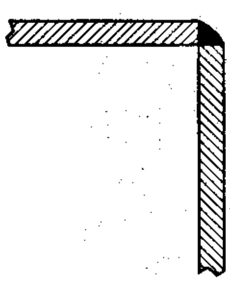
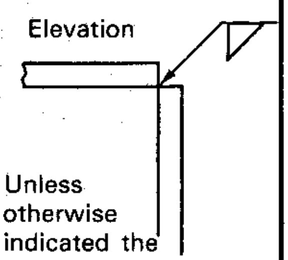
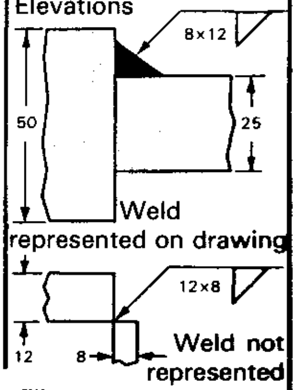
Weld symbols for types of joints

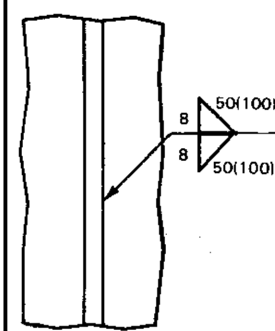
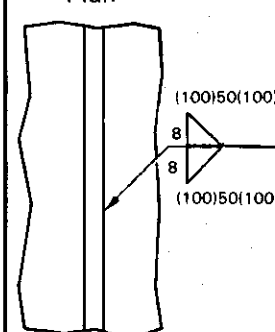
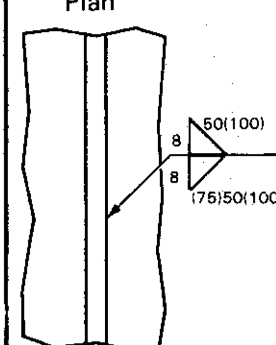
Typical joint preparation	Drawing indication	Joint
	 Plan	Close square butt joint
	 Plan	Open square butt joint with sealing run
	 Plan	Single-V butt joint with sealing run
	 Plan	Single-U butt joint with sealing run
	 Elevation	Single-bevel butt joint with sealing run
	 Elevation	Single-J butt joint with sealing run

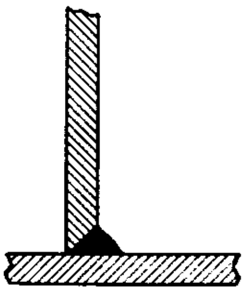
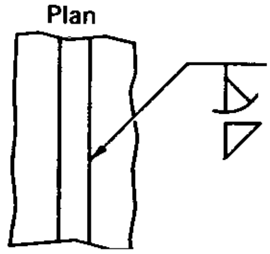
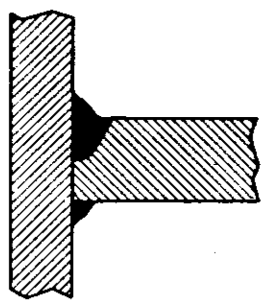
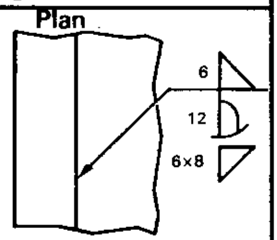
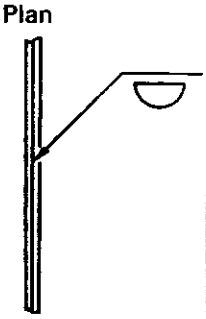
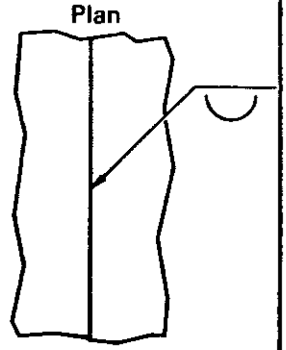
Typical joint preparation	Drawing indication	Joint
	 Plan	Double-V butt joint
	 Plan	Double-V asymmetrical butt joints
	 Plan	Double-U butt joint
	 Plan	U-V asymmetrical butt joint
	 Elevation	Double-bevel butt joint
	 Elevation	Double-J butt joint

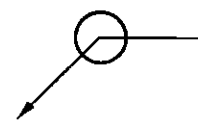
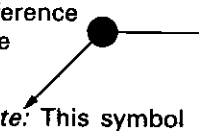
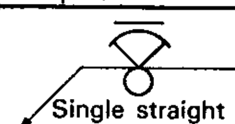
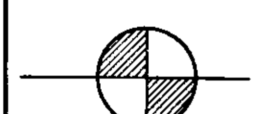
Typical joint preparation	Drawing indication
 Note that structural member may also be used as a backing strip	Plan  The backing strip is indicated by full or dotted lines as appropriate to the view
Square butt joint with permanent backing strip held in place by fillet welds	
	Plan  In all views the backing strip is indicated by chain-dotted lines
Square butt joint with backing strip that is to be removed after welding	
	Plan  The backing bar is not indicated on the drawing
Square butt joint made with use of backing bar	

Typical joint preparation	Drawing indication
Wider included angle used with the smaller gap  Backing strip or backing bar	 The same method of indicating backing strips as for the square butt joints The weld symbol is changed to indicate V-preparation
Single-V butt joint with temporary or permanent backing	
	Elevation  The vertical depth of the preparation is added at the left-hand side of the symbol
Partial penetration single-bevel joint The above applies also to partially penetrated single-V, single-U and single-J joints, except that the appropriate weld symbol is used	
	Plan  The vertical depth of the preparation is added to the left-hand side of the symbol for each side
Partial penetration double-V joint The above applies also to partially penetrated double-U, double-J and double-bevel joints, except that the appropriate weld symbol is used	

Type of joint	Drawing indication
	 The leg length of the fillet weld required is stated at the left-hand side of the symbol
Close square T-joint	
	
Double lap joint	
	 Unless otherwise indicated the leg length is the same as the plate thickness where plates are of equal thickness
Close outside corner joint	
Orientation as indicated on drawing or obvious from formation of joint	
Unequal leg length fillet	

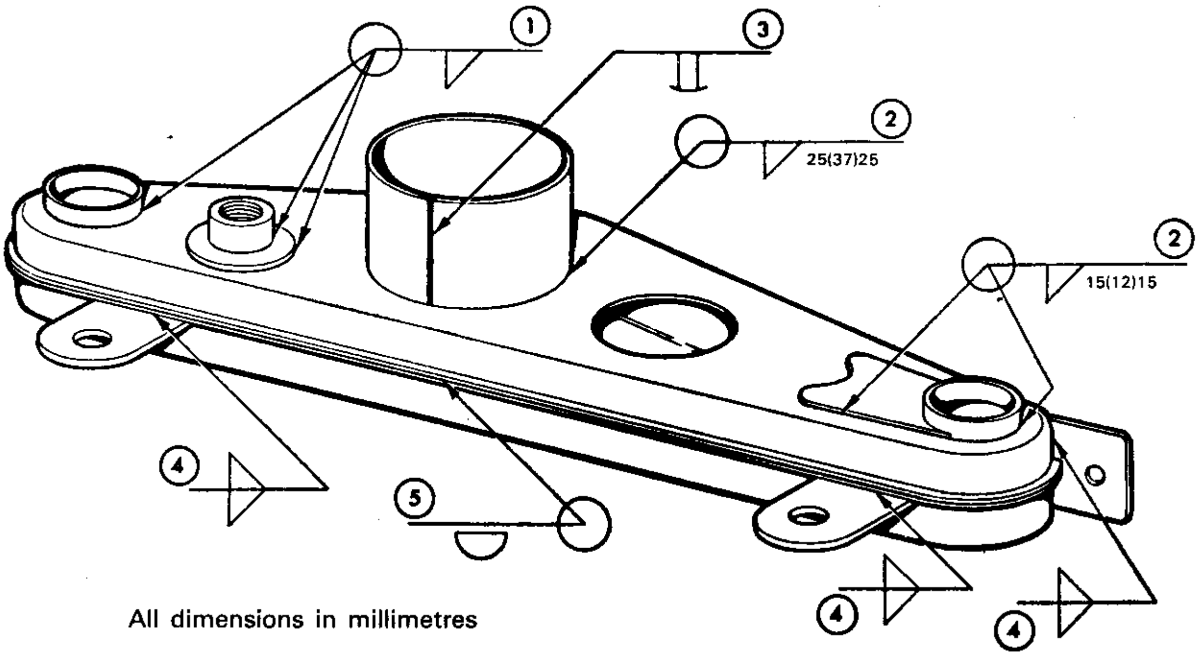
Type of joint	Drawing indication
Regular intermittent **fillet welds.** **Commencing** each **side with** a weld, **8 mm** fillet, 50 mm **welds**, 100 mm **spaces**	 The length of the weld is stated on the right-hand side of the symbol followed, in brackets, by the length between each weld
Regular intermittent **fillet welds** **Commencing** each **side with an** unwelded **length**, 8 mm fillet, **50 mm welds, 100 mm** spaces	 The commencing unwelded length is given in brackets before the weld length
Staggered intermittent **fillet welds** **Commencing** arrow **side with** an unwelded **length and** the other side **with** a weld, 8 mm **fillet**, 50 mm welds, 100 mm spaces	

Type of joint	Drawing indication
 Fillet weld superimposed on a single-bevel butt weld	Plan  Both weld symbols are used, the butt-weld symbol being nearest to the reference line. Size of fillet weld not stated unless it differs from that dictated by joint preparation
 Unequal leg length fillet weld superimposed on a partial penetration single-J butt weld with fillet at root (other side)	Plan  For other types of compound welds the appropriate symbol is used together with the symbol for the superimposed fillet weld
 Edge weld	Plan 
 Seal weld	Plan 

Supplementary instruction	Drawing indication
Sealing run to be deposited on the root side of the joint	 Immediately adjacent to the reference line above or below in accordance to the position of the root of the joint
Weld all round a joint, eg. a flange to a pipe; a stanchion to a base-plate	 Placed at 'elbow' of arrow shaft with the reference line
To be welded on site	Placed at 'elbow' of arrow shaft with the reference line  *Note:* This symbol is half the size of the weld-all-round symbol, so that both symbols can be used together, if required
Flush finish to butt weld, ie. minimum reinforcement	 Single straight line added to symbol. This may be used with any type of butt weld with appropriate symbol, and may be used to request flush finish on one or both sides of the weld
Weld to be radiographed	 Large symbol, partially shaded, to attract attention, added at end of reference line bearing appropriate weld symbols

Use of weld symbols

The following illustration shows weld symbols for various welds as they would appear on a drawing.



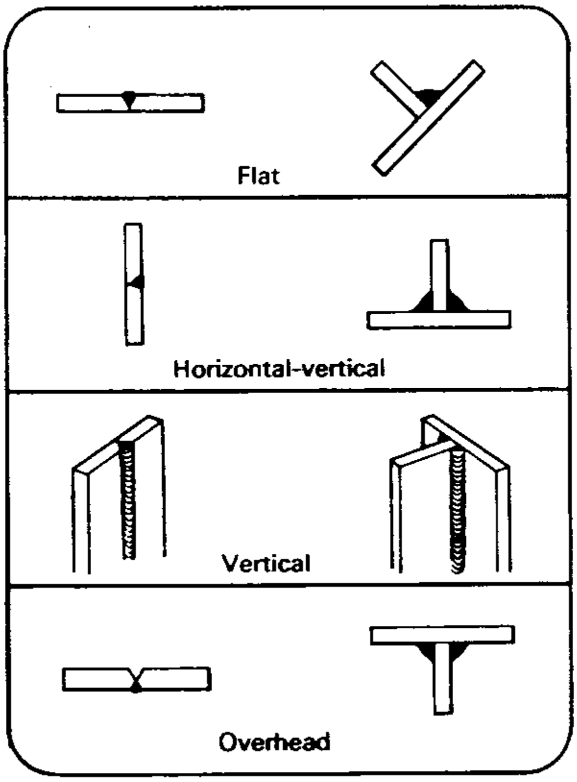
All dimensions in millimetres

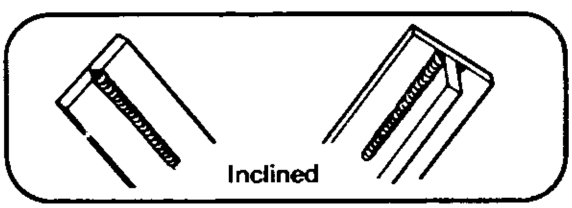
Key to weld symbols

1. Symbol shows continuous fillet welds all round.
2. Symbol shows intermittent fillet welds.
3. Symbol shows square butt weld.
4. Symbol shows fillet welds both sides of joint.
5. Symbol shows edge weld all round.

Welding positions

Simplified diagrams of the four basic welding positions of BS 499 are given on the left.





Note:
Inclined position
This term describes any welding position which is not one of the four basic positions shown.

Weld imperfections

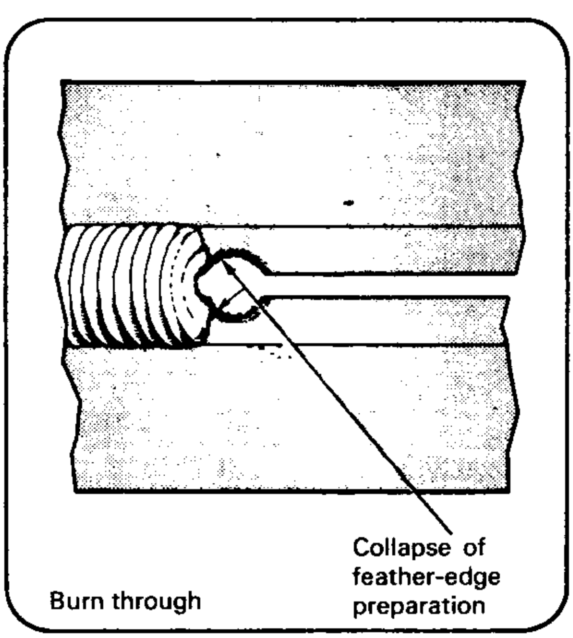
Simplified descriptions of the definitions in BS 499 Part 1 are given below:

Blow hole
A large cavity in the weld formed due to gas being trapped.

Typical causes—moisture or contamination on parent metal or filler.

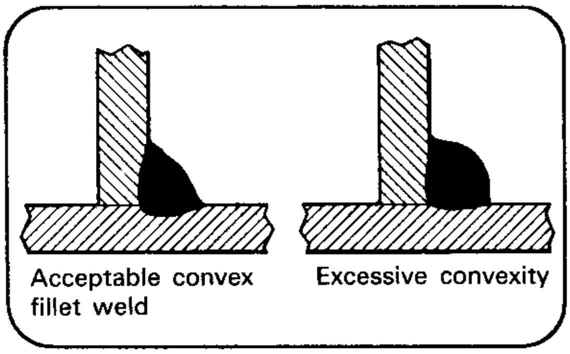
Burn-through
Collapse of weld pool due to excessive penetration.

Typical causes—unsuitable edge preparation; too high a welding current or concentration of heat.



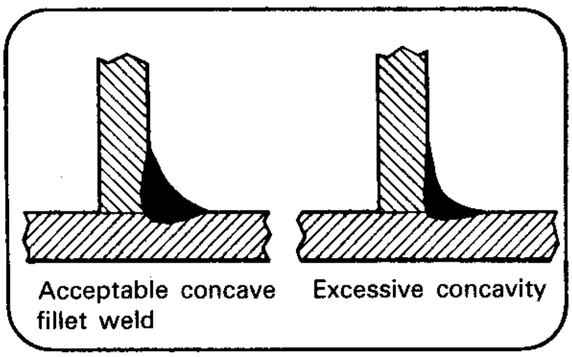
Cracking
Cracks may appear anywhere in the weld or parent metals.

Typical causes—unsuitable parent metal or inappropriate welding techniques.



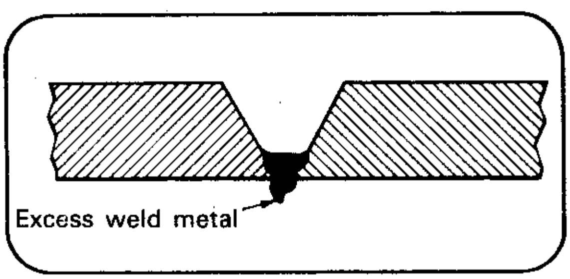
Excess convexity
Excessive thickness at the throat of the weld.

Typical causes—unsuitable filler or electrode; too low a welding current or inadequate heat.



Excessive concavity
Usually refers to fillet welds, with a too shallow throat.

Typical causes—too rapid travel with electrode or blowpipe; vertical welding using downwards method with inadequate addition of filler.

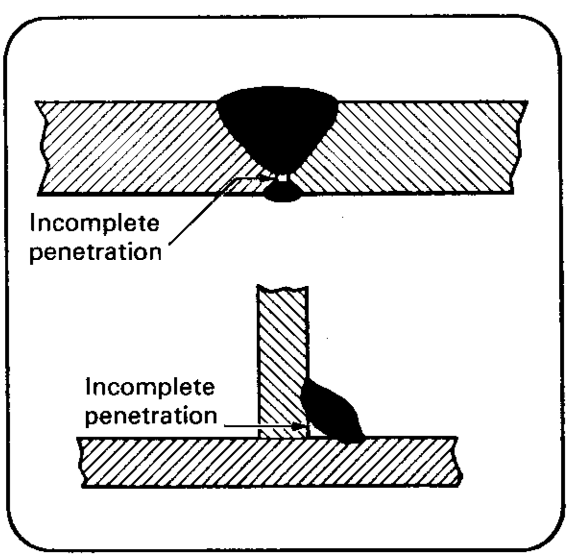


Excessive penetration
Excess weld metal protruding through the root of a joint.

Typical causes—unsuitable edge preparation; too high a welding current or concentration of heat; too slow a travel with electrode or blowpipe.

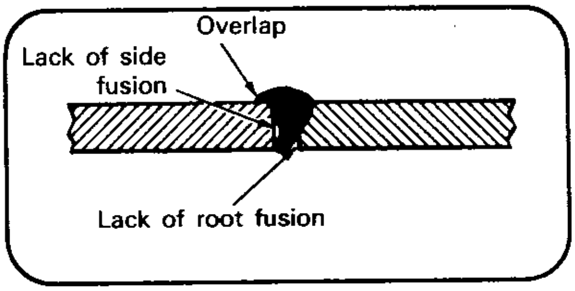
Inclusion
Slag or other foreign matter trapped in a weld.

Typical causes—unclean parent metal or filler; slag not cleaned from preceding runs; undercutting cavities or grooves; tungsten from electrode in tungsten-arc gas shielded welding; accidental contact of nozzle with weld pool.



Incomplete penetration
Failure of weld metal to extend into or fill the root of the joint.

Typical causes—unsuitable edge preparation; incorrect welding technique; inadequate back chipping or gouging of initial run before depositing sealing run.



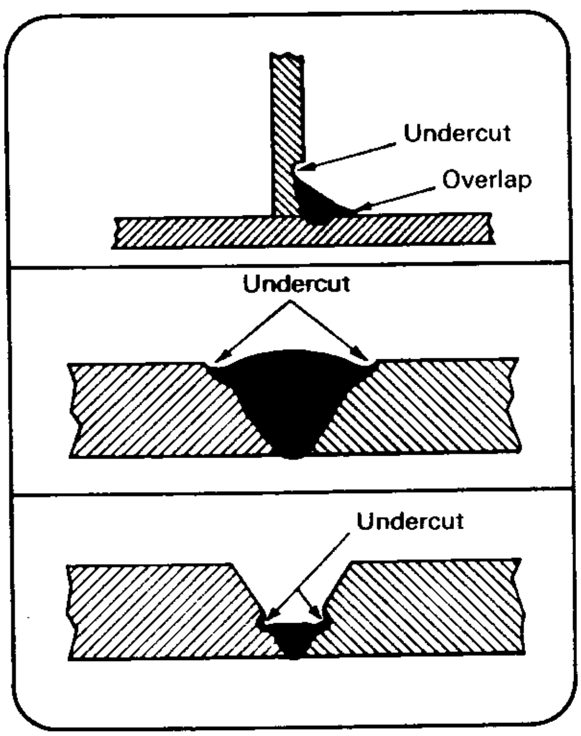
Lack of fusion
Discontinuity of weld or failure to secure weld.

Typical causes—too low welding current or inadequate heat; too rapid travel with electrode or blowpipe; failure of molten deposited metal to 'wet' the parent metal; bad disposition of runs in a multi-run weld.

Overlap (Cold lap)
Metal which has flowed on to the surface of the parent metal without fusing to it.

Typical causes—contamination of parent metal; inadequate heat at toes of weld; incorrect welding technique.

Porosity
A group of pores in a weld caused by trapped gas.



Typical causes—contamination of parent metal or filler; high sulphur content of parent metal or filler; moisture trapped between joining surfaces; too rapid cooling of weld metal.

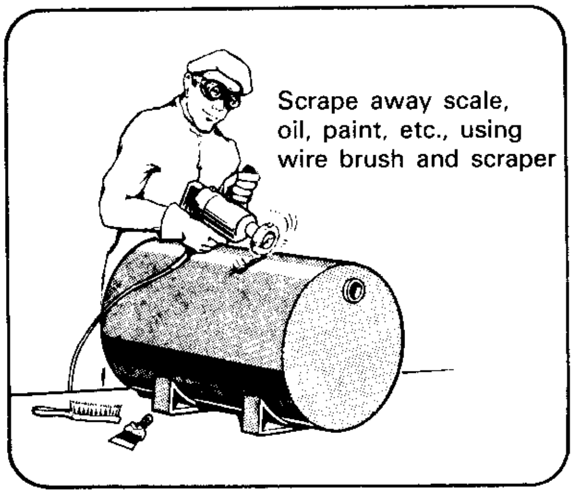
Unsatisfactory surface
For example: poor surface finish, irregular profile, or lack of smoothness in weld joint.

Typical causes—poor quality parent metal or filler; incorrect welding technique.

Undercut
A groove or hollow cut in the surface or fusion face of the parent metal at the toe of a run.

Typical causes—millscale on or near fusion face; too rapid travel of electrode or blowpipe; too high a concentration of heat; incorrect welding technique.

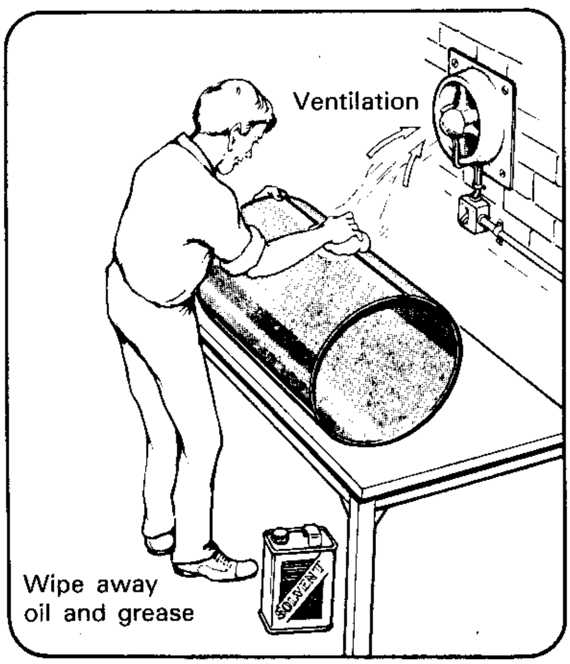
Parent metal preparation



Surface condition

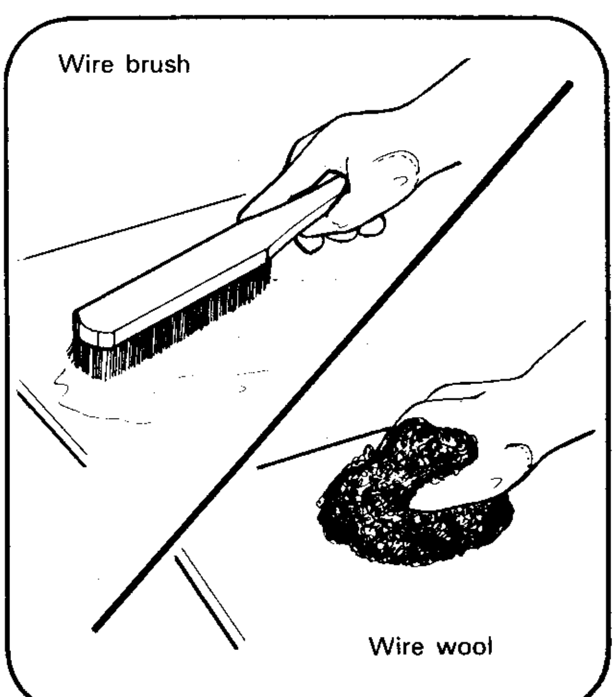
The surface of the parent metal must be cleaned in the vicinity of the fusion faces and free from contaminants. For lap joints and tee fillet joints any contamination present on contacting surfaces must be removed. Care should be taken that moisture or other contaminants are not trapped between the abutting surfaces. Neglect of this precaution will produce porosity in the weld deposit.

Preparation of worn surfaces
When worn or battered surfaces are to be built-up, the damaged metal should be removed (together with any deep cracks) by machining or grinding.



Edge preparation

May be carried out by thermal cutting, thermal gouging, shearing, planing, chipping, grinding or filing. Keep fusion faces free from irregularities to ensure accurate alignment and uniform gap dimensions.



Ensure absolute cleanliness of the joint area and fusion faces prior to welding. This can be done by degreasing treatment and/or the use of a wire scratch brush or wire wool.

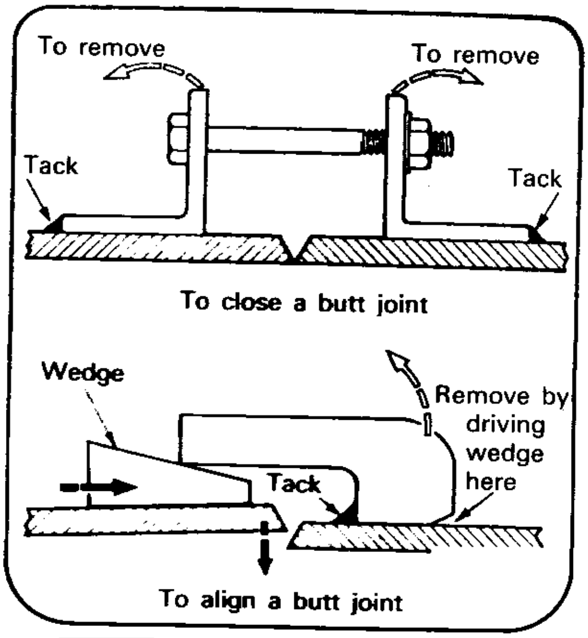
For cleaning stainless steel and similar alloys a stainless steel wire brush or wire wool should be used.

Safety

Toxic fluids must not be used for degreasing. When these substances are brought into contact with the arc zone their vapours decompose to form a toxic gas.

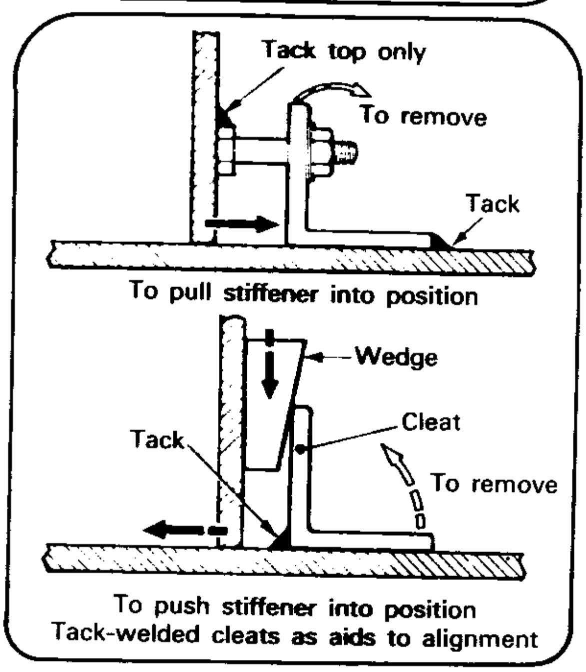
Degreasing must be done in a place away from arc welding activities. Make sure that degreased parent metal is thoroughly free from traces of the degreasing agent.

Assembly methods



To close a butt joint

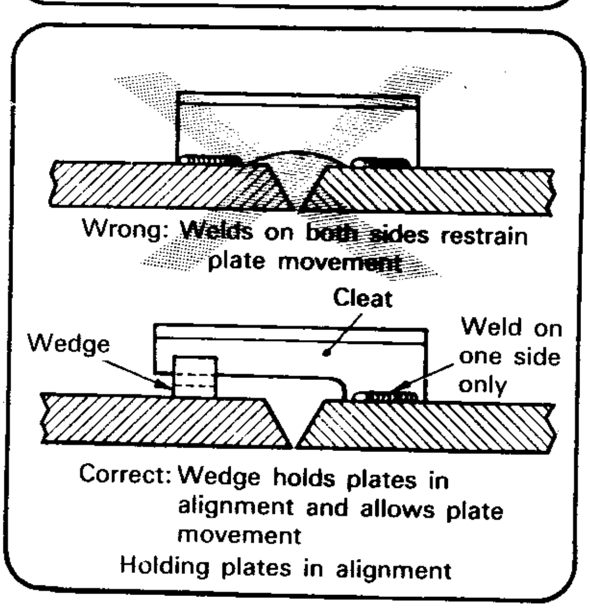
To align a butt joint



To pull stiffener into position

To push stiffener into position

Tack-welded cleats as aids to alignment



Wrong: Welds on both sides restrain plate movement

Correct: Wedge holds plates in alignment and allows plate movement

Holding plates in alignment

Joint set-up

1. For butt joints the root faces should be in alignment and the root gaps uniform.

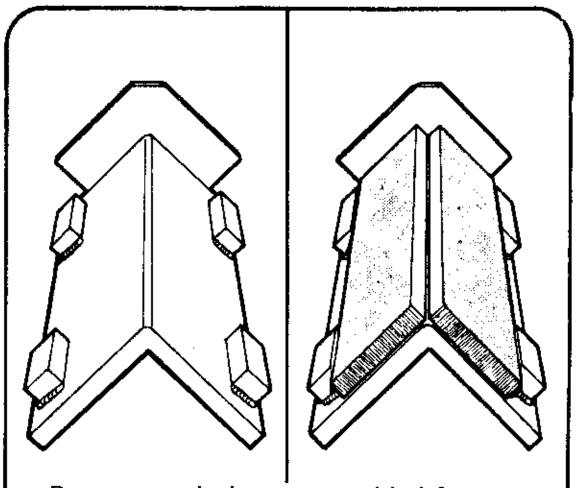
2. For joints to be fillet welded the abutting faces, or abutting edge and face, should be in full contact.

Note: Permissible fit-up tolerances should be specified on the 'procedure sheets'.

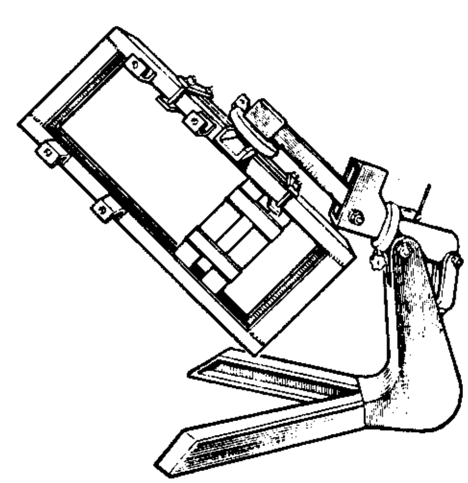
Cleats attached by tack welding can be used for aligning butt and tee joints.

Both the tack welds and the cleats should be capable of easy removal.

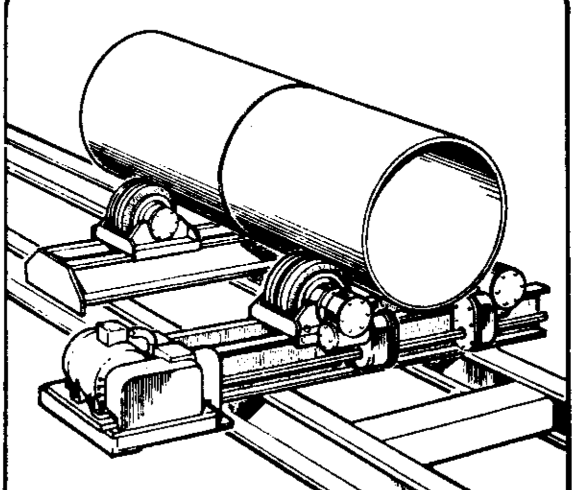
Assembly methods



Parent metal pieces assembled for corner welding, held in position by simple fixture, ready for tack welding



Bed-plate on universal balance positioner



Roller manipulator—one driven unit and one idler unit

The use of fixtures, positioners and manipulators

Mechanical aids may be used to facilitate assembly, also to position the work prior to welding.

Fixtures

(i) Eliminate the need for measurement.

(ii) Prevent incorrect assembly of components.

(iii) Control distortion and place the joint in the most convenient position for welding.

Note: Fixture design must ensure easy removal of the completed fabrications.

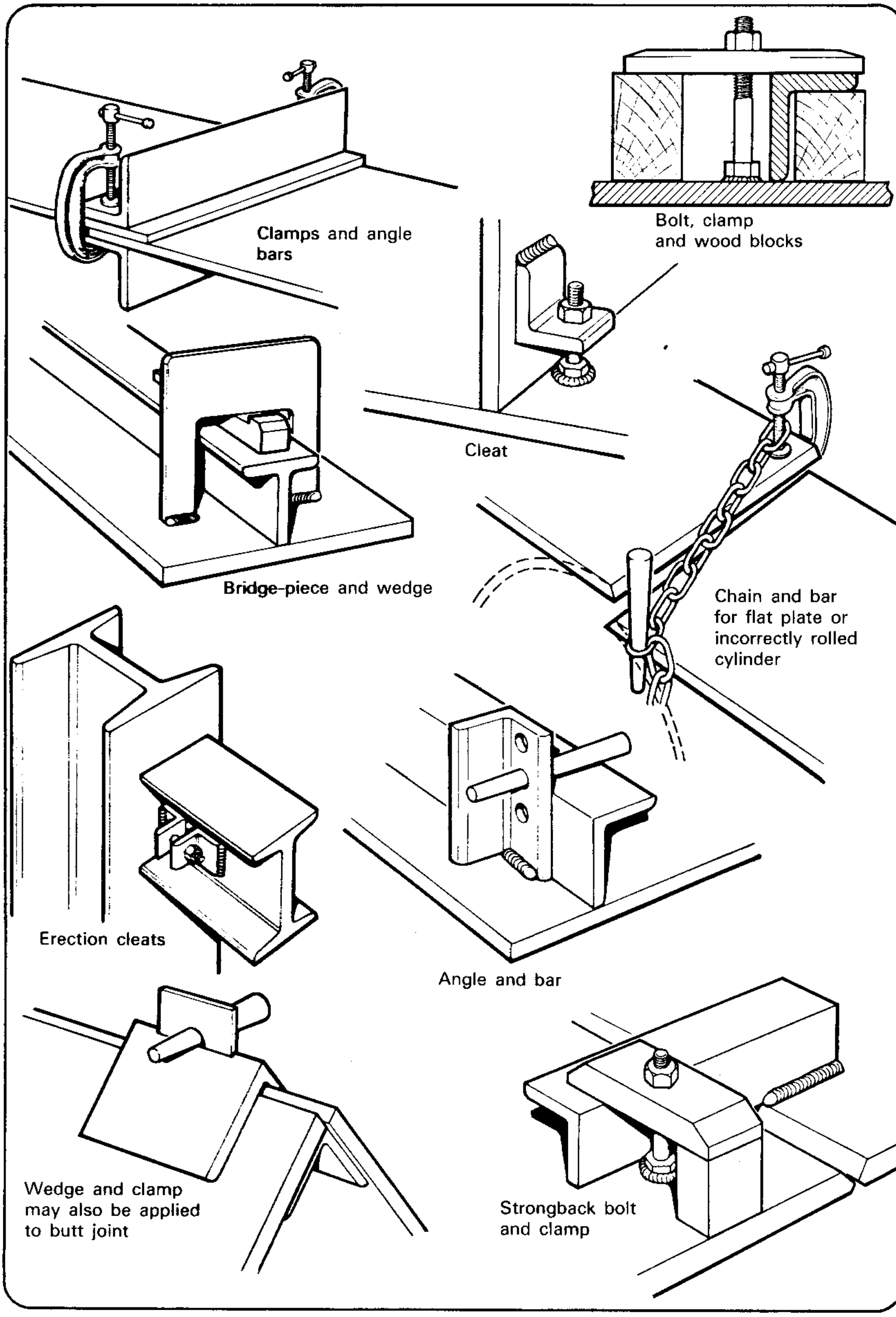
Positioners

The universal balance type enable the work-piece to be rotated through 360° and tilted through 180° with minimum effort.

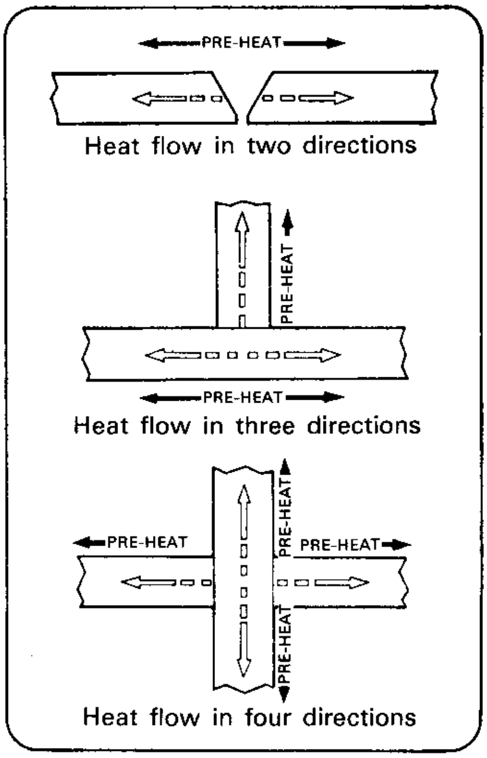
Manipulators

Position, rotate or move the work at a speed suitable for welding. The most common forms are motor-driven turntables and rotators.

Aids to erection and assembly



Pre-heating



Pre-heating of parent metal may be necessary to reduce the risk of adhesion, cracking, distortion, and liability to fracture. The pre-heating temperature will depend upon:

(a) the type of material, eg.

(i) ferrous and non-ferrous castings

(ii) ferrous and non-ferrous wrought materials

(b) the shape, size and section of the work.

It is important to pre-heat the material to the correct temperature before commencing to weld.

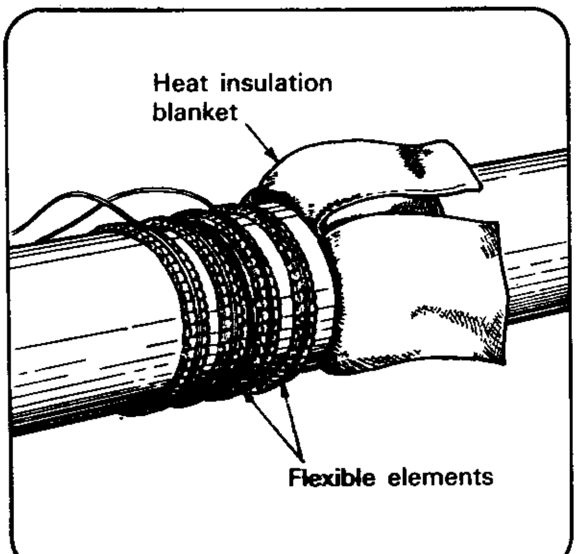
This temperature should be ascertained by a suitable method.

Appropriate pre-heating ranges for the welding of specific materials are detailed in the relevant example procedures.

Typical pre-heating conditions

MATERIAL	TYPE	PRE-HEAT METHOD	TEMPERA-TURE	PRE-HEAT TEMPERATURE CHECK	NOTES
Cast-Iron 1150°C. (2102°F.) Melting Point	Iron castings to be fusion-welded	Muffle using air/propane or air/coal gas burners or charcoal	400°–700°C. (752°–1292°F.) according to section	Dull red heat	Maintain temperature by welding the component whilst in the muffle
Cast Steel, and Cast Irons	Castings to be bronze-welded	Pre-heat using fuels as above	400°–450°C. (752°–842°F.)	Ensure uniform heat. Weld at blackheat. Check by pyrometer or Tempilstick	Keep component at a constant temperature not exceeding blackheat. Do not overheat the edges to be welded
Copper 1083°C. (1976°F.) Melting Point	Plate, castings and heavier sections to be fusion-welded	Air/propane burners Air/coal gas burners Oxy-acetylene blowpipe	750°–800°C. (1382°–1472°F.)	Red heat	Copper becomes weak at high temperature. Support thin or fragile parts to prevent distortion. Owing to high thermal conductivity of the material, the temperature must be checked frequently
Copper (All Types)	All types to be bronze-welded	Pre-heat using flames as above	350°–400°C. (662°–752°F.)	Keep workpiece below red heat. Commence bronze-welding before scale (cupric oxide) appears on the surface	To ensure good 'wetting' properties of the bronze, do not overheat
Aluminium Alloy 625°–657°C. (1157°–1215°F.) Melting Point	Castings and thick material	Uniform heat from flames as above	400°–420°C. (752°–788°F.)	Use Tempilsticks, heat-cones or temperature crayons. Wood splinters will char. White soap turns dark brown	Care must be taken not to exceed the appropriate temperature. Avoid contact of component with the heat source. Adequate support is necessary to avoid sagging
Magnesium Alloy Melting Point 635°C. (1175°F.) approx.	Castings	Muffle using fuels as above	300°–350°C. (572°–662°F.)	Use Tempilsticks or heat-cones. At temperature white soap turns light brown	As above (Greater danger of collapse.)
Hardenable Steel	All sections liable to quench hardening	Uniform heat from flames as above	Approx. 80°–120°C. (176°–248°F.)	Use Tempilsticks or temperature crayons	Maintain temperature to avoid chilling

Post-heating—Temperature measurement



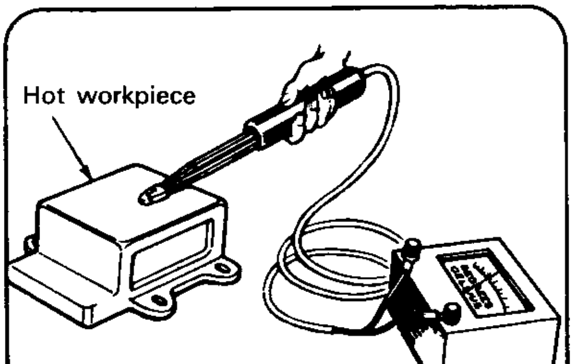
General

Stress relieving requires the heating of the fabrication to a suitable temperature.
The whole fabrication is usually maintained at this temperature for a soaking period and allowed to cool slowly in the furnace.
Local stress relieving can be used for some fabrications which cannot be heated in a furnace, eg. butt joints in pipelines. A ring gas burner or flexible resistance heating element or induction heating cable may be used. Heat the pipe sections (for a distance of about 50 mm on either side of the weld) to the stress-relieving temperature for the appropriate time. Allow to cool slowly in a heat insulation blanket or other insulating material.

Temperature

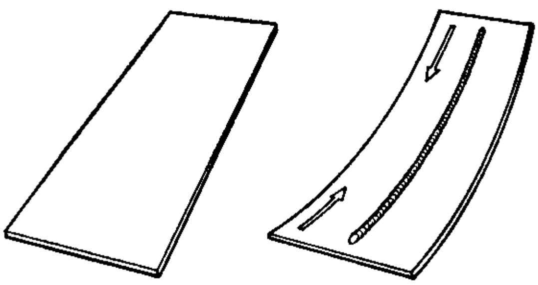
1. Low temperatures can be ascertained by means of thermometers or workshop methods (which may be less accurate) using, for example,
(a) temperature indicating paints which change colour, or
(b) crayons which fuse at certain temperature ranges.

2. High temperatures can be measured with a contact or thermo-electric pyrometer.

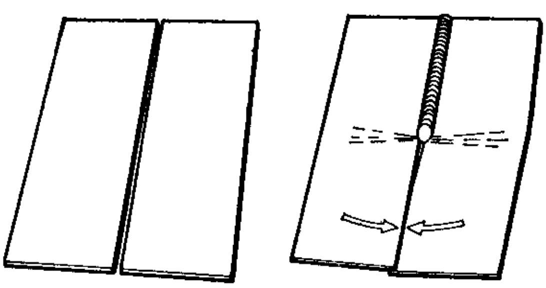


Thermo-electric pyrometer

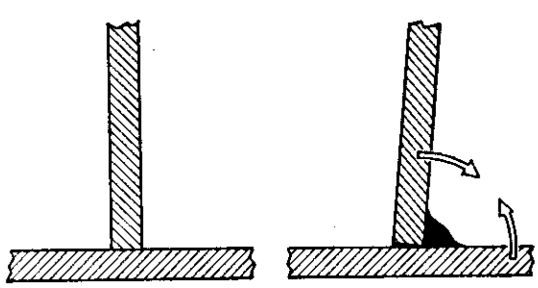
Distortion during welding



Longitudinal contraction



Transverse contraction



Angular distortion

When weld is made from one side only, angular distortion is produced

When welding is balanced, heat input is balanced, eliminating transverse angular distortion

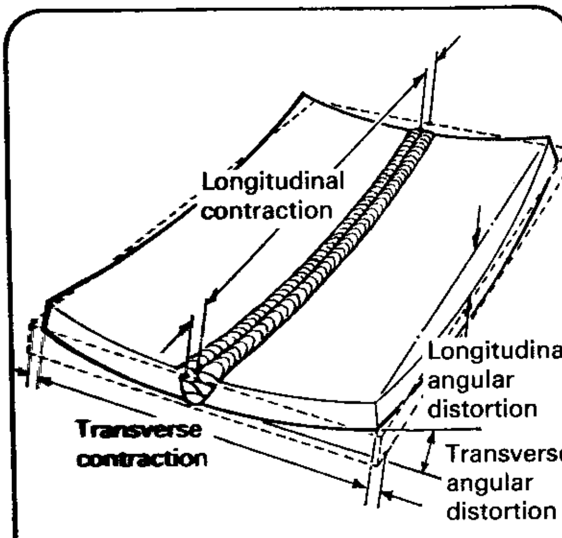
Effects of unbalanced welding about the neutral axis

Causes of distortion

(a) Longitudinal contraction
If a deposit is made on one side of a flat strip thin plate the plate bends upwards as it cools.

(b) Transverse contraction
If a butt weld is made between two thin plates that are free to move, the plate edges will be drawn together. The plate edges in advance of the weld may 'scissor' or overlap.

(c) Angular distortion
If a fillet weld is deposited between two plates in a tee joint the angle between the plates will be reduced as the weld cools. Similarly, angular distortion occurs in a butt joint as contraction of the weld metal pulls the plates out of alignment. Angular distortion increases with the number of runs deposited.

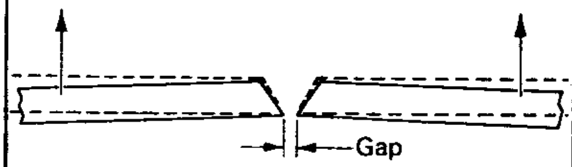


Distortion in single-sided welding of an unrestrained butt joint with several small runs

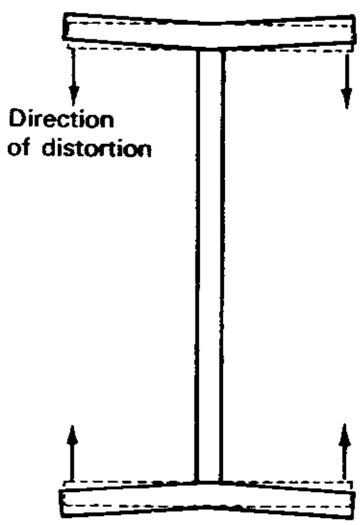
Factors affecting distortion

1. Design
2. Parent metal
3. Joint preparation and set-up
4. Assembly procedure
5. Welding process
6. Deposition technique
7. Welding sequence
8. Unbalanced heating about the neutral axis
9. Restraint imposed

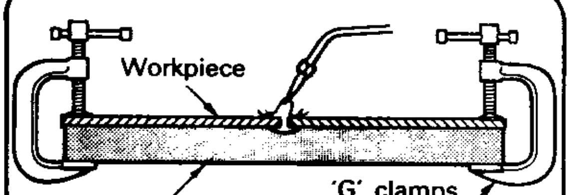
Distortion during welding



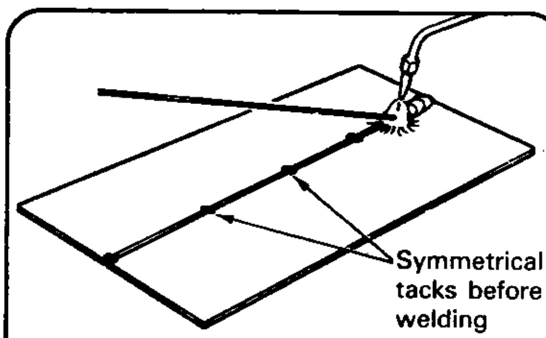
Pre-setting to compensate for angular distortion (4a)



(4a)
Pre-cambering to compensate for angular distortion



When possible clamp up plates to control distortion (allow slippage) (4b)



(4c)

Control of distortion

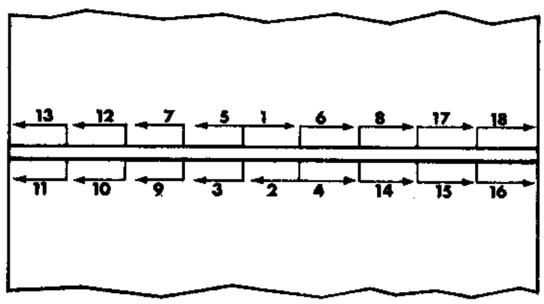
1. Design
Reduce distortion by using:
(a) minimum number of suitably arranged joints,
(b) readily accessible joints,
(c) correct weld sizes for the strength required,
(d) balanced welding about neutral axis.

2. Parent metal
Reduce distortion by using:
(a) correct procedure according to type of metal,
(b) deposition technique which ensures minimum heat input.

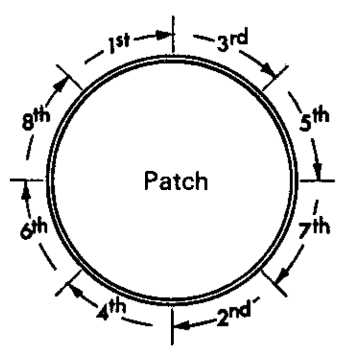
3. Joint preparation and set-up
Reduce distortion by using:
(a) smallest suitable angle of preparation,
(b) smallest suitable root gap,
(c) symmetrical joint preparation and set-up wherever possible.

4. Assembly procedure
Reduce distortion by:
(a) pre-setting or pre-cambering components, to anticipate distortion pulling components into correct alignment,
(b) restraining components with suitable slippage where necessary to control the distortion within prescribed limits,
(c) using effective symmetrical tack welding, to hold components in alignment and maintain root gap.

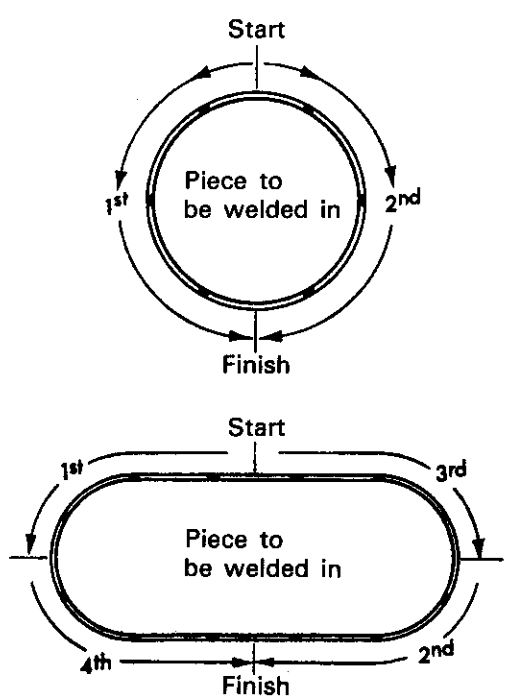
5. Welding process
In general, the greater the heat build-up produced by the process, the greater will be the distortion. The lower the heat build-up, the less will be the distortion.



Sequence of welding fillet welds on either side of a vertical member; one welder



Order of welding in a circular patch, showing sequence of welds



Note: It is essential to dish or pre-set the insert before tack welding in position

Sequence for welding in patches

6. Deposition technique

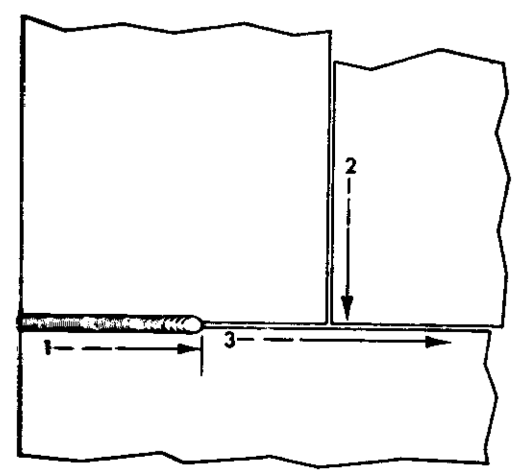
Reduce distortion by:

(a) depositing the weld with the minimum number of runs

(b) balancing the welding about the neutral axis of the fabrication. (Note that if a weld is made on one side of an unrestrained joint and allowed to cool, it will require approximately twice the amount of welding on the opposite side of the joint to eliminate the distortion caused by the first weld.)

(c) not exceeding the specified size of weld

(d) use the correct procedure and technique to give maximum welding speed.



Sequence of welding

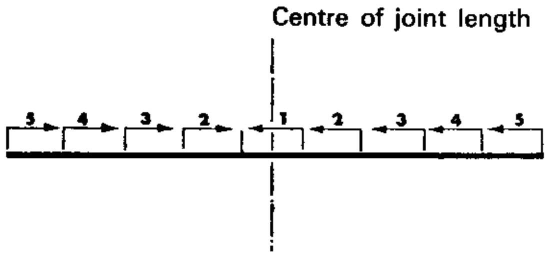
7. Welding sequence

Reduce distortion by:

(a) welding away from the point of restraint towards a free end

(b) progressing welding symmetrically about the neutral axis of the fabrication, to give a balanced procedure

(c) using 'Doubling Up' method of welding to counteract angular distortion.

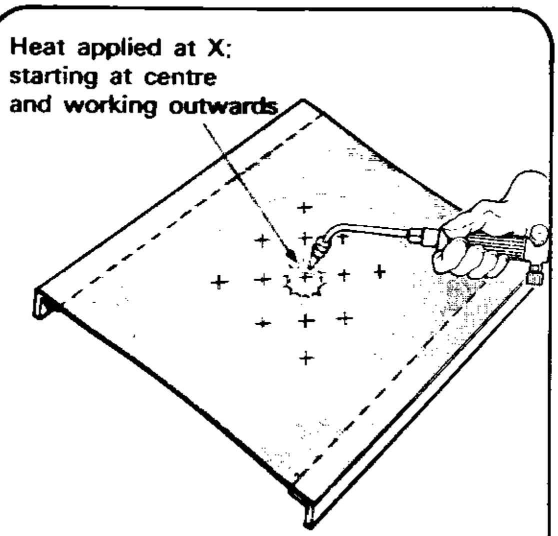


Step-back method for welding long butt joint with two welders; one each side of centre after first deposit

(d) using 'Planned Wandering' or 'Step Back' methods of welding
(e) using correct sequence when welding sections so that severe restraint in one direction does not cause distortion elsewhere.

Permissible methods of correcting distortion

Distortion may occur even if the weld has been carried out to a planned procedure. Rectification of distortion is occasionally carried out by mechanical means but more frequently by the application of heat.



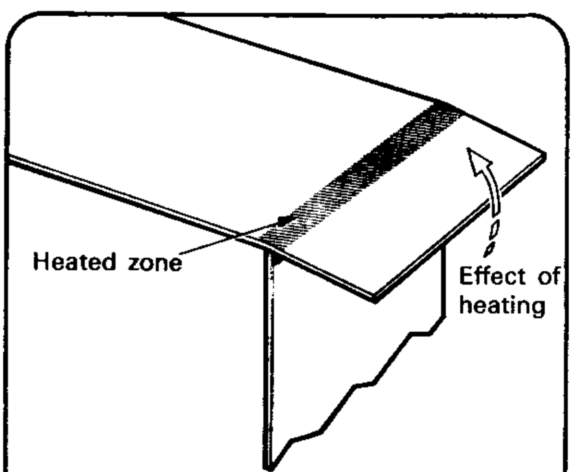
Spot heating to correct buckling of thin sheet

Mechanical methods
Small parts, cambered by angular distortion, can be straightened by the use of a press. Unrestrained parts of an assembly may be brought into alignment by hammering, drifting or jacking, but take care not to impose excessive stress.

Heating methods
Heat is used locally and rapidly while the surrounding metal is kept reasonably cool.

1. Heat small areas at a time. Do not exceed bright red heat.

2. Buckling of thin plate can be corrected by heating local spots on the convex side. Start at the centre of the buckle and work symmetrically outwards.



Correction of distortion caused by fillet weld

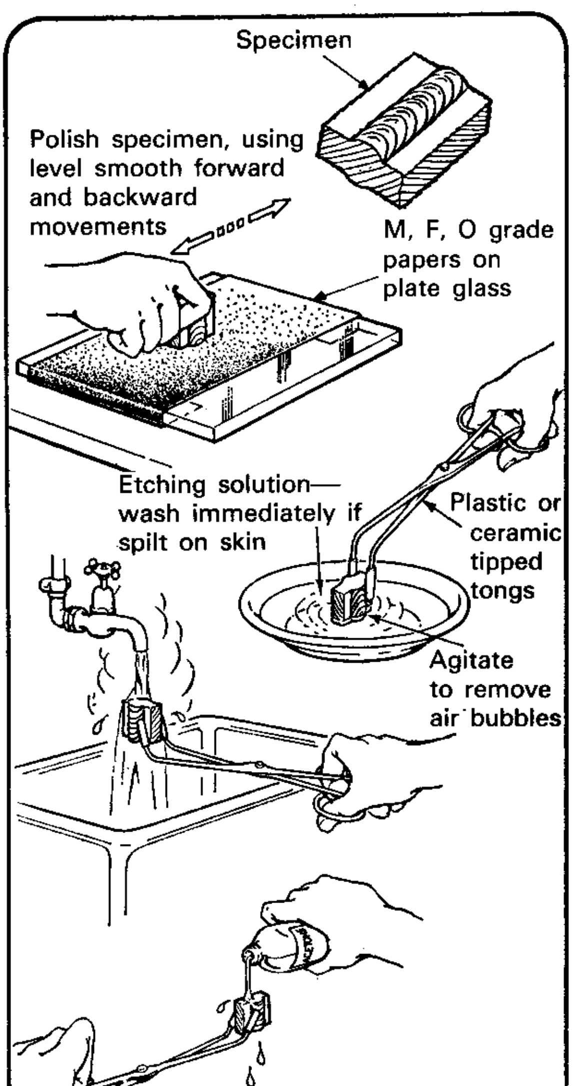
3. Correct distortion caused by fillet welds by local heating on the underside of the plate in a narrow strip following the line of the joint.

4. Correct cambers by heating a wedge-shaped zone.

Welding in exposed conditions

Do not weld when:
1. Parent metal surfaces are wet.
2. Parent metal has been in cold or freezing conditions unless pre-heated prior to welding.
3. A high wind is blowing and no protection is provided.

Visual examination of welds



Preparation of specimen for macro-examination

Visual examination is used to check or detect:
1. Weld size.
2. Profile or weld face shape.
3. Surface defects in weld face.
4. Undercut and overlap.
5. Root defects.
6. Weld penetration either before or after breaking open through the weld as appropriate.

Macro-examination

Using a low-power magnification, levelled, polished and etched sections of welds may be examined to detect:
1. Lack of fusion.
2. Lack of penetration.
3. Porosity.
4. Oxide inclusions.
5. Internal cracks.

Preparation of specimen
1. Cut-out specimen.
2. Prepare a small cross-sectional area.
3. File or grind the surface flat (use a coarse file).
4. Remove the coarse file marks with a smooth file.
5. Using emery paper laid on plate glass, polish with 'M' 'F' and 'O' grade papers. The direction of filing and polishing should be alternated at right-angles and continued until scratch marks are removed.
6. Immerse the polished surface in etching solution eg. 10% nitric acid in industrial alcohol, until good definition of weld structure is obtained. Wash the specimen in hot water, rinse with acetone and dry.

Safety

Protect your eyes — wear goggles or work behind a screen.

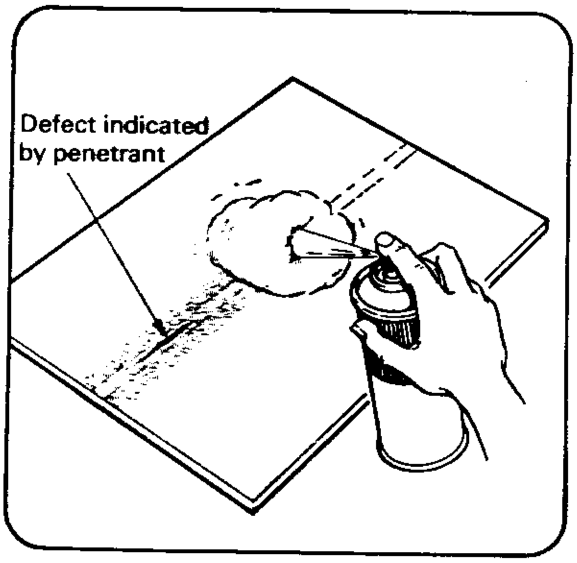
Always have an eyewash available.

Do not allow etching solution to come into contact with the skin.

Do not inhale fumes produced during etching.

Etching solutions must only be mixed by a competent person.

Visual examination of welds

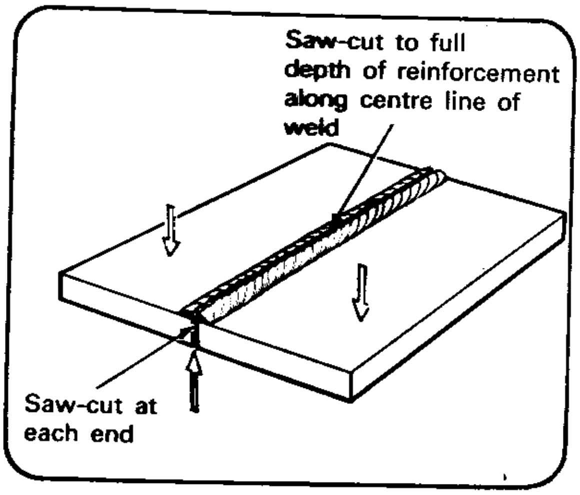


Crack detection

Dye penetrant method

A solution of coloured dye is sprayed on the weld and parent metal and allowed to soak. The dye is then washed off with either a remover or water and the surface dried with a soft cloth.

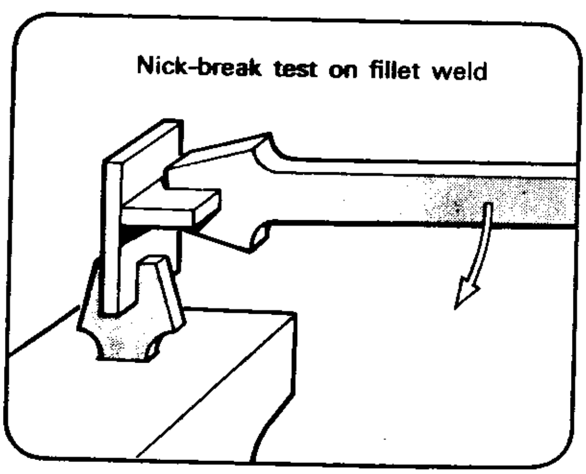
A liquid developer is then sprayed on the weld to give a uniform dry powder coating which is white in colour. The coloured dye oozes out of any cracks in the weld into the white coating and can be seen in normal lighting conditions.



Examination of weld fracture

Preparation of specimens for fracture

Butt weld specimens require to be notched usually at the ends and through the reinforcement to ensure that the fracture occurs along the centre line of the weld. They are called **nick-break tests.**



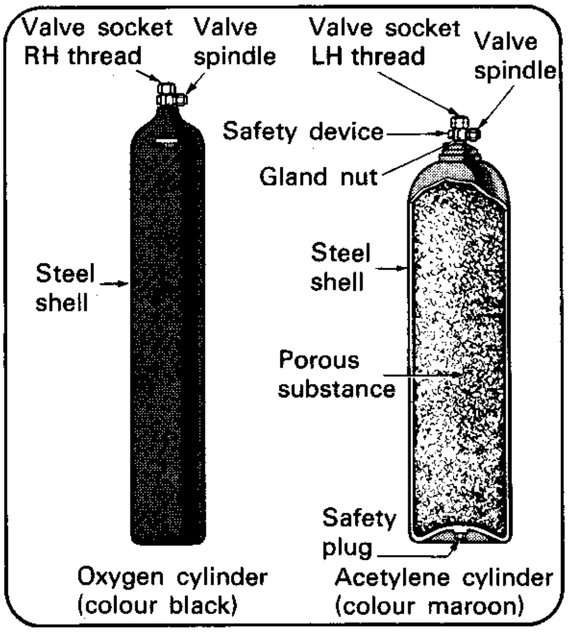
Fillet weld specimens are broken open through the root by hammer blows and/or leverage. Fillet weld specimens may require to be notched at the ends and through the reinforcement to ensure fracture through the centre line of the weld.

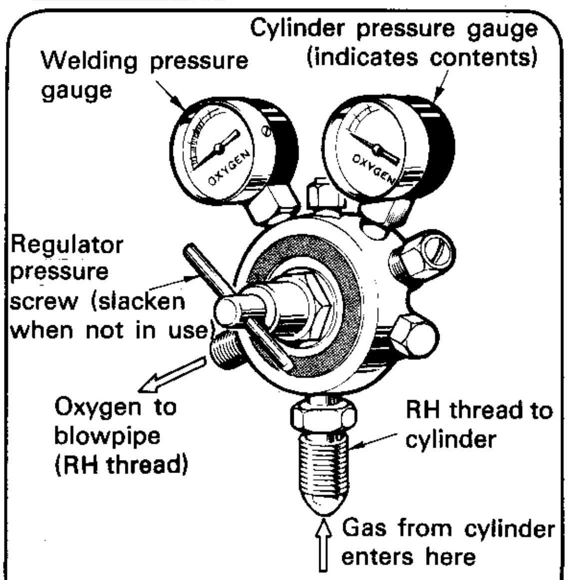
Weld fractures may be examined to detect:

1. Lack of fusion.
2. Lack of root penetration.
3. Non-metallic inclusions.
4. Gas cavities.
5. Oxide inclusions.
6. Quality of weld metal.

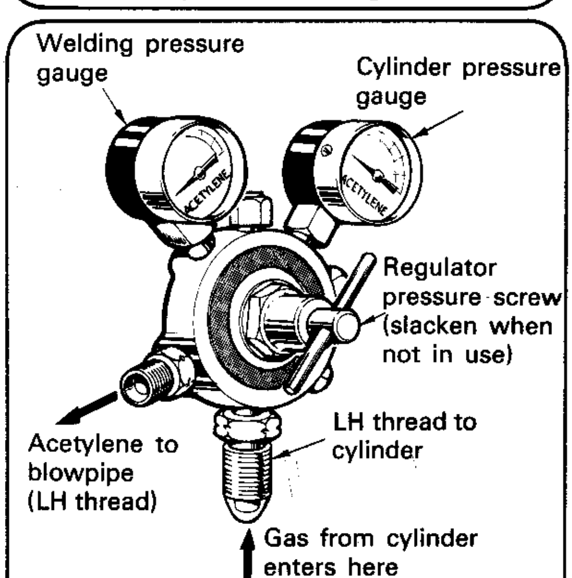
A satisfactory weld would show a clean lustrous appearance together with freedom from the above defects.

Oxy-acetylene welding





Oxygen pressure regulator



Acetylene pressure regulator

Equipment

Oxygen cylinders

The steel cylinders are painted black; the usual size is about 7 m³.

The valve outlet has a right-hand screw thread.

Cylinders are usually charged to a pressure of 137 bars.

Acetylene cylinders

The steel cylinders are painted maroon. They contain porous substances with acetone to act as solvent for the gas, hence 'dissolved acetylene'.

The usual size is about 6 m³.

The valve outlet has a left-hand screw thread.

Cylinders are charged to pressure of approx. 15 bars.

Manifolds

Two or more cylinders may be manifolded together.

Regulators

Pressure regulators are required to reduce cylinder gas pressure to required working pressure.

Regulators for oxygen cylinders have right-hand screw thread.

Regulators for acetylene cylinders have left-hand screw thread.

Outlet pressure gauges

For oxygen these should read up to 2 bars for outlet pressure.

For acetylene these should read up to 1 bar for outlet pressures.

Cylinder pressure gauges

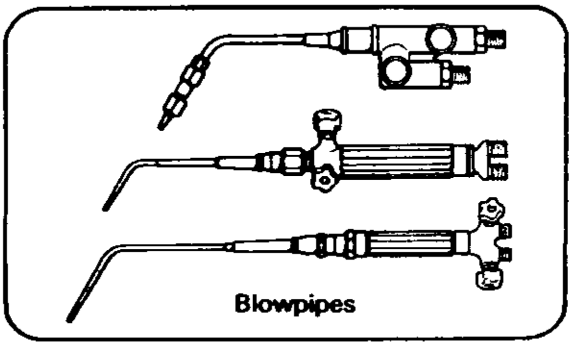
Pressure gauges can be used to indicate the amount of oxygen in the cylinder. Gauges used for this purpose should have a dial reading of not less than 250 bars.

Note: Pressure gauges cannot be used to indicate the contents of dissolved acetylene cylinders. The weight of the cylinder compared to its pre-charge weight is the only guide to content.

Nozzles

Nozzles of blowpipes used for welding may be gooseneck extensions fitting into the mixer portion of the blowpipe, or tips to screw on to the head of the blowpipe.

Size numbers for high-pressure nozzles usually indicate the approximate consumption of each gas in litres/hr., when using a neutral flame.



Hoses

Hoses for oxygen are blue and for other non-combustible gases are black. Both types have right-hand threaded connections.

Hoses for acetylene and most other combustible gases are red; propane hoses are orange. Both types have left-handed connections.

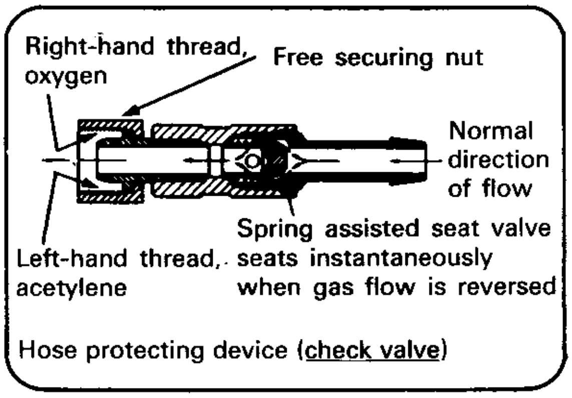
Hose protecting devices

These should be fitted at the blowpipe end of the hoses. They eliminate conditions of flashback and backfire by preventing gas in a line feeding into the other line, which is at lower pressure.

Gas economizer

The economizer will extinguish the blowpipe flame simply by the action of hanging the blowpipe on the lever of the valve controlling the gas supply.

The flame can be re-established ready for welding by lifting the blowpipe and re-lighting at the pilot light.

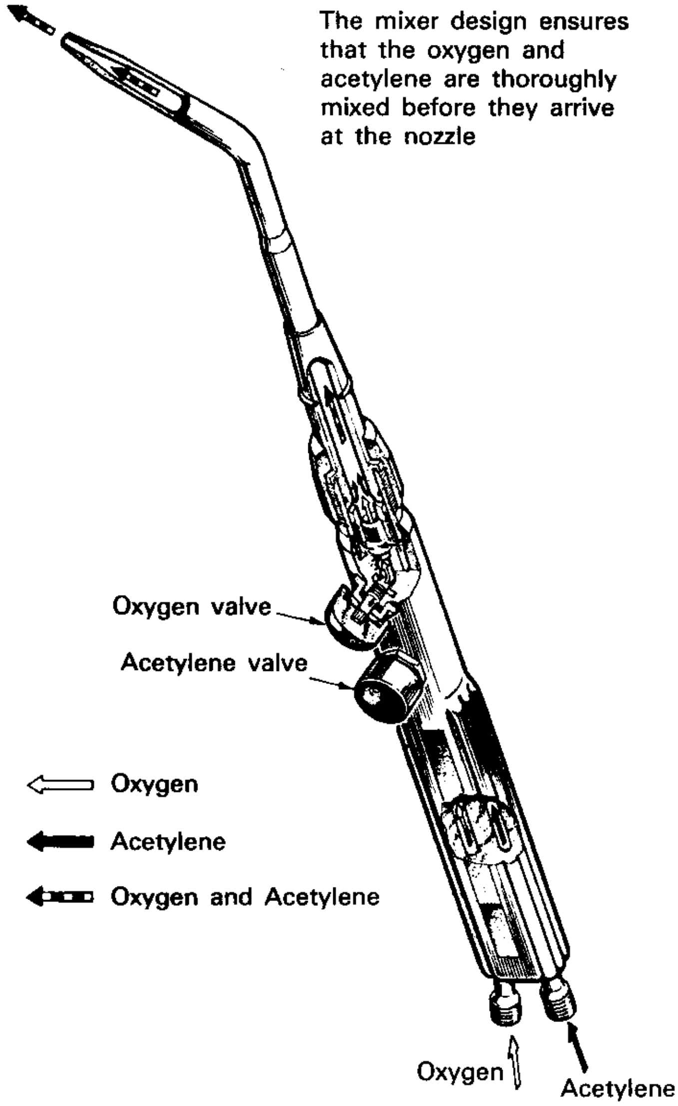


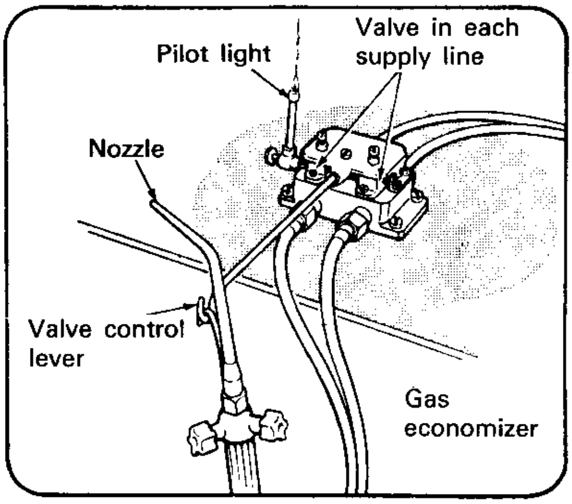
Hose protecting device (check valve)

Blowpipes

High-pressure blowpipes for use with dissolved acetylene are of the mixer pattern.

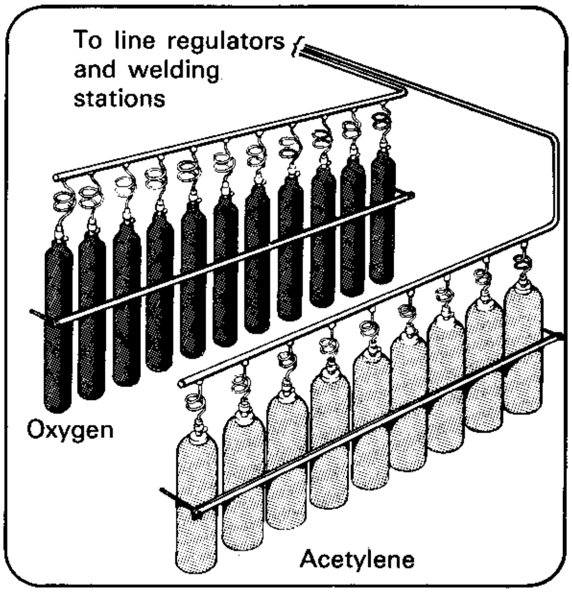
Both gases must be supplied to the blowpipe at pressures appropriate for the blowpipe nozzle in use.





Oxy-acetylene welding

Assembly of equipment

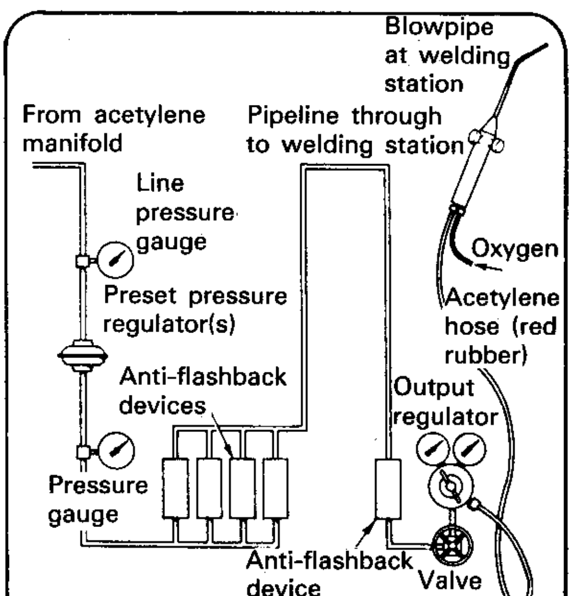


Safety
Do not use any oil, grease or oil-based substance to aid the assembly of equipment. **It may cause an explosion.**

Connections to cylinders

Gas supply may be from separate cylinders secured to a rack, workbench or mobile trolley, or piped to the welding station from an evaporator or cylinders linked by manifolds.

Note: Copper pipe must never be used for acetylene installations.

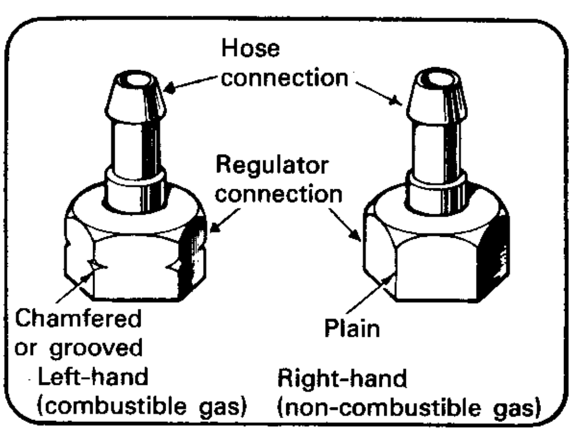


Special manifolds with flashback arrestors must be used for acetylene cylinders

At the welding station (or at the cylinders) the high-pressure gases are passed through regulators to reduce to correct working pressure.

Usually these regulators are screwed into the cylinder outlet valves.

Regulators may be fitted with gauges on the high-pressure side to indicate cylinder gas pressure, and on the low-pressure side to indicate the gas-flow pressure.



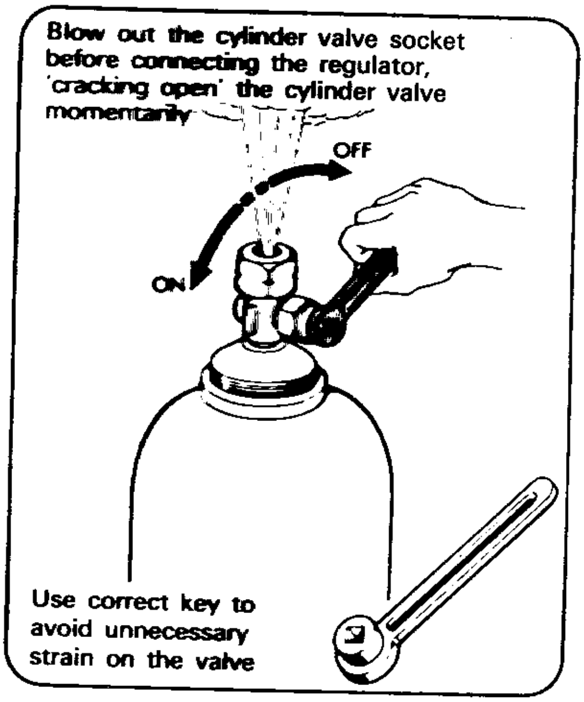
Note: All threaded connections conform to the rule:

1. *Right-hand screw thread for oxygen* (blue hose) *and other non-combustible gases* (black hose).

2. *Left-hand screw thread for acetylene and other combustible gases* (red hose).

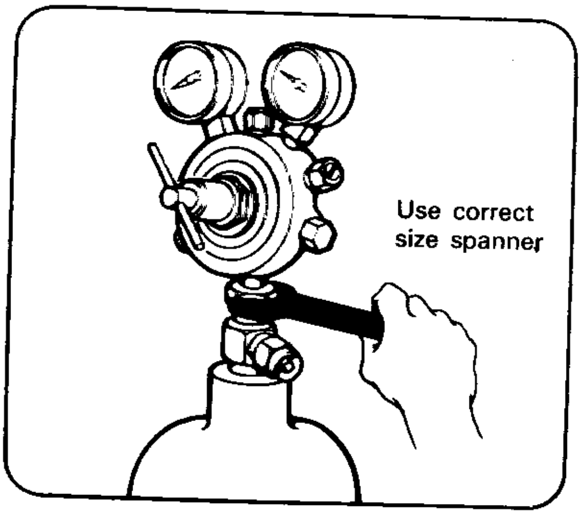
The nuts on oxygen and other non-combustible gas connectors are plain hexagons.

The nuts on acetylene and other combustible gas connectors are chamfered and/or grooved to indicate left-hand threading.



Connecting regulators

Before screwing the regulator into the outlet-valve socket make sure that the socket is clean, dry, and free from dust.



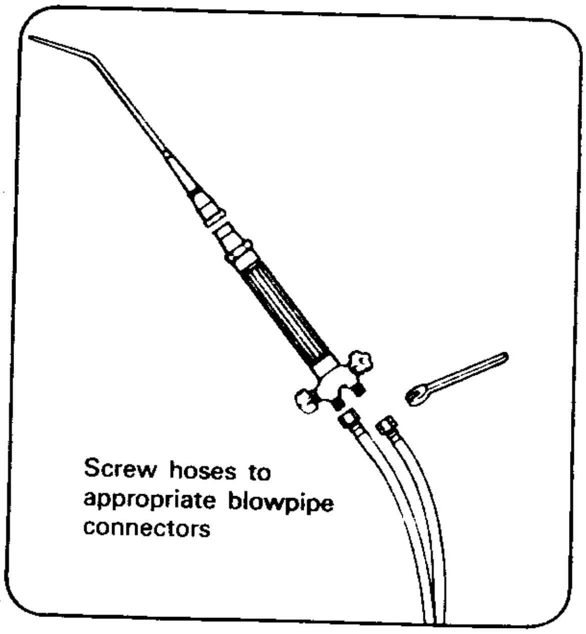
Screw regulator into valve socket until gently home, then a sharp blow with the hand on the spanner shaft will ensure a gas-tight seating.

Slacken regulator pressure-control screw to relieve pressure on the regulator diaphragm.

Connecting hoses

Attach hoses to the regulators, ensuring that an anti-flashback device is fitted at the blowpipe end of the hose. Tighten all nuts, using only the correct size spanners.

When attaching new hoses to regulators, dispel dust etc., quickly by by-passing pressurised gas to atmosphere, momentarily.
Note: This should be done *before* fitting hose protectors.

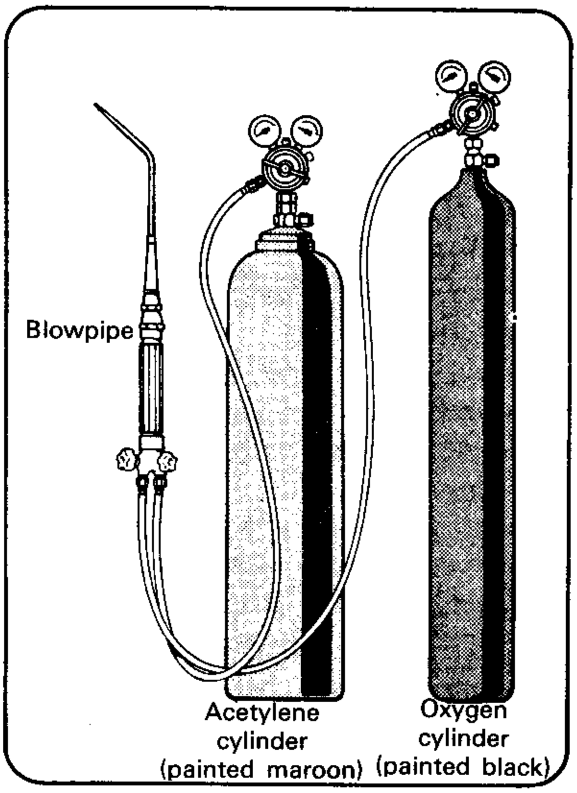


Connecting blowpipe

Using correct size spanner, screw hose connectors to the blowpipe after fitting hose protecting device (see page 73).

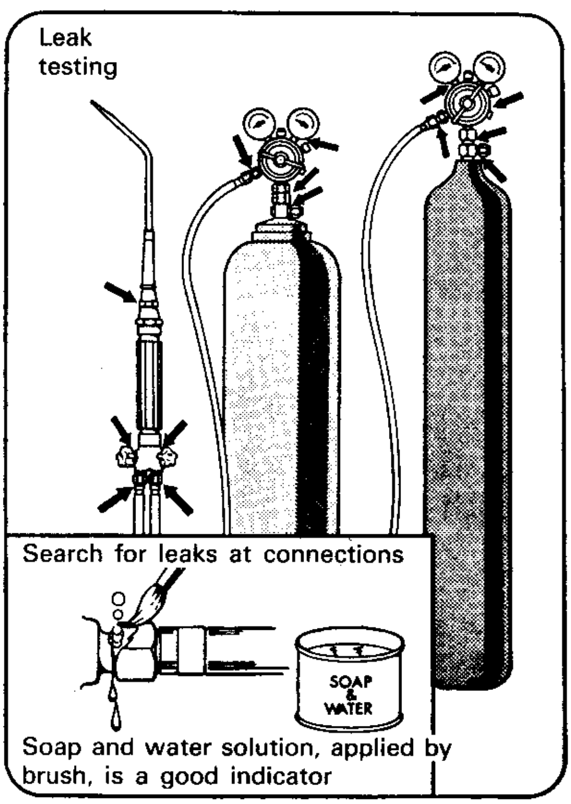
Fit welding nozzle to blowpipe; do not strain by over-tightening.

Nozzle size and gas pressures appropriate to the size are quoted by equipment manufacturers to suit thickness and type of material being welded.



Safety

Do not investigate for gas leaks with a naked flame.



Pressurizing system

1. Close the blowpipe valves.

2. Turn on the gases.

3. Dealing with one gas at a time:

(a) Open the blowpipe valve.

(b) Set the working pressure by adjusting the regulator control.

(c) **Allow gas to flow so that the hose is purged of any other gas.**

(d) Close the blowpipe valve.

4. The system is then pressurized and purged.

Leak testing

At this stage carefully check the system for leaks. Use a small soft hair brush and apply a soap and water solution or 0·5% Teepol in water solution to all connections.

Escaping gases can be detected by sight, sound and feel (or smell in the case of acetylene).

Safety

When a leak is found rectify immediately. Even small amounts of acetylene escaping into a confined space can cause a serious explosion.

Closing down procedure

At the end of the work period, or when there is a long interruption, close down the system:

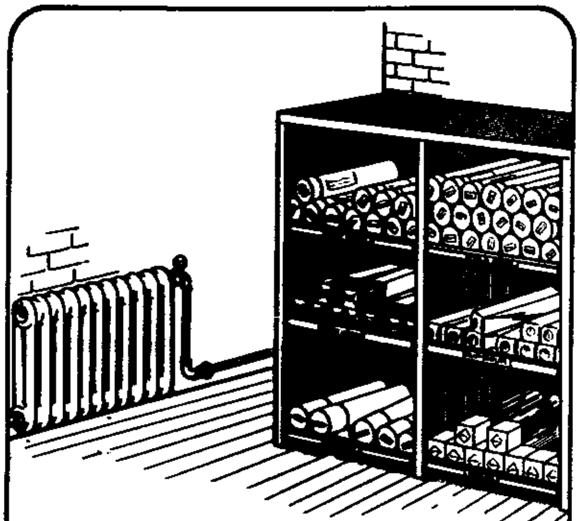
1. Turn off the blowpipe control valves, the acetylene valve first and then the oxygen valve.

2. Close the cylinder valves.

3. Release the pressure in the hoses by first opening the oxygen valve on the blowpipe and closing it; then opening the acetylene valve on the blowpipe and closing it.

4. Release the pressure on the regulator diaphragms by turning the pressure-regulating screw to the minimum pressure position.

Filler rods



Store in clean, dry conditions

Handling and storage

1. Handle filler rods with care.

2. Store under clean, dry conditions to prevent deterioration.

3. Do NOT mix different types of filler rod. Ensure that packages and their labels make for easy and correct selection.

4. Where it is not practicable to store filler rods under heated conditions, an absorbent (such as silica-gel) for moisture may be used in the storage area.

Safety

1. Always place a hot filler rod where it cannot be accidentally touched or handled.

2. Always position the filler rod to avoid personal injury whilst welding—bend filler rod end to prevent injury to the eyes and to facilitate identification of the hot end.

3. Take care to avoid fire hazards by keeping hot filler rods away from combustible materials.

Selection of correct filler rod

1. Filler rods are (a) Drawn; (b) Cast.

2. Ensure the composition of filler rod is suitable to weld the parent metal.

3. The filler rod diameters to be used depend upon the thickness to be welded and the welding position. See pages 78 and 79 for notes on the various filler rods and their applications.

4. Select a filler rod:
(a) of suitable composition,
(b) of correct diameter.

Economy in use

To ensure economy in the use of filler rods, join the short ends to a new length of filler rod.

Preparing the filler rod for use

1. Ensure the rod is free from contamination such as rust, scale, oil, grease and moisture.

2. Ensure the rod is reasonably straight to assist manipulation during welding.

Oxy-acetylene welding

A table of typical filler rods and applications for ferrous materials

Filler rod	Diameter of Filler rods		Flux	Applications	Filler rod British Standard No.	Notes
	mm	Inches				
Low carbon mild steel	1·0, 1·5, 2·0, 2·3, 3·2, 4·5, 6·4	$\frac{3}{64}$, $\frac{1}{16}$, $\frac{5}{64}$, $\frac{3}{32}$, $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$	None	Welding of mild steel and wrought iron	BS 1453:A1	Often copper coated for protection
High carbon and low alloy steels	1·5, 3·2	$\frac{1}{16}$, $\frac{1}{8}$	Use a flux to weld cast iron or high carbon steel	For building up or repair work of steel of similar composition		Not recommended for metal working tools. Hardenable in oil or water
3% Nickel steel	1·5, 3·2	$\frac{1}{16}$, $\frac{1}{8}$	None	Repair work and building up nickel steels of similar composition. Can be hardened and tempered	BS 1453:A4	Useful in the building up of worn camshafts, shafts and gears
Wear resisting alloy steel	3·2, 4·5, 6·4	$\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$	None	Restoring worn crossings and rail ends crushing tools and rock drills. Hardenable in oil. Hard facing of wearing surface	BS 1453:A5	Can be used on any steel or cast-iron surface likely to be worn or damaged by shock and abrasion
Silicon manganese steel	1·5, 2·3, 3·2, 4·5	$\frac{1}{16}$, $\frac{3}{32}$, $\frac{1}{8}$, $\frac{3}{16}$	None	Welding steel where high mechanical properties are required	BS 1453:A2	
High tensile silicon manganese steel	1·5, 2·3, 3·2, 4·5, 6·4	$\frac{1}{16}$, $\frac{3}{32}$, $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$	None	For high-tensile steels of similar composition	BS 1453:A3	Material with tensile strength 400–490N/mm²
Carbon molybdenum	1·5, 3·2, 4·5	$\frac{1}{16}$, $\frac{1}{8}$, $\frac{3}{16}$	None	Used to weld boiler and super heater tubes or any equipment of similar composition subject to heat and stress	BS 1453:A6	Creep-resisting steel rod
Pipe welding	2·3, 3·2, 4·5	$\frac{3}{32}$, $\frac{1}{8}$, $\frac{3}{16}$	None	Used for welding steel pipe	BS 1453:A2	
Stainless steel (Niobium bearing)	1·5, 2·3, 3·2, 4·5	$\frac{1}{16}$, $\frac{3}{32}$, $\frac{1}{8}$, $\frac{3}{16}$	Stainless steel flux	For welding stainless-steel tubes, sheets of matching quality. Austenitic	BS 2901:Pt 2 1970 347 S 94, 95 etc.	
Stainless steel (Molybdenum bearing)	1·5, 3·2	$\frac{1}{16}$, $\frac{1}{8}$	Stainless steel flux	Welding molybdenum bearing stainless steel	BS 1453:A12	
Heat-resisting steel	1·5, 3·2	$\frac{1}{16}$, $\frac{1}{8}$	Stainless steel flux	Welding heat-resisting steels	BS 1453:A11, Nb.	
Cast iron	4·5, 6·4, 8·0, 9·5	$\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$	Cast iron or high carbon steel	Welding high-grade castings. Deposit is machinable	BS 1453:B1	Suitable for cylinder blocks, brackets, lathe-beds and similar products

Note: The Oxy-Acetylene process is not recommended for the welding of corrosion-resisting Austenitic Stainless Steels where it is necessary to avoid dangers associated with oxidizing or carburizing atmospheres (eg. Flames).

A table of typical filler rods and applications for non-ferrous materials

Filler rod	Diameter of Filler rods		Flux	Applications	Filler rod British Standard No.	Notes
	mm	Inches				
Copper silver alloy	1·5, 3·2, 4·5, 6·4	1/16, 1/8, 3/16, 1/4	Copper silver flux	Welding of arsenical, non-arsenical, commercial and deoxidized copper	BS 1453:C1	Suitable for welding copper components, including electrical parts
Bronze welding (Silicon)	1·5, 2·3, 3·2, 4·5, 6·4	1/16, 3/32, 1/8, 3/16, 1/4	Bronzeweld	Bronzewelding copper and brass, sheet tubes, also ferrous metal	BS 1453:C2 BS 1845:CZ6	Available as a ready fluxed rod
Bronze welding (Nickel Bronze)	1·5, 3·2, 4·5	1/16, 1/8, 3/16	Bronzeweld	Bronzewelding steel or malleable iron	BS 1453:C5 and BS 1845:CZ8	Building up worn surfaces, welding copper-zinc-nickel alloys of similar composition
Bronze welding (Manganese)	3·2, 4·5, 6·4	1/8, 3/16, 1/4	Bronzeweld	Bronzewelding cast or malleable iron	BS 1453:C4 BS 1845:CZ7	Building up worn surfaces. Repair of fractured castings
Copper phosphorus brazing alloy	2·3, 3·2, 4·5	3/32, 1/8, 3/16	No flux for copper silver alloy; brass or bronze	Brazing copper, brass and bronze parts for electrical switchgear, motors, dynamos, cable joints, etc.	BS 1845:CP3	Not to be used directly on steel or cast-iron
Strip spelter (Brazing)	2·3, 6·4	3/32, 1/4	Boraxweld based flux	Brazing copper, copper alloys and ferrous metals	BS 1845:CZ1	
Aluminium bronze	3·2	1/8	Aluminium bronze	Welding aluminium bronze, eg. Crotorite, where there are conditions of shock, fatigue and dilute acid		
Aluminium (Pure)	1·5, 2·3 3·2, 4·5	1/16, 3/32, 1/8, 3/16	Aluminium welding	Used in the welding of pure aluminium sheet tube and extrusions	BS1453:G1B	
Aluminium alloy (5% Copper)	1·5, 3·2, 4·5, 6·4	1/16, 1/8, 3/16, 1/4	Aluminium welding	Welding aluminium castings especially those containing 5% copper		
Aluminium alloy (5% Silicon)	1·5, 2·3 3·2, 4·5, 6.4	1/16, 3/32, 1/8, 3/16, 1/4	Aluminium welding	Welding pure aluminium sheet, tube and extruded sections and aluminium castings not containing zinc	BS 1453:NG21 BS 1845:AL4	
Aluminium alloy (10–13% Silicon)	1·5, 2·3, 3·2, 4·5	1/16, 3/32, 1/8, 3/16	Aluminium welding or brazing	Welding high silicon aluminium alloys. Brazing pure aluminium and aluminium/magnesium alloys up to 2% magnesium	BS 1453:NG2 BS 1845:AL2	
Aluminium alloy (10% Silicon-4% Copper)	1·5, 3·2	1/16, 1/8	Aluminium brazing	Brazing aluminium and its alloys	BS 1845:AL1	Difficult to apply on aluminium alloys containing more than 2% magnesium. Heat treatable deposit
Aluminium alloy (5% Copper-2% Silicon)	6·4	1/4	Aluminium welding	Welding crankcases, gear-boxes or castings of similar composition		
Aluminium alloy (5% Magnesium)	1·5, 2·3 3·2, 4·5	1/16, 3/32, 1/8, 3/16	Aluminium welding	Welding alloy parts in MG5 for automobile and aeronautical work	BS 1453:NG6	Can be used also on corrosion-resisting tanks
Magnesium alloy (1–2% Manganese)	3·2	1/8	Magnesium	Welding alloys similar to DTD118A	BS 1453:D2	These alloys are better welded by TIG process
Magnesium alloy (10% Aluminium)	3·2, 4·5	1/8, 3/16	Magnesium	Welding alloys containing 10% aluminium	BS 1453:D1	
Zinc-base die casting metal	3·2 usually square section	1/8	Use aluminium flux if necessary	Welding castings such as carburettors, typewriters, washing-machine components	BS 1004A	
Non-ferrous hardfacing alloys	3·2, 6·4	1/8, 1/4	Set carburizing flame correctly. Use cast-iron flux for cast-iron surface	Primarily to withstand abrasion impact at various temperatures, possess low co-efficient of friction and gives high resistance to corrosion. Retains hardness at 'red' heat		A range of hardfacing alloys is available from many sources and careful choice will enable an alloy to be found to cover most requirements

Welding flux

Welding flux is available in powder or paste form. Welding flux performs a number of functions, including the formation of a fluid pool, and gives protection against oxidation. It is important to follow the manufacturer's instructions for use.

Storage of flux

1. Where the flux is in the form of a coating on the filler rod, protect carefully at all times against damage and dampness.

2. Seal flux tin-lids when storing especially for long periods.

Selection of flux

The choice of flux to be used will depend upon the type of material to be joined, the accessibility of the joint and any specific requirements relating to the component to be welded.

A flux will be necessary when welding Copper and Copper Alloys; Aluminium and Aluminium Alloys; Magnesium Alloys, and Braze Welding Stainless Steel and Cast Irons. Copper may be welded without a flux in appropriate cases.

It is not necessary to use a flux when welding wrought iron and mild steel.

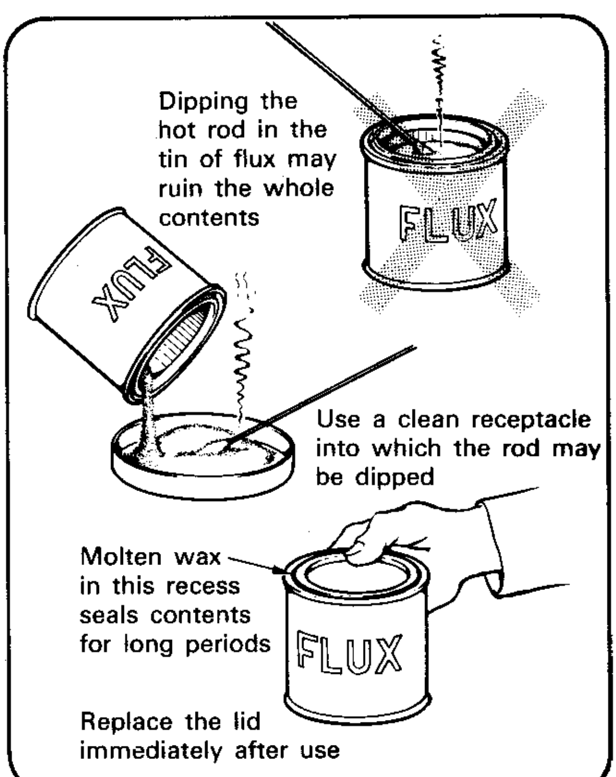
Commercial fluxes are readily available suitably prepared for various metals and welding conditions, but it is important to read the manufacturer's instructions and to ensure that the flux is appropriate for the work concerned.

Applying flux

Introduce the flux to the weld by either:

(a) dipping the heated end of the filler rod into the flux to obtain a coating (ie. tufting).

(b) applying as paste with a suitable brush.



Important

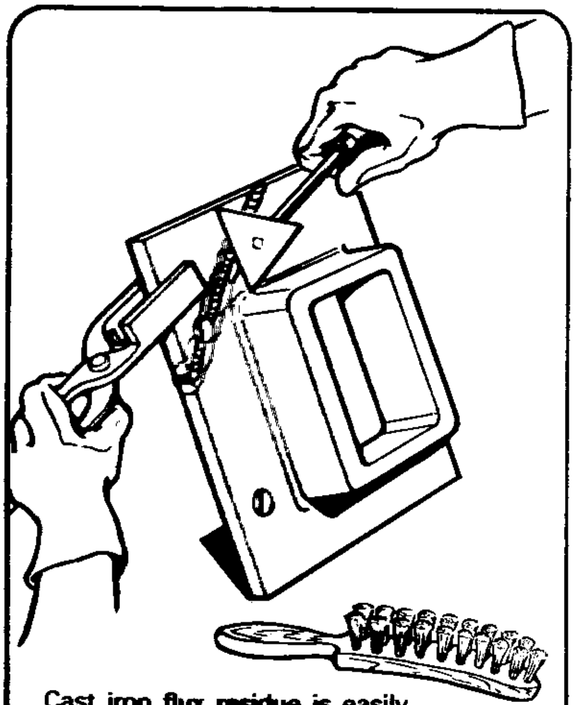
Do not dip the filler rod directly into the flux tin; place supplies of flux in a separate clean container for immediate use.

Flux residue removal

Safeguard against corrosive attack and poor weld appearance by removing all flux residue immediately the welded component is cooled.

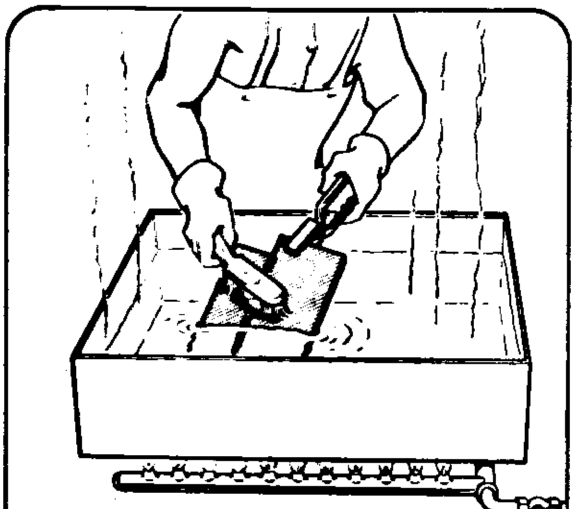
Methods of removing flux include:

1. Removal by wire brush and scraper. (This method is mainly used on cast iron.)



Cast iron flux residue is easily removed by wire brush and scraper

2. Immersing the weld in hot water and scrubbing vigorously.



Place welded parts into hot water, scrub vigorously to remove flux residue

Alternatively, a mild acid solution can be used, followed by final washing in hot water. (Suitable for aluminium, copper, brass and stainless steel.)

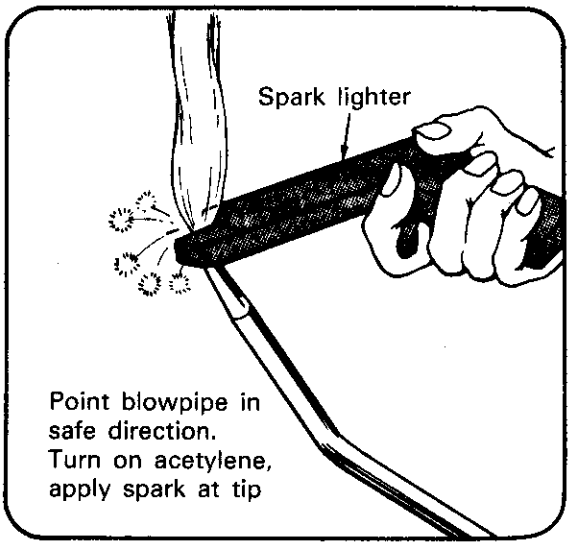
Safety

Follow the appropriate safety precautions when using acid.

Oxy-acetylene welding

The welding flame

The essential requirement for oxy-acetylene welding is a hot, controlled flame, easily manipulated, to heat or melt metal without altering the chemical composition of the metal.



Lighting and adjusting the blowpipe flame

1. Close all valves on the blowpipe.

2. Open cylinder valves very slowly by one turn *only* of the spindle.

3. Set the regulators to the correct working pressures.

4. Point the blowpipe in a safe direction and open the acetylene control valve on the blowpipe about three-quarters of a turn.

5. Wait a few seconds to flush system with acetylene. This purges the blowpipe from the mixer forward and prevents backfires on lighting up.

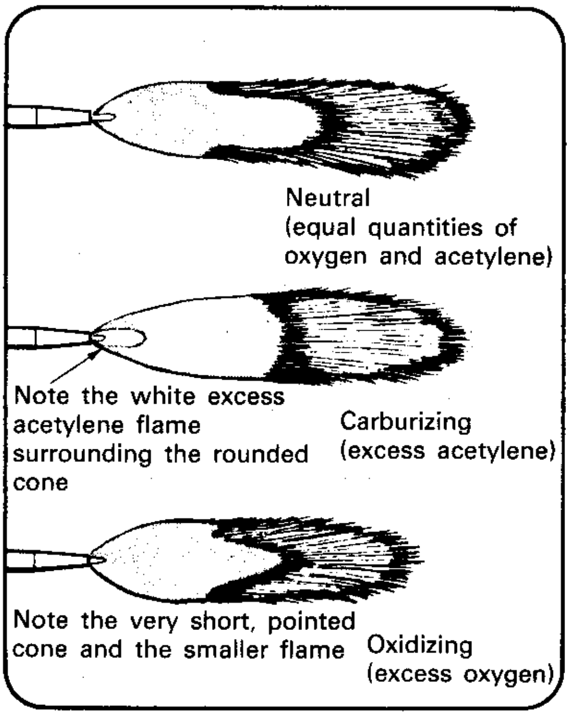
6. Using a spark lighter, light the acetylene.

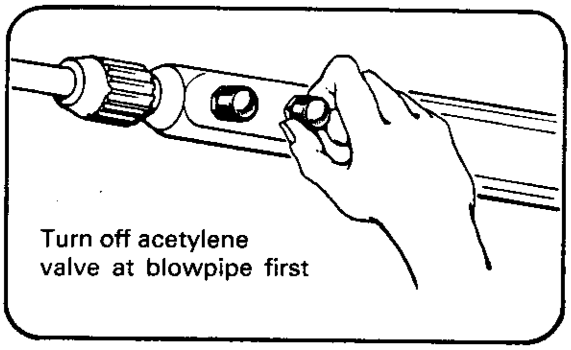
7. Reduce or increase the gas supply, by operating the blowpipe valve, until the flame just ceases to smoke.

8. Open the oxygen control valve on the blowpipe until the white inner cone in the flame is sharply defined with the merest trace of 'feather' or acetylene haze at the tip.

This is the neutral flame used for all welding of mild steel.

9. To extinguish the flame, close the acetylene valve and *then* the oxygen valve on the blowpipe. Alternatively, hang lit blowpipe on gas economizer valve-control lever.





General procedure

The following general instructions, which are not repeated later in the text, apply to oxy-acetylene welding.

Always

1. Comply with the prescribed safety precautions and fire-prevention procedure.

2. Check that hoses are not 'kinked' or otherwise obstructed.

3. Check that correct size nozzle is fitted to the blowpipe.

4. Check that cylinder valves are open.

5. Check that regulators are set to correct working pressures.

6. Use effective protective equipment and any necessary protective clothing.

7. If gas economizer is used, check that the pilot light is lit.

8. Point the blowpipe in a safe direction when lighting.

9. Handle the lit blowpipe with due caution and take care that the flame does not impinge on gas-cylinder walls.

10. Concentrate on watching the welding operation.

11. Hold the blowpipe with just sufficient grip at the point of balance to give full control.

12. Extinguish blowpipe flame when not in use or when moving location, and follow closing-down procedure when necessary.

13. Carefully segregate different types and sizes of filler rod. Ensure that they are protected from moisture.

14. Place the welding torch in a safe place when not in use.

15. Ensure complete removal of flux residue after welding.

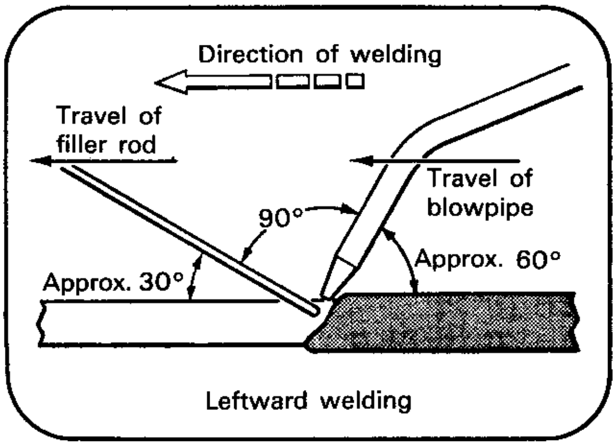
16. Ensure the main gas supplies are turned off at source at the end of the work period.

17. Ensure that the work area is left in a tidy condition and that equipment is properly stored. Return unused filler rods to store in their original packages and ensure that flux tin lids are replaced and sealed.

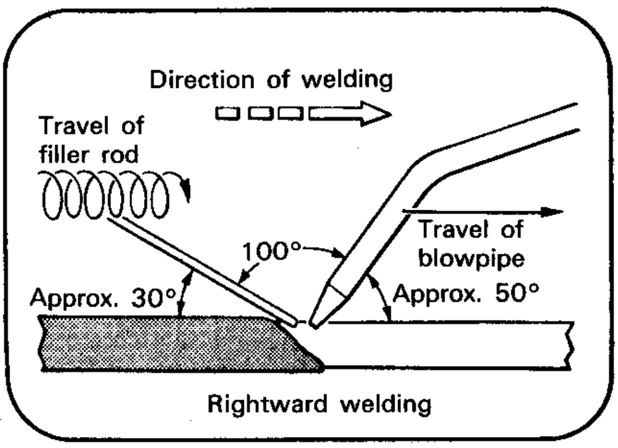
18. Before leaving the work area, ensure freedom from burning or smouldering materials. Avoid leaving any form of fire risk.

Safety

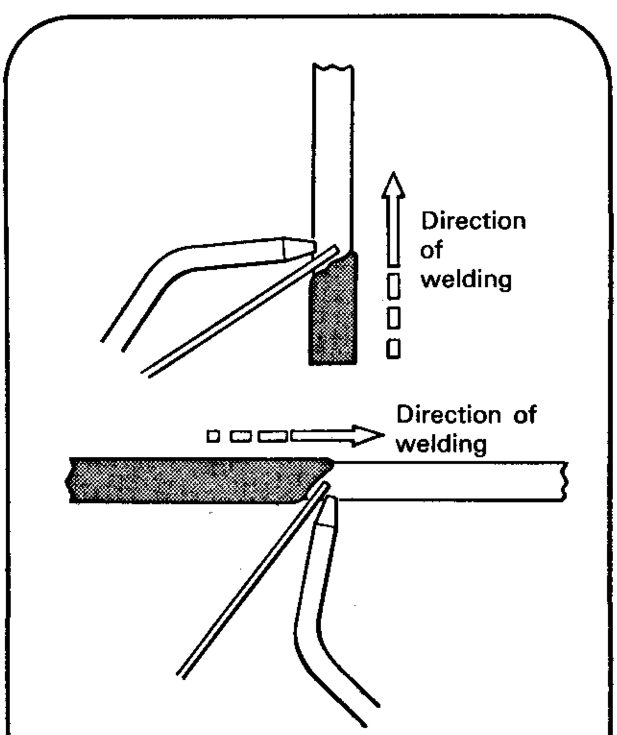
Do not remove the cylinder key from the acetylene cylinder, it may be needed urgently for fire prevention purposes. Keep fireproof gloves readily available.



Leftward welding



Rightward welding



All-position rightward weld

Welding methods

Leftward welding

In leftward welding the flame is directed towards the unwelded part, and the filler rod when used is directed towards the welded part of the joint.

With the blowpipe held in the right hand, welding proceeds from right to left; with the blowpipe held in the left hand, welding proceeds from left to right. In vertical welding the movement is upwards.

This technique is used for welding steel in thicknesses less than 5 mm. In the vertical position it is also used for the welding of plates up to 15 mm thick where two people weld each side simultaneously.

Rightward welding

The method of welding which has been termed rightward welding should be adopted for the thicker plates. For this technique the blowpipe normally makes an angle of 50° with the plane of the plate, and the welding rod an angle of 30°. The blowpipe flame in this case points towards the deposited metal. When held in the right hand, welding proceeds from left to right.

All-position rightward welding

This is a modification of the normal rightward technique, in order to be suitable for welding in all positions. The path travelled by the flame and the filler rod varies with the welding position. The angles at which the flame and the filler rod are held also vary, and these variations are referred to in detail in the Example Procedures which follow later in this section of the manual.

Material thickness and related techniques

Position	Material thickness range	Method
Flat	Not exceeding 5 mm Exceeding 5 mm	Leftward Rightward
Horizontal-Vertical	1 mm to 5 mm 5 mm and above	Leftward All-Position Rightward
Vertical (Single Operator)	1 mm to 5 mm 5 mm and above	Leftward All-Position Rightward
Vertical (Two Operator Technique)	5 mm and above	Leftward
Overhead	1 mm to 5 mm 5 mm and above	Leftward or All-Position Rightward

Welding procedure

1. Use the appropriate preparation and technique. Refer to the related tables of Nozzle Sizes and Welding Conditions.

2. The prepared plates should be correctly set-up in the welding position and suitably tack welded. Before tack welding, taper space the plates 6 mm per 400 mm run irrespective of plate thickness. The joint is set up to give the correct gap at the point where the first tack weld is made. As the tacks are progressively made, contraction will bring the plates together to the correct gap setting.

3. Fix the assembly securely in the welding position.

4. Commence to fuse the tack at the beginning of the joint.

5. Pause to allow the metal to be heated sufficiently to ensure full penetration at the commencement of the joint.

6. When the molten pool has formed, commence to travel, adding the filler rod.

7. Hold the filler rod and the blowpipe at the recommended angles. The angle of the flame to the workpiece governs the heat build-up and thus the amount of melting and penetration.

8. Carefully control the lateral movement of the blowpipe. Excessive sideways movement or too slow a speed of travel along the line of weld will enlarge the molten pool, and cause overheating, with possible burn-through.

9. Terminate the weld carefully by manipulating the blowpipe to reduce heat whilst controlling the deposit of filler metal.

10. On completion, carefully examine the weld and see that there is:

(a) uniform reinforcement, making due allowance for positional joints;

(b) freedom from blowholes, undercut, overlap, cracks, porosity and other defects;

(c) in the case of butt joints, adequate root penetration and no burn-through of the plates.

Nozzle sizes

The capacity of a nozzle (the power) is recognized by the amount of acetylene it consumes per hour at the recommended gas pressures; this is usually expressed in cubic feet or litres. Manufacturers usually mark their nozzles with a number, indicating the capacity in cubic feet or litres.

Always check the manufacturer's recommended flame setting for specific nozzles.

For any metal, and welding technique employed, the flame required has a definite relationship to the type of metal and thickness.

High Pressure or Mixer Type Blowpipes

Examples of nozzle sizes for various metal thicknesses are shown in the table below.

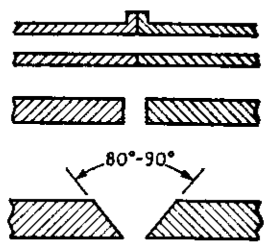
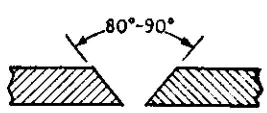
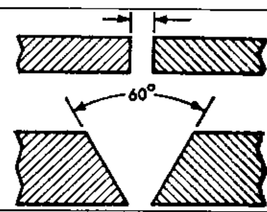
(a) Nozzle sizes indicate the approximate consumption of each gas in litres (or cubic feet) per hour using a neutral flame.

(b) The size of nozzle for a particular thickness of steel is for general guidance only, and will vary according to the skill of the welder, mass of metal, etc. The capacity of each nozzle overlaps the capacities of those next in size to it. The examples given are for butt welds in mild steel in the flat position.

Plate thickness	Nozzle size	
mm	number	litres/hr
0·8	1	29
1·2	2	57
1·6	3	86
2·4	5	140
3·0	7	200
4·0	10	280
5·0	13	370
6·0	18	520
8·0	25	710
10·0	35	1000
12·0	45	1300
19·0	55	1600
25	70	2000
Over 25	90	2500

Preparation and welding conditions for mild steel

Butt joints
Flat and horizontal-vertical positions

	Material thickness	Preparation	Final gap after tacking	Filler rod size	Welding technique
	mm		mm	mm	
Single-run deposit	1·0		Nil	—	Leftward
	1·2		1·0	1·2–1·6	Leftward
	1·6		1·5	1·6	Leftward
	3·0		3·0	3·2	Leftward
	5·0		3·0	3·2	Leftward
Multi-run deposit	5·0		3·0	3·2	Leftward
	6·0		3·0	3·2–4·0	Leftward
	10·0		3·0	4·8	Leftward
Single-run deposit	5·0		2·5–3·5	3·2	Rightward
	6·0		2·5–3·5	3·2	Rightward
	10·0		2·5–3·5	4·8	Rightward

Note: For joints to be welded in the horizontal-vertical position it may be necessary to modify single vee preparations to a single bevel preparation to ensure adequate penetration.

Butt joints
Vertical position

Material thickness	Preparation	Final gap after tacking	Filler rod size	Welding technique Vertical Upward
mm		mm	mm	
1·6		1·5	1·6	S.W.
2·4		1·5	1·0–2·4	S.W.
3·0		3·0	3·2	S.W.
*5·0		3·0	3·2	S.W.
5·0	This preparation is used for steel up to 10 mm thick	2·5	1·6	T.W.
6·0		3·0	2·4	T.W.
10·0		3·0	3·2	T.W.

Note:
S.W.—Single Welder;
T.W.—Two Welders.
*Bevel edge preparation may be considered preferable.

Butt joints
Overhead position

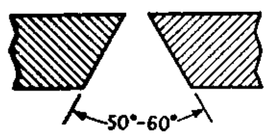
Material thickness mm	Preparation	Final gap after tacking mm	Filler rod size mm	Welding technique
1·0 2·4 3·2 5·0	 This preparation is used for steel up to 10 mm thick [See Table on page 85]	1·0 1·0 1·5 2·5	1·6 1·6 3·2 3·2	(a) Up to 3·2 mm material thickness Leftward (b) Over 3·2 mm and up to 5·0 mm thickness Rightward or Leftward
6·0 10·0		2·5 3·5	4·0 4·8	All position Rightward

	Plate thickness mm	Final gap after tacking	Filler rod size mm	Welding technique
Single-run deposit	1·2	None	1·6	Leftward
	1·6	None	1·6	Leftward
	3·2	None	3·2	Leftward
Multi-run deposit	5·0	None	3·2	Leftward
	6·0	None	4·0	Leftward
	10·0	None	4·8	Leftward
Preferred technique (See 2) single-run deposit	5·0	None	3·2	Rightward
	6·0	None	4·0	Rightward
	10·0	None	4·8	Rightward

T joints

1. For T joints in the horizontal-vertical position made from plates 5 mm thick and above, use the rightward welding technique.

2. For T joints in the vertical and overhead positions, use the above conditions, but for plates 5 mm thick and above, use the following technique:

(a) *All-position rightward* when welding upwards and

(b) *Rightward* when welding downwards.

Lap joints

	Plate thickness mm	Final gap after tacking	Filler rod size mm	Welding technique
Single-run deposit	1·0	Close fit	1·2	Leftward
	1·2	Close fit	1·6	Leftward
	1·6	Close fit	1·6	Leftward
	3·2	Close fit	3·2	Leftward
Multi-run deposit	5·0	Close fit	3·2	Leftward
	6·0	Close fit	4·0	Leftward
	10·0	Close fit	5·0	Leftward or Rightward
Preferred technique (See note) single-run deposit	5·0	Close fit	3·2	See note
	6·0	Close fit	4·0	See note
	10·0	Close fit	5·0	See note

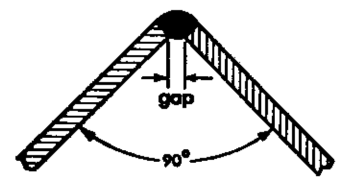
Note: **Welding** techniques when using plates 5 mm **and over:**

(a) **In the flat,** horizontal-vertical and overhead **positions, for** the upper weld use rightward **technique, and** for the lower weld use all-**position rightward** technique.

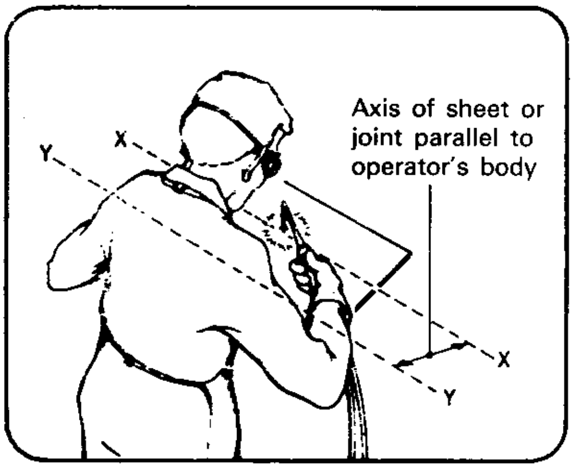
(b) **In the vertical** position, when welding **upwards use all-position** rightward, and when **welding downwards** use rightward technique.

Corner joints

	Plate thickness mm	Final gap after tacking mm	Filler rod size mm	Welding technique
Single-run deposit	1·0	Nil	None	Leftward
	1·2	Nil	None	Leftward
	1·6	Nil	None	Leftward
	3·2	3·0	3·2	Leftward
Multi-run deposit	5·0	3·0	3·2	Leftward
	6·0	3·0	3·2 or 4·0	Leftward
	10·0	3·0	4·8	Leftward
Preferred technique single-run deposit	5·0	3·0	3·2	Rightward
	6·0	3·0	3·2 or 4·0	Rightward
	10·0	3·0	4·8	Rightward

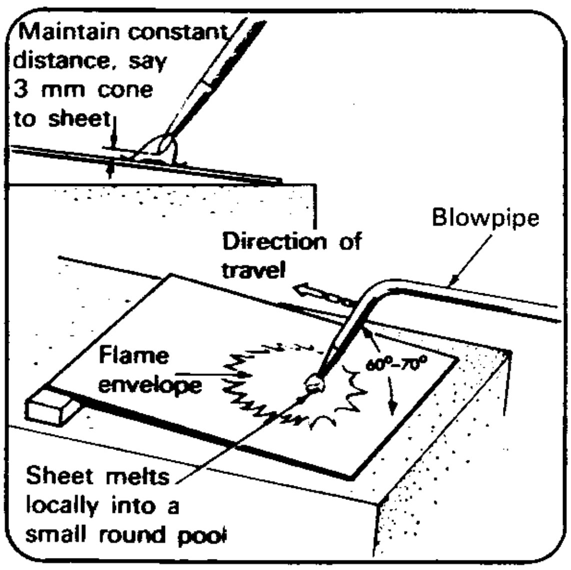


Example procedures



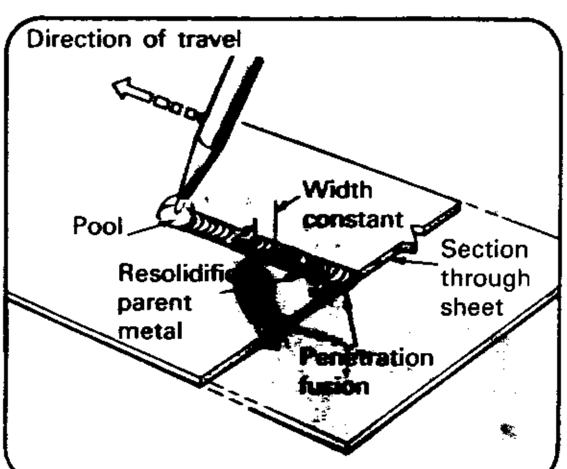
Fusion without filler metal—Flat position
Example procedure EP/OA/1

Material	One piece of mild steel 3 mm thick. Min. size 200 mm × 100 mm
Preparation	Clean surface
Assembly	Right-hand short edge of sheet resting on bench, left raised about 15 mm
Nozzle size	5 (140 litres/hr)
Regulators	Each 0·14 bar



1. Set flame to neutral, and with goggles in position, lower blowpipe until the end of the inner cone is about 3 mm above sheet surface near right-hand edge.

2. Adjust angle of nozzle to 60°–70° to sheet, pointing in direction of travel.

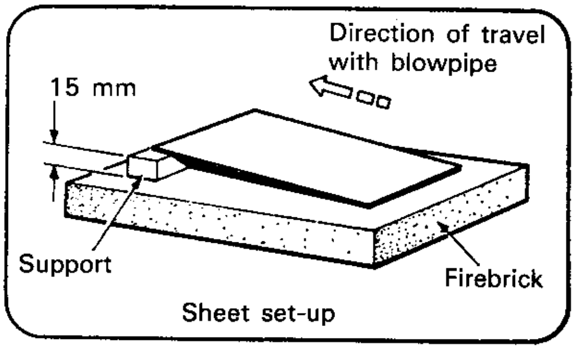


3. As soon as local fusion (to form a small round pool of molten metal) is achieved, move the blowpipe in leftwards direction.

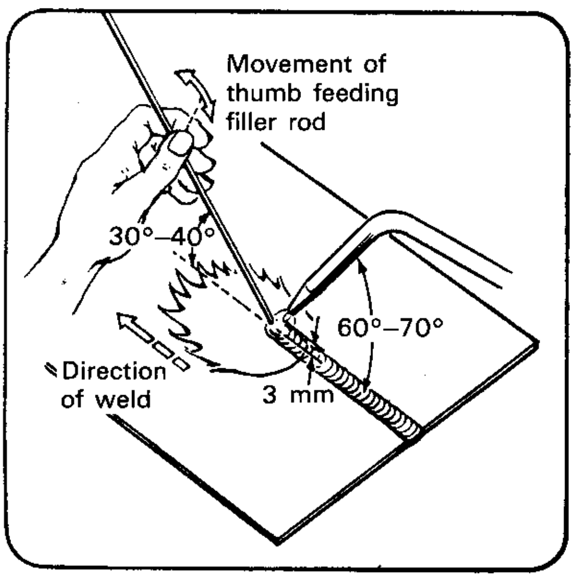
4. Synchronize rate of travel with the progressive formation of the molten pool and avoid excess concentration of heat.

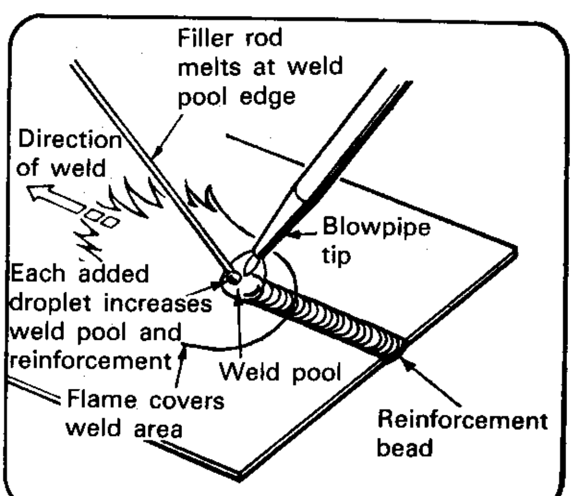
Visual examination
If speed of travel is correct the fused and solidified metal will be uniform in width.

Depositing straight runs—Flat position
Example procedure EP/OA/2



Material	One piece of mild steel 3 mm thick. Min size 200 mm × 100 mm
Preparation	Clean surface
Assembly	Support in slightly inclined position
Nozzle size	5 (140 litres/hr)
Regulators	Each 0·14 bar
Filler rod	3·2 mm BS 1453/A1





1. **With the blowpipe** nozzle held at an angle of 60°–70°, **establish** a small pool of molten **metal at the right**-hand edge of sheet.

2. **Hold filler rod** in left hand, pointing at the **front edge of molten** pool and at an angle of 30°–**40°** to **sheet** surface.

3. **Allow the flame** to melt a droplet of metal **from the end of the** filler rod.

4. **Start the progressive** leftwards movement of **blowpipe and** filler rod.

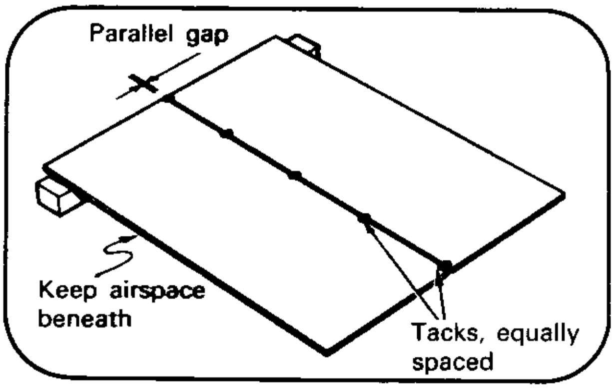
5. **Keep the end of** the filler rod within the flame **envelope but** not in the hot portion near the **cone**.

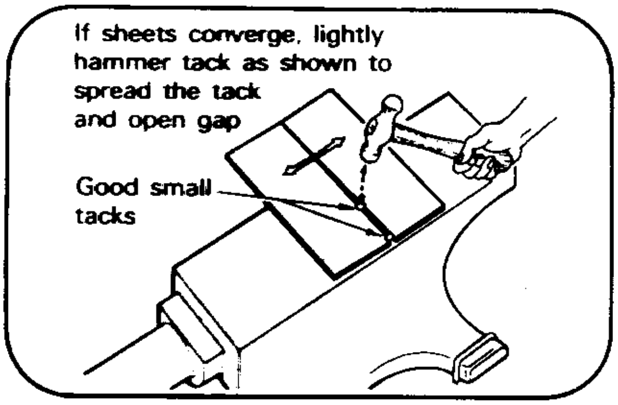
6. **Continue addition** of molten filler metal by **moving the end** of the filler rod repeatedly to **the front edge** of the molten pool and the hotter **portion of the** flame.

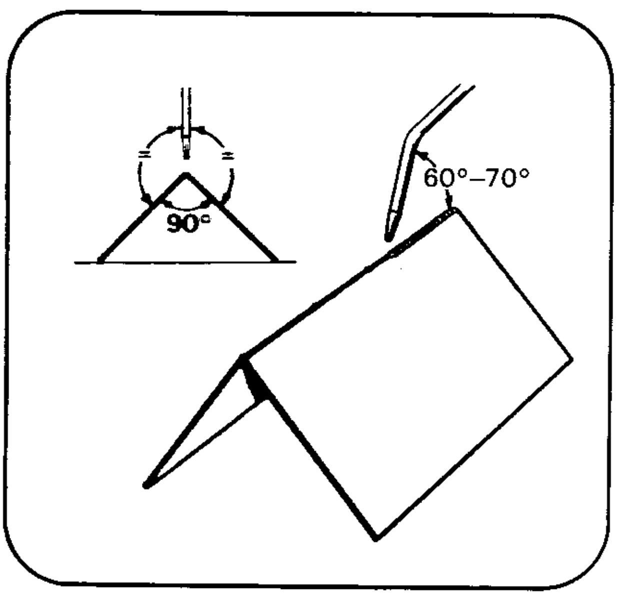
7. **Rate of** travel leftwards should be co-**ordinated with** melting of filler rod to control **size of bead** and extent of penetration.

8. **When near** the left-hand edge of the sheet **slowly withdraw** the flame.

Visual examination
If the speed of travel is correct, and the filler rod **applied correctly**, the deposition will be of even **ripple and** uniform width.







Visual examination

If the speed of travel has been correct, complete fusion of the fusion faces will be achieved. The underside of the joint will show a descaling line on each sheet near the root of the joint or a slight penetration bead.

If 'holing' of the sheet (burn-through) has occurred this will be the result of excess concentration of heat locally and indicates that the speed of leftwards travel has been too slow.

Tack welds

Tack welding is important particularly for the maintenance of gap and alignment of parts.

Tack welds on sheet metal should be short in length but must be sound and sufficient in number to prevent movement of the parts being welded.

The distance between tacks should be about 40 mm for sheet metal up to 1·5 mm and about 50 mm for sheet metal between 1·5 mm and 5 mm thickness. These distances may be doubled for fillet-welded T joints.

Tack welding procedure

1. Tack welds should be on the side to be welded and in the line of the joint.
2. Heat small triangular area with blowpipe to melt the parent metal where the tack weld is required.
3. Add filler metal to molten pool to make a small but sound weld and then remove flame.
4. Repeat until all tack welds are made making sure that the gap is kept uniform and of the correct size (where a gap is required).

Corner joint—Flat position
Example procedure EP/OA/6

Material	One piece of mild steel 3 mm thick. Min size 150 mm × 100 mm
Preparation	Square edge
Assembly	Tack weld with five tacks to give included angle of 90° without gap and no filler metal (see note)
Nozzle size	7 (200 litres/hr)
Regulators	Each 0·14 bar

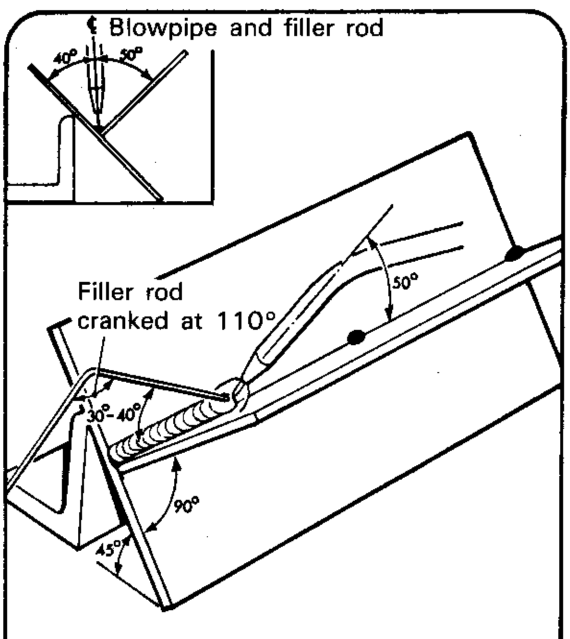
1. Heat the sheet corners at the right-hand end of the joint until the tack weld fuses.
2. Immediately progress leftwards along the joint.
3. The nozzle of the blowpipe should be at an angle of 60°–70° and directed to secure fusion of both edges of the sheets.
4. Keep the tip of the white cone about 3 mm above the weld pool.
5. Adjust the rate of leftwards travel to secure fusion without burning through the sheets.

Note: A piece of filler rod may be used to control fusion where necessary.

Oxy-acetylene welding

Close square T fillet joint—Flat position
Rightward welding
Example procedure EP/OA/7

Material	Two pieces of mild steel 6 mm thick. Min. size 250 mm × 150 mm
Preparation	Square edge
Assembly	Tack weld to form an inverted T without gap between the plate. Support the lower sheet so that it is tilted at 45° transversely
Nozzle size	18 (250 litres/hr)
Regulators	Each 0·28 bar
Filler rod	4 mm



T fillet weld, rightward technique
flat position

1. **Commence** welding at the left-hand end of the joint by fusing the tack weld and the parent metal to form the weld pool.

2. Point the blowpipe in a leftward direction at an angle of 50° and the filler rod at an angle of 30°–40°.

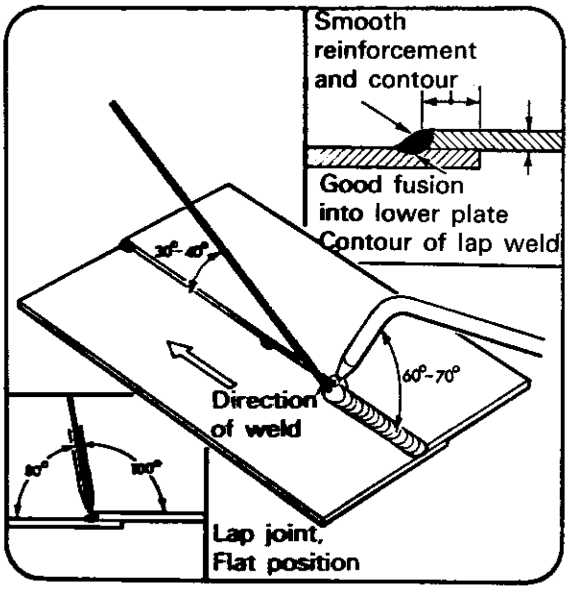
3. As the weld pool is formed, add filler metal by a progressive rotary movement, moving the flame along the line of the joint without weaving.

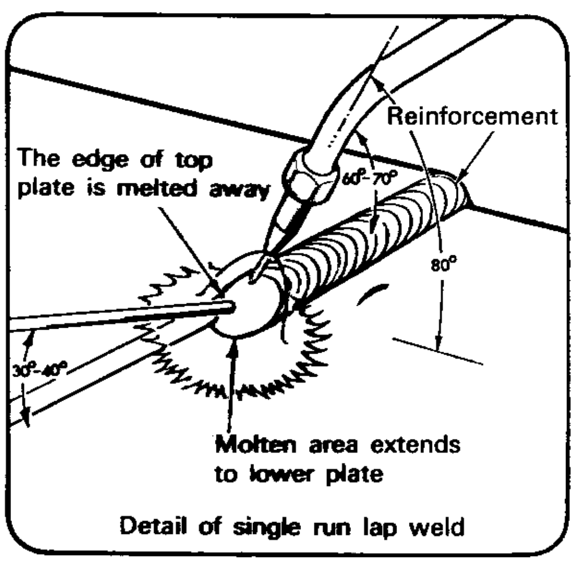
4. Adjust the rate of travel to secure even penetration into both sheets and to produce a fillet weld of equal leg lengths.

5. The weld is terminated by adding sufficient filler rod to obtain adequate build up at the end of the joint.

Visual examination
In a satisfactory weld the profile will be uniform and slightly concave. The joint should be free from undercut at the toes and of equal leg lengths.

Lap joint—single fillet weld—Flat position
Leftward welding
Example procedure EP/OA/8





Detail of single run lap weld

Material	Two pieces of mild steel 3 mm thick. Min. size 200 mm × 150 mm
Preparation	Square edge
Assembly	Place one plate overlapping the other with long sides parallel. Secure by weld tacks at each end and one at the centre. Close fit-up is necessary
Nozzle size	7 (200 litres/hr)
Regulators	Each 0·14 bar
Filler rod	3·2 mm

1. Commence welding by fusing the tack weld and parent metal at the right-hand end of the plates. Fuse the upper plate and the surface of the lower plate locally to form the weld pool. The weld pool will include, locally, the edge of the upper plate and the surface of the lower plate immediately beneath.

2. Point the blowpipe nozzle in a leftward direction at an angle of 60°–70° slope and 80° tilt from the plate surface.

3. Add the filler rod with a piston movement into the weld pool along the top of the plate edge to reduce burning away of this edge. The filler rod is held at an angle of 30°–40° slope and 80° tilt from the plate surface.

4. When fusion is progressing, co-ordinate addition of weld metal and speed of travel.

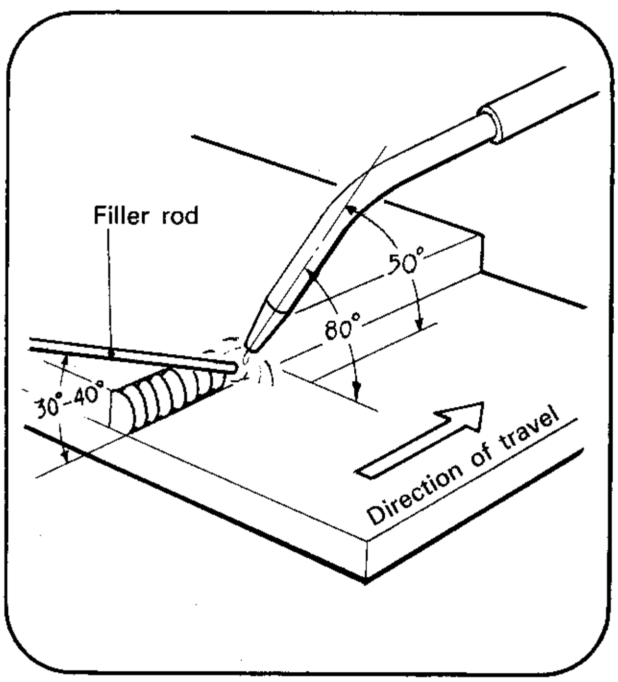
5. Pay particular attention to root penetration and full fusion to the lower plate.

6. The weld is terminated by adding sufficient filler rod to obtain adequate build up at the end of the joint. The speed of deposition must be increased and the angle of the blowpipe reduced, together with the shortening of the cone-to-pool distance with a reduced angle of filler rod.

Visual examination
The weld reinforcement and profile should be uniform along the length of the joint. The leg length should be equal with no undercut at the edges or fusing of the top plate edge.

Lap joint—single fillet weld—Flat position
Rightward welding
Example procedure EP/OA/9

Material	Two pieces of mild steel 6 mm thick. Min. size 250 mm × 150 mm
Preparation	Square edge
Assembly	Place one plate overlapping the other with the long sides parallel. Secure by tacks at each end and one in the centre. Close fit-up is necessary
Nozzle size	25 (710 litres/hr)
Regulators	Each 0·42 bar
Filler rod	4 mm



1. Commence welding by fusing the tack weld and parent metal locally at the right-hand end of the joint to form the weld pool.

2. The weld pool will include locally the edge of the upper plate and the surface of the lower plate immediately beneath.

3. Point the blowpipe nozzle in a leftward direction at an angle of 50° slope and 80° tilt from the lower plate surface.

4. Add the filler rod with a progressive gyratory movement into the weld pool. It is held at an angle of 30°–40° slope and 80° tilt from the lower plate surface.

5. When fusion is progressing, co-ordinate addition of weld metal, speed of travel and full root fusion.

6. Pay particular attention to the avoidance of adhesion to the lower plate.

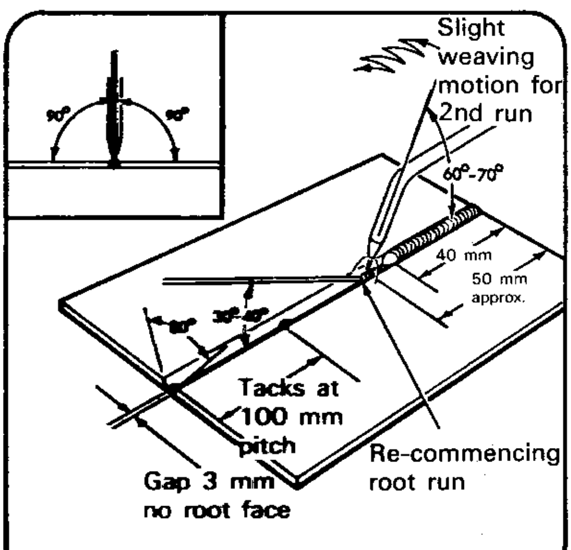
7. Terminate the weld carefully to ensure adequate build up.

Visual examination
The reinforcement should be even along the length of the seam. The contour should be smooth with no undercut at the edge or fusing away of the top plate edge.

Oxy-acetylene welding

Single Vee butt joint—Flat position
Leftward welding
Example procedure EP/OA/10

Material	Two pieces of mild steel 6 mm thick. Min. size 250 mm × 150 mm
Preparation	80° to 90° inclusive angle
Assembly	Tack weld at 100 mm pitch. Final gap 3 mm. Support the assembly above the bench in the flat position with the seam to be welded remaining unsupported
Nozzle size	18 (520 litres/hr)
Regulators	Each 0·28 bar
Filler rod	3·2 mm



1. Using the leftward technique to deposit the root run for a distance fo 50 mm, hold the filler rod and flame at the angles as shown in the illustration. Make sure fusion is complete, extending about half-way up the fusion faces. Maintain a suitable molten pool to obtain full penetration.

2. A second run of 40 mm is superimposed on to the first, using a semi-circular sideways motion of the flame to fuse the plate edges. The second run is terminated 10 mm from the end of the first run in order to facilitate the join up.

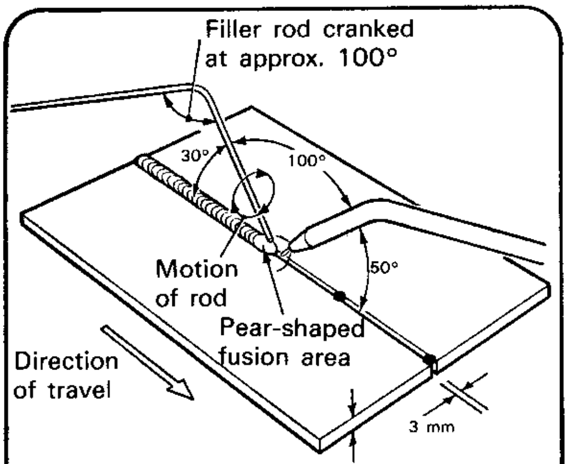
3. When recommencing both the root and second runs, re-fuse the last 6 mm back from the end of the weld to establish the molten pool and ensure an efficient join up.

By this step method, the full thickness of the plate is welded along its length in a series of superimposed runs, the flame and filler rod being manipulated at the end to ensure a suitable build up.

Visual examination
The surface of the weld should be regular with suitable reinforcement and freedom from undercut. The ripple should be consistent along the length of the seam. There should be adequate root penetration.

Square edge butt joint—Flat position
Rightward welding
Example procedure EP/OA/11

Material	Two pieces of mild steel 4 mm thick. Min. size 250 mm × 150 mm
Preparation	Square edge or 60° inclusive angle
Assembly	Tack weld the plate at 100 mm pitch. Final gap about 3 mm. Support the assembly above the bench in the flat position with the seam to be welded remaining unsupported
Nozzle size	18 (520 litres/hr)
Regulators	Each 0·28 bar
Filler rod	3·2 mm



Rightward technique—mild steel, 4 mm and above

1. **Commence** welding at the left-hand end of the **joint, holding** the filler rod and flame as **recommended** for rightward welding (see **illustration**).

2. **Ensure adequate** heating of the parent metal. **Melt the tack** and plate to establish the weld **pool before adding** filler metal.

3. **When fusion** is established, commence the **rightward movement** by introducing the end of the **filler rod into the** pool, travelling from left to **right with** a **rotating** movement. Direct the **flame into the joint** to ensure complete melting at **the fusion** faces. A hole in the front of the **pool will cause** the penetration bead to **progressively** fall. The movement and feeding in **of the filler rod** will produce the reinforcement.

4. **When a new** filler rod is necessary, maintain the **molten pool** by suitable flame manipulation **during the** introduction of the filler rod without **delay**.

5. To **complete** the seam (at approximately 5 mm **from the** end) the angles of the filler rod **and flame** are quickly adjusted to permit the **end of the seam** to be built up to full section by **adaptation of** the leftward method.

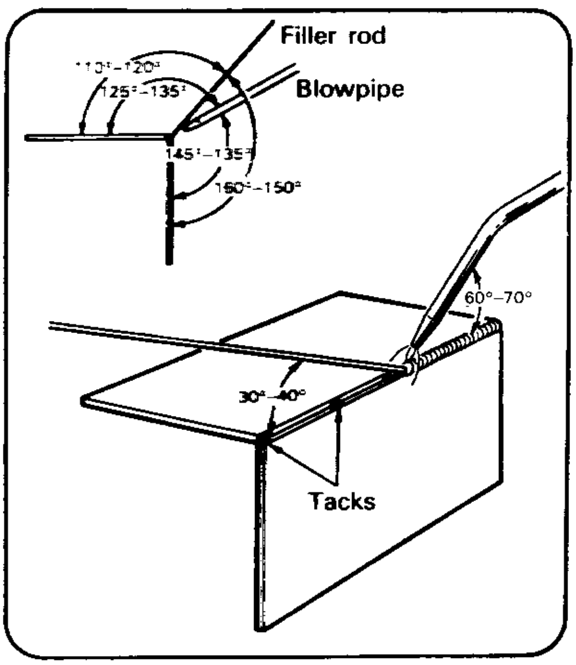
6. **Each tack** should be completely fused **through the** full thickness of the material **throughout** the welding of the joint.

Visual examination
The surface of the weld should be regular with suitable reinforcement and freedom from undercut. The ripple should be consistent along the length of the seam. There should be adequate root penetration.

Oxy-acetylene welding

Corner joint—Horizontal-vertical position
Leftward welding
Example procedure EP/OA/12

Material	Two pieces of mild steel 3 mm thick. Min. size 150 mm × 100 mm
Preparation	Square edge
Assembly	Tack weld with five tacks to form an inverted L with included angle of 90°; gap 1·5 mm. Support with the horizontal sheet pointing away from the welder
Nozzle size	7 (200 litres/hr)
Regulators	Each 0·14 bar
Filler rod	3·2 mm



1. The blowpipe nozzle should be held at the usual angle to the line of the joint but inclined so that it is at an angle of 125°–135° to the top surface of the horizontal sheet.

2. The filler rod should be held at the usual angle to the line of the joint but inclined so that it is at an angle of 110°–120° to the top surface of the horizontal sheet.

3. Direct the white cone of the flame at the root of the joint.

4. When parent metal fuses at the right-hand corners, add filler metal to form weld pool and start leftwards movement.

5. Add filler metal at top edge of weld pool, as required to build up the weld.

6. Co-ordinate rate of travel and addition of filler metal, to obtain a slightly convex profile.

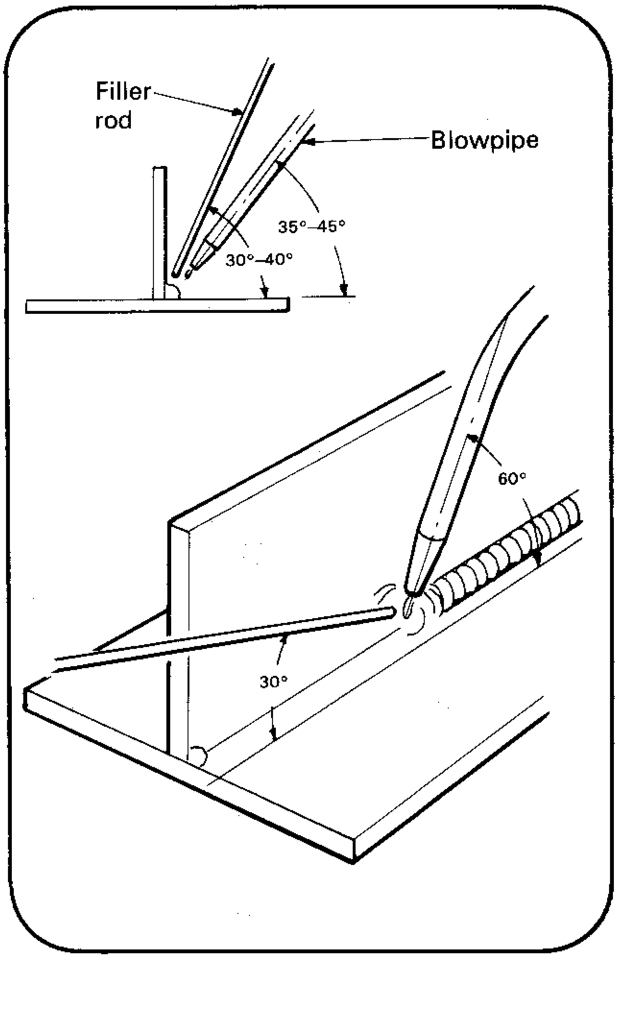
Visual examination
In a satisfactory weld the profile will be uniform and slightly convex.

A slight penetration bead or, at least, a descaling line on each sheet near the root of the joint, should show on the reverse side of the joint, to indicate fusion to the root.

Oxy-acetylene welding

Close square T fillet joint—
Single run—Horizontal-vertical position
Leftward welding
Example procedure EP/OA/13

Material	Two pieces of mild steel 4 mm thick. Min. size 250 mm × 150 mm
Preparation	Square edge
Assembly	Tack weld to form an inverted T without gap between the plates. Support assembly with lower plate horizontal
Nozzle size	18 (520 litres/hr)
Regulators	Each 0·28 bar
Filler rod	2·4 mm



1. Commence welding at right-hand end of the joint, fusing tack weld and parent metal to form the weld pool.

2. The blowpipe nozzle should be held at an angle of 60° slope, and inclined so that it is at an angle of 35°–45° of tilt.

3. The filler rod should be held at an angle of 30° slope to the line of the joint, but inclined so that it is at an angle (tilt) of 30°–40° to the vertical.

4. Direct the cone of the flame into the root of the joint giving a slight semi-circular movement.

5. The filler rod is added at the front edge of the pool alongside the vertical plate.

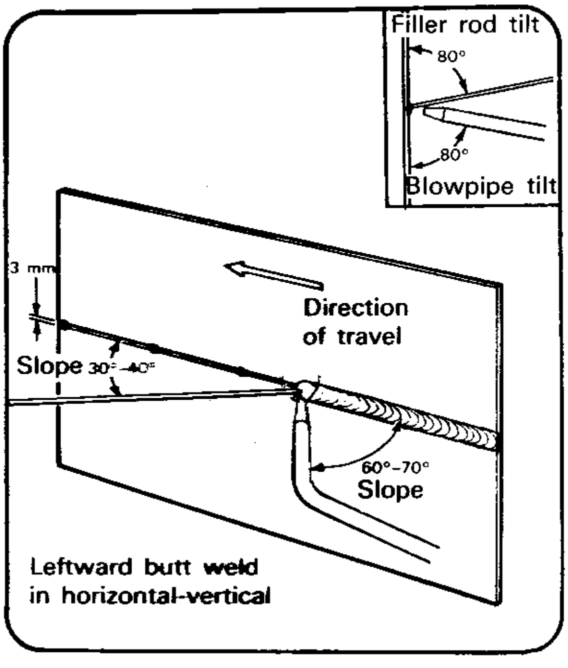
6. Co-ordinate the rate of travel in accordance with the rate of fusion to ensure control of the weld pool. Pay particular attention to the root penetration.

7. The weld is terminated by adding sufficient filler rod to obtain adequate build up at the end of the seam. The speed of deposition must be increased, and the angles of blowpipe and filler rod changed as metal is quickly added to complete the joint.

Visual examination
The weld face should be of uniform reinforcement; convex profile and free from undercut along the toes.

Open square butt joint—
Horizontal-vertical position
Leftward welding
Example procedure EP/OA/14

Material	Two pieces of mild steel 3 mm thick. Min. size 200 mm × 150 mm
Preparation	Square edge
Assembly	Tack each end of the plate and at a pitch of 75 mm along the seam. Final gap 3 mm. Secure the assembly with the joint in the horizontal-vertical position
Nozzle size	7 (200 litres/hr)
Regulators	Each 0·14 bar
Filler rod	3·2 mm



1. Commence welding from the right-hand end of the plate, holding the rod and blowpipe as shown in the diagram.

2. When the molten pool is established maintain under control, moving the flame progressively forward, and add filler rod to the molten pool by suitable piston movement.

3. Repeat this motion of rod and flame along the joint.

4. Manipulate the rod and blowpipe to ensure control and avoid collapse.

5. If the heat build up becomes excessive, remove the point of the cone temporarily from the weld.

6. The weld is terminated by adding sufficient filler rod to obtain adequate build up at the end of the joint.

7. Deposition of metal is then stopped and the filler rod removed, followed by the flame. The flame should always be removed slowly, lowering the angle of slope to ensure adequate protection and avoid defects.

Visual examination
Reinforcement should be adequate for the thickness of plate with no tendency towards pronounced irregularity and undercutting due to the effect of gravity. The root side of the plates should be completely fused along the edges.

Material	Two pieces of mild steel 6 mm thick. Min. size 200 mm × 150 mm
Preparation	Square edge or 60° inclusive angles
Assembly	Tack weld the plate at 100 mm pitch. Final gap approximately 3 mm. Secure the assembly (at a convenient working height) with the seam in the horizontal-vertical position. The seam must be welded whilst unsupported on the reverse side
Nozzle size	18 (520 litres/hr)
Regulators	Each 0·28 bar
Filler rod	3·2 mm
Angles of slope	(To line of completed weld) Blowpipe 100°–110° Filler rod 60°–70°
Angles of tilt	(Relative to upper vertical plate) Blowpipe 90° Filler rod 85°

Square edge butt joint—
Horizontal-vertical position
Rightward welding
Example procedure EP/OA/15

1. Using the rightward technique, commence welding at the left-hand end of the joint. Hold the filler rod and flame as detailed for angles of slope and tilt.

2. The fusion faces should be completely fused before adding filler rod to establish the weld pool.

3. When fusion has been established locally, introduce the end of the filler rod to the pool by a rotating motion. Direct the flame into the joint to make certain the heat is sufficient to cause complete fusion and produce a hole in front of the molten pool to cause the penetration bead to be progressively formed. Maintain the filler rod and flame at the recommended angles to ensure root penetration and complete fusion.

4. A uniform speed of travel should be maintained to ensure complete fusion without collapse or burn-through of the molten pool.

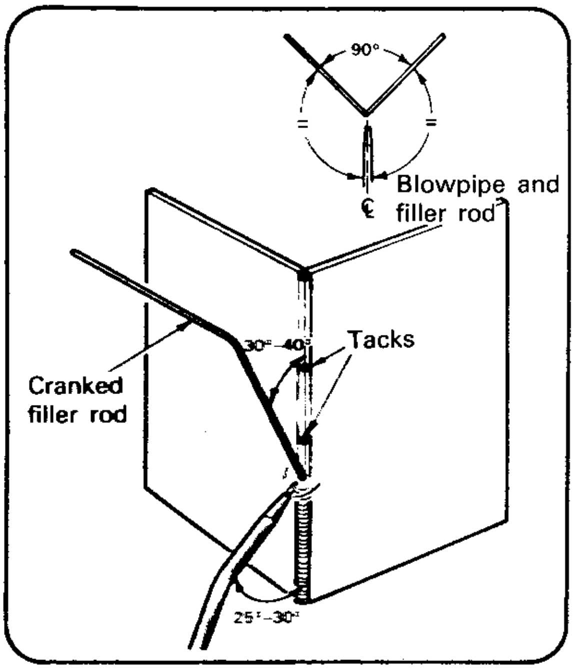
5. When a new filler rod is necessary, maintain the molten pool by suitable flame manipulation during the introduction of the filler rod without delay.

6. To complete the seam (at approximately 5 mm from the end) the angles of the filler rod and flame are quickly adjusted to permit the end of the seam to be built up to full section by adaptation of the leftward and rightward methods. Each tack should be completely fused through the full thickness of the material throughout the welding of the joint.

Visual examination
As with the 6 mm plate welded by the rightward method (in the flat position) the surface of the weld should be regular with suitable reinforcement and freedom from undercut. The ripple should be consistently uniform along the length of the seam, together with adequate root penetration.

Corner joint—Vertical position
Example procedure EP/OA/16

Material	Two pieces of mild steel 1·6 mm thick. Min. size 150 mm × 100 mm
Preparation	Square edge
Assembly	Tack weld with five tacks to give an included angle of 90°; gap 1·5 mm. Support with line of joint vertical with bottom end of joint about 150 mm above bench top and with face of joint towards operator
Nozzle size	2 (57 litres/hr)
Regulators	Each 0·14 bar
Filler rod	1·5 mm



1. Melt away tack weld at bottom of joint and, when parent metal fuses, add filler metal to form weld pool.

2. The blowpipe nozzle should be pointed upwards at an angle of 30°–40°.

3. Crank the filler rod so that it can be used without exposing hand to flame heat.

4. With 'pear shaped' melted area established in parent metal, commence upward movement.

5. Adjust the rate of travel, adding filler metal at the front edge of the molten pool, to build up the weld metal bead to a slightly convex profile.

6. Do not travel too fast or the penetration will be lost. The pear-shaped melted area in advance of the weld pool must be maintained until the crater is built up.

Visual examination
The weld profile should be reasonably uniform without any appreciable 'sagging' caused by tendency of molten metal to flow downwards.

A slight penetration bead should be present on the reverse side of the joint.

Material	Two pieces of mild steel 1·6 mm thick. Min. size 150 mm x 100 mm
Preparation	Square edge
Assembly	Tack weld to form an inverted T without gap between the sheets. Secure the assembly at a convenient working height with the seam vertical
Nozzle size	3 (86 litres/hr)
Regulators	Each 0·14 bar
Filler rod	1·6 mm
Angles of slope	Blowpipe 30°–40° Filler rod 30°
Angle of tilt	Blowpipe and Filler rod 40° to vertical plate

Close square T joint—Vertical position
Leftward welding
Example procedure EP/OA/17

1. Commence welding by fusing the tack weld and parent metal at the bottom end of the joint to form the weld pool.

2. Point the blowpipe nozzle upwards at an angle of 30°–40°.

3. Hold the filler rod at an angle of 30°.

4. Direct the cone of the flame at the root of the joint.

5. Do not weave the blowpipe but add the filler rod to the top edge of the pool.

6. Adjust the rate of travel to produce a fillet weld with leg lengths between 3 mm and 5 mm.

Visual examination
The reinforcement should be uniform along the length of the seam and free from undercut at the toes of the weld.

Material	Two pieces of mild steel 6 mm thick. Min. size 250 mm x 150 mm
Preparation	Square edge
Assembly	Tack weld to form an inverted T without gap between the plates. Secure the assembly at a convenient working height with the seam vertical
Nozzle size	18 (520 litres/hr)
Regulators	Each 0·28 bar
Filler rod	3·2 mm
Angles of slope	Blowpipe 80° Filler rod 45°–60°
Angle of tilt	Blowpipe and Filler rod 45°

Close square T joint—Vertical position
All-position rightward technique
Example procedure EP/OA/18

1. Commence welding by fusing the tack weld and parent metal at the bottom end of the joint to form the weld pool.

2. Hold the blowpipe nozzle at a slope angle of 80°. Add filler rod at an angle of 45°–60° to the molten pool under the flame.

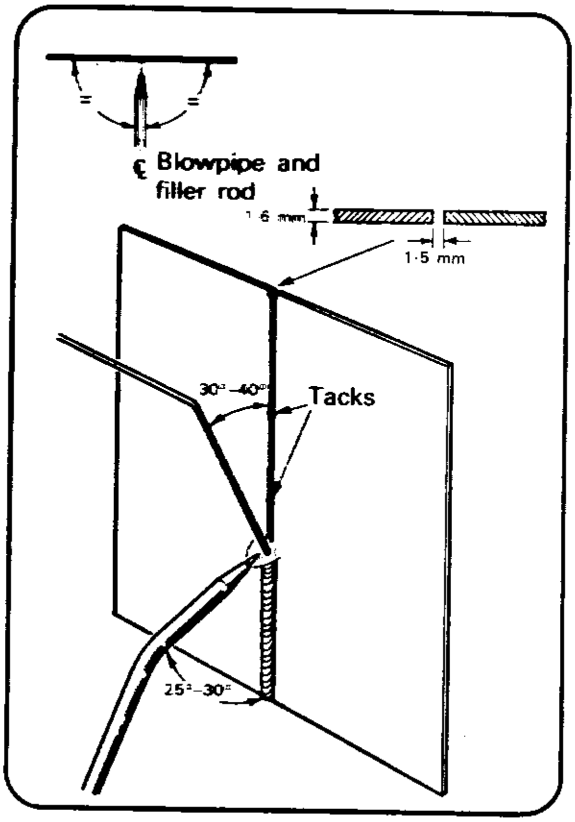
3. The flame and filler rod are moved, and the weld is progressed in the same manner as already described in the all-position rightward technique.

4. The weld is terminated by changing to the leftward technique at the end of the joint, to ensure adequate build up.

Visual examination
The weld reinforcement and profile should be uniform along the length of the joint. The leg length should be equal and there should be freedom from undercut at the toes of the weld.

Open square butt joint—Vertical position
Example procedure EP/OA/19

Material	Two pieces of mild steel 1·6 mm thick. Min. size 100 mm x 150 mm
Preparation	Square edge
Assembly	Tack weld with five tacks; gap 1·5 mm. Support with line of joint vertical with bottom end about 150 mm above bench top
Nozzle size	2 (57 litres/hr)
Regulators	Each 0·14 bar
Filler rod	1·6 mm



1. Melt away tack weld at the bottom end of joint and, when parent metal fuses, add filler metal from cranked filler rod to form weld pool.

2. The blowpipe nozzle and filler rod angles are the same as in EP/OA/16 but it may be found helpful to increase the angle of the blowpipe nozzle.

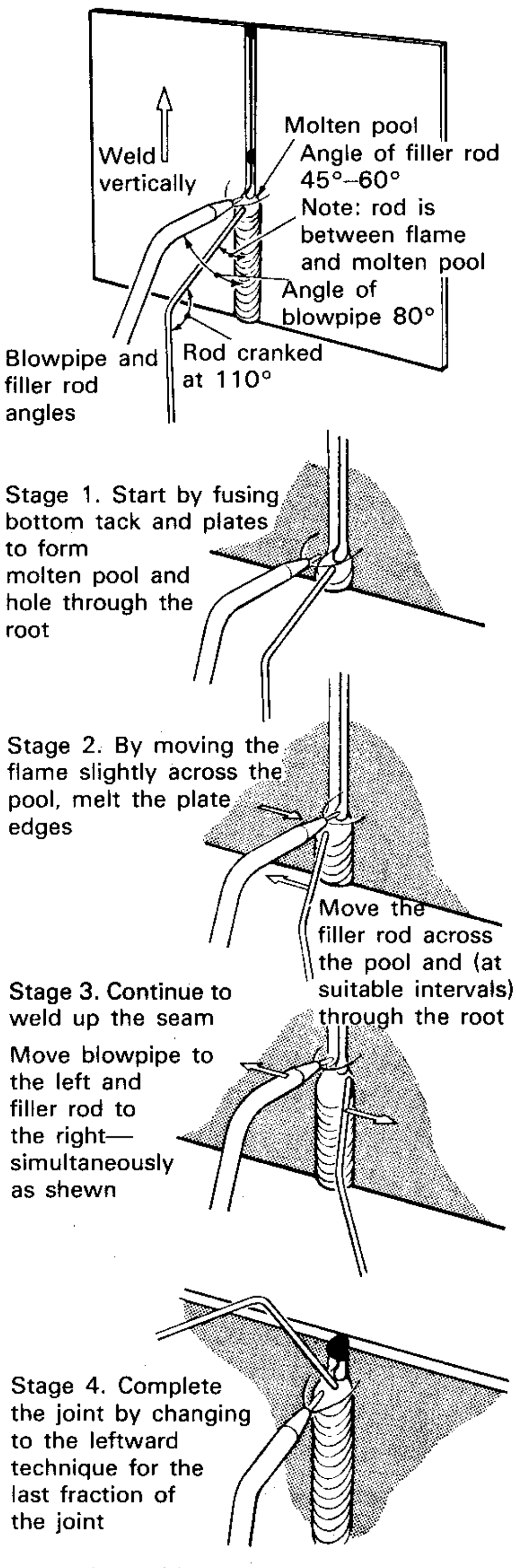
3. When a pear-shaped metal area is established in the parent metal, commence upwards movement.

4. Adjust the rate of travel so that it is only just as fast as the pear-shaped metal area can be maintained in advance of the weld pool.

5. The filler rod should be given a gentle in-and-out motion, in line with the joint to build up the weld pool as required.

Visual examination
The welded joint should be examined to see if satisfactory penetration has been obtained. A neat penetration bead should be present with an absence of 'burn-through'.

The weld profile should be slightly convex and without any appreciable 'sagging' of the weld metal.



All-position rightward welding vertical joint

Open square butt joint—Vertical position
All-position rightward technique
Example procedure EP/OA/20

Material	Two pieces of mild steel 6 mm thick. Min. size 250 mm × 150 mm
Preparation	60° inclusive angle
Assembly	Tack weld each end of the joint. Normal pitch of tacks 125 mm along the seam. Final gap 3 mm. Secure the assembly at a convenient working height with the joint in the vertical position.
Nozzle size	25 (710 litres/hr)
Regulators	Each 0·42 bar
Filler rod	3·2 mm

This technique is a modification of the rightward technique which is used in the vertical and overhead positions.

1. The blowpipe should be pointed upwards at an angle of 80° whilst the filler rod is introduced into the molten pool below the cone of the flame at an angle of 45°–60°.

2. Commence welding by fusing the tack weld and plates at the bottom end of the seam to form the molten pool.

3. The flame is given a slight side-to-side movement to ensure uniform melting of the fusion faces.

4. At the same time the rod is moved across the pool, in the opposite direction to the flame, ie. when the flame is directed to the right the rod is moved to the left.

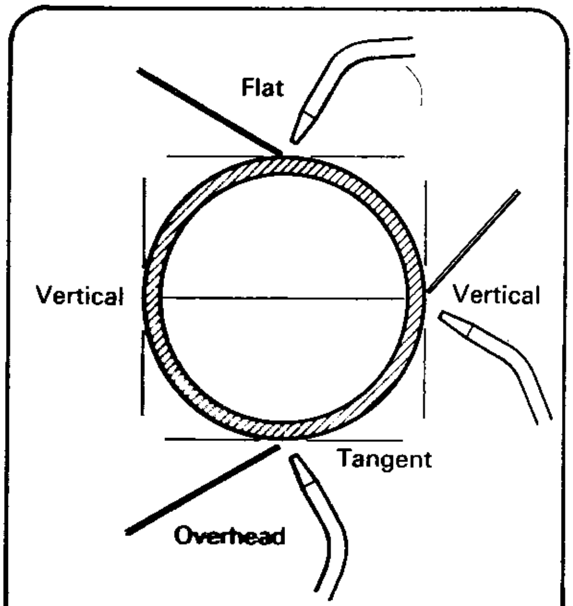
5. At the fourth movement of the filler rod across the pool it is pushed inward to ensure penetration.

6. When introducing new filler rod ensure weld area is molten.

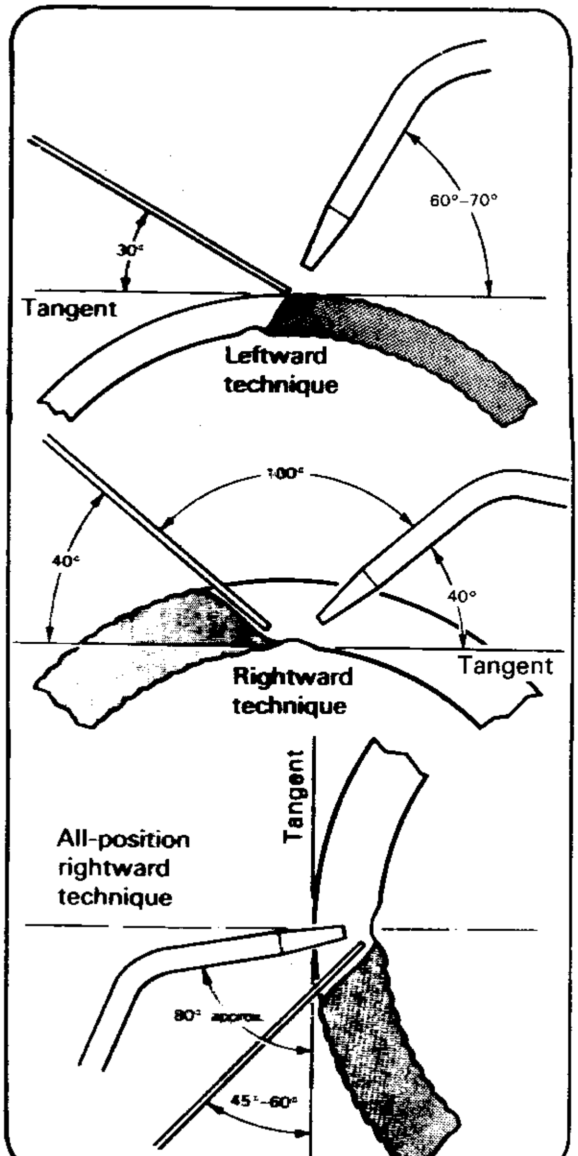
7. When the end of the seam is reached the joint is completed by the leftward technique.

Visual examination

The weld profile should be reasonably uniform and free from undercut. A complete penetration bead should be present on the reverse side of the joint.



End view of pipe showing positions of blowpipe and filler rod



Pipewelding

When welding the circumference of a mild steel (see BS 1821) pipe, the angles of the rod and blowpipe are given in relation to the tangent to the pipe at the point of welding.

The welding positions can be seen in relation to the plane of the tangent.

The technique used will depend upon:
(i) The pipe wall thickness
(ii) The welding position
(iii) Whether the pipe is fixed or can be rotated.

1. (a) The welding position may remain fixed with a sector or sectors of the circumference being welded at a time. The pipe is rotated after completion of each sector or sectors,
or
(b) the welding position may remain fixed whilst the pipe is continuously rotated at an appropriate welding speed until the weld has been completed.

2. When the pipe remains stationary, the following techniques are used:

Position	*Method*
1. At the top of the pipe; Flat position.	Leftward or Rightward
2. At the flank of a set-on branch when both pipe axes are horizontal; Flat position	Leftward or Rightward
3. When the weld is made along the vertical sides of the pipe	Leftward or Rightward or All-Position Rightward
4. The weld at the bottom of a pipe is made in the Overhead position	Leftward or Rightward or All-Position Rightward

Notes:

(i) The techniques as used for the positional welding of plate are applied when welding pipes.

(ii) For thin-walled pipes up to 5 mm the leftward technique is used in any position.

(iii) The leftward, rightward or all-position rightward techniques are used as appropriate on sections of 5 mm and above.

Oxy-acetylene welding

Mild steel butt joints (rolled/rotated) with pipes in the horizontal position
Example procedure EP/OA/21

Range 40 mm to 75 mm outside diameters.
Wall thickness 1·6 to 6·0 mm.

Wall thickness mm	Preparation technique	
3·0	Square edge	Leftward
5·0	80° Included angle	Leftward
6·0	60° Included angle	Rightward or All-Position Rightward

1. (a) (i) Select pipe and prepare for cutting.
(ii) Cut by gas, saw or by cutter and prepare joint by grinding or filing. (Illustration A refers.)
(iii) Preparation as shown above, see also Table of Conditions for Mild Steel. (See page 85).

(b) Select nozzle and gas pressure according to maker's recommendation.

(c) Secure in simple fixture to obtain:
(i) accurate tack welding.
(ii) ease of rotation.

2. Tack weld at Positions 3, 7, 11 (120° apart). (For positions, see illustration B).

100 mm dia. pipes may be tacked at Positions 3, 6, 9, 12 (90° apart).

3. (a) Start welding on the tack at Position 3, rotate pipe clockwise, weld in vertical position to Position 9, stop welding. Reverse pipe (use tongs) and commence weld at 3 to 9 (via Position 6) still welding in the vertical plane.

(b) Fuse the terminal parts of the weld.

Visual examination
Weld appearance should have good convex reinforcement, no undercut, neat weld restarts and minimum penetration.

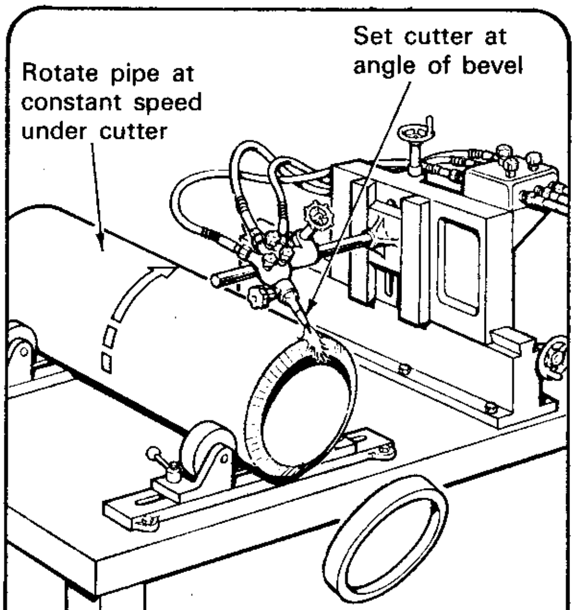


Illustration A. Cutting bevel on pipe

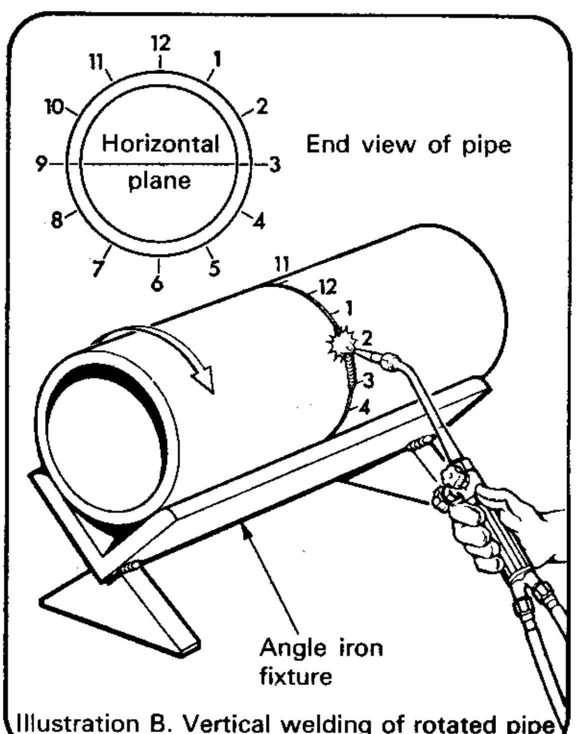


Illustration B. Vertical welding of rotated pipe

Oxy-acetylene welding

Bronze (braze) welding

Bronze welding is a method of joining metal in which the filler rod melts at a lower temperature than the base material. It is not a fusion process. Bronze welding is often used to make a joint between dissimilar thicknesses of materials.

Mild steel (Including galvanised steel)
Before commencing to Bronzeweld mild steel ensure that:
(a) the filler rod is of suitable composition (BS 1453 C2)

(b) all joint surfaces are free from oil, grease and dirt

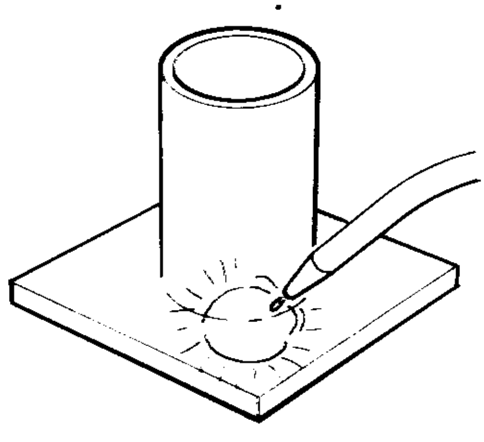
(c) all joint surfaces are freed from surface oxides by grinding, filing or wire brushing.

Note: When preparing a joint for the Bronze welding of galvanised steel care MUST be taken to preserve the zinc coating in the area to be joined. Before welding, apply a protective coating of copper welding flux in paste form to all faces affected by the heat of welding.

(d) coat the filler rod with flux either by heating and dipping into powder or by applying in paste form. Pre-fluxed rods may be used.

Bronze welding a tube to a plate joint
Example procedure EP/OA/22

Material	One piece of mild steel plate 200 mm × 200 mm. Mild steel tube 50 mm to 75 mm nominal bore. Thickness in the range 2–4 mm
Preparation	Prepare the ends of the pipe square
Filler rod	3·2 mm
Nozzle size	3 (86 litres/hr)



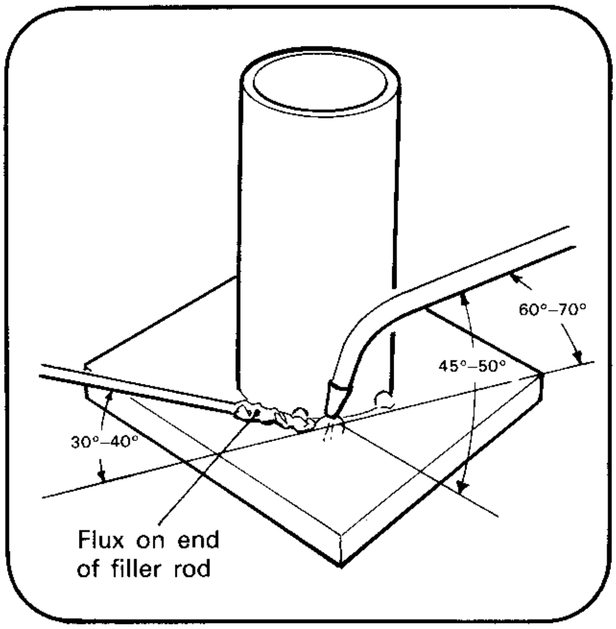
Preheating

1. Set the pipe on the plate and check that the pipe axis is at right angles to the plate.

2. Set a slightly oxidising flame.

3. Preheat an area of approximately 25 mm radius at one point on the joint line.

Do not melt the parent metal as this will cause cracking in the weld.



4. Keep the torch at an angle of 60°–70° to the line of the joint and 45°–50° to the horizontal.

5. Introduce the filler rod at an angle of 30°–40° to the joint line and to the horizontal. Deposit sufficient metal to give a short length of 4 mm leg length fillet weld.

As soon as the weld metal flows and melts the pipe and plate, remove the flame and allow the tack weld to solidify.

6. Tack at two more points at 90° intervals.

7. Clean off flux residues.

8. Start welding at the middle point of the untacked segment, using the filler rod and torch angles given for tack welding.

9. Prevent oxidation or overheating of the parent metal by ensuring that the flame impinges only on the melting filler rod or weld deposit.

10. When the pool is established (in the manner of tack welding) withdraw the flame slightly to allow partial freezing of the deposit. Reintroduce the filler rod to melt a further addition of metal and bring the torch closer to the weld pool to raise the surface temperature of the parent metal and to give good melting.

11. Progress along the joint line depositing a fillet weld of 6 mm leg length.

12. Observe that bonding with the parent metal is taking place and alter the angle of the torch to the horizontal to achieve uniform heat distribution.

13. Ensure that the tack welds are fused into the main weld.

14. To avoid a terminal crater, add filler rod to the weld pool as the flame is gradually withdrawn.

Repair of ferrous castings

When preparing castings for repair by bronze-welding, it is necessary to:

1. Identify the material to be repaired.

2. Locate the defect to be rectified.

3. Ensure freedom from contaminants. Degrease or clean as required. In the case of castings, ensure removal of any trapped impurities.

4. Remove all defects.

5. Ensure suitable joint preparation before commencing the weld repair.

> **Safety**
> Do not attempt to weld components or vessels that have contained (or might have contained) flammable substances, until every precaution has been taken to ensure the weld repair can be completed with absolute safety.

Cast-Iron

Cast-iron must be carefully identified to decide:

(a) Type of preparation to be used.

(b) Method of welding to be adopted.

Note: Grey Iron is either fusion or bronze-welded. White and Malleable Irons are bronze-welded.

1. Locate cracks by grinding the surface.

2. Where cracks or other defects cannot be readily located, use a recommended technique to find the extent and direction of the fault.

3. To prevent cracks from spreading, drill a hole of suitable diameter located slightly beyond one or both ends of the crack as appropriate.

4. To prepare cracks for welding, drill a series of holes along the crack, using a drill of diameter approximately equal to the thickness of the material. Drill holes as close together as possible, without penetrating the material. Use a chisel to cut a suitable Vee formation along the crack. Where necessary, the edges of the crack may be ground to produce a satisfactory preparation. Melting out with the flame can be carried out when the casting is at the correct pre-heat temperature.

5. To repair a casting which is in several pieces, grind the fractured edges to form a single Vee joint with a 90° included angle when assembled for welding.

6. Where the effect of heat may cause unequal expansion and cracking, the sections of the casting must be assembled in a suitable pre-heating furnace. Support the pieces with firebricks or other means to maintain alignment.

Clamps or other aids may be necessary to locate the pieces.

To ensure correct alignment, leave abutting parts (of full section) of the prepared groove in contact with each other in a minimum number of places.

7. A gap of approximately 1 mm will facilitate good weld penetration, especially when bronze-welding. When bronze-welding, always round off all sharp corners at the top and underside of the preparation to avoid over-heating and inefficient bonding.

8. Where parts are missing, replacements may be provided in mild steel or other material and bronze-welded to the casting. Cast-iron parts, where used, may be fusion-welded.

(a) It is possible to repair defective teeth on cast-iron gear-wheels by inserting screwed studs into the base material to act as a basic location for the bronze-welded repair.

In such cases the studs should be inserted at varying depths to avoid harmful stress concentrations.

(b) Webs, flanges, bosses, etc., may be incorporated in a repair for reinforcement by:

(i) building-up, using appropriate bronze filler rod

(ii) building-up, using cast-iron filler rod

(iii) fabricating suitable members such as gussets, flanges, etc., for bronze-welding as appropriate on to the casting.

Cutting and gouging processes

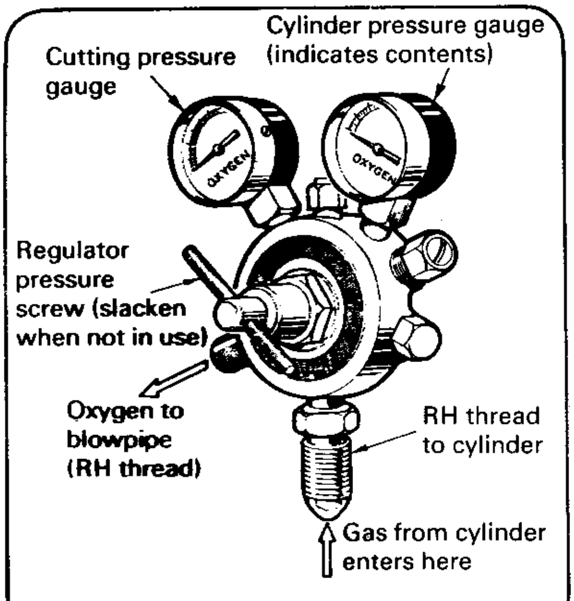
Process	Application	Material
Oxy-fuel gas	Cutting and gouging	Mild steels, alloy steels (eg. less than 5% chromium). Cast iron (using special technique). Not used with aluminium or other non-ferrous materials
Oxy-powder processes	Cutting only	High alloy steel (eg. more than 5% chromium). Cast iron. Aluminium and aluminium alloys Copper and alloys Nickel and alloys
Air-arc	Gouging and cutting	Satisfactory method of gouging most materials, particularly mild steel, alloy steel. Useful for severance cutting, but thickness is a limitation
Oxy-arc	Gouging and cutting	Satisfactory method of gouging most materials, particularly mild steel and alloy steels. Useful for severance cutting, but thickness is a limitation
Metal arc	Gouging and cutting	Metal arc cutting is used for rough, severance cuts. It is strictly limited in its applications regarding (a) range of material, (b) depth of gouging
Carbon arc	Cutting	Is used on materials that can be welded without a post-heat treatment

For relevant illustrations see page 13.

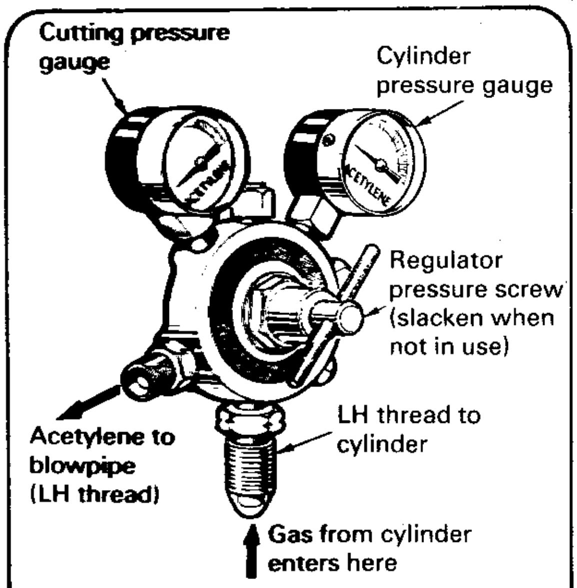
Notes:

1. Copper is very difficult to gouge.
2. The alloys of copper are liable to lose certain elements when cutting or gouging are attempted.
3. (a) In its field of application the oxy-fuel gas process achieves the greater depth of cut.
   (b) For gouging, oxy-fuel gas process is fast and controllable.
4. Powder processes have an upper limit of 750 mm thickness when cutting stainless steel. It is possible to use the powder process to a thickness of 1500 mm, but it is uneconomical. The process is used to a limited extent.

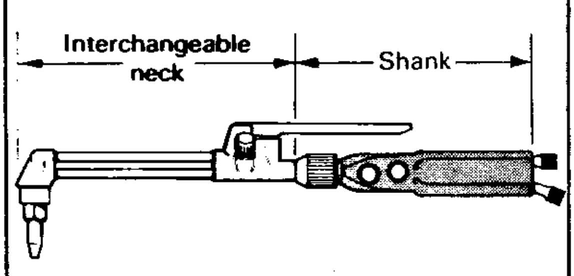
Gas cutting and gouging



Oxygen pressure regulator



Acetylene pressure regulator



Combined type of blowpipe, adaptable for cutting or gouging

Equipment

Special equipment additional to that described in the Section entitled Oxy-Acetylene Welding is as follows:

Regulators

Regulators are required to reduce cylinder gas pressure to the required working pressure. The oxygen regulators for cutting must be capable of higher outlet pressures than those used for welding processes: outlet pressures up to 5 bars are required for cutting plates up to 150 mm thick and pressures up to 10 bars may be required for thicker plate. Regulators for propane must be capable of an outlet pressure of 2 bars.

Acetylene regulators used for high-pressure (dissolved) acetylene are suitable for both welding and cutting applications.

Outlet pressure gauges

For oxygen the outlet pressures should read up to 14 bars and for acetylene these should read up to 2 bars.

Contents indicators

Pressure gauges may be used to indicate the content of oxygen in the cylinder. Gauges used for this purpose should have a reading of not less than 250 bars. A 'pop up' device to indicate the cylinder contents may be used on oxygen cylinders.

Note: Pressure gauges *cannot* be used to indicate the contents of dissolved acetylene cylinders. In this case the weight of the cylinder compared to its pre-charge weight is a guide to the contents.

Cutting and/or gouging blowpipes

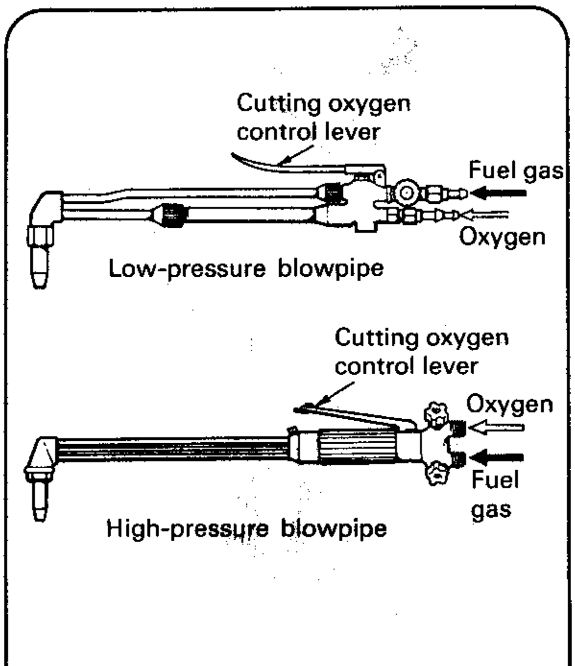
Blowpipes for use with propane or acetylene fuel gases may be either of the injector type or nozzle mixer pattern. The blowpipe may be constructed solely for cutting purposes, or the shank of a welding blowpipe may be adapted by the fitting of a cutting attachment. Oxygen and fuel gas are mixed (as in the welding blowpipe) to produce the pre-heating flame. A separate supply tube with an additional control valve conveys the additional oxygen required for the cutting operation. Gas cutting blowpipes are either:

(a) high pressure, when the gases are generally mixed in the cutting nozzle,

or

(b) low pressure, when an injector system is used.

Gas cutting and gouging



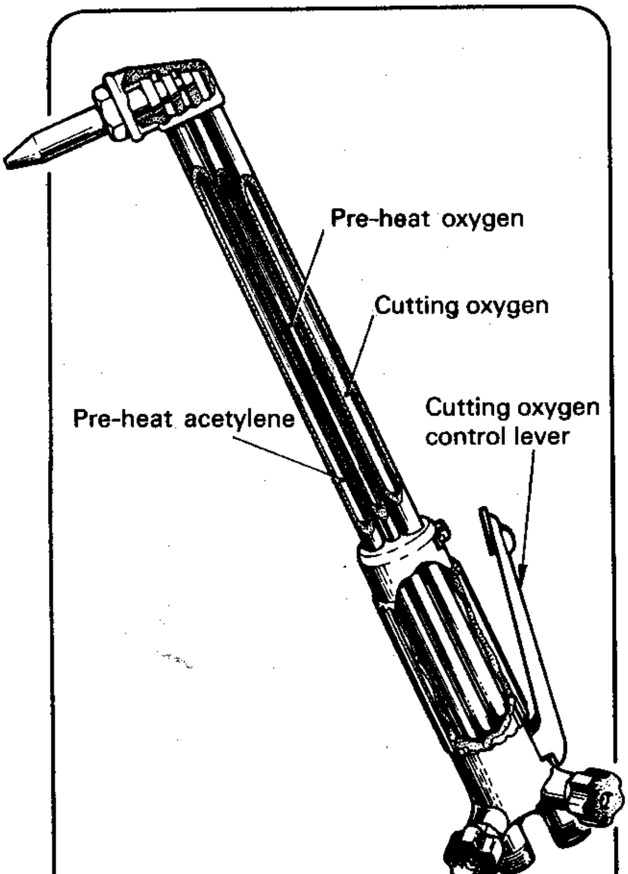
Cutting blowpipes

Oxy-fuel gas equipment

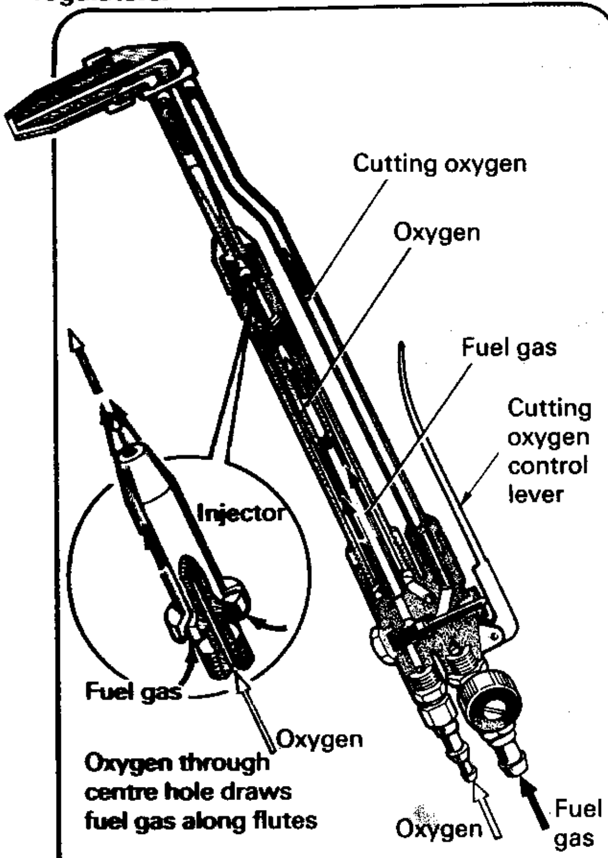
High-pressure cutting or gouging blowpipe
In this type of blowpipe the oxygen stream diverges, part going into the one-piece nozzle where it mixes with the fuel gas, the other part is brought through a valve with quick release lever to the central orifice of the nozzle as the cutting stream. The pre-heat flames are supplied through surrounding jets.

Low-pressure cutting and gouging blowpipes
In this type of blowpipe the oxygen is passed through an injector where it entrains the fuel gas to pass through the neck to the pre-heating jets. The cutting oxygen stream is led through a lever control valve to the cutting nozzle where it emerges into the centre of the pre-heat flame.

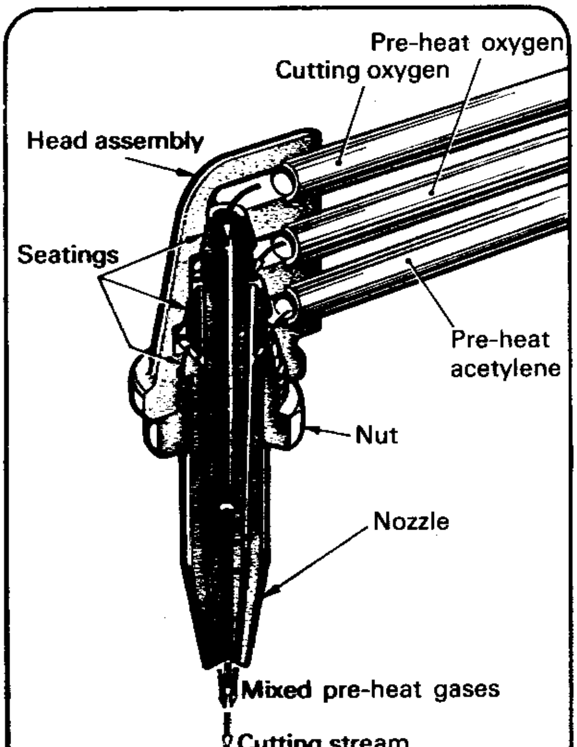
Note: Use the high-pressure cutter only with high-pressure gases from cylinders. The low-pressure type will operate with fuel gas at low pressures as in the case of acetylene piped direct from a generator, or it may also be used safely with dissolved acetylene suitably regulated. The oxygen supply in each case is from cylinders or pipeline at high pressure. The gas pressures are controlled by suitable regulators.



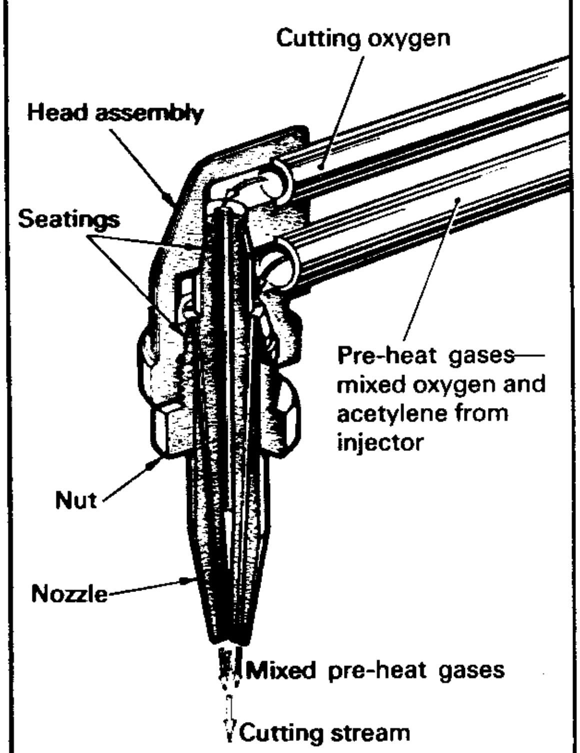
High-pressure cutting or gouging blowpipe



Low-pressure cutting or gouging blowpipe



High-pressure head assembly and three-seat nozzle



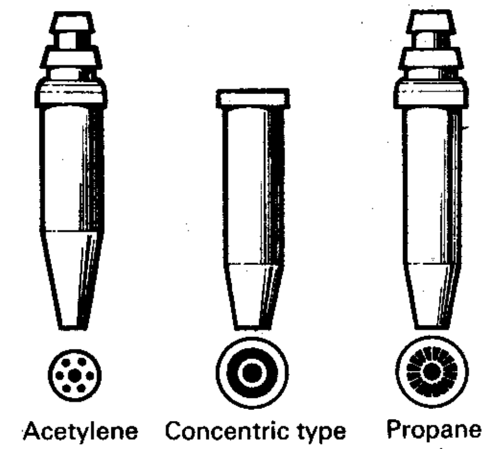
Low-pressure head assembly and two-seat nozzle

Nozzles

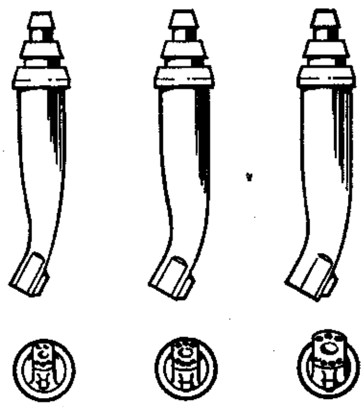
1. Nozzles for use with each type of blowpipe are distinctive:
(a) the high-pressure nozzles have three seats
(b) the low-pressure nozzles have two seats.
2. Certain types of nozzle are made in two pieces.
3. Sheet metal cutting nozzles have a single pre-heat flame orifice preceding the cutting oxygen orifice. It is important when cutting or gouging to:
(a) use a multi-stage regulator for closer and more accurate pressure control
(b) avoid long runs of hose which may result in a drop in the gas pressure, or compensate for this by increasing the outlet pressure
(c) avoid dirt on or in the nozzle as this will divert the gas stream
(d) always use the correct nozzle size as wrong selection will produce a faulty cut
(e) avoid dirt on the workpiece as this will result in the waste of gas
(f) use only sufficient oxygen to sustain ignition and maintain expulsion of oxide on the job being undertaken.

Types of nozzles

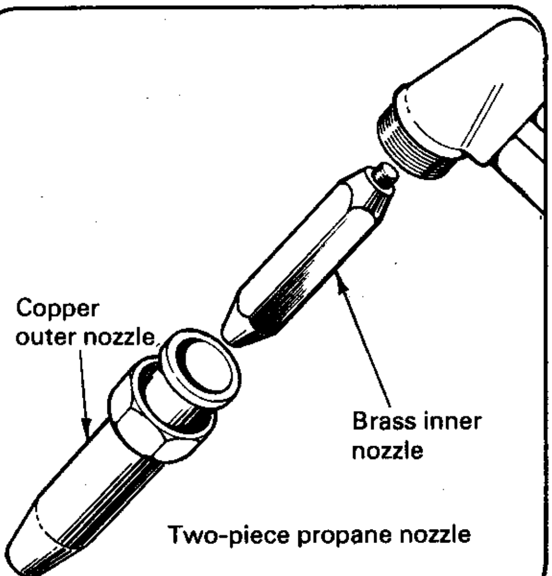
1. Acetylene nozzles may be of one- or two-piece construction.
2. Propane nozzles are of two-piece construction, comprising copper outer nozzle with recessed brass fluted inner. The cutting oxygen flows through the central hole in the nozzle whilst the pre-heat gases flow through the smaller holes or flutes which surround the cutting oxygen orifice. Nozzle sizes are indicated by the diameter of the central orifice.



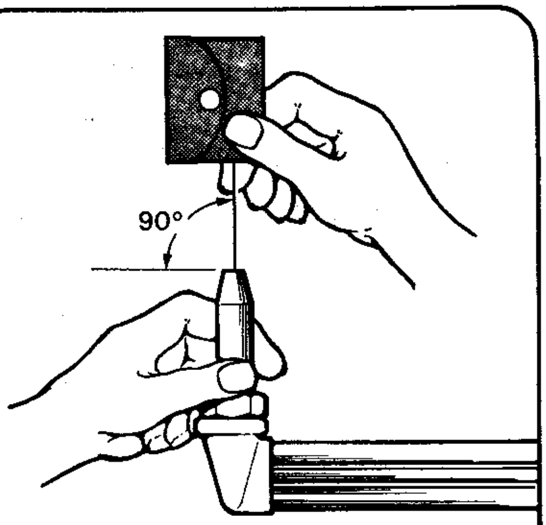
High-pressure cutting nozzles



High-pressure gouging nozzles



Two-piece propane nozzle



Cleaning the nozzle

3. Gouging nozzles are cutting nozzles of a shape appropriate to the cutting of grooves to the width and depth required.

Notes:

(i) The nozzle number indicates the size of the cutting orifice in hundredths of an inch.

(ii) The groove widths vary according to the nozzle size. The size of nozzle affects the speed of gouging.

(iii) Ensure the orifices are unobstructed using the correct nozzle cleaning tools.

(iv) Do not damage the nozzle seating. Store in a safe place.

(v) Select a nozzle suitable for the intended gouge.

Maintenance of nozzles

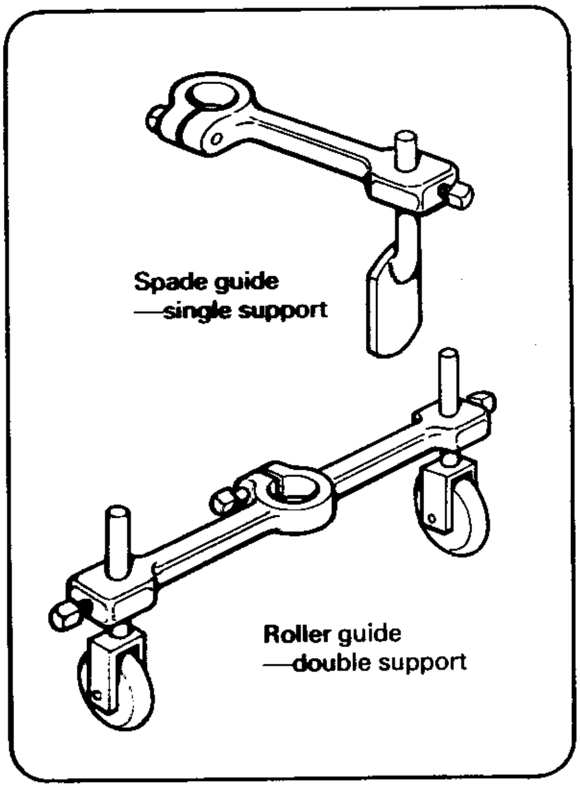
1. Nozzle ends must not be damaged.

2. The nozzle orifice must ONLY be cleaned with a special nozzle cleaner of correct size, used concentrically to the nozzle bore, or by immersing in a suitable cleaning compound.

3. If the end of the nozzle becomes damaged, rub with a piece of fine emery cloth which has been laid on a piece of plate glass. Hold the nozzle at right angles to the glass so that the edge of the orifice when rubbed on the emery cloth becomes sharp and square. Remove orifice burrs with a suitable tool.

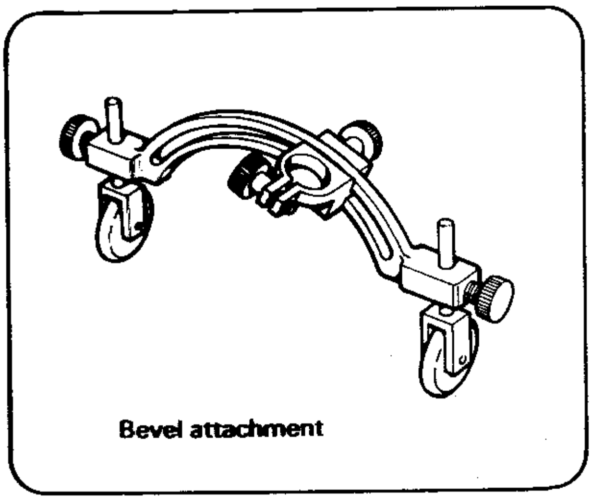
Cutter guides

1. In the form of a single support, these may be of the spade or wheel type, usually provided with vertical adjustment to obtain correct nozzle-to-plate distance. The support rides on the plate to be cut.



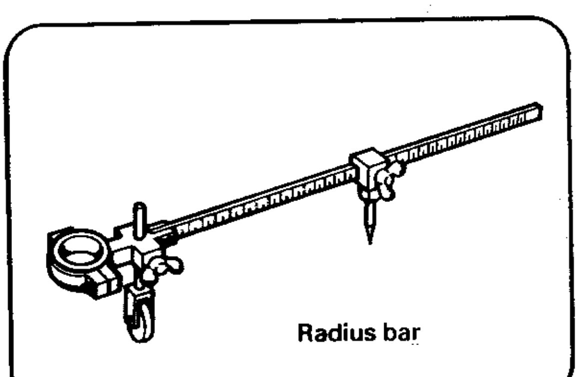
2. The double support or roller guide is used for long cuts. It also provides vertical adjustment for the nozzle height.

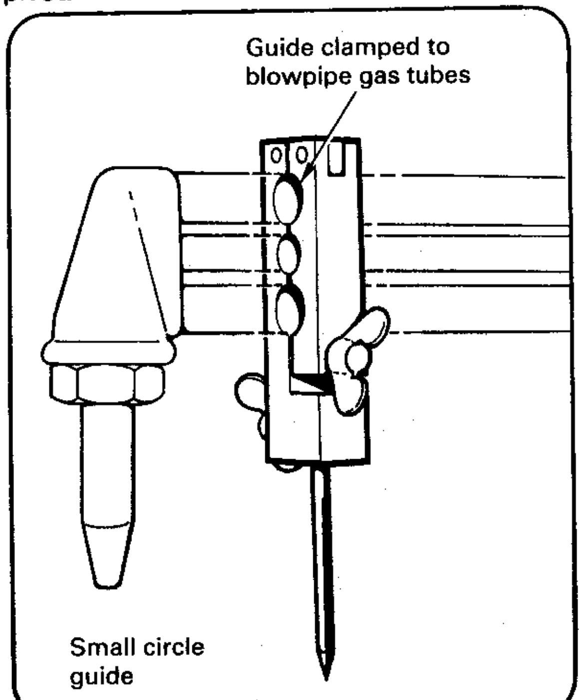
Bevel cutting may be obtained either by setting the wheels of the double support at different levels or by using a slotted clamping attachment.



Note: In (1) and (2) a straight edge may be used as a guide for straight cuts.

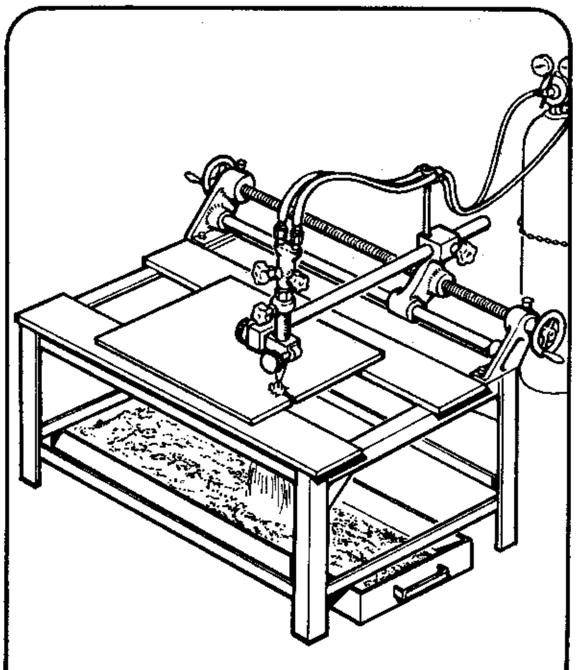
3. Small circles may be cut by clamping a pivot on to the gas tubes of the blowpipe. For large circles, a radius bar attachment is used. This bar is fitted with a wheel support and adjustable pivot.





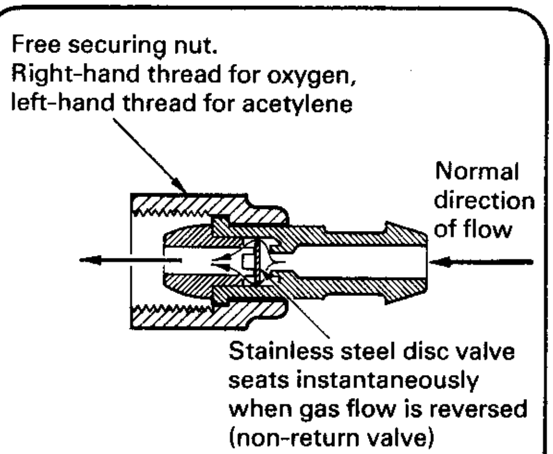
Hand-operated cutting machines

The simplest form of cutting machine is one in which the blowpipe is attached to a saddle riding on a lead screw. The lead screw is operated by a hand-wheel controlling the rate of longitudinal travel. In, out, upward and downward adjustments of the blowpipe are by means of cross shafts on the saddle.

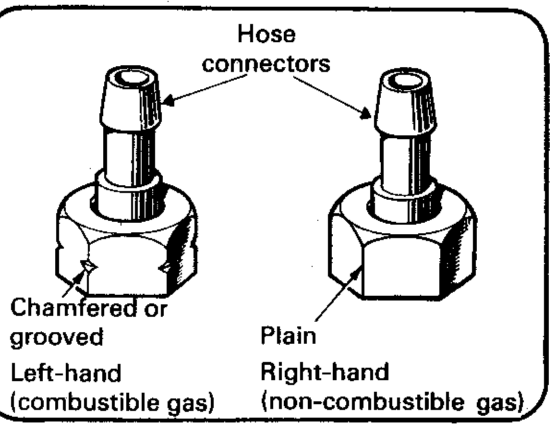


Hand-operated cutting machine

Hose protecting device should be fitted to the **hoses.**



Hose protecting device



> ***Note:* All threaded** connections conform to **the rule:**
>
> 1. **Right-hand** screw thread for oxygen **(blue hose)** and other non-combustible **gases (black hose).**
>
> 2. **Left-hand** screw thread for acetylene **and other combustible** gases (red hose).
>
> **Nuts on** oxygen and other non-**combustible** gas connectors are plain **hexagons.** Nuts on acetylene and other **combustible** gas connectors are chamfered **and/or grooved** to indicate left-hand **threading.**

Gas cutting and gouging

Selection of appropriate fuel gas

In order to ensure economy in the use of materials, it is important that the correct process is selected for cutting or gouging:

(a) Ferrous materials.

(b) Non-ferrous materials.

The table below indicates the application of processes relevant to types of material.

Fuel gases used in cutting and gouging

Gas	Cutting	Gouging
Acetylene	Used in cutting plain carbon steels and low alloy steels. Hand-cutting cast-iron using special techniques. Powder cutting process.	Plain carbon steels. Low alloy steels. It is often preferred for a quick start.
Liquid petroleum gas (LPG)	Used in cutting plain carbon steels and low alloy steels of all thicknesses. It is preferred for heavy cutting because of safety and handling.	Gouges plain carbon and low alloy steels, but initiation is slow compared with acetylene.
Town gas	Cuts plain carbon and low alloy steels, although the upper limit is restricted to about 150 mm. Slower heating and cutting speeds than either acetylene or propane. Cuts can be produced with a good finish.	
Natural gas	May be used with propane nozzles on a low-pressure system. At an adequate gas flow it is efficient as a pre-heat gas for cutting.	
Hydrogen	Used for underwater cutting of straight carbon and low alloy steels.	

Note:

1. Low alloy steel contains less than 5% chrome.

2. A number of proprietary gases are available which in general consist of mixtures of varying percentages of Liquid Petroleum Gas, Natural Gas, and Town Gas.

Pre-heating and post-heating

The cutting of high carbon and alloy steels at ambient temperature may result in hardening accompanied by cracking of the cut face. This may be overcome by pre-heating the work piece to 120°–150°C. Pre-heat to the minimum amount and proceed to make the cut without delay. With certain materials, post-heat treatment of the face may be necessary. Temperatures may be ascertained by thermo couples or temperature indicating crayons.

Control of distortion

Distortion is the result of unbalanced expansion and contraction. The correct method of cutting and gouging will assist to minimize distortion.

1. Control the amount of heat to which the component is subjected by:

(a) cutting in the correct direction

(b) cutting at the correct speed.

Travelling unnecessarily slowly tends to overheat the workpiece, thus causing:

(a) distortion

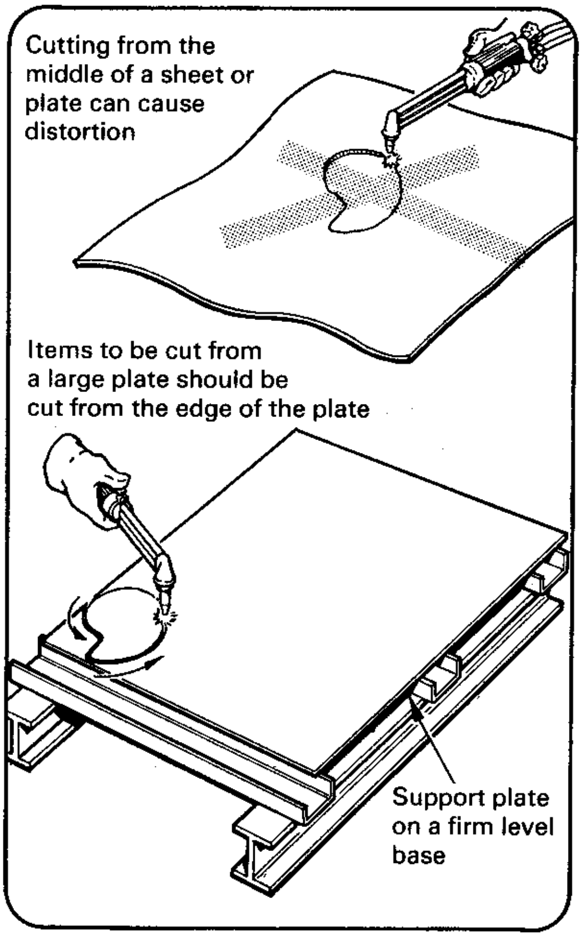
(b) inaccuracy of the cut

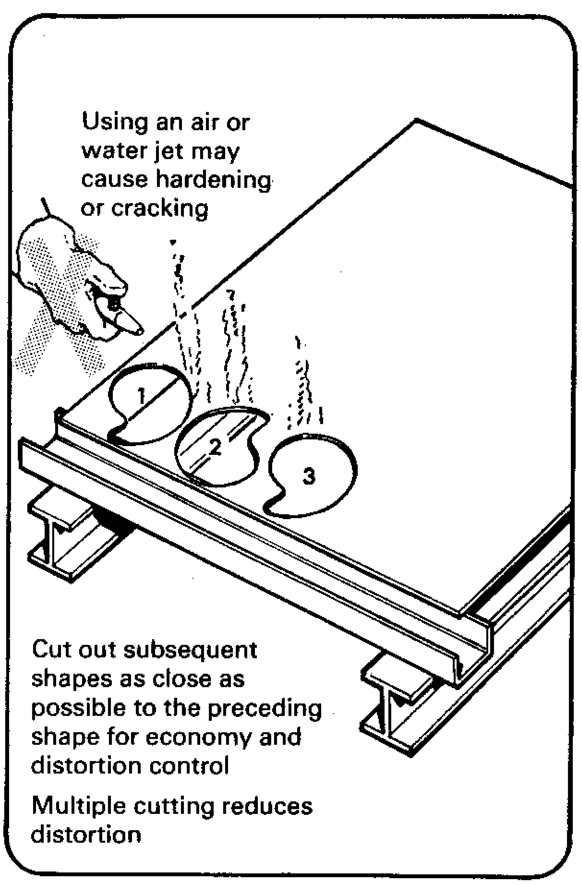
(c) poor quality cut.

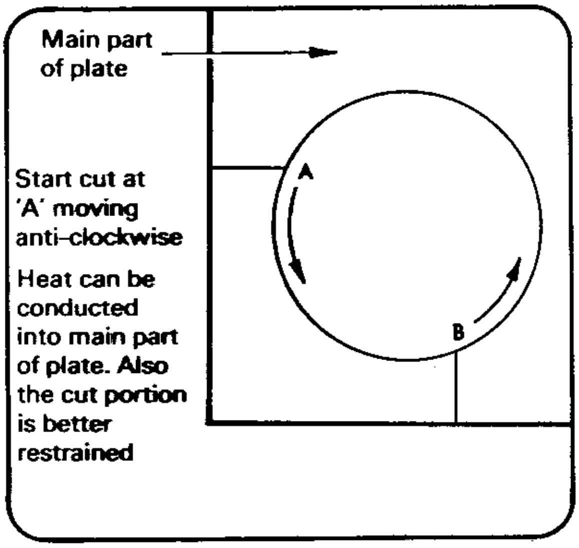
2. When cutting items from a large plate:

(a) cut from the edge of the plate

(b) subsequent shapes should be cut as close as possible to the preceding shape for both economy and control of distortion.







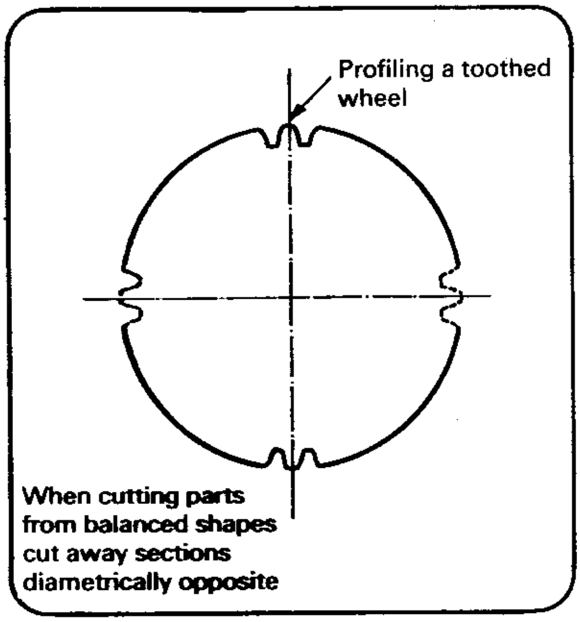
To cut out a profile, start the cut as shown in the illustration, commencing at 'A', and proceeding in an anti-clockwise direction, allowing the part to remain attached to the bulk of the plate for as long as is possible, thus allowing:

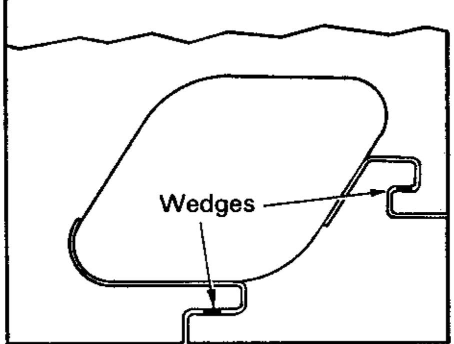
(a) the heat to be carried into the bulk of the plate to reduce distortion

(b) restraint of the cut component.

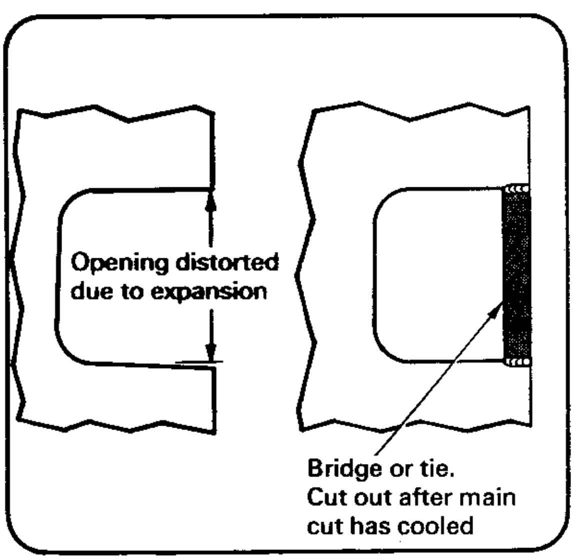
When cutting parts from balanced shapes, cut away sections which are diametrically opposite.

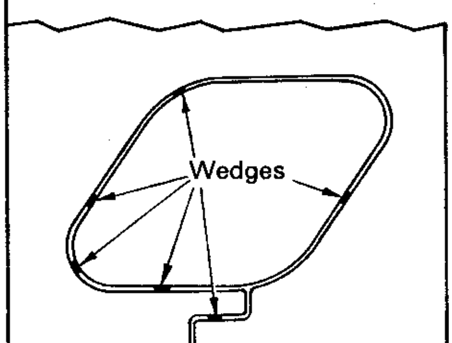
Distortion can be partially controlled by back-stepping to make the heat input even. The cut may be interrupted to allow metal to bridge from one part to another on the plate, thus allowing the heat to be spread while a restraint is put on the plate. Cut away bridged parts when the work has cooled down. Always clamp the work firmly and allow movement to occur in the scrap where the cut is near the edge of the plate. Small wedges may be used comprising flattened 6·5 mm mild steel rod to keep the kerf open, thus avoiding spoiling the job. Distortion is controlled by working outwards toward a free edge.



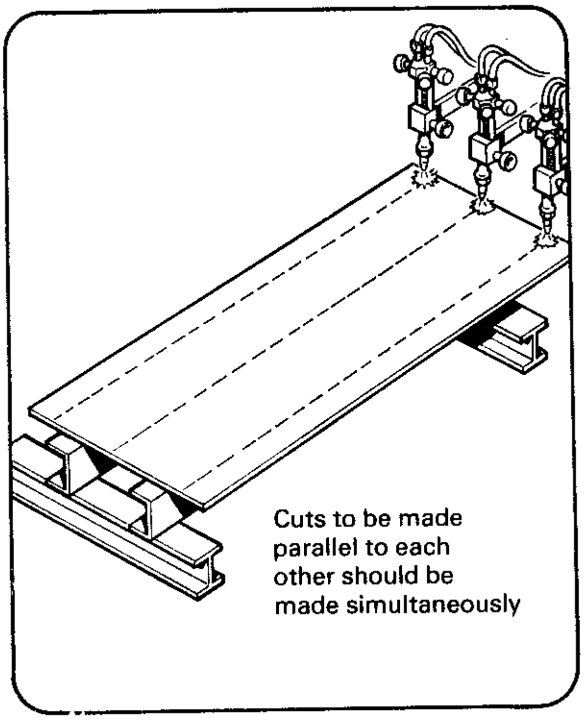


Creating a 'lock' in the lead-in cut to prevent movement of the discard





Use of wedges to prevent movement of the shape

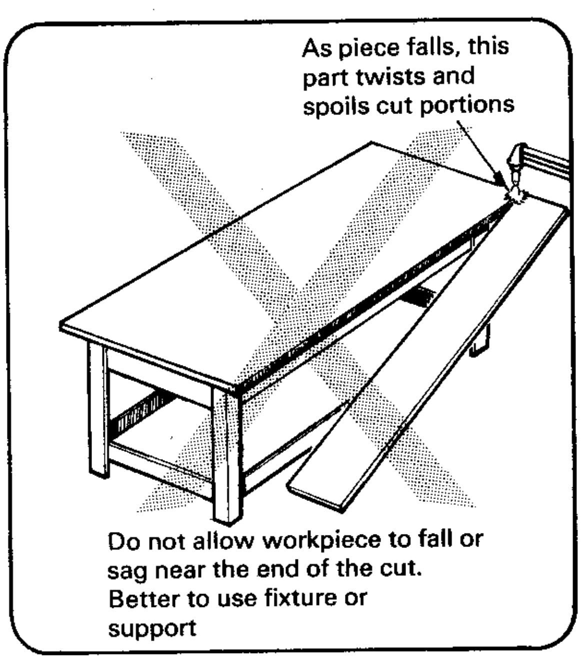


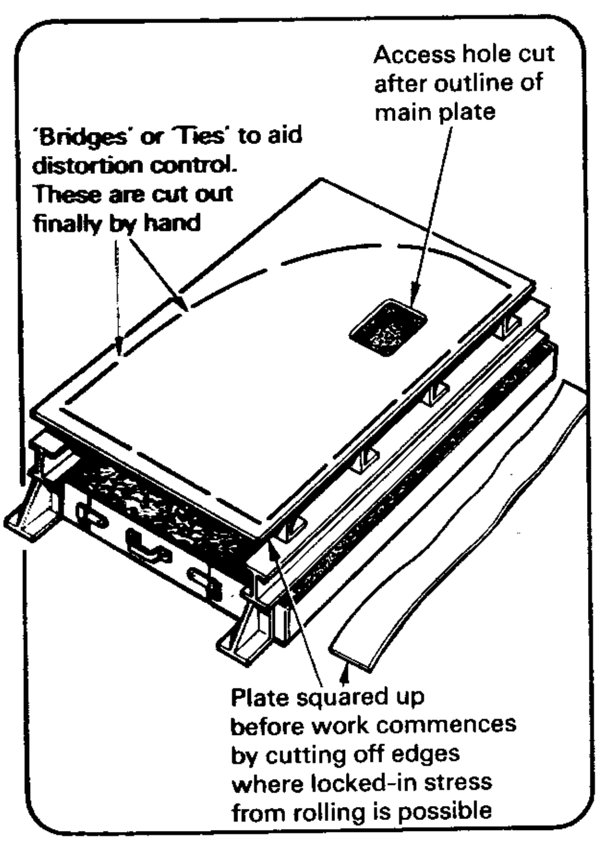
Cuts to be made parallel to each other should be made simultaneously.

Do not allow the workpiece to fall or sag toward the end of the cut otherwise distortion of the workpiece and damage to the plate will occur. Wherever possible use a simple fixture or support. It is not advisable to accelerate the rate of cooling of the plate following cutting by means of an air blast or water jet as this may lead to cracking and hardening of the material. Always ascertain the specification of the material to be cut before attempting to use any form of cooling. The burning of a hole at the commencement of a cut, except in very thin material, may cause both serious local distortion and a blocked or damaged nozzle on the machine. It is advisable to use a hand-cutter to burn the initial hole; alternatively to drill the hole mechanically.

The design and use of an accurate template will assist and minimize distortion.

A typical set up for cutting a shaped profile avoiding distortion is shown below.





Recognition of cutting and gouging defects, their causes, prevention and permissible methods of rectification

1. In a correct cut the top of the cut is both sharp and clean, the drag lines are almost invisible, producing a smooth side. Oxide is easily removed, the cut is square and the bottom edge clean and sharply defined.

Drag lines should be vertical for profiles. A small amount of drag is allowed on straight cuts.

2. Due to melting, the top edge has become rounded. Gouging is pronounced at the bottom edge, which is also rough. Scale on the cut face is difficult to remove.
To rectify: traverse at recommended speed. Increase the oxygen pressure.

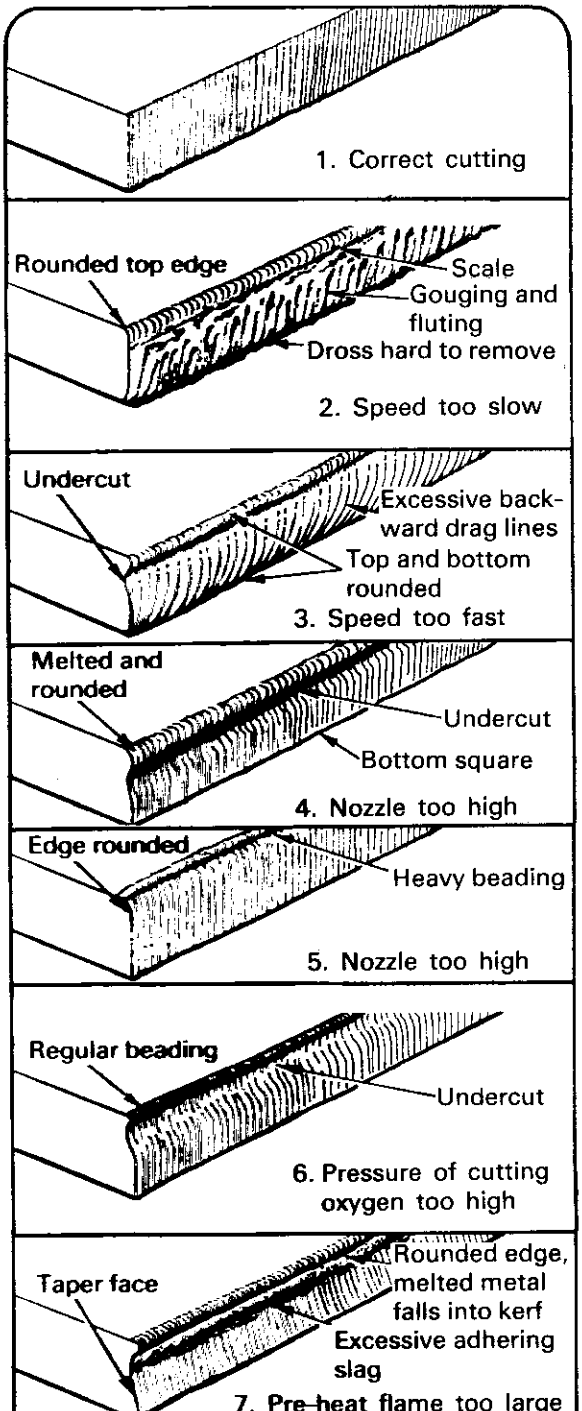
3. The top edge may not be sharp; there is a possibility of beading.
To rectify: slow down the traverse to the recommended speed. Leave the oxygen pressure as set.

4. Excessive rounding and melting of the top edge. Undercut has been caused by the oxygen stream opening out.
To rectify: adjust the stand-off distance between the nozzle and the plate.

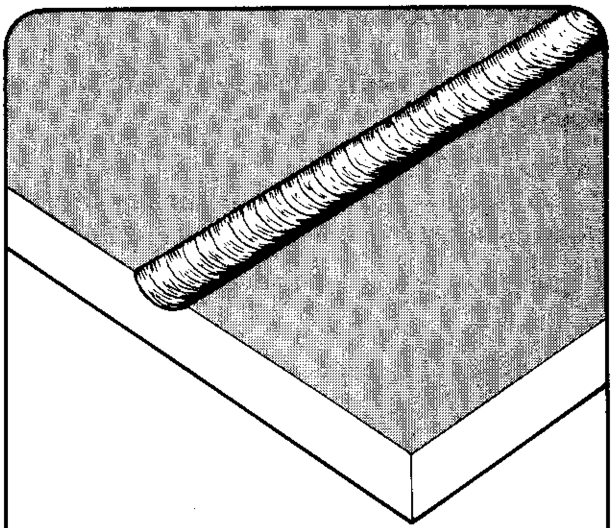
5. Heavily beaded and rounded top edge, otherwise of good appearance.
To rectify: correct the stand-off distance by raising the nozzle to the recommended height.

6. The edge has a regular bead. The kerf is wider at the top with undercutting just beneath it.
To rectify: set the oxygen at the recommended pressure (on thinner steel it can cause a taper cut likely to give the impression that the cutter is set wrongly in relation to the plate).

7. Due to excessive heat, the pre-heat flame has caused the top edge to melt and become rounded. The kerf tapers from just below the top edge to the bottom of the cut face.
To rectify: set a pre-heat flame as recommended, use the correct nozzle at the recommended gas pressures.



Variations in cutting procedure

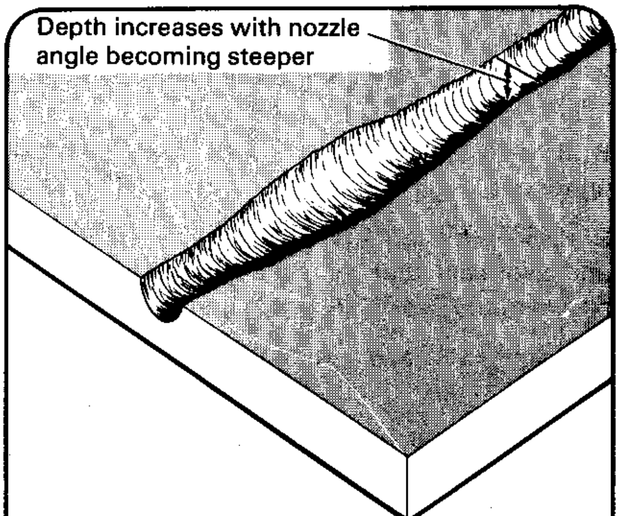


8. Correct gouging

8. In a correct gouge the groove is:
(a) of uniform width and depth

(b) free of oxide and scale, both in the groove and surrounding plate

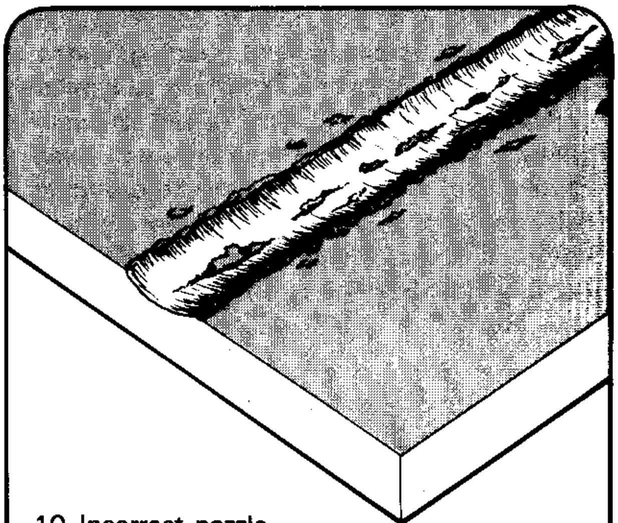
(c) has a clean metallic appearance.



9. Gouging nozzle held at wrong angle

9. A groove of varying width and depth caused by holding the gouging nozzle at the wrong angle ie.:
(a) too steep an angle increases depth and removes too much metal

(b) too shallow an angle gives a superficial gouge.

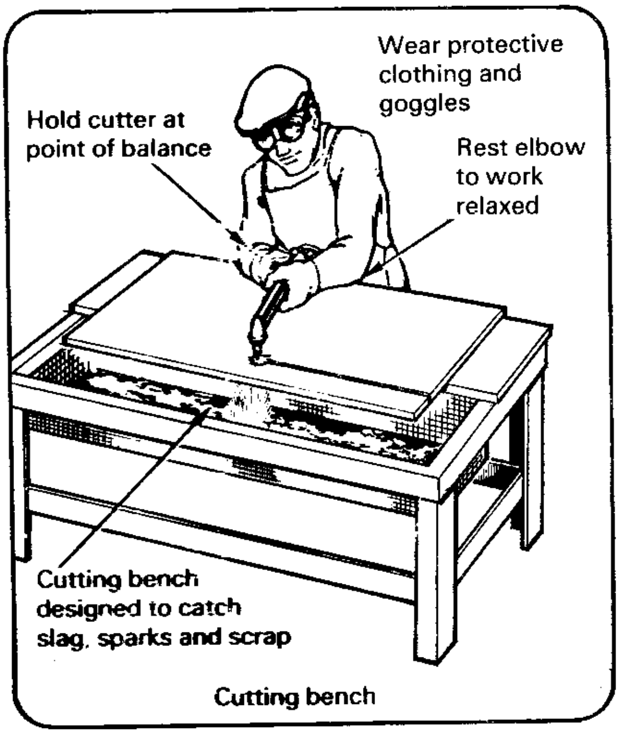


10. Incorrect nozzle alignment

10. A shallow groove with heavy oxide deposits caused by failing to present the gouging nozzle axially in line with the direction of gouging, due to:
(a) working too quickly
(b) using incorrect gas pressures
or
(c) using incorrect nozzle.

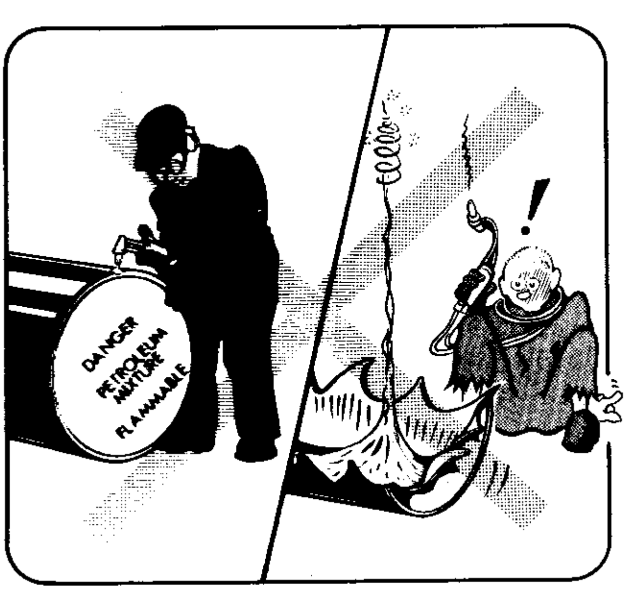
Note: Gouging defects may be corrected by rewelding the surface, using a filler material of suitable composition.

Gas cutting and gouging



Cutting bench

Safety
Do not remove the cylinder key from the acetylene cylinder. The key may be needed urgently for fire prevention purposes. Keep fireproof gloves readily available.



General procedure

The following instructions apply and are not repeated later in this Manual:

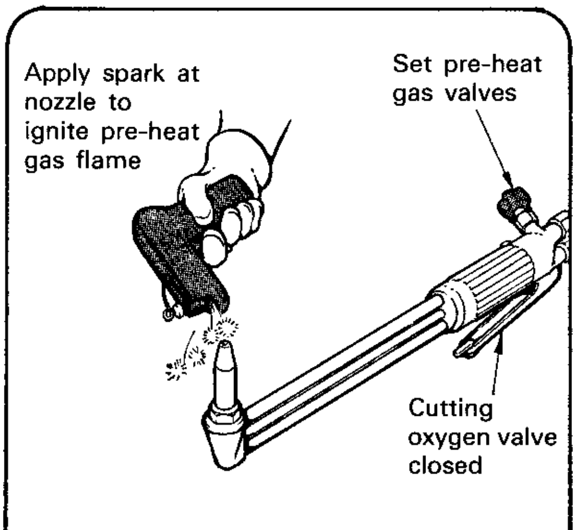
Always

1. Comply with the prescribed safety precautions and fire prevention procedure.
2. Check that hoses are not kinked or otherwise obstructed.
3. Check that the correct size nozzles are fitted to blowpipes.
4. Check that the cylinder valves are open.
5. Check that regulators have been set to the correct working pressures.
6. Use effective protective equipment and wear any necessary protective clothing.
7. Avoid using a gas economizer when cutting, gouging, or on any process demanding a large supply of gas.
8. Point the blowpipe in a safe direction when lighting it.
9. Handle the lighted blowpipe with due caution and take care that the flame does not impinge on anything, especially gas cylinder walls.
10. Concentrate on watching the progress of the work.
11. Hold the blowpipe with just sufficient grip at the point of balance to ensure full control.

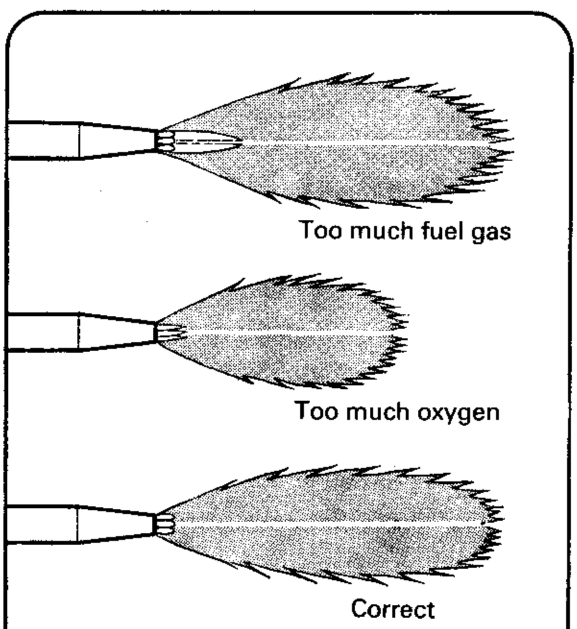
Important
Ensure that you are working under conditions where it is safe to carry out oxy-fuel gas or arc cutting and gouging. **Never** gas or arc cut a vessel or drum or similar component that has contained or may have contained flammable or toxic substance until it has been thoroughly cleaned and made safe by an appropriate process. See *Safety, Health and Welfare* new series, Booklet No. 32, published by the Health and Safety Executive.

12. Extinguish the heating flame and turn off the cutting oxygen stream when not in use or when moving location. Follow the closing down procedure when necessary. Do not walk around holding a lit blowpipe.

Example procedures



Lighting cutting blowpipe



Flame adjustment for cutting

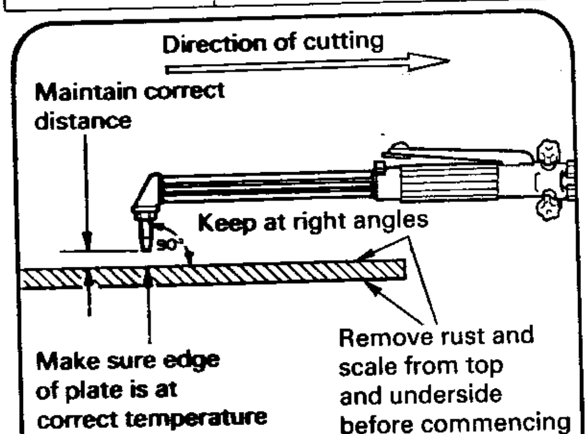
Lighting the blowpipe
Familiarization of lighting up and closing down procedures.

Example procedure EP/CG/1
1. Close all the valves on the blowpipe.
2. Open the cylinder valves slowly using one turn of the spindle.
3. Set the fuel gas regulator to the correct working pressure with the appropriate valve open. Close the valve.
4. Open the cutting oxygen valve and set the oxygen regulator to the correct working pressure.
5. Close the cutting oxygen valve and open the fuel gas valve on the blowpipe about three-quarters of a turn.
6. Wait a few seconds to flush the system with fuel gas, pointing the blowpipe in a safe direction.
7. Use a spark lighter to light the fuel gas and adjust the gas supply until the flame ceases to smoke.
8. Open the heating oxygen valve and adjust to the correct flame setting.
9. Open the cutting oxygen valve again, adjusting the heating gas controls to give a neutral flame. Close the cutting oxygen valve and the cutting blowpipe is ready for use.
10. To extinguish the flame:
(a) turn off the cutting oxygen
(b) close the fuel gas control valve
(c) close the heating oxygen control valve.

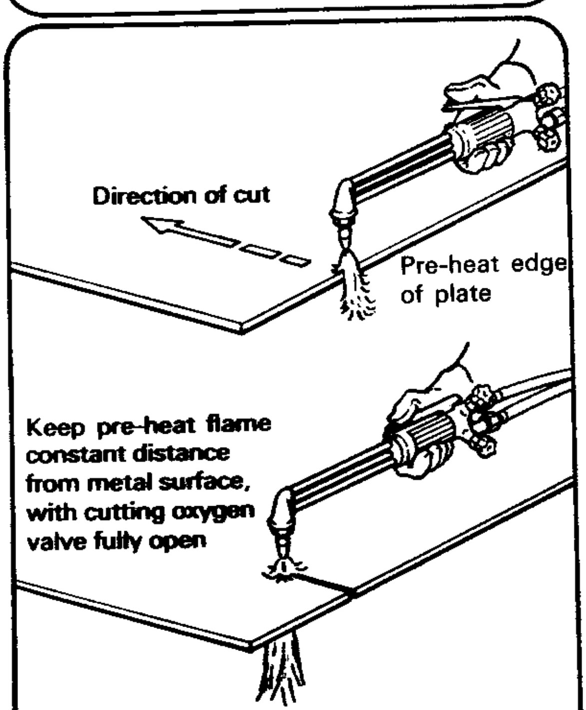
Note: Always follow the above procedure in the stated order.

Steels suitable for cutting
1. Low carbon steels such as mild steel and medium tensile structural steels.
2. Alloy steels (containing less than 5% chrome).
Material clad on one side only poses special problems and expert guidance should be sought.

Material	12 mm mild steel
Preparation	Clean surface where cut is to be made. Mark the line of cut
Assembly	Place plate in flat position on supports with metal box below line of cut to catch dross
Nozzle	1·0 mm
Oxygen	2·1 bars
Fuel gas	Acetylene 0·14 bar LPG 0·21 bar



Points to watch when cutting



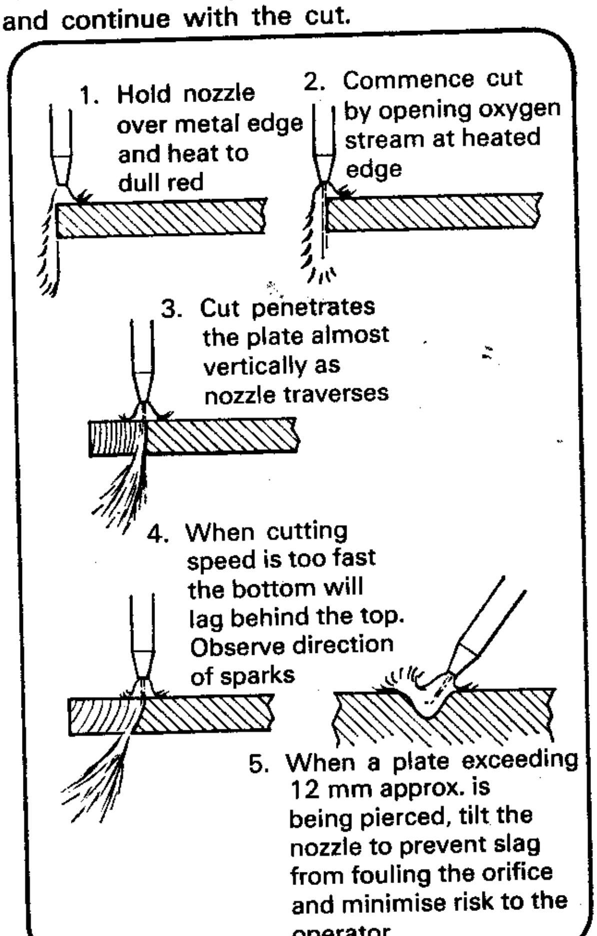
Freehand cutting

Freehand cutting—Blowpipe control
Example procedure EP/CG/2

1. Using a neutral pre-heating flame, pre-heat the edge of the plate at the point where the cut is to start.
2. Direct the flame vertically downwards with the tips of the cones 3 mm to 5 mm above the surface of the plate.
3. Hold the shank of the blowpipe so that it lies in the direction that the cut is required.
4. When the edge is locally heated to a dull red (with a small white hot spot) open the cutting oxygen valve slowly until full flow is obtained.
5. Move the blowpipe towards the body at a uniform speed along the line to be cut with the nozzle held at a constant distance from the plate surface. Focus the eyes on a point just in advance of the nozzle.
6. Ensure the correct cutting speed.

(a) The speed is correct when the oxide sprays straight downwards.
(b) The speed is too slow if the oxide sprays forward in the direction of cutting.

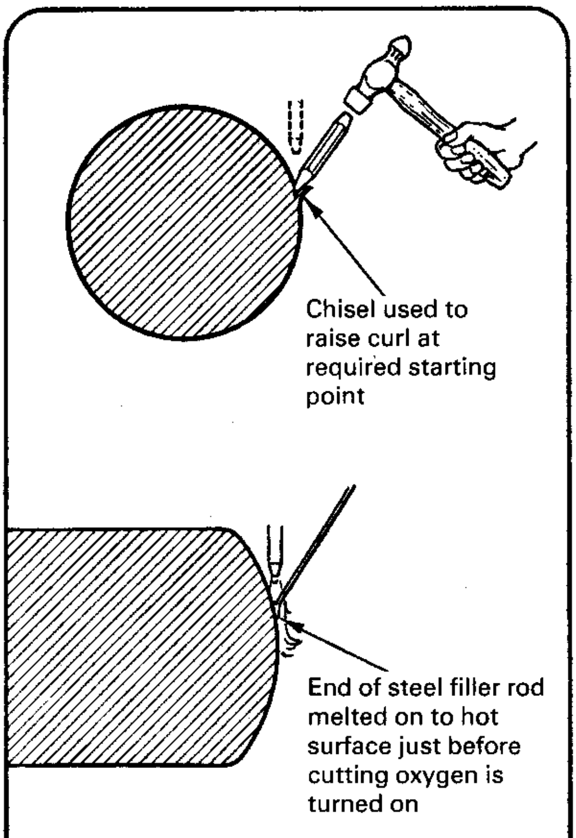
Note: If the blowpipe is moved too fast the white hot spot will disappear and the cut may fail to penetrate the plate. If this occurs, turn off the cutting oxygen and apply the pre-heating flame until the ignition temperature has been re-obtained. Re-open the cutting oxygen valve and continue with the cut.



Methods of starting and blowpipe control
Example procedure EP/CG/3

The material to be cut may have a curved surface and this will require a modified procedure in order to start the cutting action quickly.

When cutting round bar the starting point may be prepared by raising a small curl of metal with the aid of a chisel.



Starting the cut on curved surfaces of thick material

A neutral pre-heating flame is used to heat the raised curl of metal and facilitate rapid starting of the cut as described in EP/CG/2. The cutting action is progressed into the curved surface by correct manipulation of the blowpipe maintaining a suitable speed of travel and the correct distance from the material surface to complete severance of the round bar material.

When cutting curved thick section material either the raised curl method may be used to start the cut or a heated steel filler rod may be applied. The filler rod is introduced by heating the end in the neutral pre-heating flame at the desired starting point to a sufficiently high temperature.

The cutting action may then be started by turning on the cutting oxygen and progressing the cut into the curved surface by maintaining the blowpipe in a vertical position, following the contour of the bar from the commencement point up and over the top, proceeding down to the midway point at the opposite side. The blowpipe must be manipulated as in EP/CG/2 at a suitable speed of travel and the correct distance from the material surface to completely sever off the material.

When the bar material is of other than rounded surface the cutting action may readily be started at the edges or corners without the necessity for the above procedures.

Visual examination

A satisfactory cut will have the following characteristics:

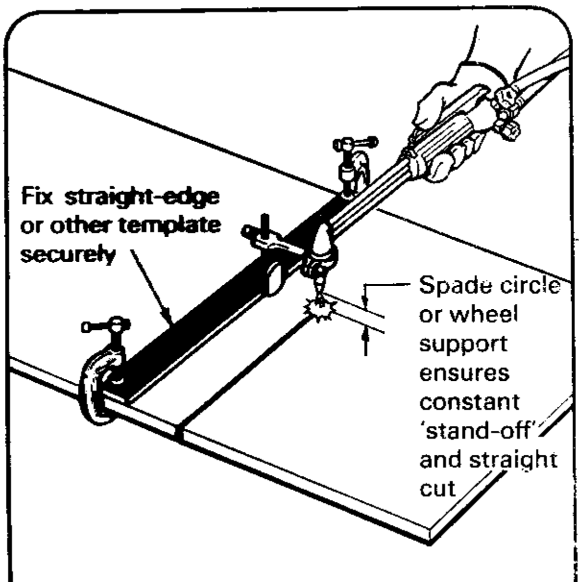
1. A sharp top edge.
2. Almost vertical drag lines that are not too pronounced.
3. A square face with only a light but easily removable oxide scale.
4. Sharp bottom edge without adhering oxide.
5. The cut edge will be true to the planned line of cut with a uniform kerf width.

Examine the cut edge and where the desired standard has not been achieved make reference to the 'recognition of defects' explained on pages 122–123. Repeat the procedure until a good quality cut can be readily obtained.

Gas cutting and gouging

Cutting sections up to 50 mm—
Straight-line, square-edge cutting
Example procedure EP/CG/4

Material	6·5 mm mild steel
Preparation	Clean surfaces above and below, then mark line of cut
Assembly	Place plate in flat position on supports. Fix straight-edge securely with clamps parallel to and at the correct distance from the line of cut
Nozzle	0·75 mm
Oxygen	1·8 bars
Fuel gases	Acetylene 0·14 bar LPG 0·21 bar



Cutting with straight-edge and single support

1. Fit single support cutter guide to blowpipe and adjust to correct height.

2. Check that the nozzle is centred over line of cut when cutter guide is in contact with straight-edge.

3. Light blowpipe and adjust to neutral pre-heating flame with cutting oxygen flowing.

4. Pre-heat at point where cut is to start.

5. Open cutting oxygen valve slowly and start cutting.

6. Keep the cutter guide resting on the surface of the plate and pressed sideways in light contact with the straight-edge.

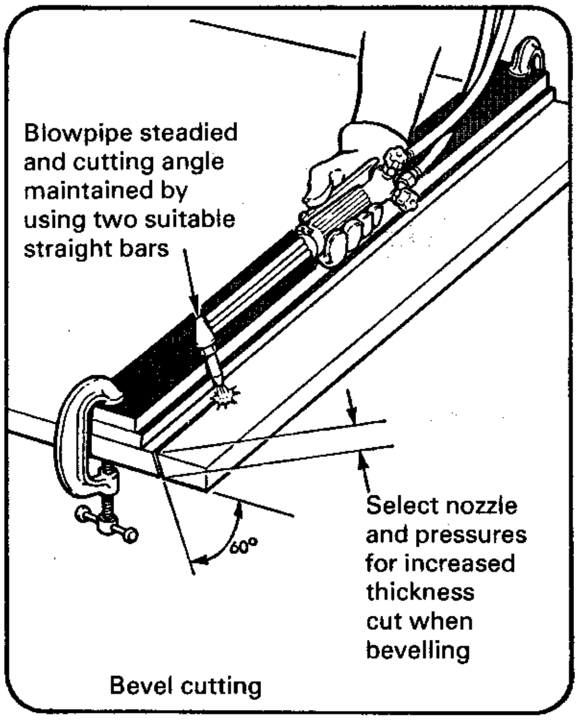
7. Adjust cutting speed so that the molten spray is approximately vertical.

Visual examination
Examine the cut edges and note the effects of variation in procedure. Repeat until good quality cuts are obtained.

Bevel cutting—Flat position
Effective bevel cutting depends upon the accuracy of edge preparation. Small pieces may be inclined at the appropriate angle and cut from the back. The most common practice is to keep the plate in the flat position and angle the cutting nozzle by means of an adjustable cutter guide. Alternatively, two straight-edges off-set to give appropriate inclination can be used as a direct guide for the cutting nozzle.

In general, a larger pre-heat flame is used for bevel cutting than that used when square-edge cutting.

For bevel cutting it is customary to use acetylene as the fuel gas, together with increased oxygen cutting pressure for the greater thickness to be cut.



Bevel cutting

Bevel cutting—Flat position
Example procedure EP/CG/5

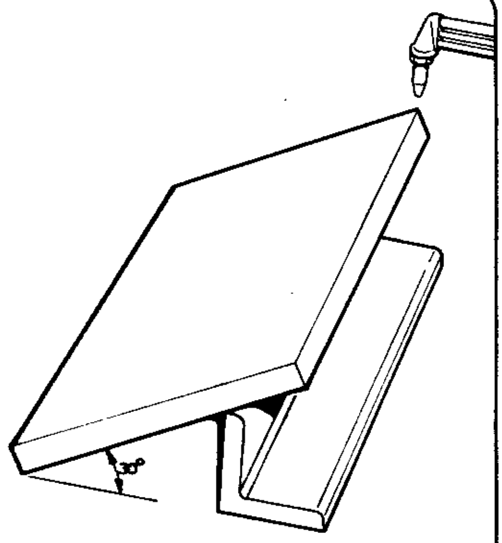
Material	25 mm mild steel
Preparation	As EP/CG/4
Assembly	As for EP/CG/4
Nozzle	1·6 mm
Oxygen	2·8 bars
Fuel gases	Acetylene 0·14 bar LPG 0·28 bar

As for EP/CG/4 except for amended cutting conditions. Note that pre-heating time will be longer.

Visual examination
Examine the cut edges and note the effects of variation in procedure. Repeat until good quality cuts are obtained.

Bevel cutting—30° incline
Example procedure EP/CG/6

Material	38 mm or 50 mm mild steel plate
Preparation	Clean the surface and mark the line of cut. Assemble angle iron guide or set up for wheeled guide with protractor
Assembly	Place the plate in the flat position on supports with metal box to catch oxide. Pre-heat as necessary
Nozzle	1·5 mm
Oxygen	3·5 bars
Fuel gases	Acetylene 0·14 bar LPG 0·28 bar



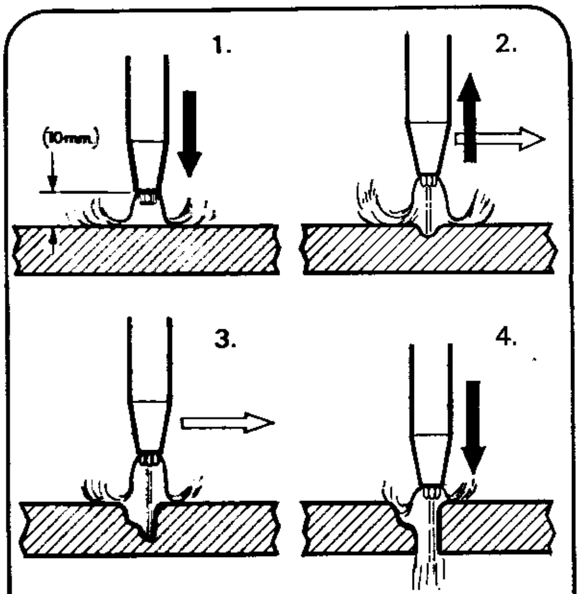
Alternative method of cutting bevelled edge on incline

1. Check that the nozzle is positioned so that its centre line (or longitudinal axis) intersects the line of cut when the nozzle is in contact with the off-set bars.

2. Pre-heat at the point where the cut is to start and proceed with the cutting operation.

3. Adjust the rate of travel so that the molten spray is almost in line with the longitudinal axis of the nozzle.

Visual examination
Examine the cut edges and note the effects of variation in procedure. Repeat until good quality cuts at the required angle are obtained.



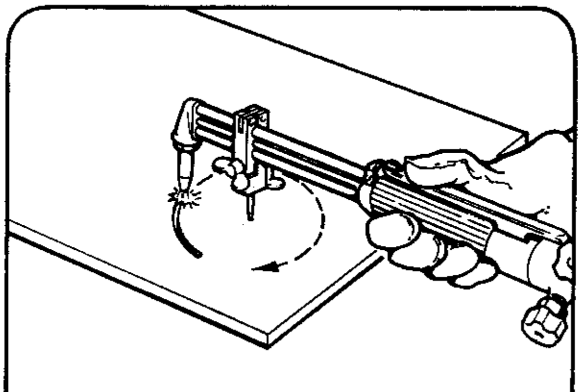
Piercing a hole
Note: This method of piercing is recommended for thicknesses up to 38 mm steel

1. Lower the blowpipe and pre-heat locally to bright red.

2. Open the cutting oxygen valve slowly. At the same time move the blowpipe upwards and sideways. Tilt the blowpipe when cutting plate 12·5 mm thick and over.

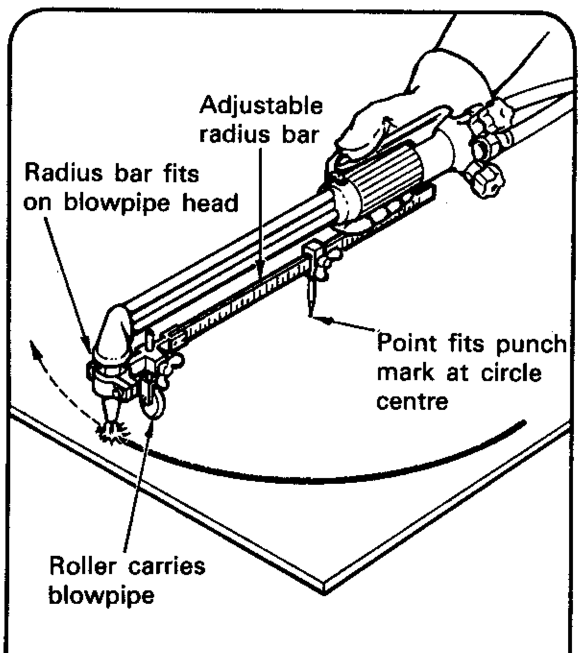
3. Move the blowpipe slightly sideways.

4. Lower the blowpipe to the correct distance from the plate and cut.


Small circle cutting

Circle cutting—Small
Example procedure EP/CG/7

1. Fit the small circle-cutting attachment to the blowpipe and adjust to correct height.
2. Check that the nozzle-to-plate and pivot distances are correct.
3. Light the blowpipe and adjust to neutral pre-heating flame with cutting oxygen flowing.
4. Pre-heat at a point near the circumference until a local hot spot is developed.
5. Open the cutting oxygen valve slowly until fully open.
6. As soon as a hole is pierced, travel to where the cut is to start on the circumference. Locate and maintain the pivot in the centre punch mark and continue cutting action as the blowpipe is moved in a circular path at right-angles to the plate surface.

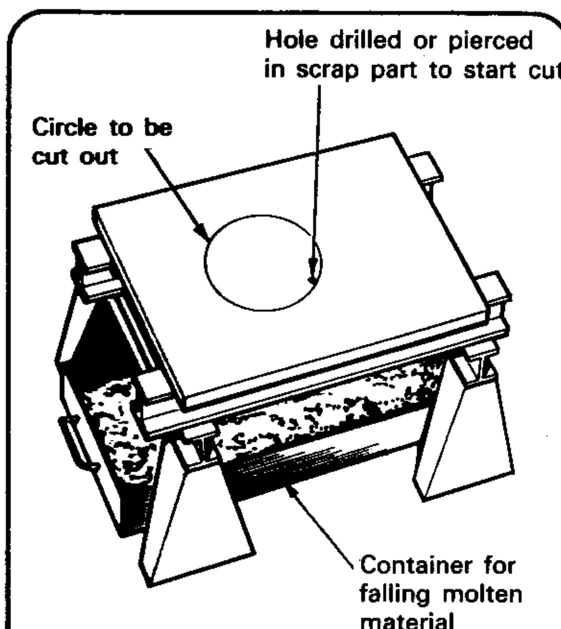


Large circle cutting

Circle cutting—Large
Example procedure EP/CG/8

1. Repeat EP/CG/7 except that the large circle-cutting attachment is used to cut a larger diameter circle.

Note: An alternative method for starting circular cuts is to drill a hole, approximately 6 mm in diameter, in the scrap portion of the plate, so that a point on its circumference coincides with the circumference of the circle to be cut. The edge of this hole is used as the starting point.



Cutting from a thick plate

Material	38 mm or 50 mm mild steel or metal as available
Preparation	Clean the surface and mark out the desired contours leaving at least 50 mm between each component
Assembly	Place the plate in a vertical position. Pre-heat as necessary. Make provision to catch hot components
Nozzle	1·5 mm
Oxygen	3·5 bars
Fuel gases	Acetylene 0·14 bar LPG 0·28 bar

Contour cutting in vertical position
Example procedure EP/CG/9

1. Pierce start hole.

2. When cutting a circular or irregularly shaped part, as distinct from simply piercing, commence cutting at the top of the contour.

3. Cut right round the contour observing:
(a) correct stand off

(b) correct speed.

Cut in either clockwise or anti-clockwise direction.

4. Finish with a small tongue of metal to be severed on completion.

Material	12 mm and 25 mm mild steel
Preparation	Clean the surface where cut is to be made. Mark the line of cut
Assembly	Place the plate in flat position on supports with metal box below line of cut to catch oxide
Nozzle	1 mm (for 12 mm material) 1·5 mm (for 25 mm material)
Oxygen	2·1 bars (for 12 mm material), 2·8 bars (for 25 mm material)
Fuel gases	Acetylene 0·14 bar LPG 0·21 bar (for 12 mm material), 0·28 bar (for 25 mm material)

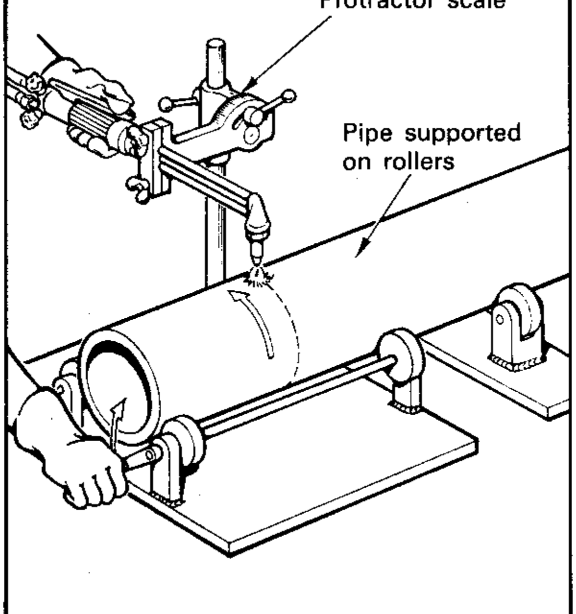
Freehand and guide-assisted cutting
Example procedure EP/CG/10 and 11

Exercise in manual cutting should be carried out in 12 mm and 25 mm thick mild steel for square and bevel cuts. Maximum benefit will be derived if the cutting involves irregular shapes with maximum perimeters.

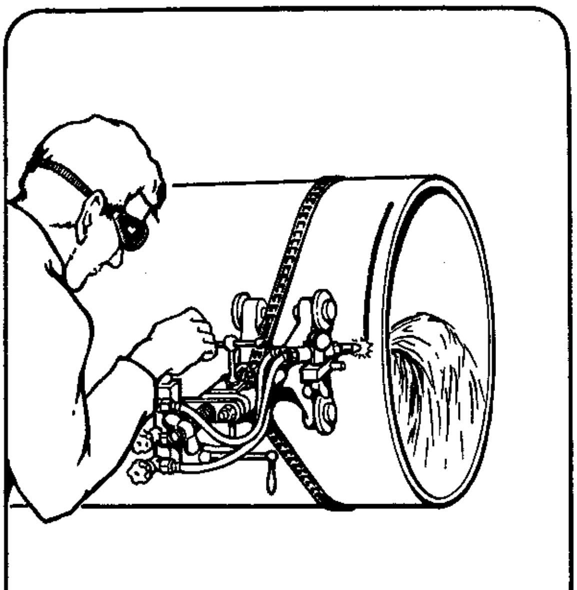
Material	50 mm mild steel
Preparation	Clean the surface where cut is to be made. Mark the line of cut (when alloy steel is used pre-heating will be necessary to avoid cracking)
Assembly	Place the plate in flat position on supports with metal box below line of cut to catch oxide
Nozzle	1·5 mm
Oxygen	3·5 bars
Fuel gases	Acetylene 0·14 bar LPG 0·28 bar

Example procedure EP/CG/12

In 50 mm thickness, accurate cuts are best made by hand guide assistance, eg.
(i) straight edge—spade,
(ii) radius bar—roller,
(iii) template.



Simple pipe-cutting arrangement


Rotated pipe-cutting head

Preparation of mild steel pipe (or tube) flanges, branches and other fittings

Preparation of mild steel pipes, using the gas-cutting process, is dependent upon:

1. A knowledge of marking out methods, making due allowance for the type of joint and pipe dimensions.
2. An understanding of the limitations of the process.

Cutting conditions

The cutting conditions for pipes (or tubes) are similar to those used when cutting sheet or plate of comparable section and composition.

Manipulation

The cutting head is either:
(a) fixed with the pipe rotated at the appropriate uniform cutting speed
or
(b) rotated at the appropriate uniform cutting speed whilst the pipe remains stationary.

Square-edge cutting

The cutting nozzle must be maintained at right-angles to the centre line of the pipe and so directed that the cutting stream passes through the centre of the pipe.

Deviations in angle will cause:
(a) incorrect edge preparation,
(b) variations in depth of cut, affecting quality.

Bevel-edge cutting

Set the nozzle at the required degree of bevel. Regulate speed of cutting in accordance with the increased thickness, ensuring that the nozzle size and cutting conditions are suitable.

Profile or circumferential cutting by machine

A true bevel can only be produced from a stationary cutter when the cut is at 90° to the pipe (or tube) axis.

Machines, which are mechanically or manually operated, can cut a variety of shapes in pipe (or tube) and produce more accurate profiles at greater speed than is possible by freehand cutting, eg.

1. Saddle ends.
2. Holes.
3. Oblique (or mitre) ends.

For preference use mechanically driven machines with
(i) variable speed motor,
(ii) sound positive drive, to avoid inaccuracies through slip.

The maker's or supplier's advice in regard to operation should be carefully observed.

Material	6 mm wall thickness mild steel pipe of appropriate diameter
Preparation	Clean surface and mark line of cut
Assembly	Place pipe on roller or V supports. Set nozzle of blowpipe in vertical position
Nozzle	0·75 mm
Oxygen	1·8 bars
Fuel gases	Acetylene 0·14 bar Propane 0·21 bar

Pipe cutting
Example procedure EP/CG/13

1. Check that the pipe is positioned so that the centre line (or longitudinal axis) of the nozzle intersects the line of cut.

2. Light blowpipe and adjust to neutral pre-heating flame.

3. Pre-heat, at a point on the periphery where the cut is to start, until a local white hot spot is developed.

4. Open the cutting oxygen valve slowly until fully open.

5. When the oxygen jet has pierced the wall thickness, commence the rotation of the pipe in co-ordination with cutting action.

Material	Cut pipe from EP13
Preparation	Mark line of cut at 5 mm from cut edge
Assembly	Place pipe on roller or V supports. Set nozzle of blowpipe at 35°–37·5° from vertical
Nozzle	1 mm
Oxygen	2·1 bars
Fuel gases	Acetylene 0·14 bar Propane 0·21 bar

Pipe-end preparation
Example procedure EP/CG/14

1. Check that the pipe is positioned to that the longitudinal axis of the angled nozzle intersects the line of cut.

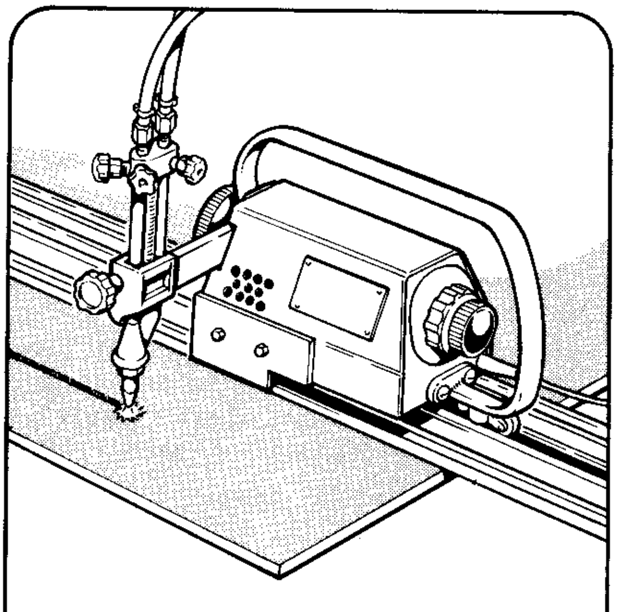
2. Proceed as for EP/CG/13, using the amended cutting conditions required for the increased depth of cut with bevel-end preparation.

The use of manually and electrically driven cutting machines

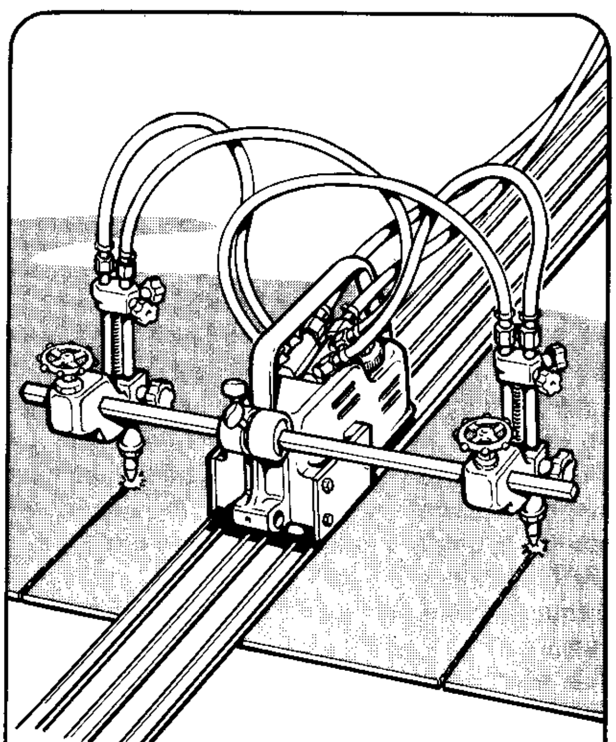
When setting up the machine, select a nozzle size, and the relevant speed and pressures determined from the supplier's recommendations based on the fuel gas available. In all work, see that the nozzle is correctly positioned in relation to the pipe surface.

Cutting machines can be operated either manually or electrically.
The cutting head is usually purpose made, having either:
(a) a rack and pinion,
or
(b) nut and screwthread or similar device to adjust the 'stand-off' distance, with
(c) provision to set the nozzle at an angle for bevel cutting.

The assembly of the machine, the use of templates or systems of reproduction, the position of the work, speed range and cutters vary according to the make of machine. Instruction books should be consulted and followed.



Straight line cutting with machine on track



Portable machine with multiple cutting heads

Manually driven cutting machines

These normally consist of:

(a) A crank or wheel to drive the cutter via a screwthread. Suitable for square or bevel cuts.

(b) A system of links, or rods, for producing simple shapes such as circles, ellipses, squares, etc.

By following a drawing, or template, the shape is transferred by a form of cross carriage or pantograph to the cutter motion.

The speed of hand-operated machines is liable to variation and the range of speed is limited.

Electrically driven cutting machines

Portable machines

Electrically driven portable cutting machines generally consist of:

(i) a variable speed motor-driven carriage or tractor,

(ii) a track for straight line cutting,

(iii) radius or trammel bars for circle or curve cutting,

(iv) hand guided attachments for profile cutting.

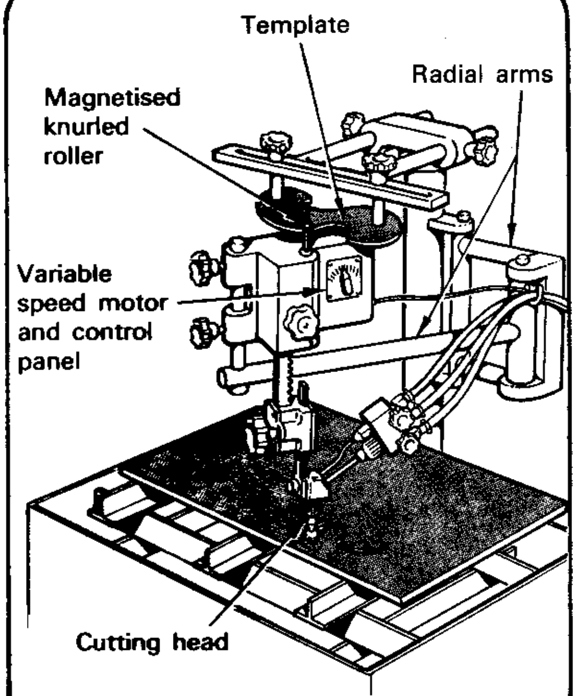
Provision is made to enable full adjustment of the cutting head to be carried out over the cutting area.

The speed of an electrically driven machine, when set, is constant, and normally it is able to produce better cuts than a manually driven machine. The speed range of an electrically driven machine is greater than the manual type and the adjustment of speed is more accurately controlled. Multiple cutting heads can be mounted to increase the volume of cutting; these cutting heads may be mounted on an adjustable boom extending to either side of the tractor at 90° to its direction of travel.

Static machines

These machines usually produce more accurate work than manually operated or portable cutters. The construction is usually more robust, thus eliminating vibration. Using multiple cutters the cross-carriage types can reproduce as many shapes as there are cutters. Productivity of these machines is improved by their ability to accurately stack cut.

In general, the work is brought to the machine. Provision is made for straight line, circle and profile cutting.



Radial arm cutting machine

The radial arm machine

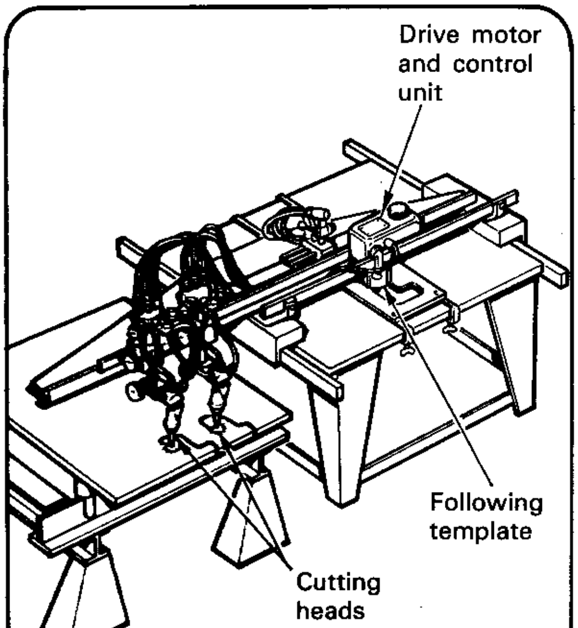
The simplest form of machine in universal use is the radial arm type:
(i) with a straight edge it cuts straight lines,
(ii) with an attachment it cuts circles,
(iii) with templates it profiles. Some types may be used to follow a drawing outline.

Most cutting machines of this type use the principle of a magnetized, knurled roller, guided by contact with a steel template of suitable shape and thickness.

The usual form of drive is by variable speed motor which turns a knurled roller to follow the template contour.

The type of nozzle is dependent on:
(a) speed of cutting,
(b) available fuel gas.

In principle, these nozzles are similar to those used in hand-cutting or similar machine cutting. The operation of these specialized cutting machines is described in the handbooks from the suppliers. The operator should set up, work and maintain the machine accordingly.



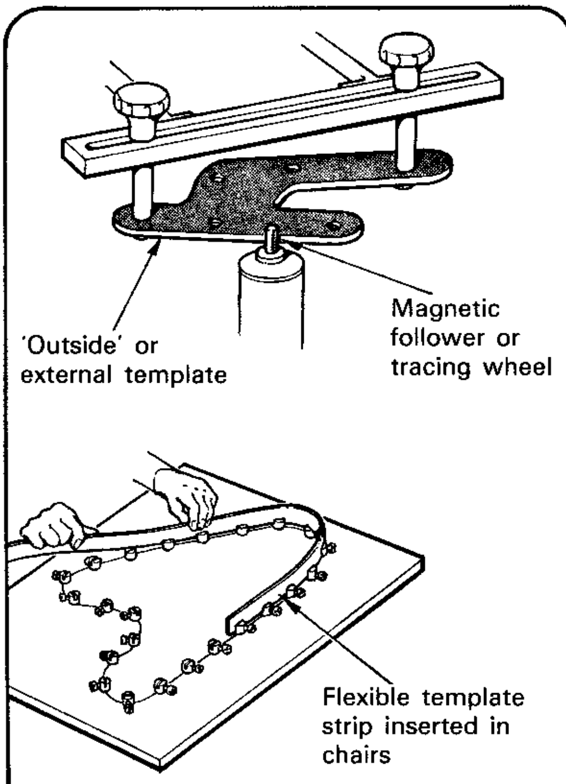
Cross-carriage cutting machine

The cross-carriage machine

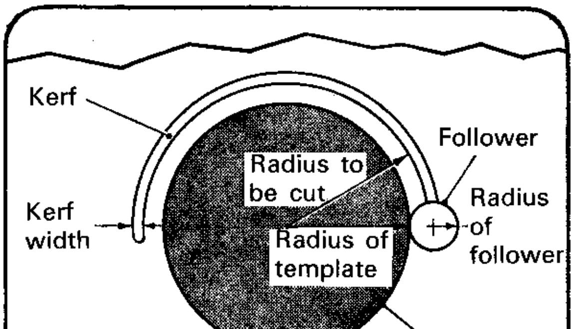
These machines are designed to follow:
1. Templates—(the roller may be modified to enable wooden or non-ferrous metal templates to be used).
2. Drawings:
(a) by tracing the outline manually, generally using a wheel with a suitable tread, or using a light cross,
(b) by using a photo-electric cell to follow the outline and impart motion to the cutters.
3. Electronically—The information from the drawing may be translated on to:
(a) punched paper,
(b) magnetic tape,
where it can be stored to be fed into the cutting machine when needed. This is known as computer control. In this case the information is given to the cutting machine when it is run through a device to impart motion to the cutters.

The arm of the cross-carriage machine may carry several cutters to produce as many shapes from a single pattern.

On certain machines the cutters are lit automatically and simultaneously.



Templates



External template
Radius of template = Radius to be cut *minus* Radius of follower − $\frac{\text{Kerf width}}{2}$

Making templates for machine cutting

The template is a reproduction of the shape to be cut with due allowance for:

(a) the roller drive radius,
(b) the width of the kerf.

Templates are made from wood, hardboard, aluminium plate, steel plate, steel and aluminium strip.

The follower is usually a wheel, preferably knurled to follow the outline of the template:
either
(a) around the outside—known as an outside template,
or
(b) around the inside—known as an inside template.

The knurled wheel can be magnetized to adhere to the outline of the template when the template is:
(i) made of steel or iron,
or
(ii) ferrous material bound to non-magnetic material.

External template

The outline of the template will be the shape to be cut reduced in size by the radius of the following wheel or roller less half the kerf width.

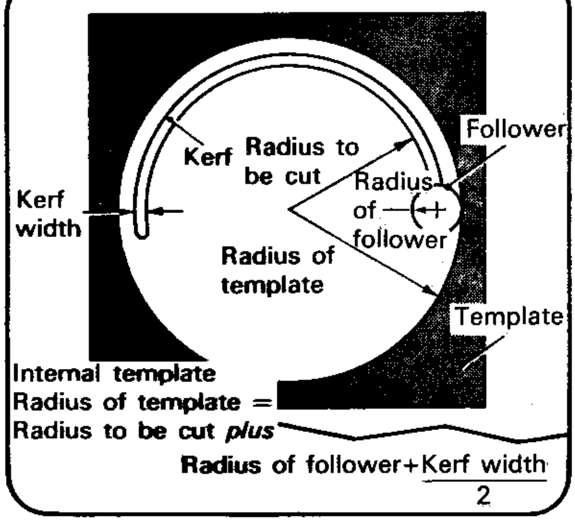
For example;
to cut a circle using an *external* template

Radius of circle	100 mm
Radius of tracing wheel	6·5 mm (a)
Half the kerf width	0·8 mm (b)

difference ((a)−(b)) = 5·7 mm

Radius of external template 100 mm−5·7 mm = 94·3 mm

Note: Kerf width is variable according to:
1. Nozzle size, type and condition.
2. Plate thickness.
3. Cutting speed.
4. Pressure of cutting oxygen.
5. Pre-heat flame size.



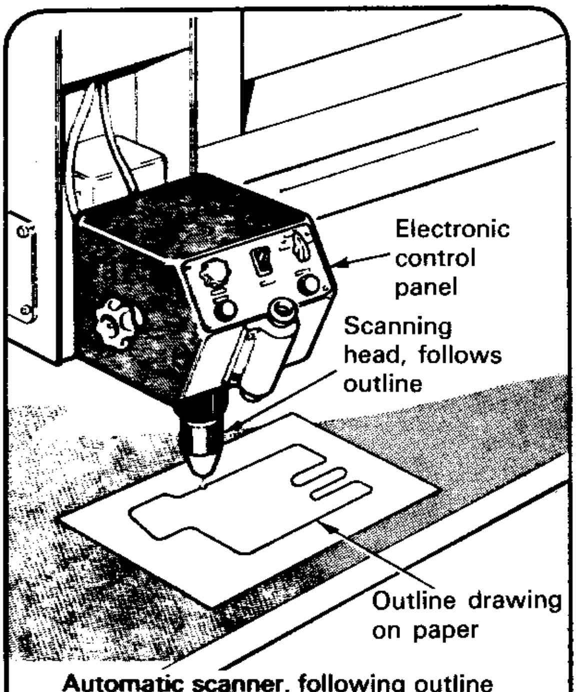
Internal template
The shape of the template will be the shape to be cut increased by the radius of the following roller plus half the kerf width. For example; to cut a circle using an *internal* template:

Radius of circle	100 mm
Radius of tracing wheel	6·5 mm (a)
Half the kerf width	0·8 mm (b)

Sum of a+b = 7·3 mm

Radius of external template 100 mm+7·3 mm
= 107·3 mm

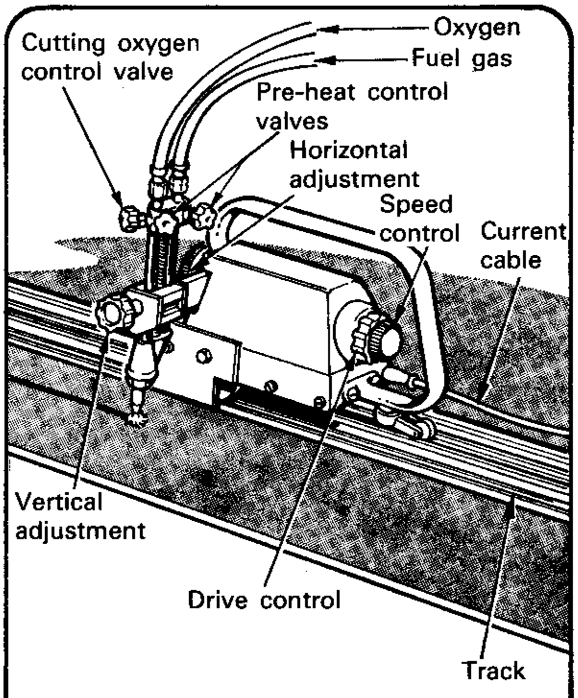
The addition or subtraction shown applies to any shape, in respect of external or internal template. Make allowance for any possible machining. To make certain a knurled roller, or follower, adheres closely to the corners of the template and is not thrown off by kinetic energy the minimum radius should be greater than 0·8 mm.



Automatic scanner, following outline drawing on paper

Line scanning
Make line drawings for scanners on good clean white paper using a line of 0·2 mm to 1·0 mm in Indian ink or suitable pencil. Observe all radii have no sharp corners, allow at least 3·25 mm radius to prevent the forces set up in the moving linkage from causing the scanner to leave the outline. The work can be spoiled if the line following device has (1) erratic motion, (2) difficulty in negotiating corners, causing loss of the cutting action through interruption.

Portable machines
Portable machines may run on either a special track or on the plate in contact with a straight-edge to produce straight-line cutting.
The track or straight-edge must be at least 600 mm longer than the length of cut to be made. Where cutting is to extend to the full plate width and a track is not used, support the machine beyond the plate edges being cut, eg. using on-and-off plates of the same thickness alongside the plate to be cut. The plates must be properly aligned and supported.
When using a track, lock the swivelling castor and place the machine on the track, making sure that all three wheels are located in their track guides and that the track is correctly positioned. When using a straight-edge, lock the swivelling castor and place the machine on the plate between the straight-edge and the line of cut. The straight-edge should be clamped to



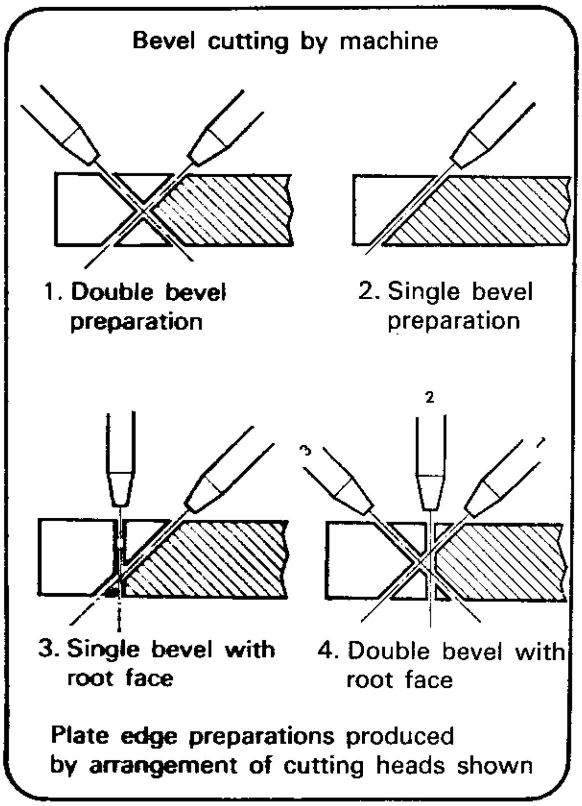
Portable cutting machine

the plate, parallel to and at the correct distance from the line of the cut. The free wheel and the cutting guide or rubbing pads should be placed in contact with the straight-edge such that the action of the driven wheel maintains this contact.
Ensure that the tractor motor switch is in the 'off' position before inserting electrical supply lead plug.

Straight-line cutting
Example procedure EP/CG/15

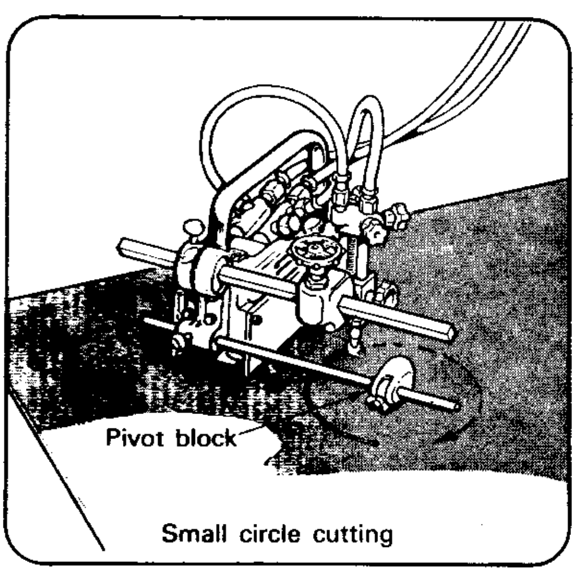
Material	12 mm mild steel
Preparation	Clean surface and mark line of cut
Assembly	Place plate in flat position and prepare for cutting as detailed
Nozzle	1 mm
Oxygen	2·1 bars
Fuel gases	Acetylene: 0·14 bar LPG: 0·21 bar

1. Check the running of the machine in relation to line of cut.
2. Adjust nozzle height and check that the nozzle is centred over line of cut.
3. Position machine so that the central orifice of nozzle is just clear of plate edge where cut is to start.
4. Check that valves on cutter are closed then open oxygen and fuel gas cylinder valves.
5. Set cutting speed on tractor control to 400 mm/min.
6. Light and adjust to neutral heating flame with cutting oxygen flowing.
7. Pre-heat edge of plate to bright red colour.
8. Turn on the cutting oxygen and switch on the tractor motor.
9. At the end of the cut:
(a) turn off the cutting oxygen
(b) turn off the fuel gas
(c) turn off the heating oxygen
(d) switch off the tractor motor.



Bevel cutting by machine

Plate edge preparations produced by arrangement of cutting heads shown



Small circle cutting

The machine runs on the plate to be cut and care must be taken to ensure that the machine will be adequately supported when the circle has been cut.

Bevel-edge cutting

Example procedure EP/CG/16

1. Check that the longitudinal axis of the angled nozzle intersects the line of cut.

2. Proceed as for EP/CG/15, using the amended cutting conditions required for the increased depth of cut with bevel-edge preparation. Use increased oxygen pressure and larger pre-heat flame.

Circle cutting

Example procedure EP/CG/17

To cut circles it is usual to fit a radius bar assembly to the machine. This consists of a clamp block, a weight and a pivot mounted on a bar.

1. Support the cutting area to:

(a) avoid damage to the machine as the disc drops,

and/or

(b) maintain the cut quality.

When cutting small circles, the radius bar weight is positioned on the same side of the tractor as the cutter.

For cutting larger circles, usually greater than 500 mm in diameter, the radius bar must be positioned on the side of the tractor opposite to the cutter.

2. The castor must be unlocked so that it has free movement.

3. Loop or support the gas hoses and motor cable in such a manner that they will remain clear of the machine to prevent excessive hose drag.

Note: Speed of travel may need adjustment during cutting.

Circle cutting—small

Example procedure EP/CG/18

1. Place machine on plate and assemble radius bar for cutting small circles.

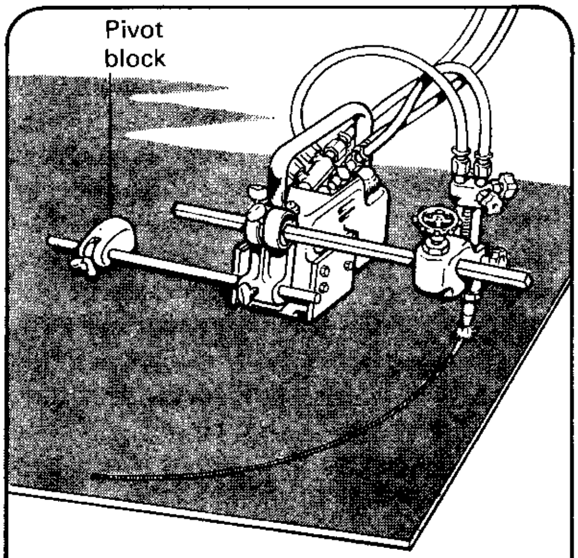
2. Place the pivot pin in the centre punch mark. The cutting radius should be adjusted to make allowance for the kerf width.

3. Adjust nozzle to correct height.

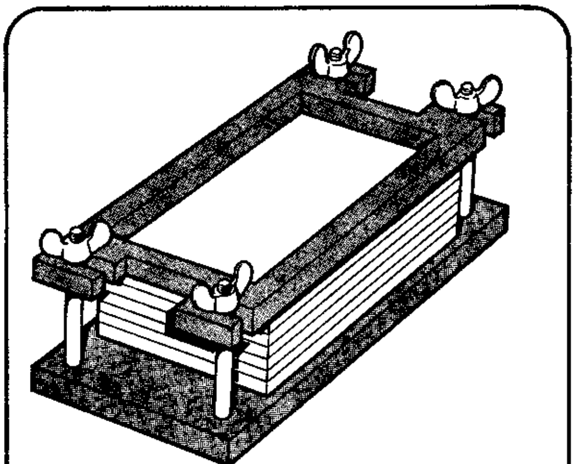
4. Move the nozzle approximately 12 mm away from the line of cut into the scrap or piece to be discarded portion of the plate.

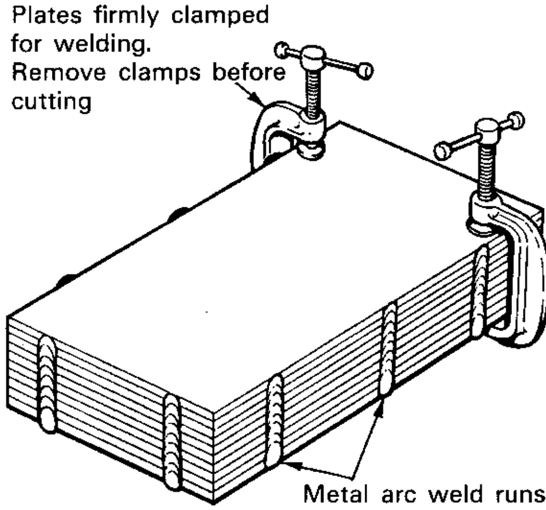
5. Light the gases and adjust to neutral condition with cutting oxygen off.

6. Pre-heat locally to ignition temperature and open the cutting oxygen valve slowly until full on.



Large circle cutting


Simple clamp for stack cutting



Metal arc welding of plates to be retained as a stack for cutting

7. When the oxygen jet has pierced the plate slowly move the nozzle back to the line of the circumference of the circle to be cut.
8. When the circle circumference is reached centralize the nozzle on the line of cut.
9. Switch on the tractor motor and allow cutting to proceed, adjusting speed to suit.
10. At the end of the cut:
(a) turn off cutting oxygen
(b) turn off the fuel gas
(c) turn off heating oxygen
(d) switch off the tractor motor.

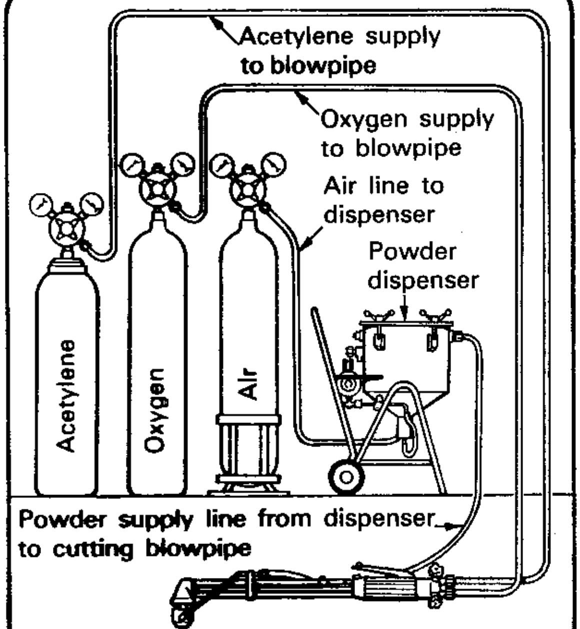
Circle cutting—large
Example procedure EP/CG/19
1. Repeat the procedure EP/CG/18 except that the radius bar should be assembled to enable a much larger diameter circle to be cut.

Profile cutting
Example procedure EP/CG/20
1. Select plate, approximate thickness 6·5 mm, and mark out by hand a suitable irregular profile.
2. Using the appropriate hand process, cut out the profile and, if necessary, dress the edges by filing or grinding.
3. With the aid of this template, cut from a range of thicknesses eg. 6·5 mm to 50 mm (using a profile type machine) a sample piece in each selected thickness.
4. Compare the dimensional accuracy of the samples with that of the template and observe the quality of the cut face.

Note: It is desirable that both inside and outside templates be used in this procedure.

Stack cutting by the oxy-fuel gas process

Where a number of identical shapes are to be cut it is possible to use a procedure known as stack cutting. This consists in clamping a number or stack of sheets or plates together and then cutting the stack formed as a single thickness of material.
The thickness of the stack to be cut will be determined by the quality of cut edge and accuracy of dimensions required in the finished profile.
The stacked components may be retained either by means of suitable clamping or by the use of metal arc welding across the stacked edges.



Assembly of equipment for powder cutting

Powder cutting process

The powder cutting process is an adaptation of oxygen cutting. It is used when metals having tenacious, refractory oxides (such as stainless steel) are to be cut. Iron powder is introduced into the cutting oxygen stream to react and generate sufficient heat and temperature to melt the refractory oxides. The stream of iron oxide has a powerful scouring action.
The iron powder is fed from a dispenser (by compressed air, or nitrogen) into the cutting stream, by way of a multi-orifice shroud surrounding the cutting nozzle or by means of a single tube attachment.

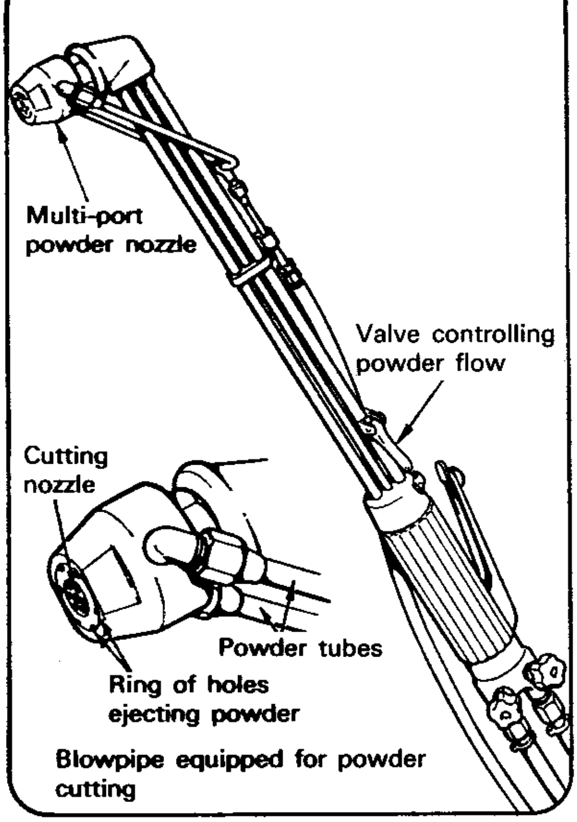
In no circumstances should oxygen be used instead of air or nitrogen for operating the dispenser.

Ensure the use of adequate (forced) ventilation when operating powder cutting process.

To prevent clogging, the dispenser incorporates a wire mesh screen and a moisture absorption unit.
Powder nozzles are designed to inject the iron powder through the flame into the cutting oxygen stream about 25 mm below the nozzle orifice.

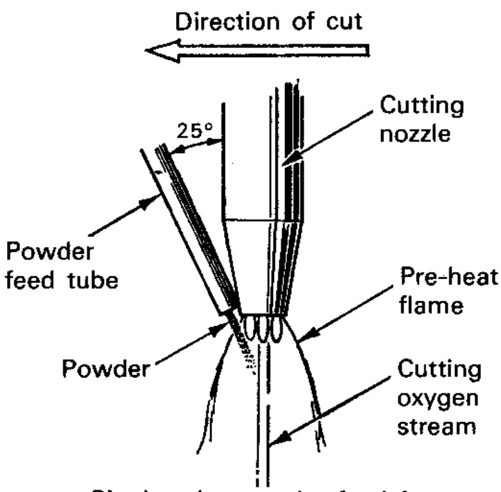
Typical nozzle 'stand-off' distances for powder cutting stainless steel are:

Nozzle stand-off	Material thickness
25 mm	Up to 100 mm
40 mm	100 mm to 150 mm
50 mm	Over 150 mm
Powder flow is varied as required by adjusting: (a) the air pressure (b) the injector	

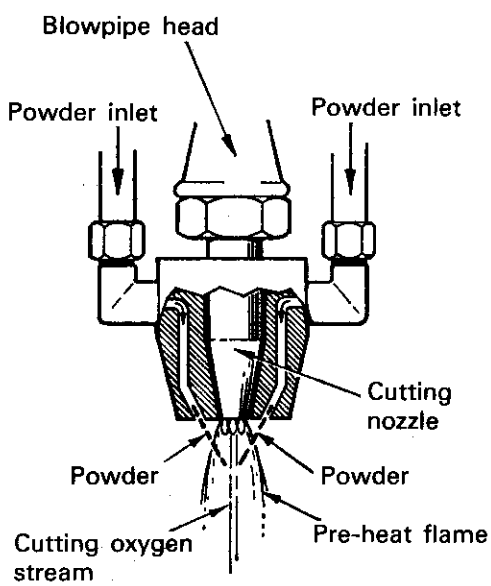


Blowpipe equipped for powder cutting

The air/powder flow is controlled by lever adjacent to the other cutting valves on the blowpipe. Successful operation of the powder cutting equipment depends upon:
1. Freedom from leaks of gas or air.
2. Selecting the correct nozzle and pressure.
3. Maintaining constant control over:
(a) the powder/air flow
(b) rate of traverse
(c) correct stand-off distance.



Single tube powder feed for straight cuts



Principle of multi-port feed cutting nozzle

> **Important**
>
> **Powder cutting process**
>
> Wear leather gloves, apron, goggles, flameproof clothing and safety boots. In confined area wear a face mask or respirator. Ensure adequate (forced) ventilation.

Powder cutting

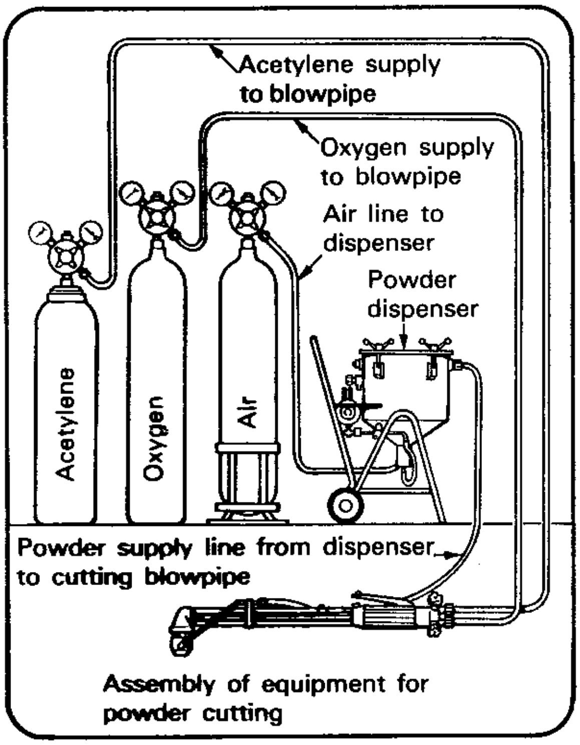
Example procedure EP/CG/21

Material	One piece of stainless steel 12·5 mm thick. Min. size 250 mm × 125 mm
Preparation	Degrease and clean
Assembly	Secure firmly in the flat position over metal container to trap sparks, slag and falling metal
Nozzle size (cutter)	No. 43
Nozzle size (powder)	Standard
Cutting	400 mm/min, 450 mm/min or above by machine in ratio to powder flow rate
Oxygen pressure	Pre-heat 2·4–2·8 bars
Acetylene pressure	0·21 bar
Oxygen pressure (cutting)	4·8–5·5 bars
Operating air pressure	between 0·07–0·70 bar
Iron powder flow rate	142 g/min
Nozzle height to workpiece	30–35 mm

1. Set up the equipment, check gas and air flows with powder entrainment.
2. Light blowpipe and check powder is reaching cutting stream.
3. Hold the nozzle at 90° to the plate edge, depress the cutting lever and air/powder flow lever simultaneously. Pre-heating is unnecessary.
4. Travel in a straight line maintaining stand-off.
5. On completion of the cut turn off:
(a) powder flow
(b) cutting oxygen
(c) fuel gas
(d) heating oxygen.

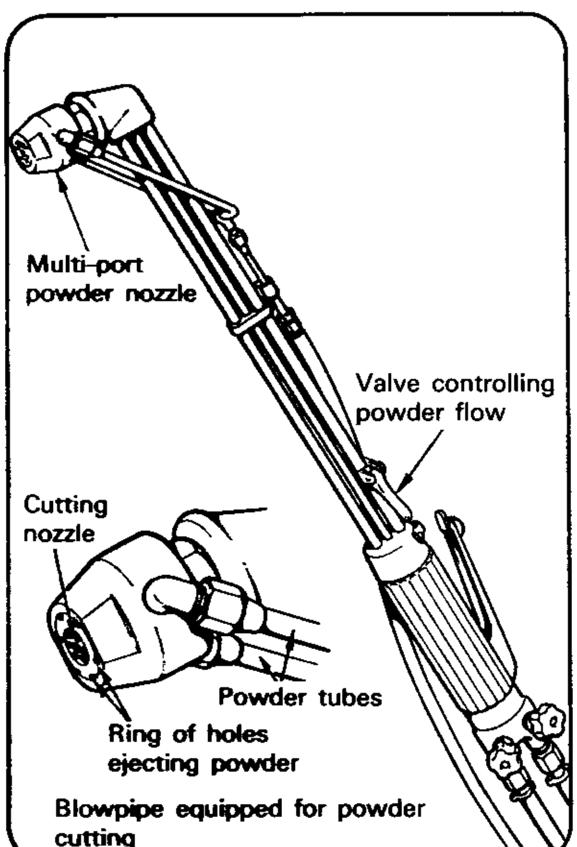
Visual examination

The cut face will have a rough cast appearance. Check for satisfactory profile after removing adhering dross.



Assembly of equipment for powder cutting

Ensure the use of adequate (forced) ventilation when operating powder cutting process.



Blowpipe equipped for powder cutting

Powder cutting process

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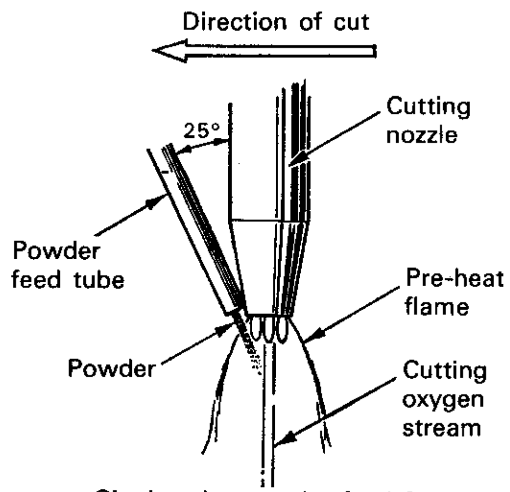
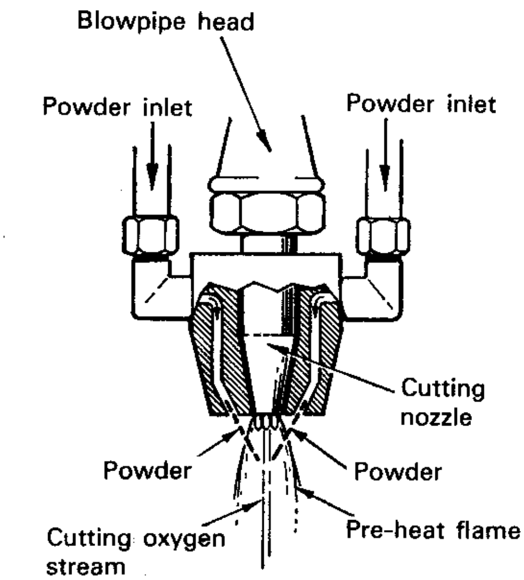
The air/powder flow is controlled by lever adjacent to the other cutting valves on the blowpipe. Successful operation of the powder cutting equipment depends upon:

1. Freedom from leaks of gas or air.
2. Selecting the correct nozzle and pressure.
3. Maintaining constant control over:

(a) the powder/air flow
(b) rate of traverse
(c) correct stand-off distance.



Single tube powder feed for straight cuts



Principle of multi-port feed cutting nozzle

Important

Powder cutting process

Wear leather gloves, apron, goggles, flameproof clothing and safety boots. In confined area wear a face mask or respirator. Ensure adequate (forced) ventilation.

Powder cutting

Example procedure EP/CG/21

Material	One piece of stainless steel 12·5 mm thick. Min. size 250 mm × 125 mm
Preparation	Degrease and clean
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4. Travel in a straight line maintaining stand-off.
5. On completion of the cut turn off:
(a) powder flow
(b) cutting oxygen
(c) fuel gas
(d) heating oxygen.

Visual examination

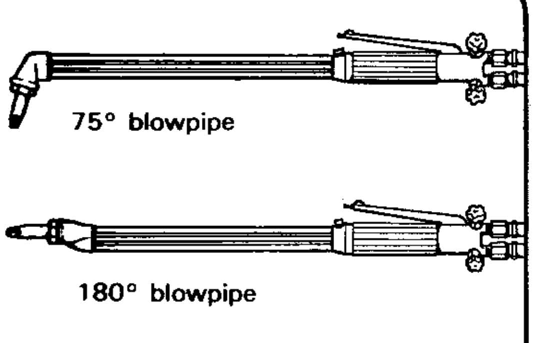
The cut face will have a rough cast appearance. Check for satisfactory profile after removing adhering dross.

Oxy-fuel gas gouging process

Recommended data for straight line gouging (Manual oxy-acetylene gouging)

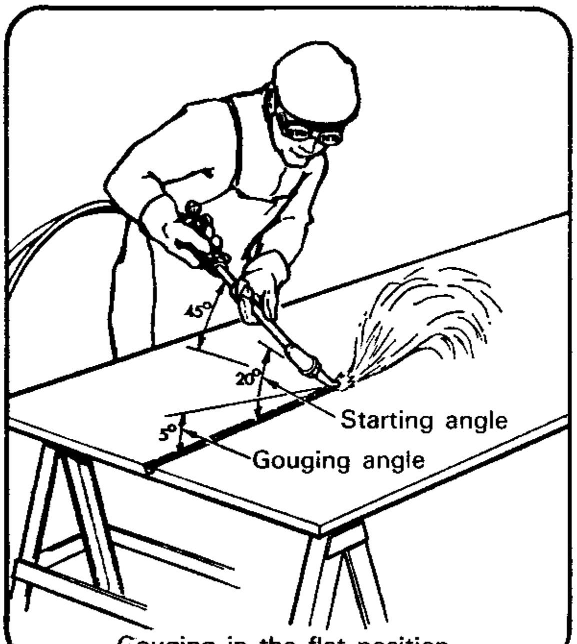
Gouging orifice nozzle dias.	Approximate Dimensions of groove		Approximate regulator pressure in bars*		Approximate gouging speed in mm/min	Approximate gas consumption litres/min		
	Width mm	Depth mm	Acetylene	Cutting oxygen		Acetylene	Oxygen	
							Pre-heat	Cutting
3 mm	6–8	3–9	0·48	4·2	600	15	22	62
5 mm	8–11	6–11	0·48	5·2	1000	29	31	158
6·5 mm	10–13	10–13	0·55	5·5	1200	36	43	276

Notes:
(i) The figures in these tables are given as a guide and may vary with different operators, flame settings, site conditions, steel quality, etc.
(ii)* When gouging curves reduce these pressures slightly.
(iii) See pages 113 and 115 for illustrations of nozzles.



Blowpipes for gouging

Materials suitable for gouging
1. Low alloy steel (such as boiler plate) and plain carbon steels.
2. Air-hardening steels where the part to be gouged is to be welded or post-heated, thus eliminating any hard zone.
3. Alloy steels, provided that they are examined before gas gouging to ascertain that they will not (a) harden (b) crack.
Alloy steels may normally be gouged where pre-heating is possible to a temperature of 400°C.–450°C. (black heat) with freedom from chilling when cooling.

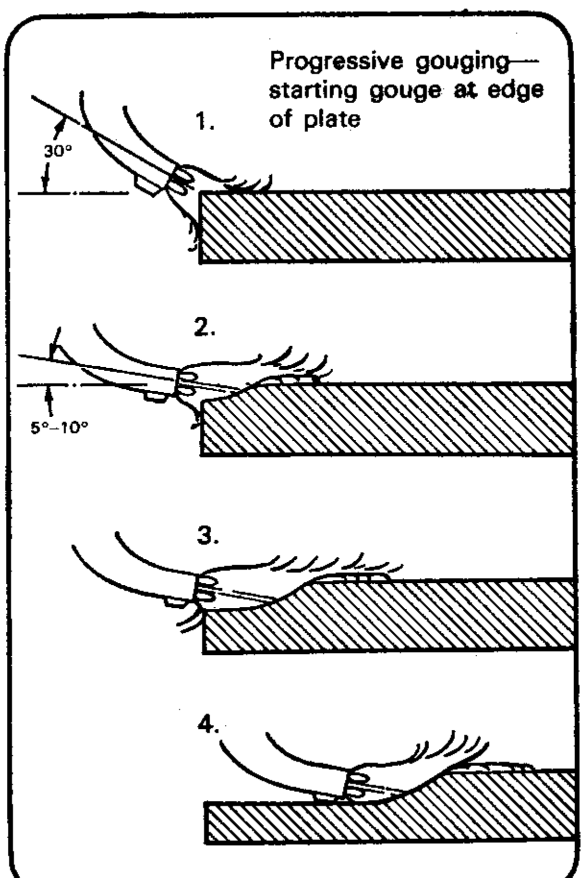


Gouging in the flat position

The gouging process
The oxy-fuel gas cutting flame is also used for gouging. This is the cutting of grooves to the depth required into the material surface in order to remove either material and/or defects on or below the surface. There are three techniques used for this process, which consist of the following:
(a) Progressive gouging.
(b) Spot gouging.
(c) Deep gouging.
The process requires the addition of specially designed gouging nozzles and/or blowpipes to the standard oxy-fuel gas cutting equipment.

Progressive gouging
1. Pre-heat the starting point to bright red with nozzle held at approx. 30° to the plate.
2. Reduce angle of gouging nozzle to 5°–10°.
3. Gently open oxygen valve to start the gouge.

Gouging in the horizontal-vertical position

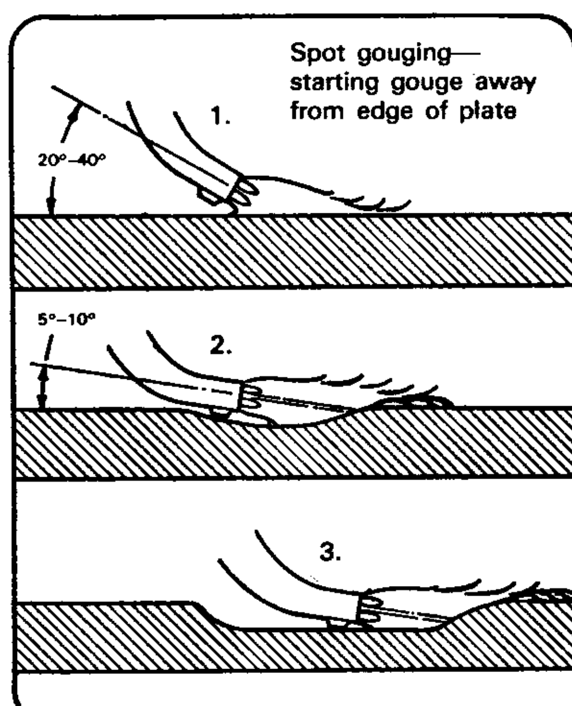


Progressive gouging—starting gouge at edge of plate

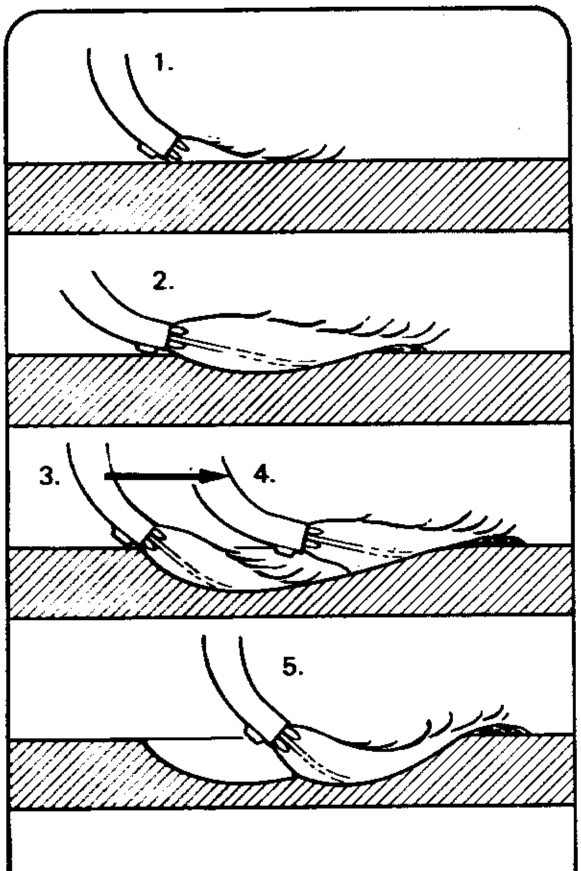
4. When the desired depth of groove is reached, proceed along the length to be gouged.
5. Ensure the nozzle angle is correct.
Too steep an angle causes a deep gouge with slag flowing back into the groove.
Too acute an angle causes the groove to be shallow and the reaction easily lost.
Note: The thicker the material the greater the need to pre-heat, especially at low ambient temperature. In normal circumstances pre-heating mild and structural steels is unnecessary save for imparting superficial heat with the pre-heat flame especially when the metal is bulky.

Spot or intermittent gouging
Spot gouging may be used to remove defects in metal.
When gouging proceeds, the part which is to be removed will be clearly seen when the metal is hot.

Simulated defect
The procedure can be simulated if a hole is drilled from the side, or the surface, of a plate then completely removed by gouging. The hole should be about 3 mm dia. and as deep as is necessary.



Spot gouging—starting gouge away from edge of plate



Deep gouging technique

Deep gouging

This is a combination of progressive and spot gouging.

1. Pre-heat the surface of the plate.
2. Set up reaction by turning on oxygen.
3. Increase blowpipe angle to obtain the depth of groove required.
4. Move the blowpipe forwards, decreasing the angle again.
5. At the end of the forward stroke the angle is again increased and the sequence of movements repeated through the length of the gouge.

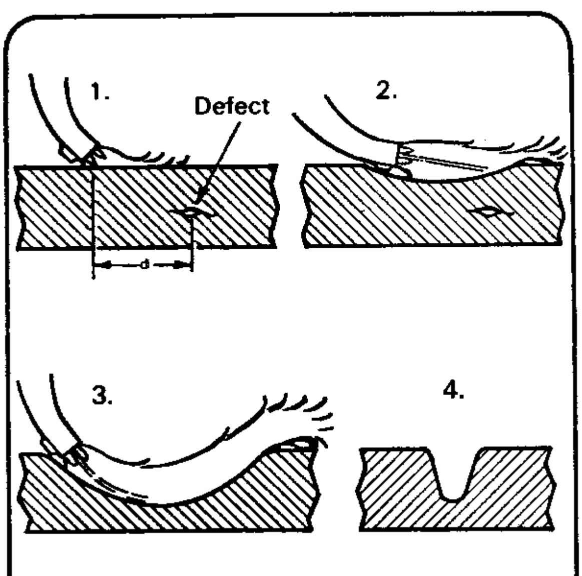
If the groove is to taper from top to bottom the gouges may be made in a series of passes starting with the No. 25 nozzle and using Nos. 19 or 13 as required.

Note: On sections such as round stock, the reaction is sometimes difficult to start. Starting can be aided by:

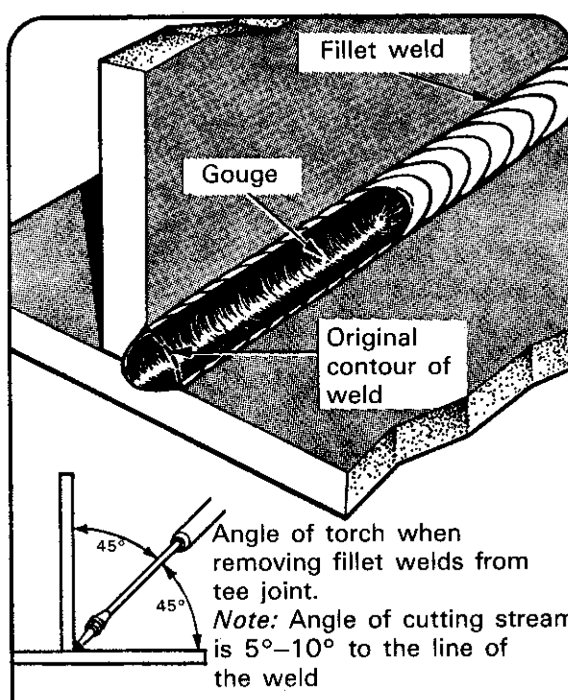
1. Raising a 'fin' by chiselling the surface.
2. By using a piece of iron or steel wire at the point where the reaction is to start.
3. Using a slightly oxidizing flame.

Removing defective welds by gas gouging

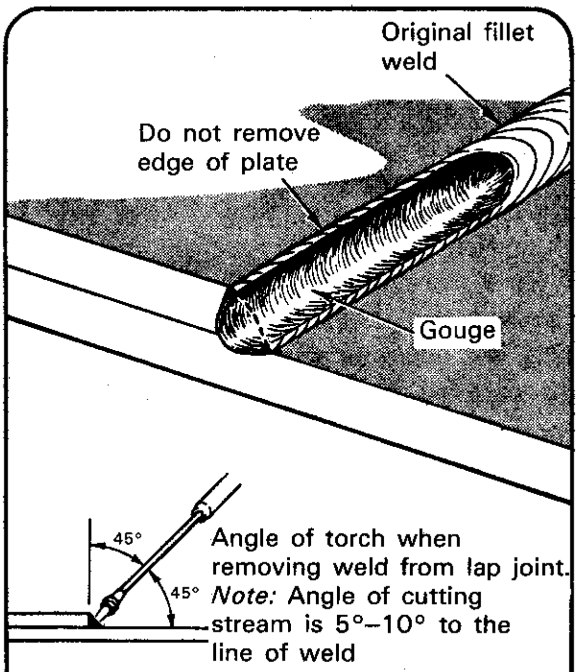
1. Select a nozzle to give the contour and depth of gouge required.



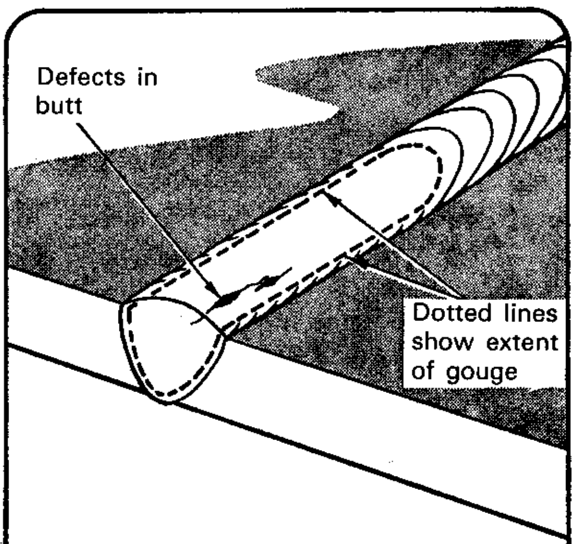
Removal of defect by gouging



Gouging a fillet weld



Removal of weld by gouging



Removing defective butt weld

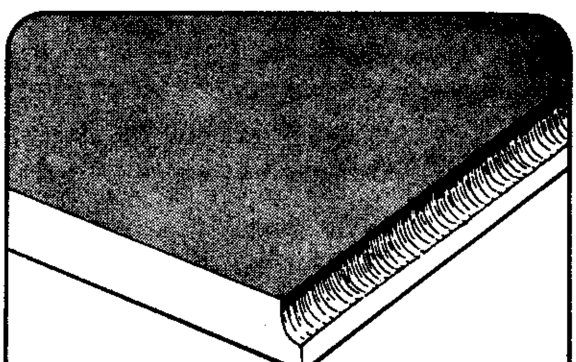
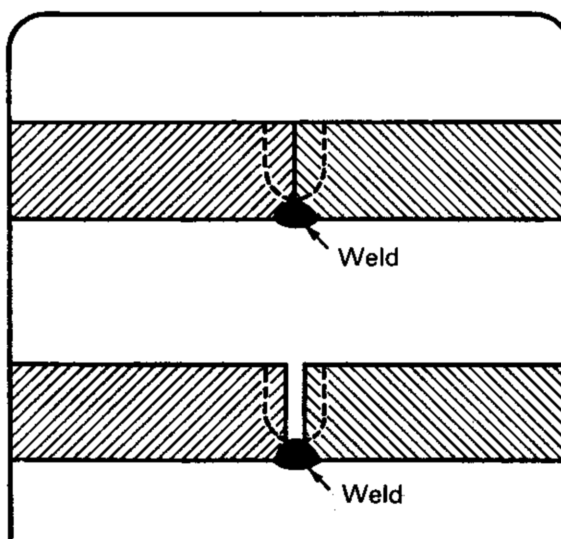


Plate edge flame gouged for welding

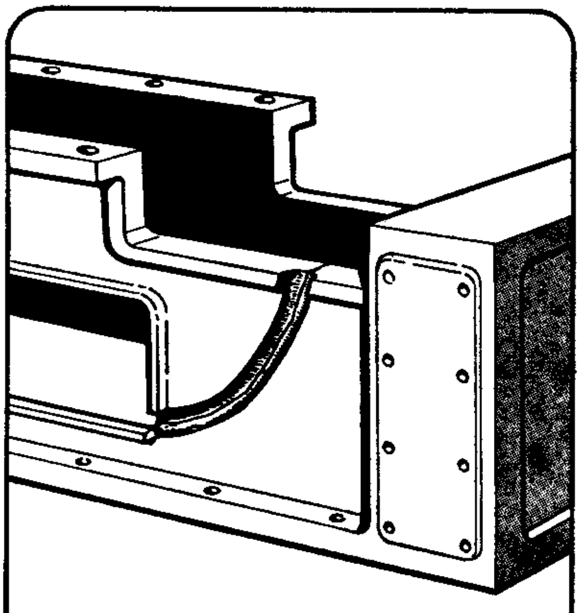
2. The weld metal in the defective area must be completely removed.
3. In the case of fillet, butt and lap welds the torch bisects the angle between the plates in the direction of travel.
The cutting stream is held initially at 20°–40° to the line of weld.
When the reaction is established, the cutting stream angle is reduced to the normal 5°–10°.
Note: The gouge should not extend beyond the weld metal being removed.
The area gouged should have:
1. Uniformly shaped groove.
2. Bright metallic appearance.
3. No adhering dross.

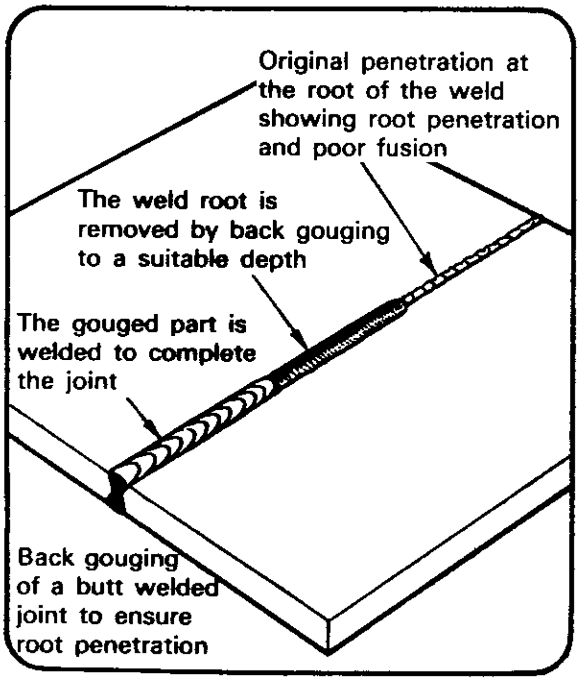
Preparation of plate edges for welding
To prepare plate edges for welding, butt or space as shown in the illustration.
Remove the dotted portion by flame gouging to make a clean 'U', forming a groove with a backing-up bead, already in place.
Thicker plate may be gouged from both sides to form a double 'U'. Single 'J' grooves may be gouged on plate edges.
Plate edges may be prepared by gouging in the vertical position. The blowpipe traverses the workpiece from top to bottom, such that the slag flows away under influence of gravity.
The angles of blowpipes at the beginning and during gouging correspond to those in the flat position.
The gas pressures should be reduced slightly.



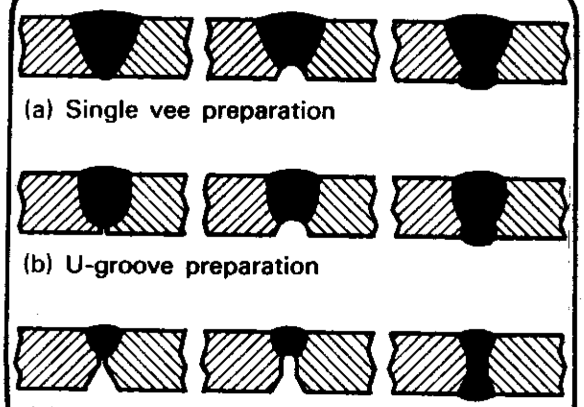
Preparation of plate edges for welding

Gas gouging cracks and other defects in iron and steel castings and weld preparation


Crack in cast frame prepared by gouging



Back gouging of a butt welded joint to ensure root penetration


(a) Single vee preparation
(b) U-groove preparation
(c) Double vee preparation

Removal of defects

The flame-gouging process is used to remove:
1. Surface holes and porosity.
2. Defects within ferrous castings.
3. Cracks.

As a general rule, ferrous material that can be gas cut may also be gouged.

The presence of certain alloying elements affect the gouging quality with liability to:
(a) cracking,
(b) hardening.

Alloy steels require pre-heating in a muffle or furnace before gouging.

Cast-iron must be pre-heated.

An excess of acetylene is necessary in the pre-heat flame when gouging cast-iron.

Malleable iron will gouge successfully although:
1. The heat-affected zone will tend to be hardened.
2. The properties of malleable iron will alter.

Make test gouge where:
1. The quality of the material is doubtful.
2. Hardening, cracking or other faults are likely to be caused.

Observe normal pre- and post-heat provisions.

Back gouging welds

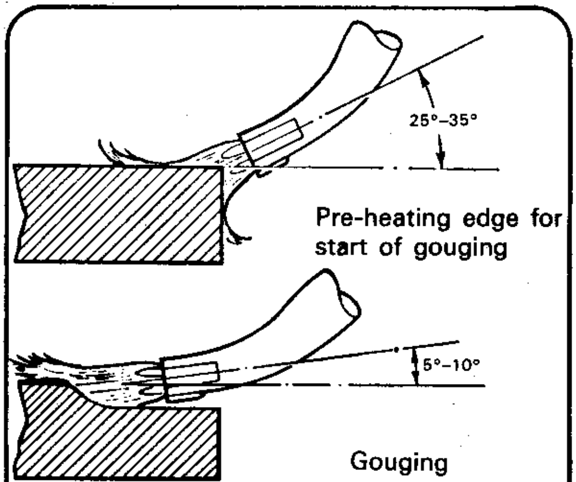
Incomplete root-penetration and poor fusion are corrected by back gouging the weld and then re-welding.
1. Back gouge the weld root to a suitable depth.
2. Fill the gouged part of the weld to complete the joint.

Examples of back gouging the underside of:
(a) Single Vee welds.
(b) U-groove welds.
(c) Double Vee welds in preparation for re-welding are illustrated.

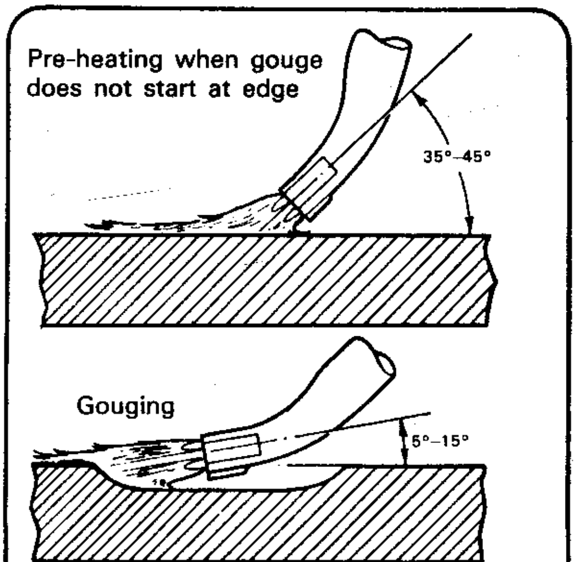
The gouge should be made in the most convenient position, preferably flat.

The procedure when back gouging is the same as when preparing plates or removing weld beads.

Material	One piece of mild steel 25 mm thick. Min. size 200 mm x 150 mm
Preparation	Mark off 150 mm width into four equal parts to provide six groove lines, three on each face
Assembly	Place plate in flat position on low bench with the longitudinal axis parallel to front of bench
Nozzle	3·25 mm
Oxygen	4·2–4·8 bars
Acetylene	0·55 bar



Angles of nozzles for gouging, starting at edge



Angles of nozzles for gouging, not starting at edge

Progressive gouging

Example procedure EP/CG/22

1. Light the blowpipe and adjust to a neutral flame.
2. Hold the blowpipe so that the swaged end of the nozzle is at an angle of 25°–35° to the horizontal.
3. Blowpipe gas tubes should be approximately at right angles to the line of the proposed groove and inclined at about 45° to the horizontal.
4. Point the nozzle in line with the proposed groove.
5. Pre-heat the right-hand edge where the groove is to start, with the tips of the white cones just touching the parent metal.
6. When surface is at bright red heat locally, open the cutting oxygen valve slowly until fully open.
7. As the cut proceeds, immediately but gradually reduce the angle that the nozzle makes with the plate to between 5° and 10°.
8. Maintain the tips of the white cones about 10 mm behind the reaction zone.
9. Just clear the bottom of the groove as the nozzle progresses along the cut to the left-hand edge of the plate.

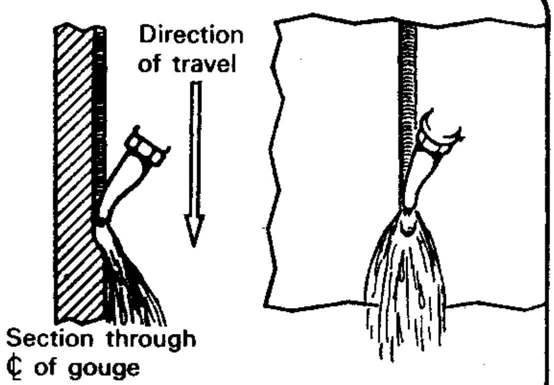
Spot gouging

Example procedure EP/CG/23

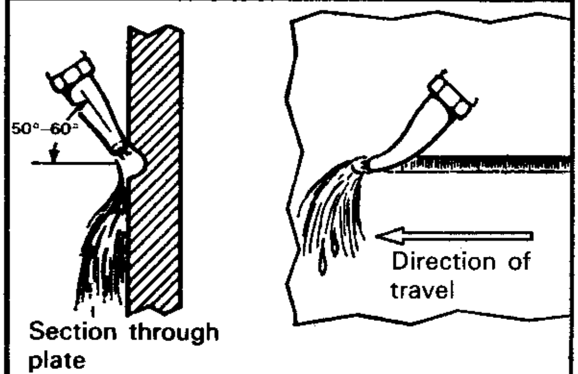
1. Pre-heat locally a spot about 50 mm from the right-hand edge of the plate.
2. Hold the blowpipe as before except that the angle of the nozzle is increased to 35°–45°.
3. When a bright red spot has developed, open the cutting oxygen valve and start grooving.
4. As cut proceeds, reduce the nozzle angle to between 5° and 15°.
5. Finish groove when a length of about 10 mm has been cut.

Visual examination

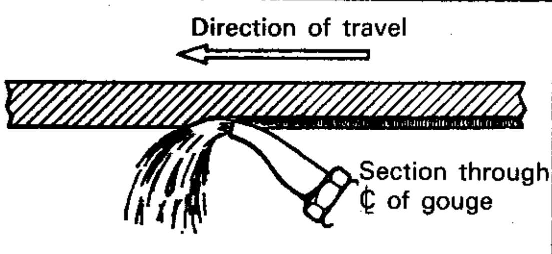
The grooves should be about 6·5 mm wide and 5 mm deep. If the groove varies in depth or width, the angle of nozzle or variation in the rate of travel may be the cause. Too shallow a groove may be caused by low pressure of cutting oxygen or too low nozzle angle. Gouging action will be slow and groove rippled. Too deep a groove may be caused by high pressure of cutting oxygen or too steep nozzle angle. Gouging action may become out of control.



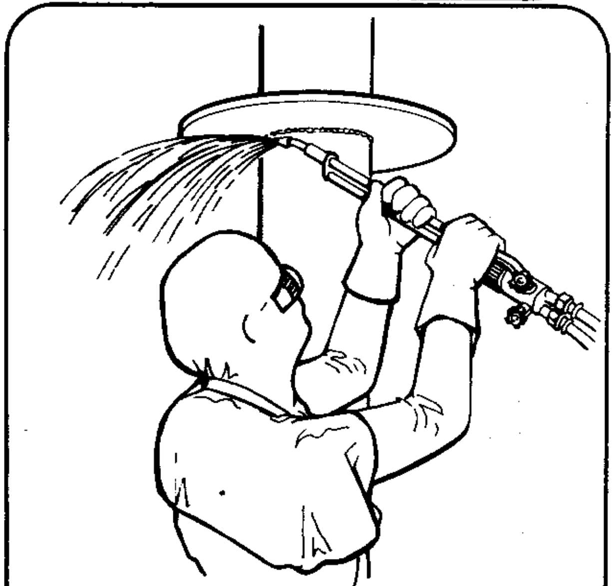
Progressive gouging—vertical position



Progressive gouging—horizontal-vertical position



Progressive gouging—overhead position



Overhead gouging using 180° blowpipe

Positional gouging

When gouging is to be carried out in the vertical, horizontal-vertical and overhead positions the technique used must be suitably modified to ensure efficient gouging. It is essential for appropriate protective clothing to be worn when operating in any of these positions, as a safeguard from falling molten material. All gouging techniques may be carried out by the use of a straight or 180° angle head to facilitate manipulation and removal of molten material together with maximum visibility.

Vertical position

The gas pressures used should be slightly reduced and gravity flow utilized to facilitate the removal of the molten material by travelling in a downwards direction. The starting and operating angles of the gouging nozzle to the vertical plate surface should be modified as required to maintain a constant flow of molten material during gouging.

Horizontal-vertical position

The gas pressures should be varied as necessary to ensure adequate heating together with continuous formation and removal of the molten material utilizing the influence of gravity. The starting and operating angles of the gouging nozzle taken laterally across the vertical plate surface should be modified as required and the direction of travel maintained away from the operator. The blowpipe is held at an angle of approximately 50°–60° above the horizontal during gouging.

Overhead position

The gas pressures will normally be the same as those used when gouging in the flat position. The starting and operating angles of the gouging nozzle to the overhead plate surface should be modified as required to maintain a controlled flow of molten material during gouging in spite of the influence of gravity. It will be essential to speed up the change from the starting to the operating angle in order to avoid the tendency of the molten material to flow towards the nozzle and the craftsman.

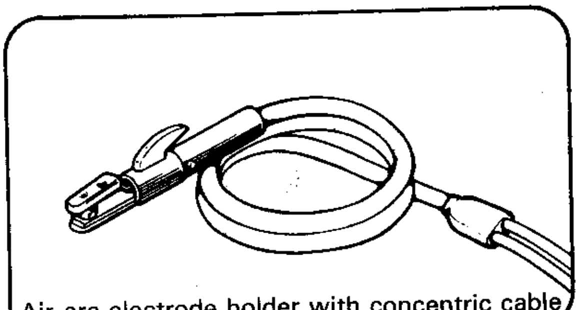
The direction of travel must always be maintained away from the craftsman during gouging operations.

Arc cutting and gouging

Air-arc process

Power source

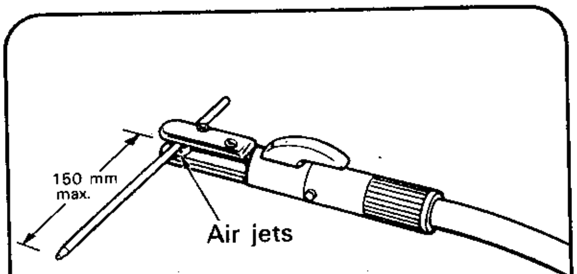
A DC power source as used for manual metal arc welding is suitable. An AC power source may be used provided suitable electrodes are available.
In either case the power source should have a continuous rating for the current values to be used.
An output of up to 450 amperes is required for general purpose air-arc cutting and gouging.



Air-arc electrode holder with concentric cable

Electrode holder

The gripping jaw of the holder is fitted with a self-aligning rotating head. When the valve in the holder is opened, twin jets of compressed air are emitted parallel to the axis of the carbon electrode.
A concentric cable fitted to the electrode holder handle carries current from the power source and air from the air supply.



Electrodes

Electrodes are made of a blended mixture of carbon and graphite, bonded together and enveloped in a thin layer of copper. The copper reduces the heat radiation and prevents tapering of the electrode.
Electrodes for use with AC increase the electron emission and thus improve the stability of the arc.
Electrodes are manufactured in standard 300 mm lengths in sizes from 4 mm to 20 mm.

Assembly of equipment

The assembly of equipment is described in the section on manual metal-arc welding. For air-arc processes a special electrode holder is required and compressed air must be supplied to the holder. The air supply hose must have a bore not less than 6·5 mm and be capable of conveying air at pressures up to 8·4 bars and flow rates up to 800 litres/min.

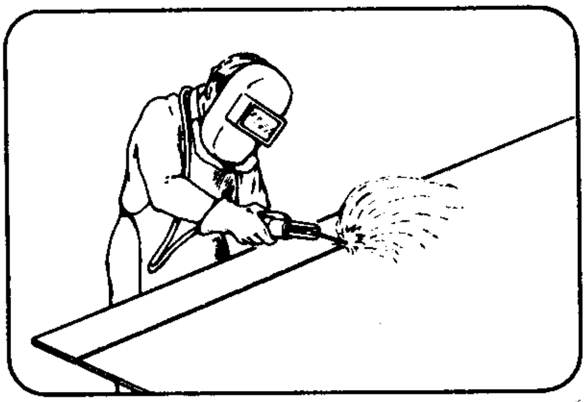
Safety precautions

When cutting material make sure that the detached portion cannot fall and cause personal injury.
Wear safety boots to avoid injury from falling dross and hot metal.

Operating the equipment

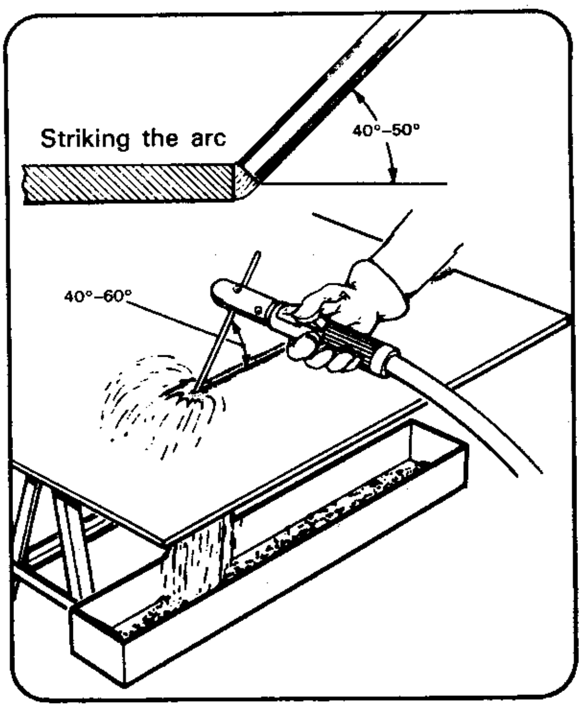
The following general instructions which are not repeated in the text apply to air-arc cutting and gouging.

1. Comply with the prescribed safety precautions and fire prevention procedure.
2. Check that return lead is firmly connected to bench or workpiece and to power source terminal.
3. Check that welding lead is connected to terminal on power source. (Positive terminal when using DC).
4. Check that cable and air hose connections to electrode holder are tight and sound.
5. Check that power source is switched on.
6. Check that the air supply is on and that the air hose is not kinked or obstructed.
7. Use effective protective equipment and any necessary protective clothing.



Safety precautions
When cutting or gouging make sure that sparks are not thrown on to combustible material.

Material	10 mm mild steel
Preparation	Mark line of cut
Assembly	Place plate in flat position on supports with metal box below to catch metal and dross
Electrode	8 mm
Current	350–400 amperes
Air	6·3–6·9 bars



8. When placing electrode in holder ensure that not more than 150 mm protrudes and that the air jets are pointed towards arc end of electrode. The air jets must always be behind the carbon electrode, in relation to the direction of travel.

9. Check that portable screens are in position and warn persons in the vicinity before striking the arc.

10. The air valve must be open before striking the arc and kept open during the cutting or gouging operation.

11. Ensure that the welding screen is in position before striking the arc and kept there until the arc is broken.

12. Ensure that any cutting guide used is insulated from the metal being cut.

Freehand air-arc cutting
Example procedure EP/CG/24

1. With welding screen in position open air supply.

2. With the electrode pointed downwards at an angle of 40°–50° away from the body, lower the electrode holder until the electrode striking end is about 25 mm away from the right-hand edge of the plate.

3. Strike the arc by touching the end of the electrode lightly on the edge of the plate at about the mid-thickness.

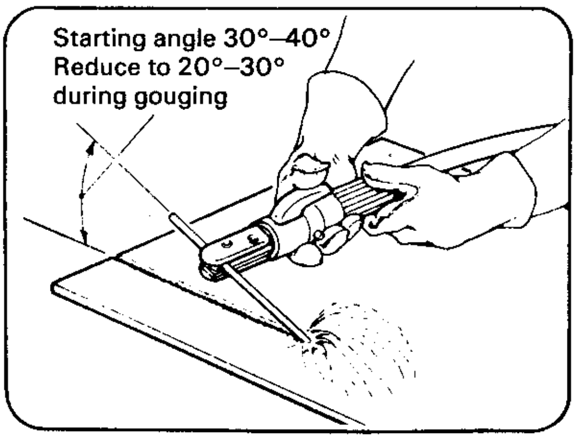
4. Do not withdraw the electrode as in metal-arc welding. The technique is different as metal is being removed not deposited.

5. Maintain a short arc by moving the electrode end forward along the line of cut.

6. Travel fast enough to keep up with the melting and removal of metal.

7. Adjust the angle and relative position of the electrode end within the plate thickness to ensure a clear cut through the plate and effective removal of the melted metal.

Material	One piece of mild steel 25 mm thick. Min. size 200 mm × 150 mm
Preparation	Mark off the 150 mm width into four equal parts to provide six groove lines, three on each face
Assembly	Place plate in flat position on bench with the longitudinal axis parallel to front of bench
Electrode	10 mm
Current	400–450 amperes
Air	6·3–6·9 bars



Freehand air-arc gouging
Example procedure EP/CG/25

1. Point the electrode downwards at an angle of 30°–40° to the plate surface and establish the arc at a point near the right-hand edge of the plate, with the air flow full on.

2. When gouging starts, reduce the angle of the electrode to between 20° and 30° and start the leftwards travel.

3. Maintain a short arc by progressing the electrode end forward along the line of grooving fast enough to keep up with the ejection of metal.

4. Maintain the angle of electrode constant and the rate of travel uniform to obtain a groove of even width and depth.

The correct procedure should produce a groove approximately 12·5 mm wide and between 8 mm and 10 mm deep.

Effect of variations in gouging procedure

Electrode angle	Travel speed	Indications
—	Correct	Smooth and continuous 'hissing' sound
—	Irregular	Produces irregular-shaped groove
—	Too slow	Causes deep groove and excess molten metal tends to interrupt cutting action
—	Too fast	Causes groove to become shallow
Too steep	—	Causes deep groove
Too small	—	Causes shallow groove
Too steep	Too slow	Produces narrow and deep groove
Too small	Too fast	Produces wide and shallow groove

1. Optimum depth of groove is equal to electrode diameter.
2. Optimum width of groove is 3 mm wider than the electrode diameter.

Current	Indications
Correct	Copper layer on electrode burns back approx. 20 mm
Too low	Causes slow cutting and spluttering arc
Too high	Causes over-rapid burning of copper layer on electrode

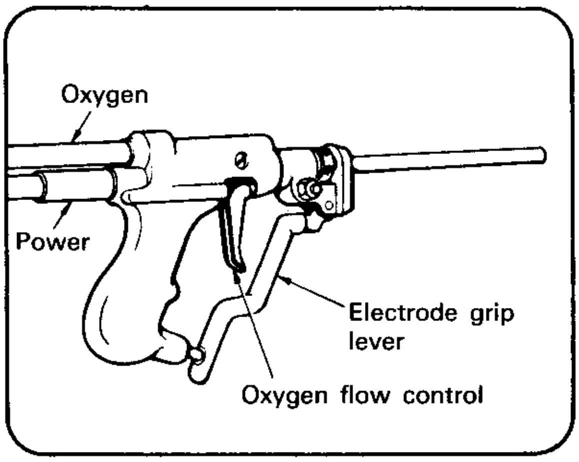
Air pressure	Indications
Too low	Metal and dross adhere to edge of groove

Oxygen-arc process

Power source

Either AC or DC power sources (as for manual metal-arc welding) may be used. DC gives a faster cutting-speed. An output of up to 300 amperes at a near or continuous rating is desirable.

The oxygen supply is normally taken from cylinders fitted with high-pressure regulators as in the oxy-fuel gas cutting process.



Electrode holder

The electrode holder takes the form of a gun with a trigger-controlled oxygen valve. The gun contains an oxygen seal washer to ensure a gas-tight sealing between the oxygen supply tube and electrode end.

Electrodes

Coated tubular steel electrodes are used. The cutting oxygen passes down the tube and the coating helps to stabilize the arc.

Usual sizes are 5 mm with 2 mm bore and 7 mm with 3·5 mm bore.

Assembly of equipment

The assembly of equipment is as described in the section on manual metal-arc welding except that the special electrode holder is required and oxygen must be supplied to the holder.

To fit electrode in gun:

1. Pull back front lever.
2. Insert electrode and push end lightly against the oxygen seal.
3. Release front lever and electrode is gripped in position.
4. Check the grip and thereby the oxygen sealing and electrical contact by attempting to withdraw or move electrode by hand.

Good electrical contact and efficient oxygen sealing are essential for correct operation.

Operating the equipment

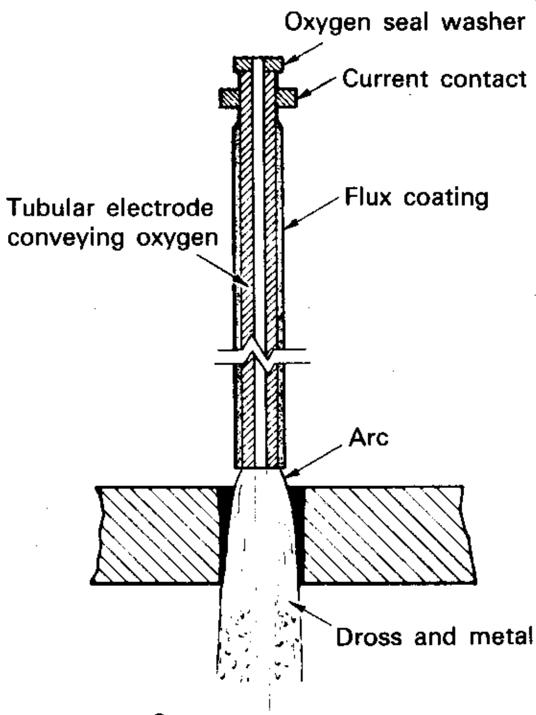
The following general instructions which are not repeated in the text apply to oxygen-arc cutting and gouging.

Always:

1. Comply with the prescribed safety precautions and fire prevention procedure.
2. Check that the return lead is firmly connected to the bench or workpiece and to the power source terminal.
3. Check that the welding lead is connected to the power source terminal. (Negative terminal when using DC).
4. Check that cable and oxygen hose connections to electrode holder are tight and sound.
5. Check that the power source is switched on.

Safety precautions

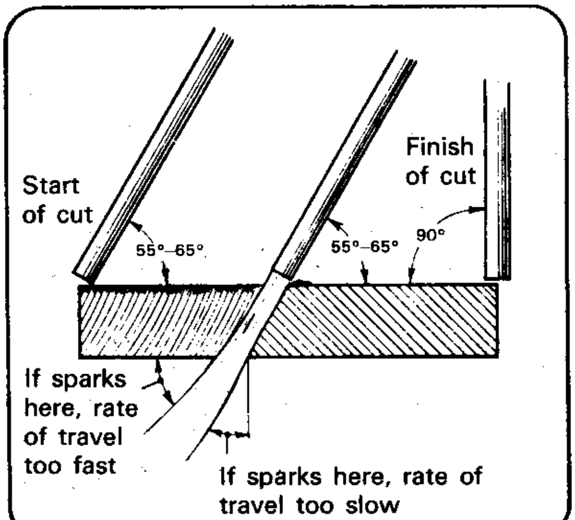
Ensure that the oxygen cylinder is so positioned that there is no possibility of accidental 'arcing' occurring on the cylinder.
When cutting material make sure that the detached portion cannot fall and cause personal injury.
Wear safety boots to avoid injury from falling dross and hot metal.



Oxygen-arc process

6. Check that the oxygen cylinder valve is open and the regulator set to the correct working pressure.
7. Check that the oxygen hose is not kinked or obstructed.
8. Use effective protective equipment and any necessary protective clothing.
9. Check that portable screens are in position and warn persons in the vicinity when about to strike the arc.
10. Ensure that the welding screen is in position before striking the arc and that it is kept there until the arc is broken.
11. Keep oxygen valve closed when striking the arc and open when arc is established.
12. Make sure that any cutting guide used is insulated from the metal being cut.

Material	12 mm mild steel
Preparation	Mark line of cut
Assembly	Place plate in flat position on supports with metal box below to catch metal and dross
Electrode	5 mm
Current	120–125 amperes
Oxygen	4·8–5·2 bars



Freehand oxygen-arc cutting
Example procedure EP/CG/26

1. Point the electrode downwards and away from the body at an angle of 55°–65° to the surface of the plate. Lower the electrode holder until the electrode end is near the point at which the cut is to start at the left-hand edge of the plate.
2. Position welding screen. Strike the arc as in manual metal-arc welding.
3. Immediately the arc is established, open the oxygen valve.
4. Traverse the electrode rightwards co-ordinating rate of travel with cutting action.
5. Keep the heel of the electrode coating in contact with the plate surface.

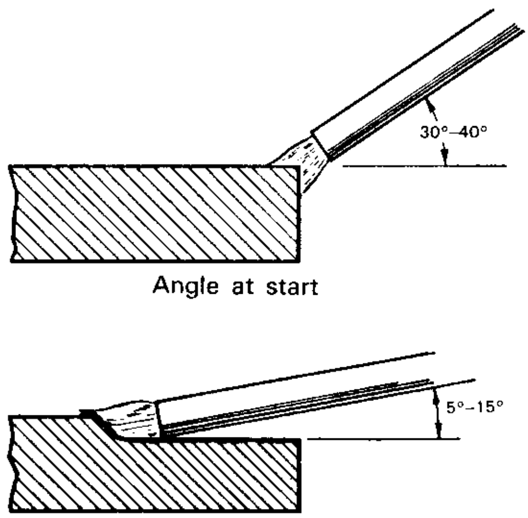
The coating burns off at a slower rate than the steel tube core, thus insulating the core from the workpiece and automatically maintaining the correct arc length.

6. When the electrode approaches the right-hand edge of the plate, gradually increase the angle of the electrode until, at the finish of the cut, it is held vertical.

Material	One piece of mild steel 25 mm thick. Min. size 200 mm × 150 mm
Preparation	Mark off the 150 mm width into four equal parts to provide six groove lines, three on each face
Assembly	Place plate in flat position on bench with the longitudinal axis parallel to front of bench
Electrode	7 mm
Current	100–105 amperes
Oxygen	2·8–3·1 bars

Safety

Make sure that sparks cannot come in contact with combustible material when gouging.



Angle at start

Angle when gouging

Freehand oxygen-arc gouging
Example procedure EP/CG/27

1. Point the electrode downwards and away from the body at an angle of 30°–40° to the plate. Lower the electrode holder until the electrode end is at the right-hand end of the proposed grooving.

2. Position the welding screen. Strike the arc as in manual metal-arc welding.

3. When the arc is established open the oxygen valve slightly to provide a gentle flow until a small molten pool is formed.

4. Lower the electrode holder so that the angle of the electrode is between 5° and 15° to the surface of the plate and at the same time open the oxygen valve gradually to full open.

5. Move the electrode leftwards at a uniform rate of travel.

6. Keep the heel of the electrode coating in contact with the bottom of the groove.

7. When the left-hand end of the proposed grooving is reached, raise the electrode sharply away from the plate to break the arc and at the same time close the oxygen valve on the holder.

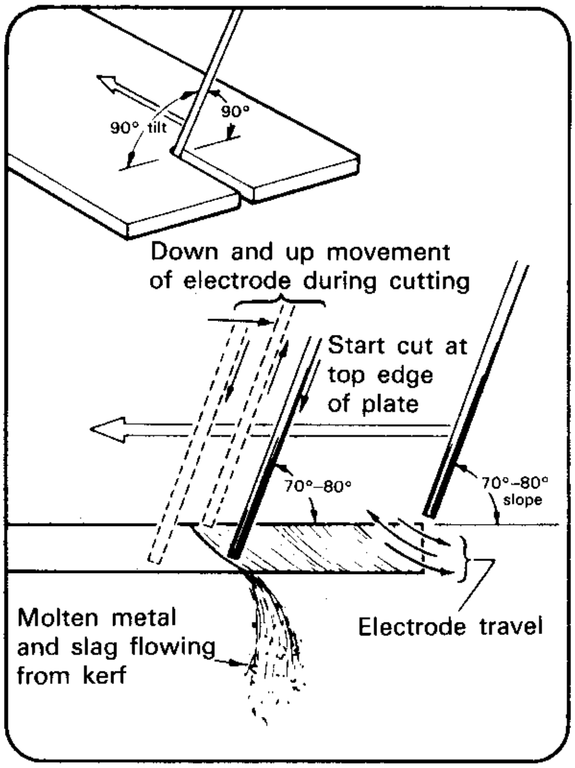
Effect of variations in gouging procedure

1. To obtain a shallow groove, reduce the angle of the electrode.

2. To obtain a deeper groove, increase the angle of the electrode to not more than 20°. Otherwise make two passes.

It is possible to make a deeper groove by reducing the rate of travel but this may cause difficulty in controlling the molten metal and slag.

Material	12·7 mm mild steel
Preparation	Clean surface and mark the line of cut
Assembly	Support and secure plate in the flat position with a metal box to catch the molten material
Electrode	4 mm either specifically designed for cutting or other suitable type
Current	AC or DC 250–300 A according to type to be used



Metal-arc cutting
Example procedure EP/CG/28

1. Point the electrode downwards and away from the body at an angle of slope 70°–80° with an angle of tilt at 90° to the surface of the plate. Lower the electrode holder until the electrode end is near the point at which the cut is to be started at the top right-hand edge of the plate.

2. With welding screen in position strike the arc in the normal manner.

3. As the edge begins to fuse move the electrode tip backwards and forwards working the electrode (down and up) in a sawing movement.

4. Ensure that the sawing movement is sufficient to cut through the underside of the plate.

5. Keep the molten metal flowing out of the kerf by co-ordinating the movement of electrode and the force of the arc with the rate at which the metal is fused.

6. Adjust the speed of travel to keep up with the melting of the metal and its removal by suitable manipulation.

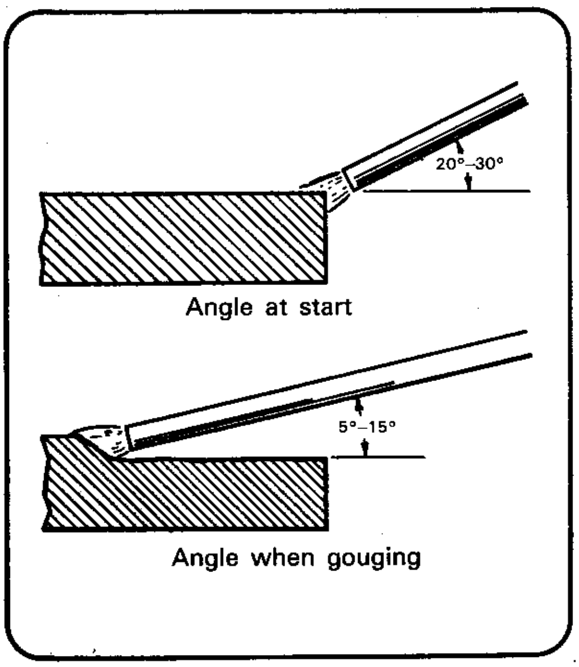
7. The angles and relative positions of the electrode end with the plate thickness are maintained and progressed along the line of the cut to the left-hand edge of the plate. The cut is completed by the fusing and removal of the lower part of the left-hand edge of the plate in a similar manner.

Note: Change electrodes as quickly as possible. Re-start at the top edge of the cutting face so that the metal melted (on striking the arc) will run away constantly during manipulation to recommence the cutting operation.

Safey precautions

When cutting material make sure that the detached portion cannot fall and cause personal injury.
Wear safety boots to avoid injury from falling slag and hot metal.

Material	One piece of mild steel 25 mm thick. Min. size 200 mm x 150 mm
Preparation	Mark off 150 mm width into four equal parts, to provide six groove lines, three on each 150 mm x 200 mm face. Suitably mark the lines to be clearly visible during gouging
Assembly	Secure plate in the flat position on the bench with the longitudinal axis parallel to the front of the bench
Electrode	4 mm either specifically designed for gouging or other suitable type
Current	250–300 A according to type to be used AC or DC



Metal-arc gouging
Example procedure EP/CG/29

1. Point the electrode downwards and away from the body at an angle of slope of 20°–30° with an angle of tilt of 90° to the surface of the plate. Lower the electrode holder until the electrode end is at the right-hand edge of the plate and the starting point of the proposed grooving.

2. With welding screen in position strike the arc.

3. As a molten pool is established lower the electrode holder so that the angle of slope is reduced to between 5°–15° and start the travel towards the left-hand edge of the plate.

4. Utilize the rapid fusion by the arc heat and the force of the arc to push the molten metal and slag away and form the gouged groove.

5. Use a fast speed of travel to maintain control of the gouging operation as the metal is rapidly fused.

6. Ensure that the angle of slope is not too steep and avoid grooving too deeply. The increased amount of slag and molten metal resultant from too steep an angle will cause difficulty in control.

7. Maintain the angles of electrode constant and the rate of travel uniform to obtain a groove of uniform width and depth.

8. Repeat the procedure along the six lines marked out.

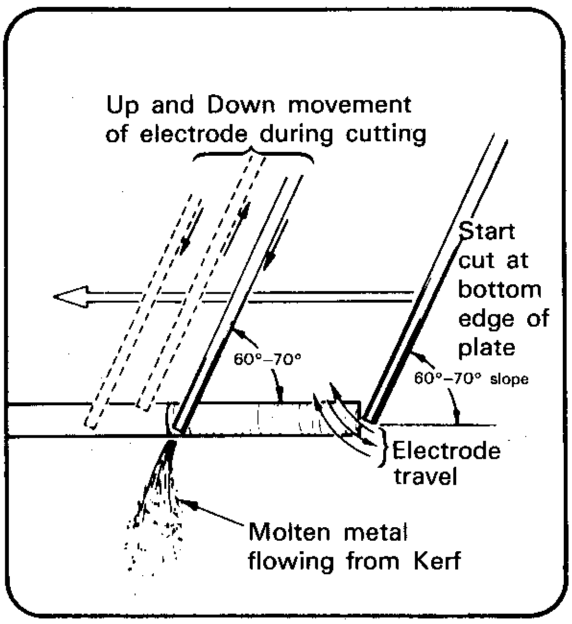
Safety precautions

When gouging make sure that sparks cannot come in contact with combustible material.

Carbon-arc process

DC equipment either as for normal manual metal-arc welding or of the constant potential type is used for carbon-arc cutting together with suitable carbon or graphite electrodes. The electrode used should be tapered from approximately half the diameter of the size to be used at the end gradually back to the normal diameter of the electrode at the point where it is gripped in the holder. The carbon should be fixed in the holder as close to the arc as practicable to minimize the burn-off rate of the electrode. When currents in excess of 300 A have to be used it is usual to have a water cooled electrode holder. The electrode should be connected to the negative polarity.

Material	6·5 mm mild steel
Preparation	Clean surface and mark the line of cut
Assembly	Support and secure plate in the flat position with a metal box to catch the molten metal
Electrode	12·7 mm suitably tapered down to 8 mm diameter at the end
Current	235–260 A DC Negative polarity



Carbon-arc cutting EP/CG/30

1. Point the electrode downwards and away from the body at an angle of slope of 60°–70° with an angle of tilt of 90° to the surface of the plate. Lower the electrode holder until the electrode end is near the point at which the cut is to be started, at the bottom right-hand edge of the plate.

2. With welding screen in position strike the arc, at the point from which the metal may readily flow, at the bottom edge of the plate.

3. As the edge begins to fuse move the electrode tip backwards and forwards working the electrode up to the top edge and down again in a sawing movement.

4. Ensure that the sawing movement is sufficient to cut through the full plate thickness keeping the end of the electrode close to the cut face to maintain the arc.

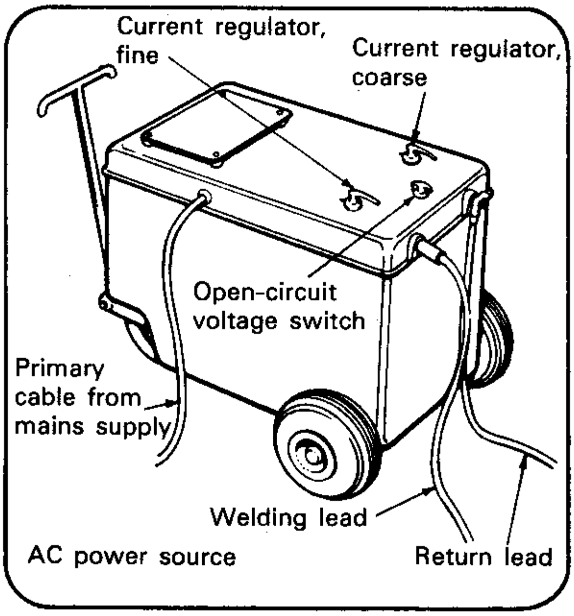
5. Keep the molten metal flowing out of the kerf by co-ordinating the movement of the electrode with the rate at which the metal is fused.

6. Adjust the speed of travel to keep up with the melting of the metal and its removal by suitable manipulation.

7. The angles and relative positions of the electrode end with the plate thickness are maintained and progressed along the line of the cut to the left-hand edge of the plate. The cut is completed by the fusing and removal of the lower part of the left-hand edge of the plate in a similar manner.

Note: Change electrodes as quickly as possible. Do not attempt to retaper electrodes when a cut is required to be completed. Avoid this by ensuring sufficient prepared electrodes before starting the cut.

Re-start at the bottom edge of the cutting face so that the metal melted (on striking the arc) may readily flow to recommence the cutting operation.



AC power source

Equipment

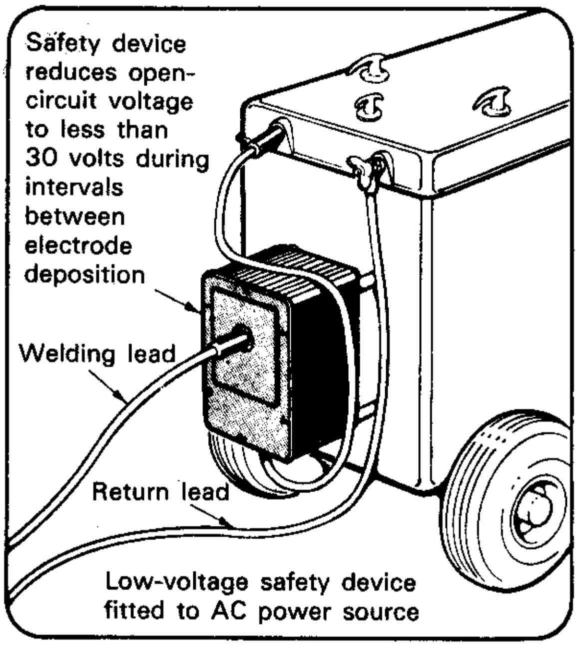
Power sources

These are classified into two groups, Alternating current (AC) or Direct current (DC) according to the output current.

Where input is from the mains the power source must:

1. Reduce the mains input voltage to give an output open-circuit voltage between 40 and 100 volts.

2. Increase the mains input current to give the output currents required for welding.

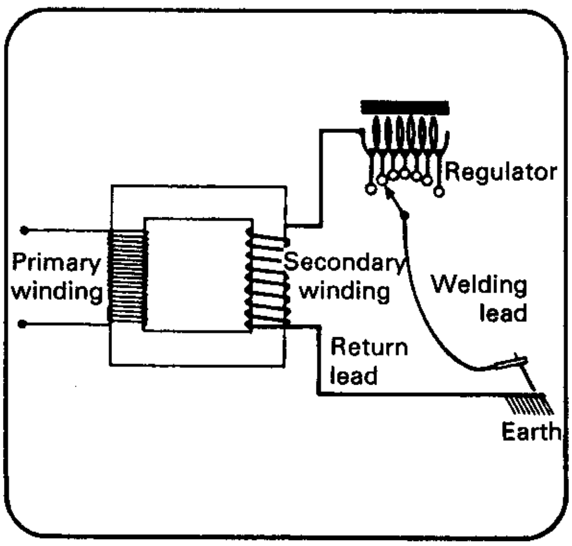


Low-voltage safety device fitted to AC power source

Alternating current (AC) equipment

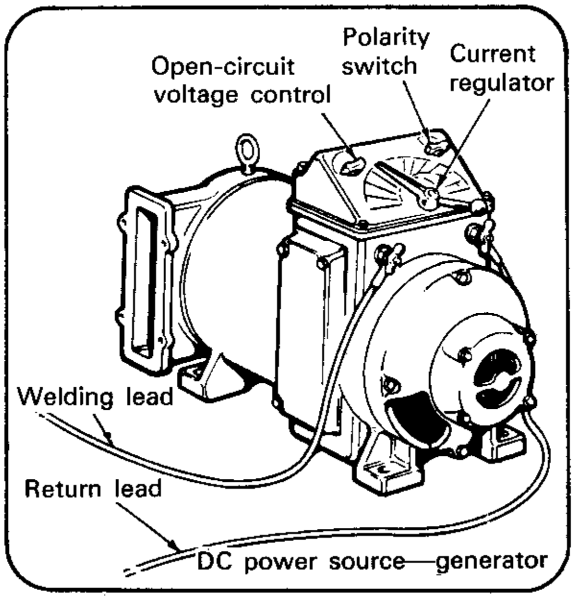
The illustrations show AC power sources.

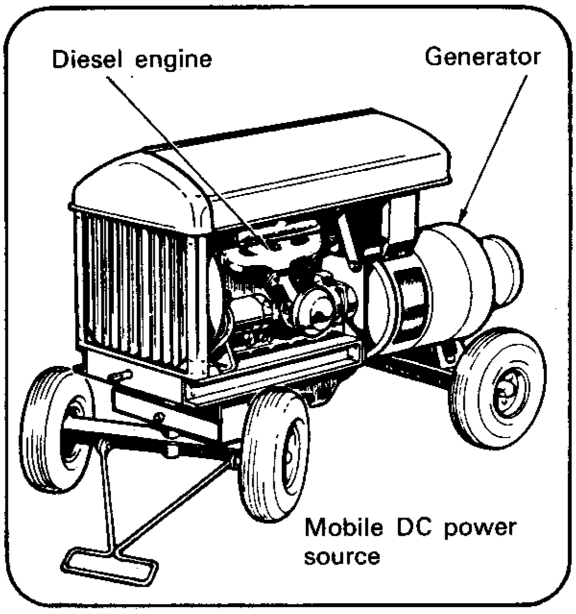
> *Note:* The use of a low-voltage safety device is recommended when using an AC power source in a confined space or other potentially dangerous situation.

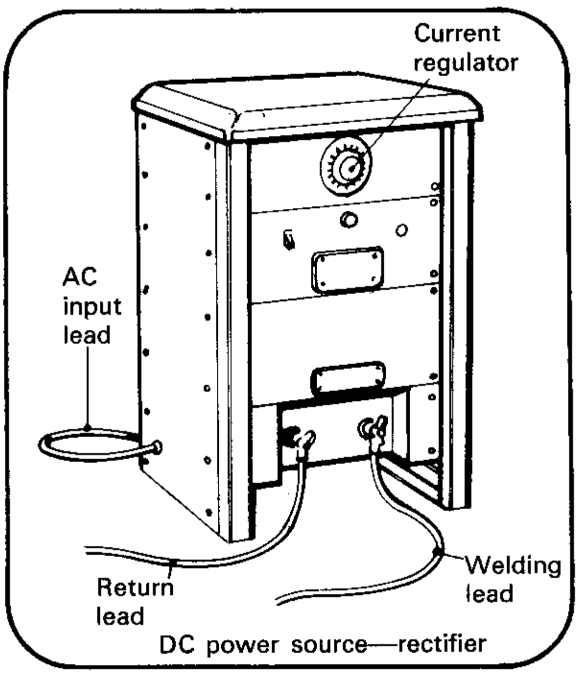


The illustration shows a schematic diagram of an AC welding transformer and regulator.

Manual metal-arc welding







Direct current (DC) equipment

This is classified into two groups: generators and rectifiers.

Generators may be driven by:

1. Motor connected to mains supply.

2. Petrol or diesel engine.

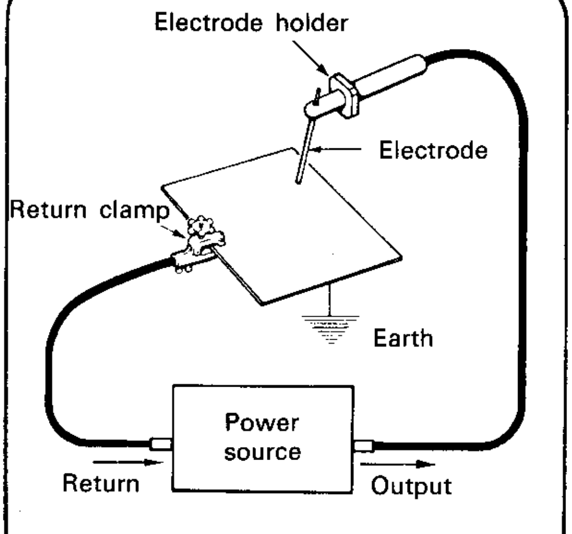
A rectifier takes AC current from a transformer, via a current regulator.

AC/DC equipment

In a single-phase transformer and rectifier:

1. AC output is taken from the secondary side of the transformer via a current regulator.

2. DC output is taken from the rectifier output terminals.



Cable connections (secondary side)

Assembly of equipment

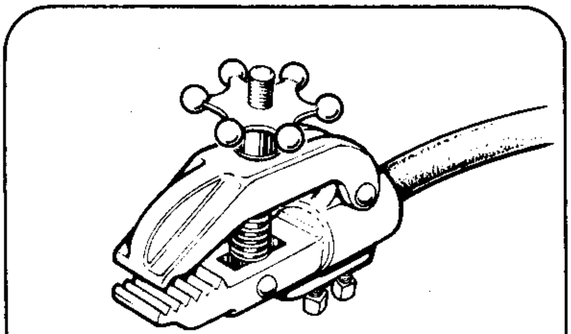
The initial installation and connection of the power source to the appropriate mains supply should be carried out by a competent person. Ensure that the equipment is adequately earthed.

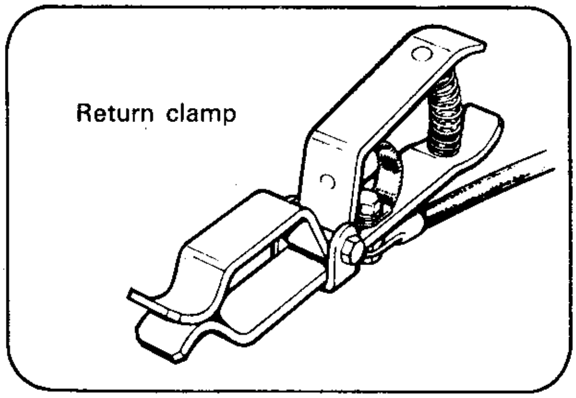
Connections for secondary side
Use secondary cables of a suitable size for the maximum welding current.

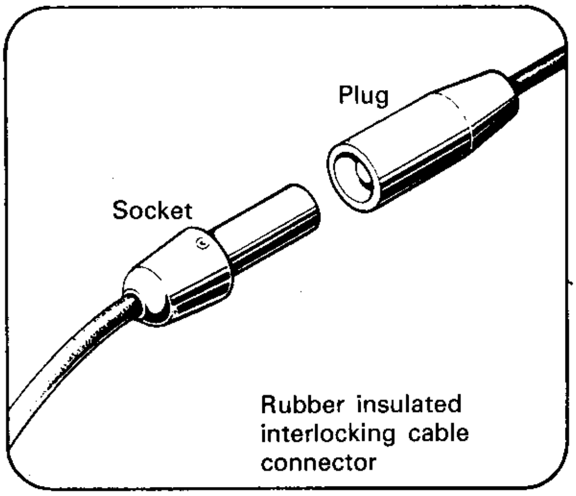
1. Connect one end of the welding lead to the electrode holder then connect the other end to the output terminal on the power source.

2. Connect one end of the return lead to a clamp or terminal on the workpiece, then connect the other end to the return terminal on the power source.

3. Ensure that the work has a direct earth connection.


Return clamp





Rubber insulated interlocking cable connector

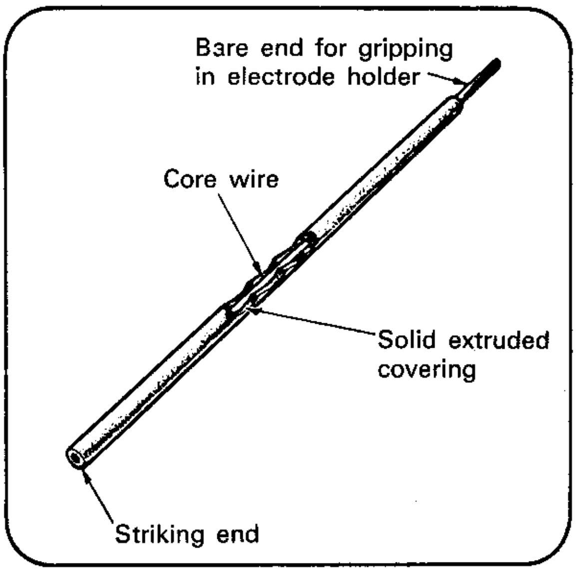
Joints
Loose joints or bad contacts cause over-heating of cable, electrode-holder handle etc., and adversely affect the welding arc.

1. Make any necessary joints in cables, using properly designed cable connectors.

2. Make sure that good electrical contact is always obtained when connecting cables to power source, electrode holder, and return clamp.

3. Pay particular attention to mechanical joints that may work loose, especially when using AC.

Manual metal-arc welding



Electrodes

The filler metal is provided by the melting of an electrode. The grip end, which is inserted in the electrode holder, is bare of covering for a distance of approximately 30 mm.

The other end, known as the striking end, is sometimes pointed to ensure good electrical contact when striking the arc.

Purposes of the electrode covering are:

1. To give stability to the arc.

2. To provide good arc transfer conditions.

3. To control the reactions occurring during welding.

4. To protect the molten metal during transfer.

5. To provide good welding characteristics.

6. To provide a suitable slag protection for the cooling weld.

7. To ensure that the deposited metal has satisfactory chemical, physical, and mechanical properties.

Important!

Electrodes should be stored and used in a dry condition.

Carefully segregate different types and sizes of electrode.

Sizes of electrodes

Size is designated by the diameter of the core wire. The range of sizes is:

Metric	Imperial
1·6 mm	16 s.w.g.
2·0 mm	14 s.w.g.
2·5 mm	12 s.w.g.
3·25 mm	10 s.w.g.
4·0 mm	8 s.w.g.
5·0 mm	6 s.w.g.
6·0 mm	4 s.w.g.
6·3 mm	$\frac{1}{4}$ in.
8·0 mm	$\frac{5}{16}$ in.
10·0 mm	$\frac{3}{8}$ in.

Classification of electrodes

BS 639 covers the classification of electrodes for welding carbon steels and carbon-manganese steels according to the properties of the deposit, type of covering and the operating characteristics of the electrode. This standard replaces BS 1719.

Electrodes are described by a code number eg.

E4321 R 13

- Mechanical properties ← E4321
- Type of covering ← R
- Position of welding ← 1
- Electrical requirements ← 3

When selecting an electrode, *check that:*

1. Mechanical properties correspond to specification.

2. Type of covering is suitable.

Typical examples:

Rutile (R) Suitable for general purpose work. Good slag control. Easy to deslag. May be unsuitable for higher strength steels.

Basic (B) Used for the welding of higher strength steels which are prone to heat affected zone cracking. (Sometimes these electrodes are called 'lime coated').

Cellulosic (C) Give a deep penetrating weld with coarse profile. More difficult to control than rutile or basic. Used principally for large diameter pipe work.

3. Electrode is suitable for position of welding.

Code	Welding position
1	All positions
2	All positions except vertical down
3	Flat butt weld, flat fillet weld, horizontal-vertical fillet weld
4	Flat butt weld, flat fillet weld
5	As 3 and recommended for vertical down

4. Electrode can be used with power supply available.

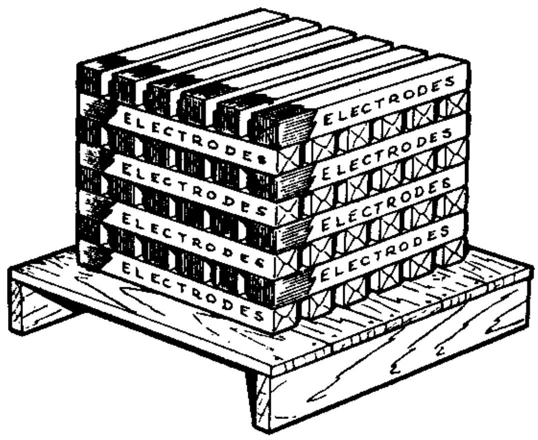
Code	Direct current, recommended electrode polarity	Alternating current, minimum open-circuit voltage, V
0	Polarity as recommended by manufacturer	Not suitable for use on AC
1	+ or −	50
2	−	50
3	+	50
4	+ or −	70
5	−	70
6	+	70
7	+ or −	90
8	−	90
9	+	90

Iron powder electrodes

Electrodes containing iron powder in the covering give increased deposition rates. These electrodes are indicated in the code by inserting the percentage efficiency of recovery rate after the letter indicating the type of covering, thus:

E 4321 R 130 13

130 → Indicates 130% efficiency



Storage under heated conditions

Storage of electrodes
The efficiency of an electrode is impaired if the covering becomes damp.

1. Keep electrodes in unopened packets in a dry store.

2. Place packages on duckboard or pallet, not directly on the floor.

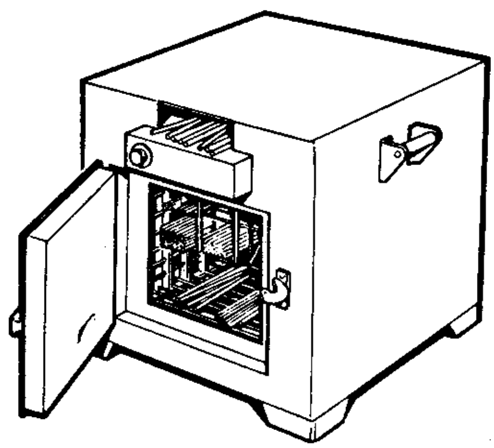
3. Store so that air can circulate around and through the stack.

4. Do not allow packages to be in contact with walls or other surfaces down which moisture can run.

5. The temperature of the store should be about 5°C. (10°F.) higher than the outside shade temperature to prevent condensation of moisture.

6. Free air circulation in the store is as important as heating. Avoid wide fluctuations in the store temperature.

7. Where electrodes cannot be stored in ideal conditions place a moisture-absorbent material (eg. silica-gel) inside each storage container.


Electrode drying oven

Drying electrodes
Water in electrode coverings is a potential source of hydrogen in the deposited metal and thus may cause:
1. Porosity in the weld.
2. Cracking in the heat-affected zone.

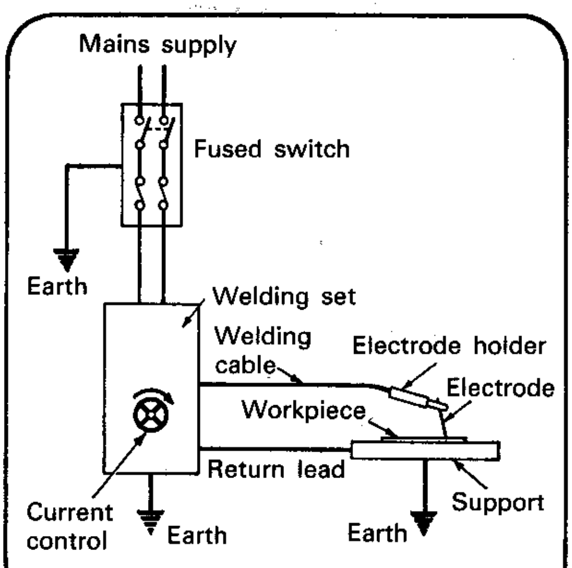
Indications of electrodes affected by moisture are:
1. White layer on covering.
2. Swelling of covering during welding.
3. Disintegration of covering during welding.
4. Excessive spatter.
5. Excessive rusting of the core wire.

Electrodes affected by moisture may be dried before use by putting them in a controlled drying oven for approximately one hour at a temperature around 110–150°C. (230–300°F.). This should not be done without reference to the conditions laid down by the manufacturer. It is important that hydrogen-controlled electrodes are stored in dry, heated conditions at all times.

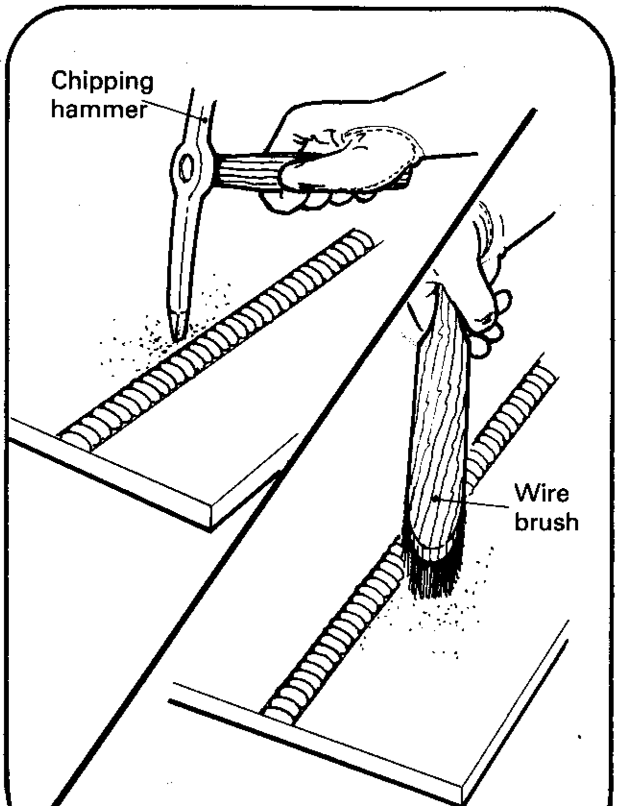
Warning

Special drying procedures apply to hydrogen-controlled electrodes. Follow the manufacturer's instructions.

Manual metal-arc welding



Manual metal-arc welding circuit diagram



Remove all slag and spatter

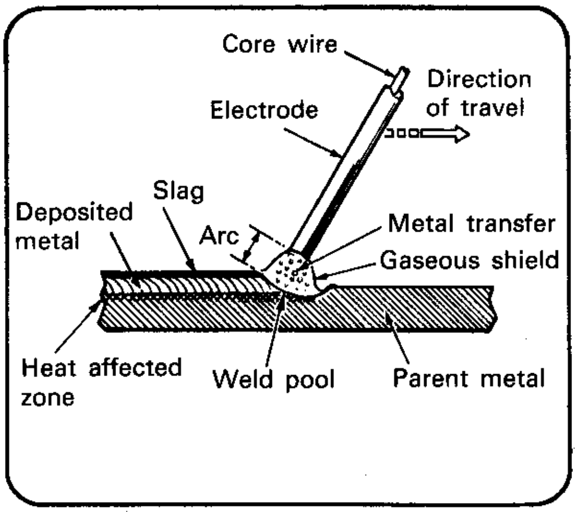
General procedure

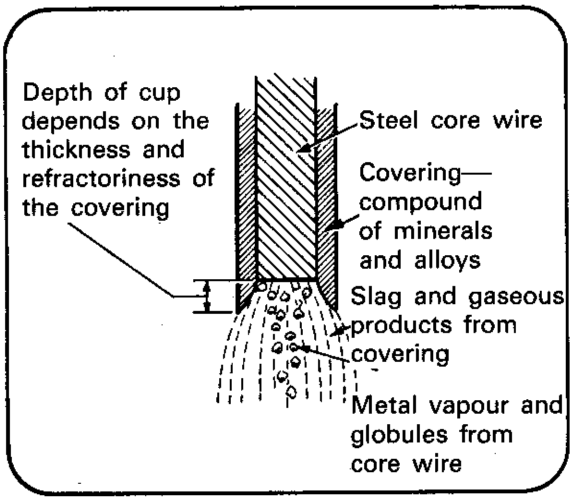
The following instructions (which are not repeated later in the text) apply to manual metal-arc welding.

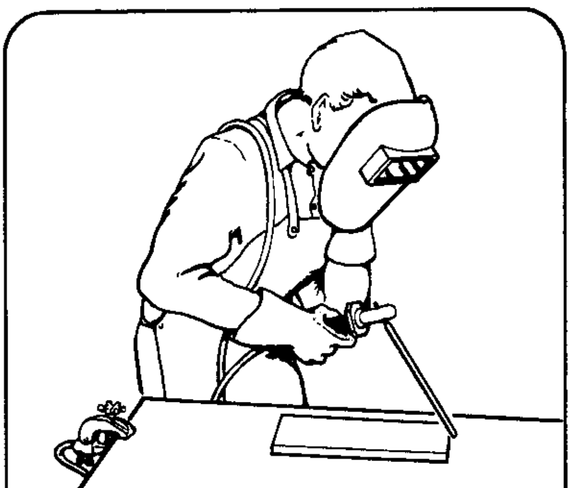
Always:

1. Comply with the prescribed safety precautions and fire prevention procedure.
2. Check that the return and earth leads are firmly connected to the bench or workpiece and to power source.
3. Check that the welding lead is connected to power source and that the connection to the electrode holder is tight and sound.
4. Check that the power source is switched on.
5. Use effective protective equipment and wear the necessary protective clothing.
6. Concentrate on watching the welding operation.
7. Have full control of the movements of the electrode and hold it steady.
8. Hold the electrode holder with just sufficient grip to give control—tight gripping will cause muscle fatigue.
9. Position yourself to avoid stretching and the risk of over-balancing.
10. Support the arm holding the electrode holder by keeping it near the body, but do not restrict freedom of movement.
11. Check that portable screens are in position. Warn unscreened observers before the arc is struck.
12. Ensure that the welding screen is in front of the eyes before striking the arc; keep it there until the arc is broken.
13. Place the electrode holder in a safe place when not in use.
14. Use goggles when chipping off hot slag.
15. Ensure that all slag and spatter is cleaned off fusion faces and previously deposited metal before starting the next run.
16. Switch off power source when not in use.
17. Switch off mains supply to power source at end of work period.
18. Leave the work area in a tidy and orderly manner and ensure that equipment is properly stowed.

Manual metal-arc welding







Operator about to strike an arc

The welding arc

When the current is switched on an electrode is placed in the holder and the electrode end is placed in firm contact with the workpiece (ie. short circuited). Current will flow through the circuit.

This flow is interrupted by breaking the contact with the workpiece. When the gap is narrow, and if the open-circuit voltage of the power source is high enough, the current leaps across the gap and creates an arc.

When the arc is struck the voltage falls to what is known as the arc voltage.

The arc voltage is between 20 and 25 volts for most types of electrodes at normal arc length.

The arc voltage depends upon:
1. The type of electrode used.

2. The length of the arc.

When the arc is made, the end of the electrode and the local area of the workpiece rapidly reach fusion temperature. The electrode core wire melts. The molten metal is transferred across the arc gap to fuse with the workpiece.

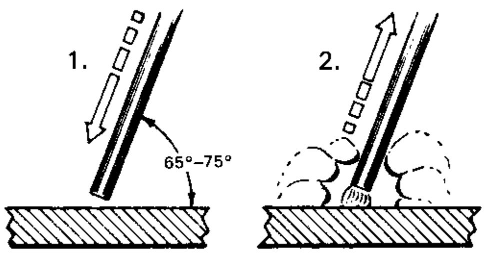
Example procedures

Striking the arc
Example procedure EP/MMA/1

Material	One piece of mild steel 10 mm thick. Min. size 300 mm x 150 mm
Preparation	Clean surface
Electrode	4 mm Rutile
Current	150–170 A

1. Ensure that the electrical contact between plate and bench is good. The plate should be in the flat position.

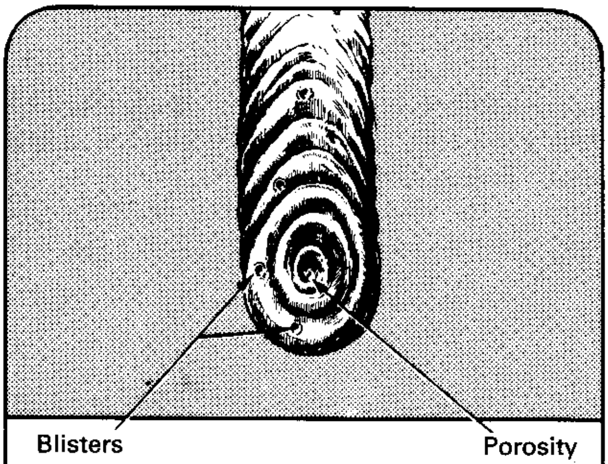
2. Use gloved hand to insert the grip end of the electrode in the electrode holder.



Striking the arc

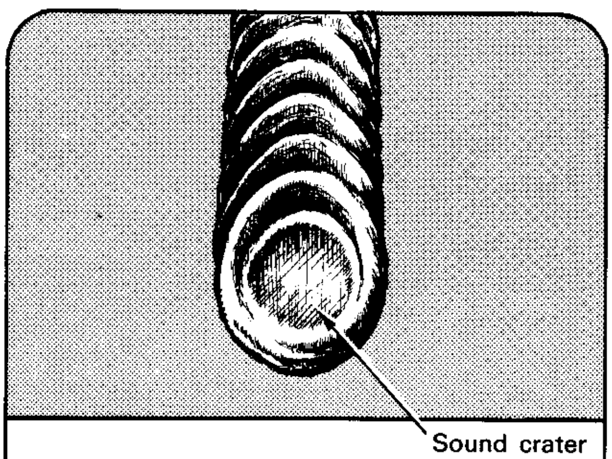
3. Point electrode downwards, and away from the body at an angle of 65°–75° to the plate surface.
4. Lower the electrode holder until the electrode striking end is about 25 mm away from the plate at the point where deposition is to start.
5. With welding screen in position, lower the electrode until the striking end touches the plate (use an action similar to that of gently striking a match).
6. Contact of the electrode end with the plate closes the electrical circuit and current flows. Immediately withdraw the electrode a slight distance from the plate to establish the welding arc.
7. After a few seconds break the arc by withdrawing the electrode end smartly from the plate.
8. Repeat this procedure until skill in establishing the arc is attained.

Note: Difficulty is often experienced in making the arc. The electrode end may be withdrawn too far or allowed to fuse (or freeze), to the plate, because it is not withdrawn quickly enough.
If freezing occurs give the electrode holder a sharp twist to wrench the electrode free. Keep the welding screen in front of the eyes.
If the electrode is not freed, immediately open the electrode holder jaws and move the holder away (or switch off the welding current), remove the electrode with a chisel.

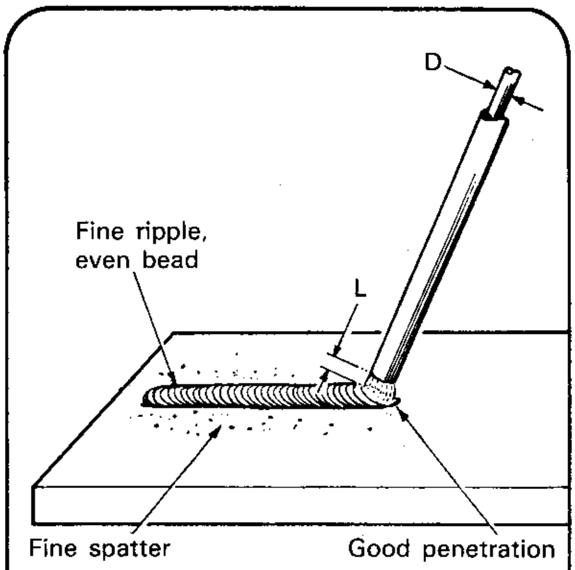


Bad crater

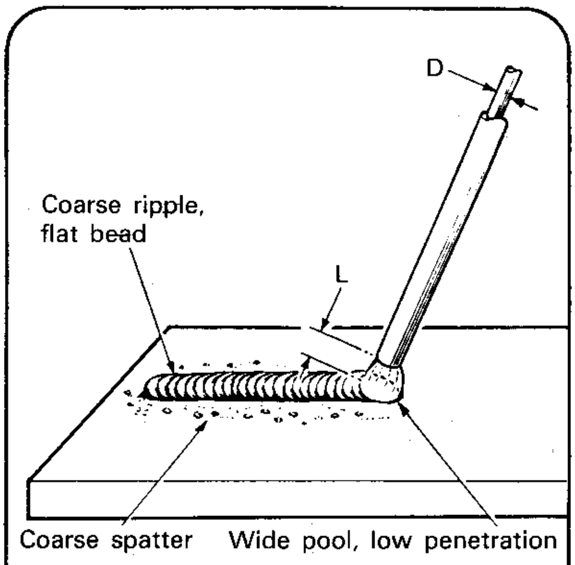
Breaking the arc
A simple withdrawal of the electrode end will break the arc.
Before breaking the arc:
1. Pause with the electrode held in position long enough to build up the weld pool.
2. Move the electrode quickly sideways and away from the plate surface.
The above procedure will avoid the formation of:
(a) cavities
(b) blisters
(c) porosity or fine cracks in the crater,
which result from premature or hasty breaking of the arc.
The trainee will learn later how to strengthen the end of the weld run.



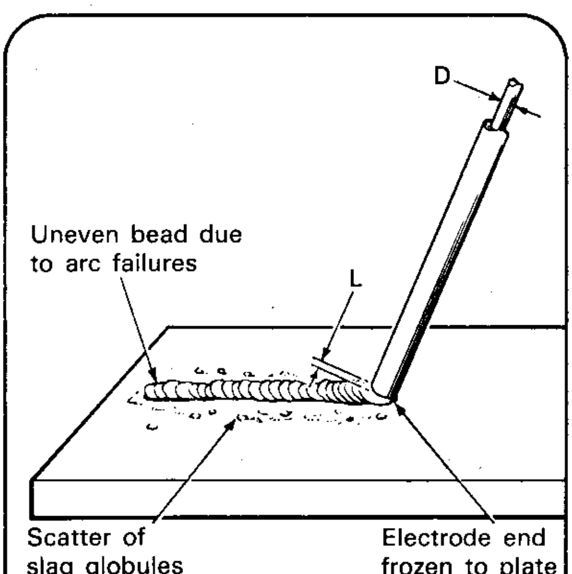
Good crater



Visible arc length (L approximately equal to D)



Arc length too long (L more than 1½ times D)



Arc length too short (L less than ½ D)

Arc length
Example procedure EP/MMA/2

Material	One piece of mild steel 10 mm thick. Min. size 300 mm × 150 mm
Preparation	Clean surface
Electrode	4 mm Rutile
Current	150–170 A

1. Use the same method as in EP/MMA/1 to establish the arc at the left-hand edge.
2. Move the electrode holder progressively towards the plate to maintain the arc.
3. Combine this with a progressive movement along the plate at a rate of about 150 mm per minute. The direction of deposition should be either from left to right or from the starting point towards the person.
4. Aim to synchronize these movements to produce a bead of deposited metal on the surface of the plate. Avoid producing a large pool of molten metal in one spot.
5. The arc length, ie. the distance between the electrode end and the surface of the weld pool, should be approximately 4 mm (about the same as the diameter of the core wire).
6. Watch the arc length and keep it as constant as possible.
7. Keep an even rate of travel to ensure an even deposit. The length of movement along the plate should be about 230 mm in the time taken to deposit 400 mm of electrode, ie. the run length per electrode.

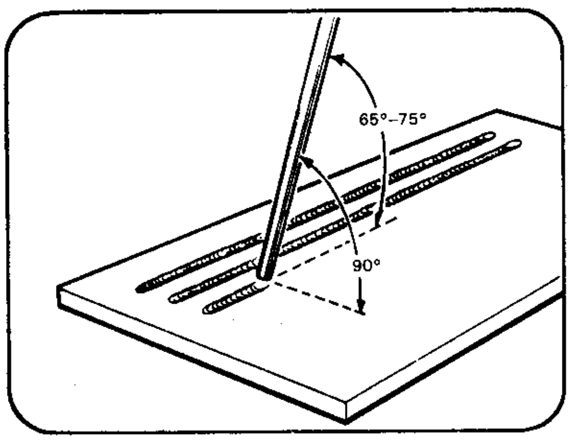
Effects of variation in arc length
1. If the arc length is correct, the electrode metal will be deposited in a stream of small particles.
2. If too long, the arc will be noisy; deposition will be erratic; large globules of metal will be ejected; excessive spatter will result.
3. If too short, it will be difficult to maintain the arc; freezing of the electrode end in the weld pool may occur.

Slag
Whilst maintaining the arc and controlling the rate of travel of the electrode, learn to distinguish between the molten metal and molten slag.
Slag appears to be cloudier but brighter than the clear weld metal. It will flow away and float to the top of the cooling metal if:
(a) the electrode end is directed at the correct angle to the plate surface
(b) the correct welding conditions and techniques are used.

Effects of current and travel on deposition
Example procedure EP/MMA/3

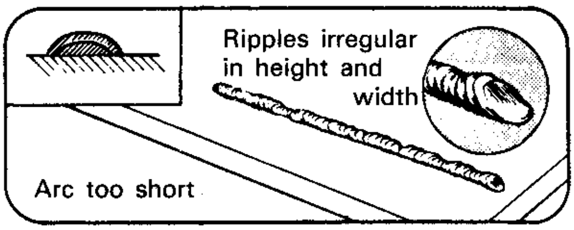
Material	One piece of mild steel 10 mm thick. Min. size 300 mm x 150 mm
Preparation	Clean surface
Electrode	4 mm Rutile
Current	150–170 A

1. Use the same method as in EP/MMA/1 to establish the arc at the left-hand edge.
2. Move the electrode end in a straight line along the plate.
3. Develop a sense of direction with the welding screen in position.
4. Weld first on one side of the plate and then on the other side to keep the plate fairly level.
5. The plate may be water (or air) cooled between runs provided it is allowed to dry off.
6. Leave a space of about 12·5 mm between the parallel runs.
7. Use different rates of travel to see the effect of the change in speed on the shape of the weld bead.
8. Use welding currents about 20% lower and higher to see the effect of the change in current on the appearance of the weld bead.

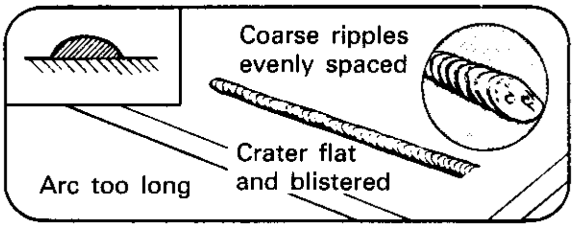


Visual examination
Examine deposited beads and note any variations in width, thickness, depth of fusion, and length of runs.
These may be caused by intentional or unintentional variations in arc length, rate of travel, or welding current.
Assess causes and take corrective action until straight, parallel runs of even shape and uniform width can be produced.

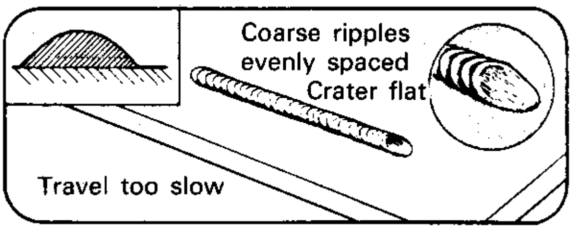
Effect of variations in procedure



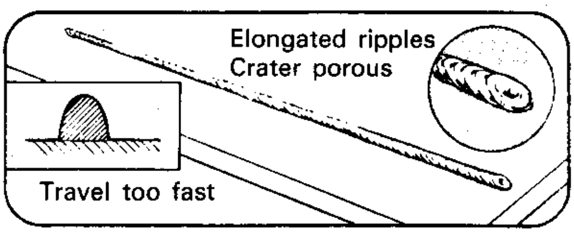
1. Too short an arc length will cause irregular piling of the weld metal.



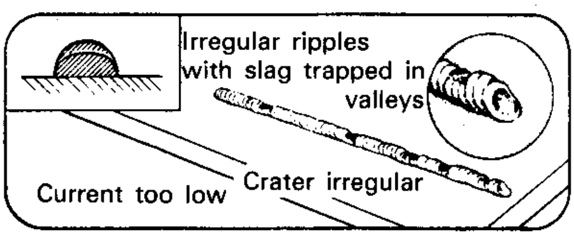
2. Too long an arc length will cause the deposit to be coarse rippled and flatter than normal.



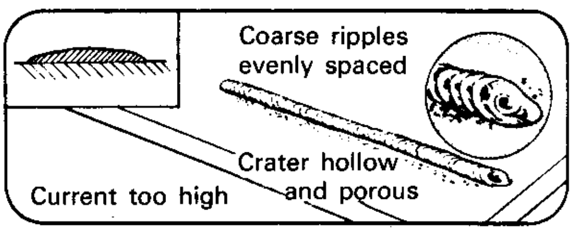
3. A slow rate of travel gives a wider, thicker deposit, shorter than normal length; too slow a rate of travel may allow the slag to flood the weld pool causing difficulty in controlling deposition.



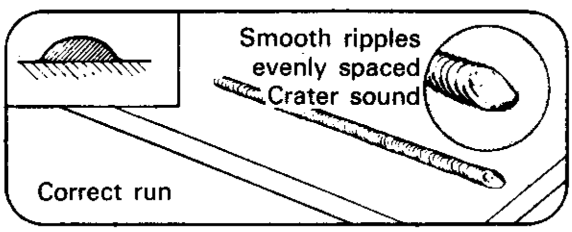
4. A fast rate of travel gives a narrower, thinner deposit, longer than normal length; too fast a rate of travel may prevent adequate interfusion with the parent metal.



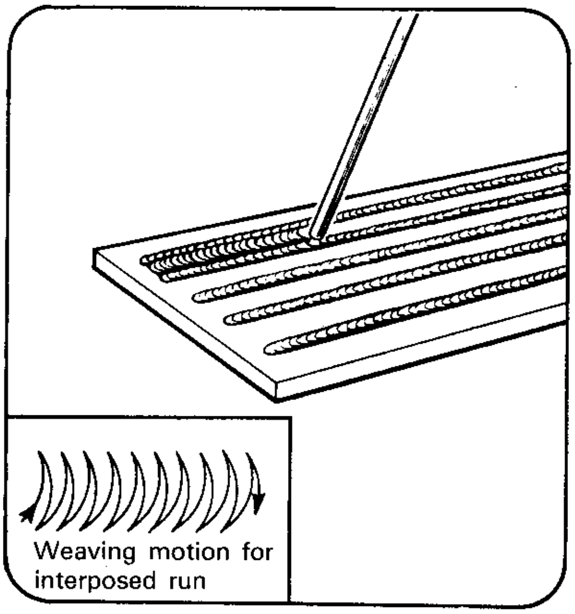
5. A low welding current tends to cause the weld metal to pile up without adequate penetration into the parent metal; too low a welding current makes the slag difficult to control.



6. A high welding current gives a deposit that is flatter and wider than normal with excessive penetration into the parent metal; too high a welding current causes considerable spatter.



7. With the correct arc length; correct rate of travel; correct angle of electrode; correct welding conditions and technique; the run deposited metal will be regular in thickness and width, with a neat finely rippled surface, free from porosity or any slag entrapment.

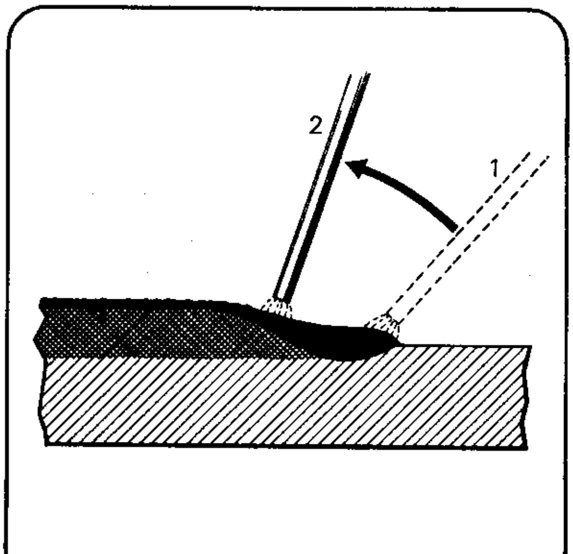


Weaving

Example procedure EP/MMA/4

Material—Use the plates from previous examples on which separate parallel runs have been deposited.

1. Using the same welding conditions as in EP/MMA/3 establish the arc between two previous deposits.
2. Use a transverse weaving motion of the electrode to increase the width of the deposit. The weaving motion should be slow and in a slightly curved path.
3. Pause slightly at each side to control the slag and ensure side fusion into previous deposit. The deposit width should be equal to four or five times the diameter of the electrode core wire. Do not try to exceed this width or difficulty may be found in controlling slag.

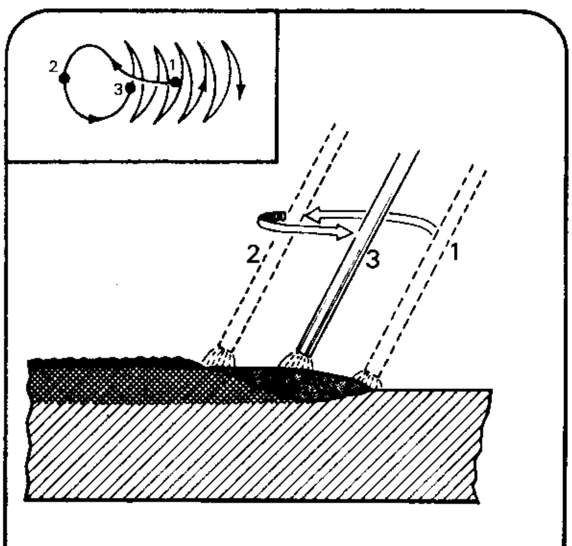


Building-up crater

Building-up the crater

Example procedure EP/MMA/5

1. Using the welding conditions as for previous examples.
2. Pause at the end of the run and shorten the arc length slightly.
3. Move the arc slowly backwards until over the centre of weld pool. At the same time increase the angle of the electrode until it is at right angles to the plate surface.
4. Maintain the very short arc until the crater is built up with deposited metal and then break the arc.



Re-starting with new electrode

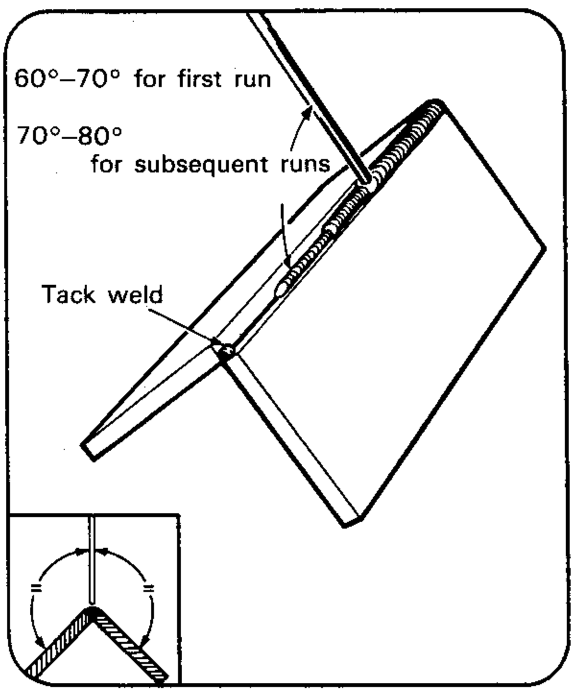
Re-starting runs

Example procedure EP/MMA/6

1. Using the welding conditions as for previous examples.
2. After depositing one electrode, break the arc after only a slight pause over the weld pool.
3. With a new electrode, re-strike the arc at the leading edge of the deposit crater.
4. Move the arc slowly back over the crater in a loop movement to the back edge of the crater.
5. Resume weaving motion in the correct direction of travel and at the normal rate.
6. Break the arc. Repeat the procedure until a smooth join-up can be obtained.

Tack welds

A tack weld is a short weld used to help assembly and to maintain the position of parts during welding.
Tack welds should be between three and four times the plate thickness, up to a maximum length of 35 mm at the ends of the joint.
For intermediate tack welds the length should be between two and three times the plate thickness, up to a maximum length of 35 mm.



Pitch of tack welds
For mild steel plates, of 3 mm thickness, the pitch (ie. distance between centres) of tack welds in butt joints should be 150 mm. The pitch should be increased by about 15 mm for each 1 mm increase in plate thickness, up to a maximum of 600 mm for thicknesses of 33 mm and above.
For lengths less than twice the normal pitch distance, end tack welds only are required.
The above pitch distances should be doubled for fillet-welded T-joints.

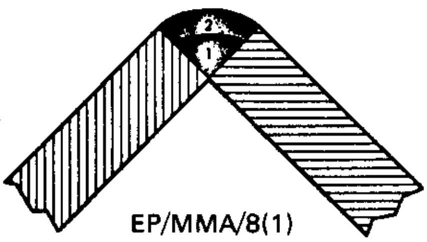
Corner joint—Flat position
Example procedure EP/MMA/7

Material	Two pieces of mild steel 10 mm thick. Min. size 200 mm x 75 mm
Preparation	Square edge
Assembly	Tack weld both ends to give included angle of 90°: 0·75 mm–1·5 mm gap at root
Electrode	4 mm Rutile
Current	150–170 A

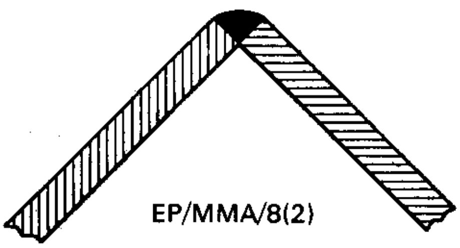
1. Deposit the root run, without weaving, with the electrode angle at 60°–70°.
2. Adjust rate of travel so that metal is deposited equally on lower portion of each fusion face and just penetrates the root.
3. Deposit a second run in the same direction but this time, using slight transverse weaving motion, with the electrode angle increased to 70°–80°.
4. Make a slight pause in the weaving motion at each fusion face. This will help to prevent undercut and secure a flat weld face.
5. Reduce welding current slightly.
6. Complete the weld with a third run deposited in a similar manner to that of the second run.
7. Take care to only just fuse the top edges of the fusion faces and to obtain a slightly convex weld profile.

Corner joint—Flat position
Example procedure EP/MMA/8

Material	(1) as for EP/MMA/7 (2) as for EP/MMA/7 except 4 mm thick
Preparation	Square edge
Assembly	As for EP/MMA/7
Electrode	(1) 5 mm Rutile (2) 3·25 mm Rutile
Current	(1) 180–200 A (2) 100–110 A



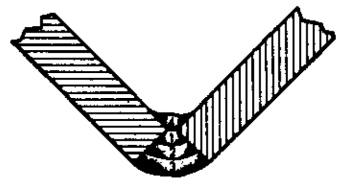
EP/MMA/8(1)


EP/MMA/8(2)

1. This is a repeat of EP/MMA/7 using a larger size of electrode.
Complete the weld in two runs using a 5 mm electrode.
With this first (root) run it is more difficult to avoid lack of or excess of root penetration.
With the second run it is more difficult to avoid excessive fusion of the top edges of the fusion faces.

2. This is a repeat of EP/MMA/7 using a smaller size of electrode and thinner plate.
Complete the weld in one run.
In this weld, ensure penetration to the root and at the same time avoid excessive fusion of the top edges of the fusion faces.

Sealing run
To eliminate weakness, or possible notch effect, a butt weld (and sometimes a corner weld) is completed by depositing a small sealing run on the root side.
Frequently, in fabrication work, such a run would have to be deposited in the overhead position because the work could not be turned over. At this stage, complete the practice butt welds by turning them over and depositing the sealing run in the flat position.
For good quality welding the back of a butt joint should be chipped out with a round-nose chisel, or gouged by flame or air-arc gouging process, so that clean metal at the root of the first run is exposed. A large deposit is not necessary and excessive reinforcement should be avoided.
It is unnecessary to back chip or back gouge fillet-welded corner joints.

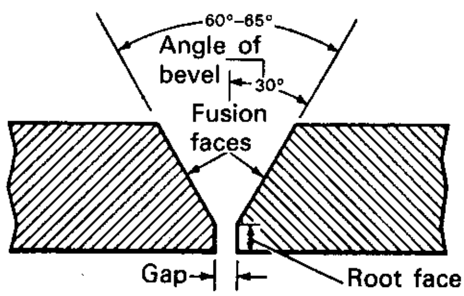


Sealing run in corner joint

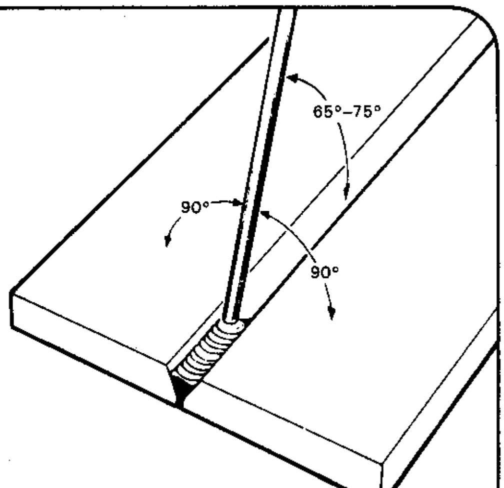
Sealing run—Flat position
Example procedure EP/MMA/9

Material	From EP/MMA/7 and EP/MMA/8(1) as welded
Preparation	Wire brush back side of joint, chip off any excess of penetration bead
Assembly	Place welded joint on bench with face of weld downwards
Electrode	4 mm Rutile
Current	160–180 A

1. Deposit the sealing run, with a very slight transverse weaving motion and with the electrode angle at 65°–75°.
2. Adjust the rate of travel to give a fillet weld having a leg length of 4·5 mm.



Single V penetration for butt joint



Single V butt weld in flat position

Single V butt joint—Flat position
Example procedure EP/MMA/10

Material	Two pieces of mild steel 10 mm thick. Min. size 300 mm × 150 mm
Preparation	Angle of bevel 30°. Root face 1·5 mm ± 0·75 mm
Assembly	Tack weld both ends to give included angle 60°–65°: gap 1·5 mm ± 0·75 mm
Electrodes	1st run 3·25 mm Rutile 2nd run 5·00 mm Rutile
Current	1st run 100–110 A 2nd run 200–220 A

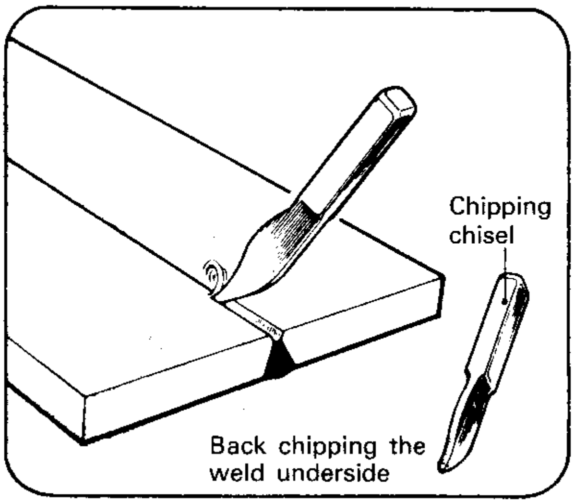
1. Deposit root run, without weaving, with the electrode angle at 65°–75°.
2. Adjust the rate of travel to secure penetration into the root faces but to avoid risk of excess penetration.
3. Deposit the second run, using transverse weaving motion.

Visual examination
The surface of the weld should show a neat even ripple. The vee must be completely filled without undercut at the toes of the weld.
On the reverse side there should be evident penetration into the root faces without any excessive penetration bead.

4. Adjust the rate of travel so that the deposited metal is built up just above the level of the top surface of the plates.
5. Carry out visual examination.
6. If satisfactory, back chip the weld and deposit a sealing run with 3·25 mm electrode.

Single V butt joint—Flat position
Example procedure EP/MMA/11

Material	(a) as for EP/MMA/10 (b) as for EP/MMA/10 except 6 mm thick
Preparation	As for EP/MMA/10
Assembly	As for EP/MMA/10
Electrode	4 mm except (b) root run 3·25 mm Rutile
Current	160–180 A except (b) root run 100–120 A



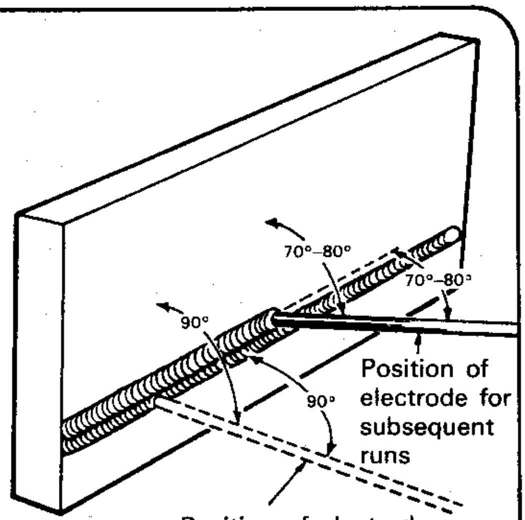
(a) This is a repeat of EP/MMA/10, using another size of electrode.
1. Complete the welding of the face side of the joint in two runs, using a 4 mm electrode.
2. Back chip the weld and with the same size electrode deposit a sealing run.
With the use of a larger electrode, for the root run, it is more difficult to control the amount of penetration.

(b) This is a repeat of EP/MMA/10, using thinner plate and a 4 mm electrode.
1. Complete the face weld in one run.
2. Back chip the weld and with a 3·25 mm electrode deposit a sealing run.
In this procedure, the difficulty is to secure a full weld with effective penetration into the root faces.

Visual examination
Examine the face welds, before the back chipping operation, to check that the difficulties mentioned have been overcome. With satisfactory welds, the amount of back chipping required should not exceed the original depth of the root faces.

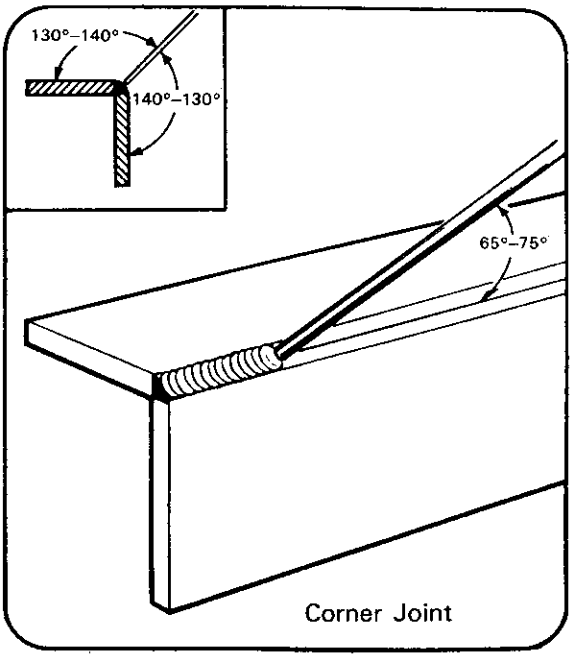
Reinforcement—Horizontal-vertical position
Example procedure EP/MMA/12

Material	One piece of mild steel 12·5 mm thick. Min. size 300 mm × 150 mm
Preparation	Clean surface
Assembly	Support in a vertical position on long edge near front of bench
Electrode	4 mm Rutile
Current	140–160 A



1. Choose a fairly low current.
2. Hold the electrode at right-angles to the plate surface, without weaving.
Adjust the rate of travel so as to deposit a narrow run with a pronounced convex profile.
3. Deposit the first run horizontally from left to right and near the lower edge of the plate.
4. Increase the current slightly for the second run.
5. Hold the electrode at an angle of 70°–80° to the vertical plate surface and also at 70°–80° to the plate in the direction of travel and deposit the second run alongside and above the first run.
Note: The first run provides a ledge on which the second run is deposited.
6. Subsequent runs should be deposited alongside and immediately above the preceding run, in a similar manner to the second run, making any necessary adjustments to the current used as the plate heats up.

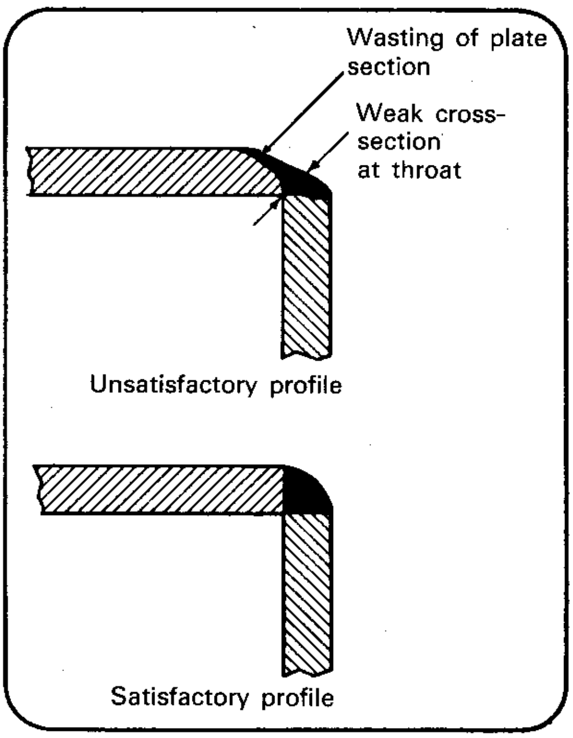
Visual examination
Saw through the reinforced section of the plate and visually examine the cross-section. Correctly deposited reinforcement should be free from marked valleys or ridges between the runs. The general profile may show a tendency for the metal to fall slightly. The deposit should be free from any entrapped slag.



Corner joint—Horizontal-vertical position
Example procedure EP/MMA/13

Material	Two pieces of mild steel 6 mm thick. Min. size 300 mm × 150 mm
Preparation	Square edge
Assembly	Tack weld both ends to give included angle of 90°; no gap at root. Support to form an inverted L with the horizontal plate pointing away from the body
Electrode	4 mm Rutile
Current	150–170 A

1. Deposit the corner weld in one run.
2. Hold the electrode, without weaving, at an angle of 40°–50° to the vertical fusion face and at 65°–75° to the line of the joint.
3. Adjust the rate of travel so as to secure a full section weld without undue melting away of the top edge of the fusion face on the horizontal plate.



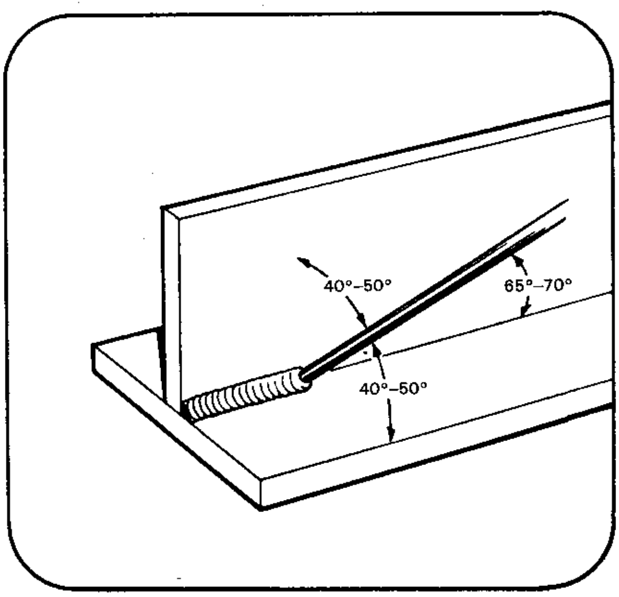
Corner joint—Horizontal-vertical position
Example procedure EP/MMA/14

Material	3·25 mm mild steel, otherwise as for EP/MMA/13
Preparation	As for EP/MMA/13
Assembly	As for EP/MMA/13
Electrode	2·5 mm Rutile
Current	70–80 A

1. This is a repeat of EP/MMA/13 using a smaller size of electrode and thinner plate.
2. Use the same technique as for EP/MMA/13. In this example it is a little more difficult to avoid reducing the section of the horizontal plate.

T joint—Horizontal-vertical position
Example procedure EP/MMA/15

Material	Two pieces of mild steel 12·5 mm thick. Min. size 300 mm x 50 mm
Preparation	Square edge
Assembly	Tack weld both ends so that the plates form an inverted T without any gap between the plates
Electrode	1st side 4 mm Rutile 2nd side 5 mm Rutile
Current	1st side 160–170 A 2nd side 200–220 A



1. Deposit a fillet weld with the 4 mm electrode.
2. Hold the electrode at an angle of 40°–50° to the vertical plate and at 65°–75° to the line of the joint, without weaving.
3. Counteract any tendency of deposited metal to fall towards the horizontal plate by increasing slightly the electrode angle to the vertical plate.
4. Adjust the rate of travel so that a weld of equal leg length approximately 6·5 mm is deposited.
5. After the joint has cooled sufficiently to be handled, weld the other side with the 5 mm electrode, using same technique but with slightly faster rate of travel to deposit same size of weld.

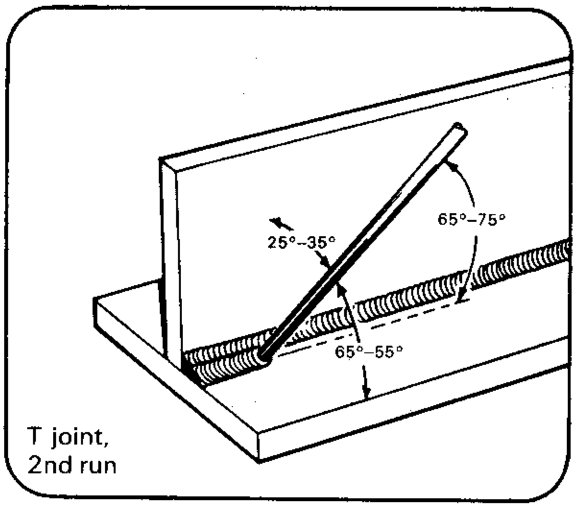
Visual examination

Saw through the welded assembly so that the transverse cross sections of the welds can be examined.

The profile of the weld should be slightly convex, without any undercutting at the toes of the weld.

Penetration to the root without any trapped slag should be achieved. At this stage, and using this type of electrode, penetration beyond the apex of the angle formed by the fusion faces should not be expected.

Multi-run fillet weld—Horizontal-vertical position
Example procedure EP/MMA/16



T joint,
2nd run

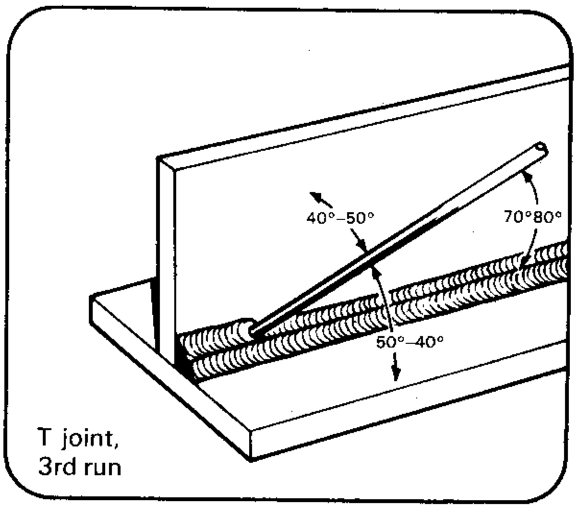
Material	Welded T joint from EP/MMA/15
Electrodes	As for EP/MMA/15
Current	As for EP/MMA/15

1. Over the first run, deposited with the 4 mm electrode, deposit a second run with the same size electrode.

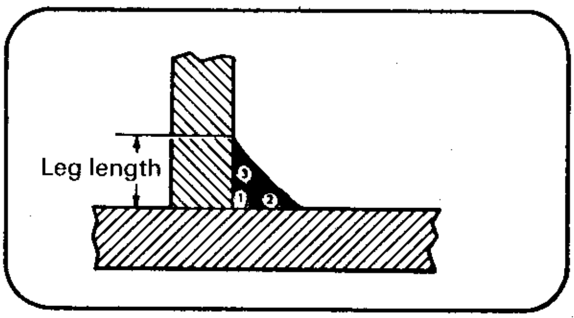
2. Direct the electrode on to the horizontal portion of the first run, altering the angle of the electrode to 25°–35° to the vertical plate.

3. Use a transverse slight weaving motion to obtain a 10 mm leg length on the horizontal plate and fusion to a little higher than the centre line of the first run.

4. Deposit the third run, above the upper portion of the first run, altering the angle of the electrode to 40°–50° to the vertical plate.



T joint,
3rd run

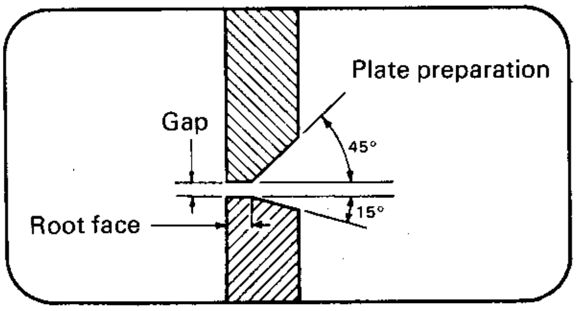


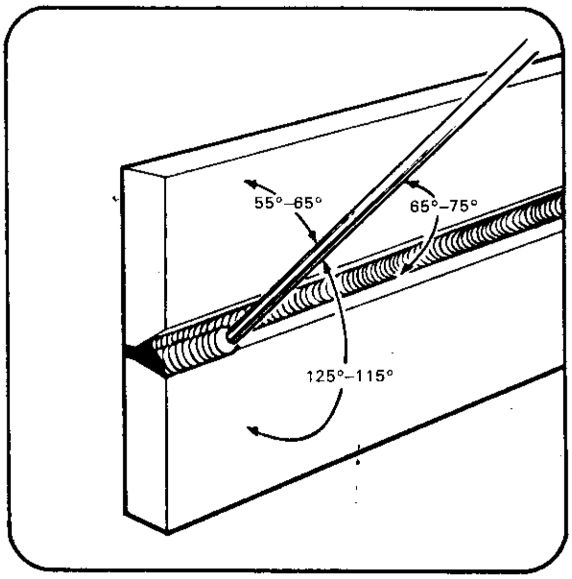
5. Direct the electrode to obtain a 10 mm leg length on the vertical plate and smooth fusion with the upper toe of the second run.

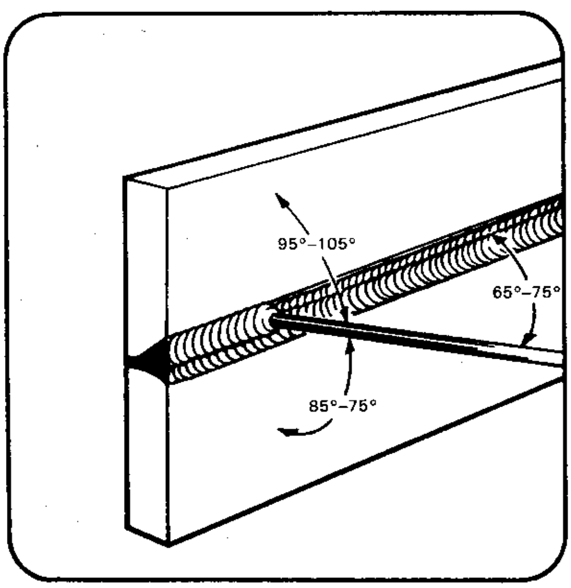
6. Cool the assembly and then weld the other side of the joint with 5 mm electrodes.

7. Deposit two runs over the root run in a similar manner to the first side, to obtain the same size weld. A slightly faster rate of travel will be necessary.

Single V butt joint—Horizontal-vertical position
Example procedure EP/MMA/17







Material	Two pieces of mild steel 10 mm thick. Min. size 300 mm x 50 mm
Preparation	Lower plate angle of bevel 15°; upper plate angle of bevel 45°; root face on both plates 1·5 mm ± 0·75 mm
Assembly	Tack weld both ends to give an included angle of 60°–65°; gap 1·5 mm ± 0·75 mm. Support in a vertical position with line of joint horizontal and face of joint towards operator
Electrodes	1st run 3·25 mm 2nd and 3rd runs 4 mm Rutile
Current	1st run 110–120 A 2nd and 3rd runs 160–170 A

1. Deposit the root run without weaving; electrode angles 90° to the vertical plate and 65°–75° to the line of the joint.

2. Adjust the rate of travel to secure penetration into the root faces.

3. Deposit the second run, using a slight weaving motion to bring the deposit to the outer edge of the lower fusion face. Reduce the electrode angle to the upper vertical plate to 55°–65°.

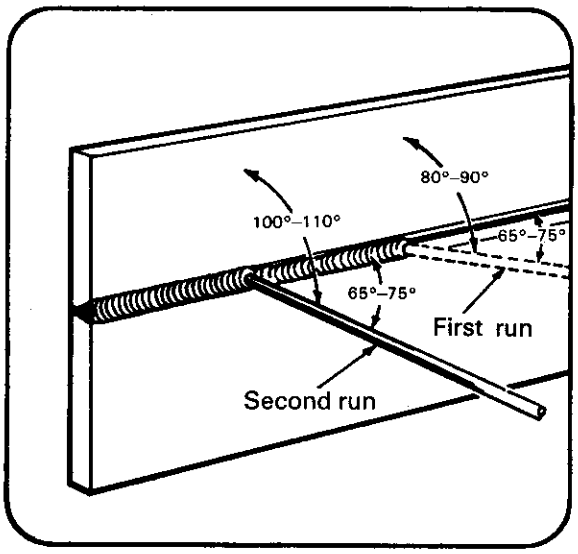
4. Leave space for the deposition of the third run by making the upper toe of the second run not more than half-way up the face of the first run.

5. Deposit the third run, using a slight weaving motion to bring the deposit to the outer edge of the upper fusion face and securing smooth fusion at the junction with the second run. For this run increase the angle of the electrode to the upper vertical plate to 95°–105°.

6. Back chip the weld and deposit a sealing run with a 3·25 mm electrode in the horizontal-vertical position.

Single V butt joint—Horizontal-vertical position
Example procedure EP/MMA/18

Material	Two pieces of mild steel 6 mm thick. Min. size 300 mm × 50 mm
Preparation	Lower plate angle of bevel 15°; upper plate angle of bevel 45°; root face on both plates 1·5 mm ± 0·75 mm. [See diagram for EP/MMA/17.]
Assembly	Tack weld both ends to give an included angle of 60°–65°; gap 1·5 mm ± 0·75 mm. Support in a vertical position with line of joint horizontal and face of joint towards welder
Electrodes	3·25 mm Rutile
Current	110–120 A



1. Hold the electrode so that the angle to the upper vertical plate is 80°–90° and at 65°–75° to the line of the joint.

2. Deposit the root run, using a slight weaving motion to bring the deposit to the outer edge of the lower fusion face and securing penetration into the root faces.

3. For the second run increase the angle of the electrode to the upper vertical plate to 100°–110°.

4. Deposit the second run, with a slight weaving motion, to bring the deposit to the outer edge of the upper fusion face and securing smooth interfusion into the weld face of the first run at the outer edge of the lower fusion face.

5. Back chip the weld and deposit a sealing run in the horizontal-vertical position.

Visual examination
The welded joints from EP/MMA/17 and EP/MMA/18 should be sawn through and the cross-sections visually examined.
A satisfactory welded joint should show that the vee has been completely filled, that fusion is complete over the fusion faces and that fusion of the runs of weld metal has been obtained. The sealing-run profile should not be excessively convex.

Vertical position

When welding upwards on a vertical surface, the molten deposited metal tends to fall down. To obtain a satisfactory profile for the weld pay careful attention to:

(a) correct adjustment of current value to suit the thickness and mass of the parent metal.

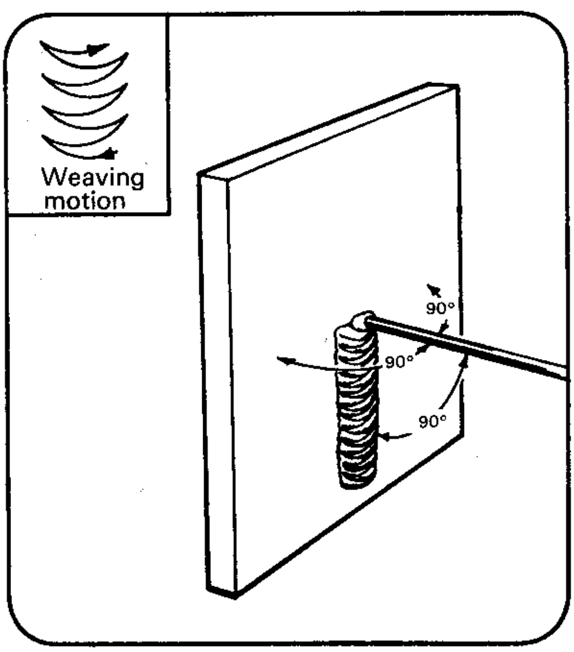
(b) correct electrode angles in relation to the type of joint.

(c) correct weaving motion to control the deposition.

(d) a short arc length.

Reinforcement—Vertical position
Example procedure EP/MMA/19

Material	One piece of mild steel 12·5 mm thick. Min. size 300 mm × 150 mm
Preparation	Clean surface
Assembly	Support in a vertical position near front of bench; long edge vertical
Electrode	3·25 mm Rutile
Current	100–110 A



1. Deposit the first run holding the electrode at right-angles to surface of plate.

2. Commence near the bottom edge of the plate and move upwards.

3. Use a fairly low current and a transverse weaving motion, whipping upwards a little at the sides and making the deposit about 10 mm wide.

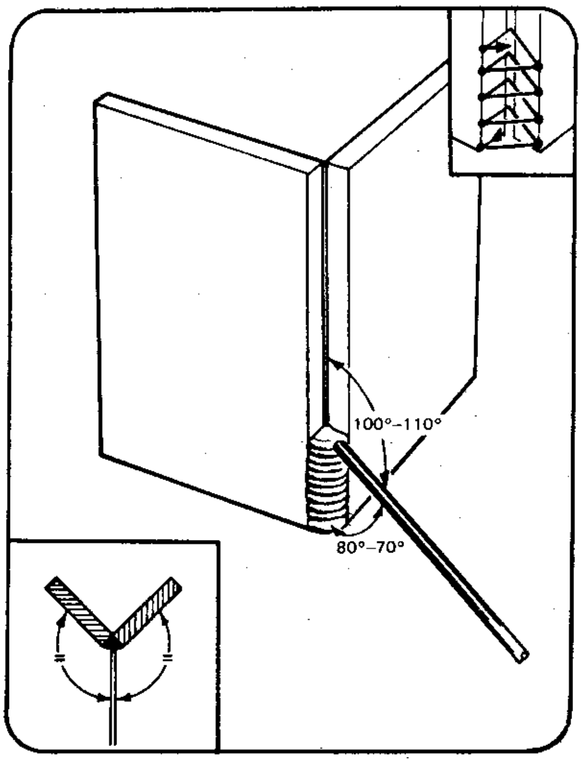
4. Adjust the rate of travel so as to secure a uniform bead without appreciable run down of molten metal.

5. Deposit the second run alongside and partly overlapping the first run to secure neat fusion.

6. Subsequent runs should be deposited in a similar manner to the second run, making any necessary adjustments to current as the plate heats up.

Corner joint— Vertical position
Example procedure EP/MMA/20

Material	Two pieces of mild steel 6 mm thick. Min. size 300 mm × 50 mm
Preparation	Square edge
Assembly	Tack weld both ends to give an included angle of 90°; no gap at root. Support with line of joint vertical with bottom end about 150 mm above bench top, and face of joint towards welder
Electrode	3·25 mm Rutile
Current	105–115 A



1. Deposit the corner weld in one run commencing at the bottom of the joint.

2. Hold the electrode pointing upwards at an angle of 100°–110° to the line of the joint.

3. Establish the arc at the root near the bottom of the joint.

4. After a short pause, move downwards and take the arc to the outer edge of the left-hand fusion face.

5. After a further short pause, move the electrode across so that the arc is at the outer edge of the right-hand fusion face.

6. After a further pause, move upwards and to the left so that the arc is again directed centrally at the root of the joint but at a slightly higher point.

7. This fairly rapid triangular weaving motion is designed to keep the root of the weld at a slightly higher level than the face and thus prevent slag entrapment at the root.

8. Repeat this motion throughout the weld, adjusting the rate of vertical travel so as to secure a uniform bead that fills the joint.

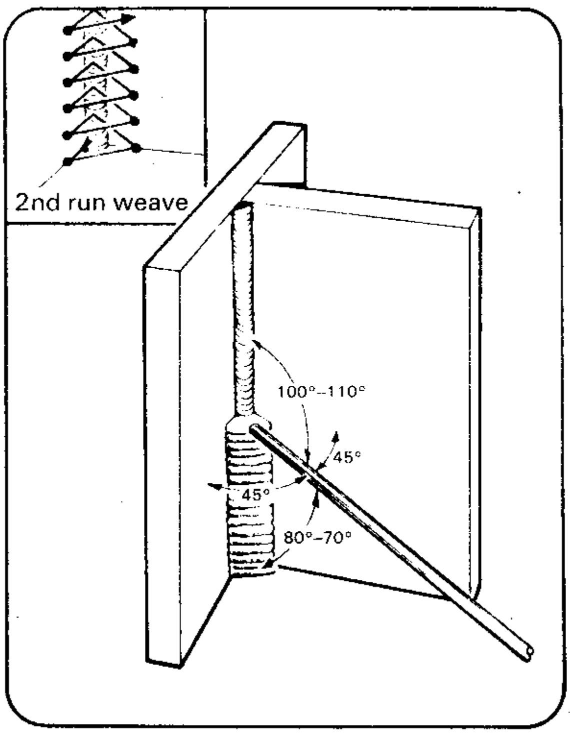
Visual examination

Cool and saw through the welded assembly and examine the cross-section.

A satisfactory weld should have a slightly convex profile without excessive sagging of the weld metal. There should be penetration to the root of the joint without any slag entrapment at the root.

T joint—Vertical position
Example procedure EP/MMA/21

Material	Two pieces of mild steel 10 mm thick. Min. size 300 mm x 50 mm
Preparation	Square edge
Assembly	Tack weld both ends to form a T joint without gap between the plates. Support with line of joint vertical with bottom end about 150 mm above bench top and face of joint towards welder
Electrode	1st run 3·25 mm Rutile 2nd run 4 mm Rutile
Current	1st run 105–115 A 2nd run 150–160 A



1. Deposit the root run, without weaving, commencing at the bottom of the joint.

2. Hold the electrode pointing upwards at an angle of 100°–110° to the line of the joint.

3. Adjust the rate of vertical travel to avoid under-cutting and/or fall of molten metal.

4. Deposit the second run, using the electrode at the same angle but this time with the triangular weaving motion. Pause slightly at the sides to ensure full fusion and adjust the rate of vertical travel so as to give a leg length of 10 mm on each plate.

T joint—Vertical position
Example procedure EP/MMA/22

This is a repeat of EP/MMA/21 but using one run only with 4 mm electrode.

1. Establish the arc at the root near the bottom of the joint.

2. Move downwards and to the left-hand fusion face to give a leg length of 8 mm.

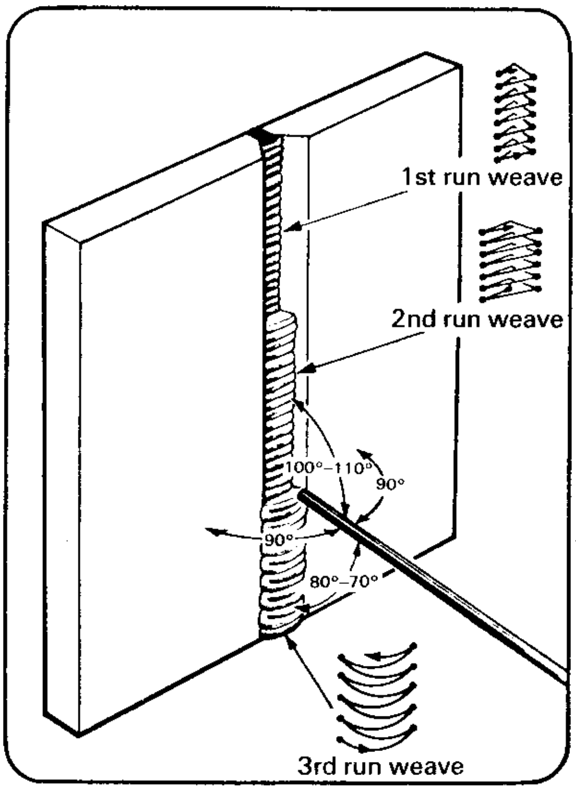
3. After pausing, move across to the right-hand fusion face to establish the 8 mm leg length there.

4. After a short pause, the electrode should be moved upwards and to the left so that the arc is again directed at the root.

5. Repeat this motion throughout the weld. In this procedure it is a little more difficult to obtain penetration to the root and to avoid undercut.

Single V butt joint—Vertical position
Example procedure EP/MMA/23

Material	Two pieces of mild steel 12·5 mm thick. Min. size 300 mm × 50 mm
Preparation	Angle of bevel 35°, root face 1·5 ± 0·75 mm
Assembly	Tack weld both ends to give included angle of 70°–75°; gap 1·5 mm ± 0·75 mm. Support with line of joint vertical, with bottom end about 150 mm above bench top and face of joint towards welder
Electrode	1st run 3·25 mm Rutile 2nd and 3rd runs 4 mm Rutile
Current	1st run 110–120 A 2nd and 3rd runs 150–160 A



Deposit the root run, using a very small triangular weaving motion.

2. Hold the electrode, pointing upwards, at an angle of 100°–110° to the line of the joint.

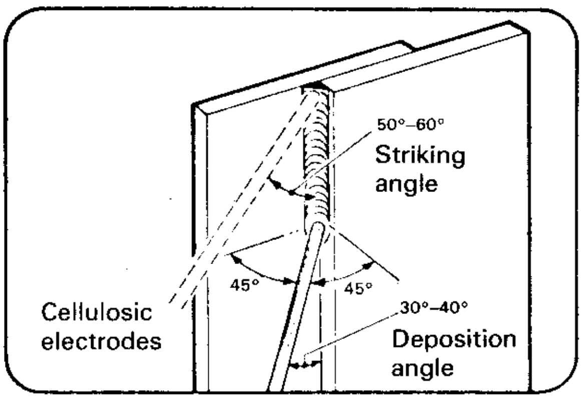
3. Deposit the second run, using a more pronounced weave and bringing the weld to within 3 mm of the outer edges of the fusion faces.

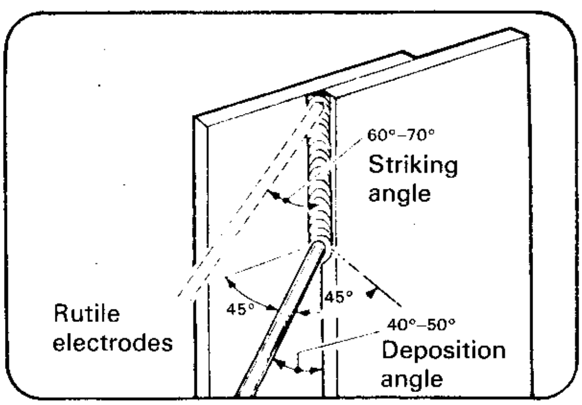
4. Deposit the third run, using a rapid crescent weave in which the electrode is moved slightly upwards as the arc plays on the outer edge of each fusion face. Make sure that the deposit fills the vee.

Visual examination

The surface of the weld should have a slightly convex profile without excessive sagging of the weld metal. The vee must be completely filled without undercut at the toes of the weld.
On the reverse side, there should be evident penetration into the root faces without any excessive penetration bead.

5. Back-chip the weld and deposit a sealing run in the vertical position, using a 3·25 mm electrode.





Deposition runs in the vertical downwards position
Vertical downwards welding is used for pipe welding, storage tanks, butt welds, lap welds, light sealing runs, edge welds and some sheet metal welding. Only electrodes approved for this method should be used. The section of metal deposited in each run is comparatively thin and there are risks of the weld cracking if the joint is highly restrained.

Lap joint—Vertical downwards position
Example procedure EP/MMA/24

Material	Two pieces of mild steel 6 mm thick. Min. size 400 mm × 100 mm
Preparation	Square edge
Assembly	Overlap plates and tack weld together for lap joint. No gap. Support with line of joint vertical, with bottom end approx. 150 mm above bench top and face of joint towards welder
Electrode	4 mm Rutile or Cellulosic
Current	Near to maximum of recommended range

The angle for the electrode depends upon the class of electrode used. Guidance is given in the illustrations but always follow the manufacturer's instructions.

1. Reduce the angle of the electrode to the line of the joint by lowering the holder immediately after the arc is established.

2. Commence the downward movement; the leading edge of the covering cup should be brought into contact with both fusion faces.

3. Hold the electrode pointed directly at the root, without weaving.

4. Adjust the rate of travel, up to 500 mm per electrode, so that the arc will control the deposition.

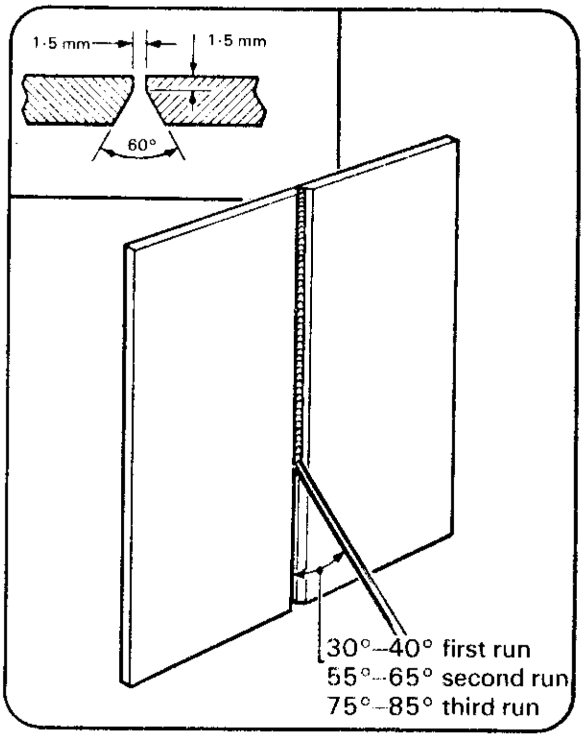
Visual examination
The fillet weld produced should be uniform in leg length and concave in profile. The leg length to be approximately 5 mm.

Butt joints
Cellulosic electrodes are used (except on sheet metal) for the vertical downwards welding of butt joints. When using cellulosic electrodes a stub ebd of 75 to 100 mm is discarded. If using an A.C. power source, open-circuit voltage must not be less than 95 volts.

Single V butt joint—Vertical downwards position
Example procedure EP/MMA/25

Material	Two pieces of mild steel 6 mm thick. Min. size 300 mm × 150 mm
Preparation	Angle of bevel 30°. Root face 1·5 mm
Assembly	Tack weld to give included angle of 60° to 65°; gap 1·5 mm. Support with line of joint vertical, with bottom end about 150 mm above bench top and face of joint towards welder
Electrode	4 mm Cellulosic
Current	1st and 2nd runs 155–165 A 3rd run 135–145 A Sealing run 150–160 A

Note: Check the current with tong-test ammeter. The power source calibration may not be accurate for this type of electrode.



1. Establish arc. Immediately bring the leading edge of the electrode covering into firm contact with both fusion faces.

2. Use a fairly rapid rate of travel, 32 mm run length per 25 mm of electrode deposited. Do not weave the electrode.

3. Deposit second run as quickly as possible after completion of root run and whilst still hot.

4. Use a close arc with a slight upward and downward movement. This removes any undercut caused by the first run. Reduce the run length to about 20 mm per 25 mm of electrode.

5. Deposit third run as quickly as possible after completion of second run. Use a rapid side-to-side weaving motion. Pause at the sides to prevent undercut at the toes. Adjust rate of travel downwards to fill the V and give slight reinforcement.

6. Remove slag globules from the root. Deposit sealing run. Concentrate the arc on the root of the joint without weaving motion. Angle of electrode should be 70° to 80° to the line of joint.

Thickness	Electrode size	
mm	mm	swg.
6 8	3·15 4	10 8
Preparation	Square edge	
Assembly	No gap. To enable joint to be seen clearly, chamfer sharp corner of the plate edges before tacking together or make a chalk line along the joint.	
Current	Use maximum of recommended range. Check current with a tong-test ammeter. The power source calibration may not be accurate for this class of electrode.	
Electrode	Check that the electrode used is of the deep penetration type.	

Deep penetration welding
Square edge butt joint—Flat position
Example procedure EP/MMA/26

Deep penetration welding of butt joints should achieve fusion in a close butt joint to a depth equal to the core wire diameter of the electrode.

If using AC power source, open-circuit voltage must be not less than 95 volts.

To enable consistent deep penetration, use:
(a) correct welding current
(b) correct angle of electrode
(c) minimum arc length
(d) correct speed of travel.

The optimum conditions depend upon type of electrode used. Follow the manufacturer's recommendations. Typical examples are:

Angle of electrode
Perpendicular to the plates but may be sloped at 75°–85° in the direction of welding. Do not weave.

Arc length
Keep the electrode cup in touch with the leading edge of the weld pool. The cup is usually deep with this type of electrode.

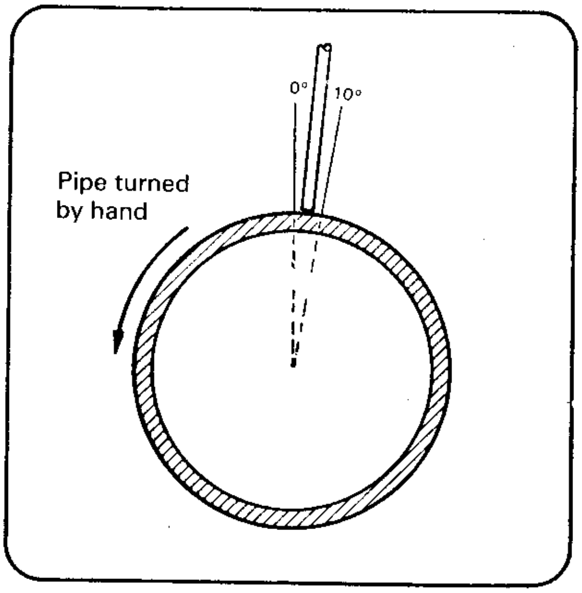
Speed of travel
This should not exceed a run length of 25 mm per 25 mm of electrode deposited.

Deposit one run either side. Obtain competency on small assemblies before attempting deep penetration welding techniques on complex work.

Visual examination
This should include the macro-examination of specimens for lack of inter-penetration and slag inclusions.

Pipe welding

Satisfactory welding of butt joints in pipes depends upon the correct preparation of pipe ends and careful assembly of the joint to be welded. Ensure that the bores and root faces are in correct alignment and that the gap is correct.

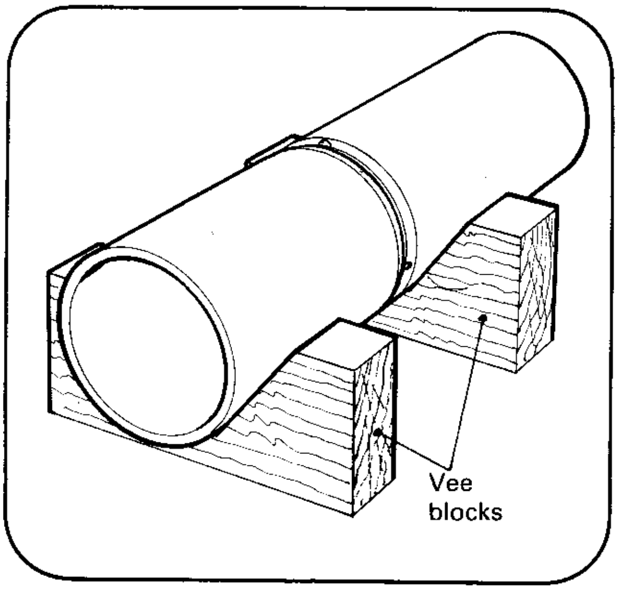


Visual examination
The profile of the weld should be slightly convex and the joins in the weld runs as smooth as practicable, with no pronounced hump or crater. The surface of the weld should be free from defects. There should be freedom from undercut—but slight intermittent occurrences of undercut may at this stage be disregarded. Penetration should be slight—although occasional lack of penetration may be disregarded at this stage. The bead should not protrude into the bore more than 3 mm.
A nick-break test specimen should be prepared to include the start of the weld. This should be notched, broken open along the weld and the fracture surfaces examined for clean appearance. The weld metal should be free from voids, slag inclusions and oxide films. There should be complete interfusion of runs of weld metal with each other and the fusion faces.

Butt welds without backing
(Pipe horizontal and rolled (rotated) during welding)
Example procedure EP/MMA/27

Material	Two pieces of mild steel pipe each 200 mm long; 90 mm outside diameter × 4·5 mm wall thickness
Preparation	Angle of bevel 35°. Root face 1·5 to 2·5 mm
Assembly	Tack weld together with 4 small equally spaced tacks, or hold in suitable fixture or clamp. The gap should be equal to the root face dimension plus 0·75 mm. Support the tacked assembly on V blocks or rollers so that the assembly can be rolled or rotated with the free hand
Electrode	1st run 2·5 mm 2nd run 3·25 mm Rutile or Basic
Current	1st run 70–80 A 2nd run 100–110 A

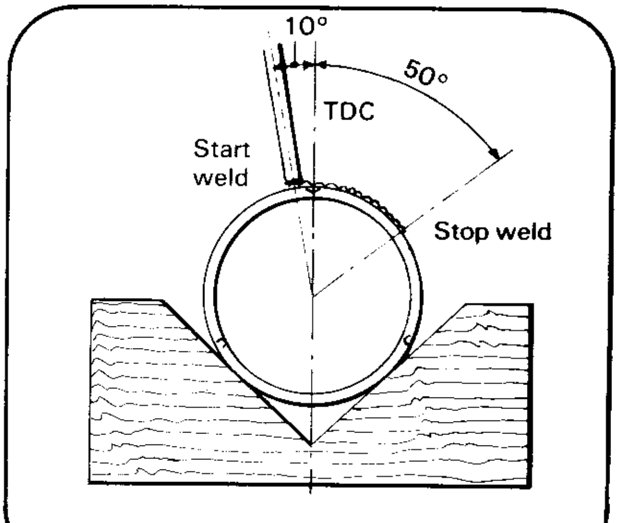
Rotate the assembly as welding proceeds, keeping the welding arc within an area between vertical and 10° from the vertical in the direction of welding (use a helmet-type screen).
1. Direct the electrode centrally at the root of the joint and in line with the radius of the pipe at the point of welding.
2. Strike the arc near the top-centre, and hold the arc length as short as possible.
3. Deposit first run by weaving the electrode very slightly from root face to root face.
4. Adjust the speed of rotation to obtain full fusion of the root faces without excessive penetration.
5. Chip out tack welds as they are approached. Do not weld over tacks otherwise loss of penetration at the tacking points may occur.
6. Complete the weld with the second run. Adjust the speed of rotation to secure fusion to the outer edge of each fusion face. The amount of reinforcement should be even around the edge of the joint.



Butt joint—Segmentally welded
Example procedure EP/MMA/28

1. Use material and conditions specified for EP/MMA/27.

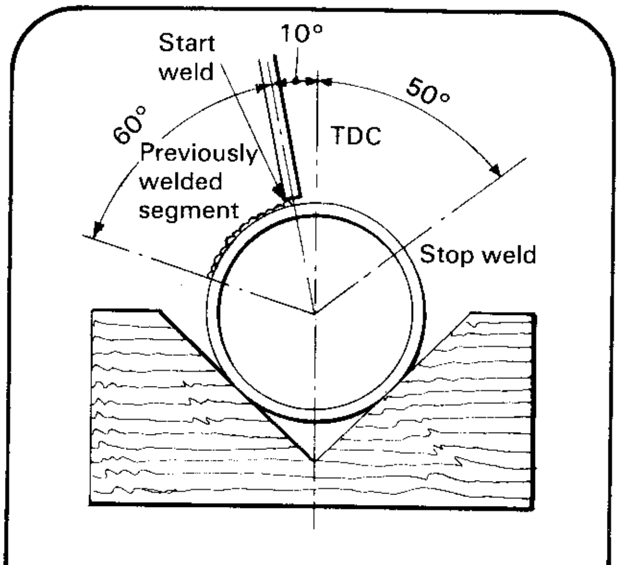
2. Tack the pipe as before and support the assembly on two vee blocks.



Welding first segment

3. Strike the arc at 10° from Top Dead Centre (TDC) and deposit the root run. Use a small weaving motion to achieve fusion of the root faces. Adjust travel speed to control root penetration.

4. When a segment equivalent to 60° has been welded, terminate the weld run. Avoid the formation of a crater.



Welding second segment

5. Move the pipe until the end of the segment is at 10° before TDC.

6. Strike the arc on the end of the previous weld run and establish a weld pool.

7. Weld a further 60° segment.

8. Continue welding in segments until the root run has been completed.

9. Move the pipe until the mid point of one of the segments is at TDC.

10. Strike the arc and deposit the second (filling) run. Use a side-to-side weaving position to fill the preparation and to achieve fusion of the pipe edges.

11. Complete the filling run in 60° segments.

Repair of castings

Foundry defects in castings should be opened out and trapped sand removed. Spongy metal and cracks should be cut out with a round-nosed chisel or by gouging. The area to be repaired must be free from paint, grease, oil or any other contamination. Prevent cracks from spreading by drilling a small hole at each end. The crack should be cut out by chipping or gouging.

Where possible edge preparation should permit welding to be done from both sides of the joint. Partial penetration welds are usually adequate for cast iron repairs. Thermal gouging or cutting can be used for edge preparation work, take care if used on cast iron.

Grey cast iron may be welded without pre-heating. Full pre-heating of iron castings to about 300°–500°C. (575–930°F.) is desirable. Malleable iron and austenitic iron castings should not be pre-heated. Intense local pre-heating of iron castings is undesirable. Carbon steel and low-alloy steel castings should be pre-heated as for wrought materials of similar composition.

Grey cast iron

1. Electrodes

Categories in common use include those with:

(a) A core wire of monel metal.
(b) A core wire of 55/45 nickel-iron alloy
(c) A core wire of low-carbon mild steel.
(d) A core wire or silicon-bronze or tin-bronze.
(e) A core wire of pure nickel.

Types (a), (b) and (e) deposit machinable metal and are used for repairing castings with or without pre-heating.

Type (c) is suitable for use in thick section repairs. Full pre-heating to 550°C. or more is required to permit machining.

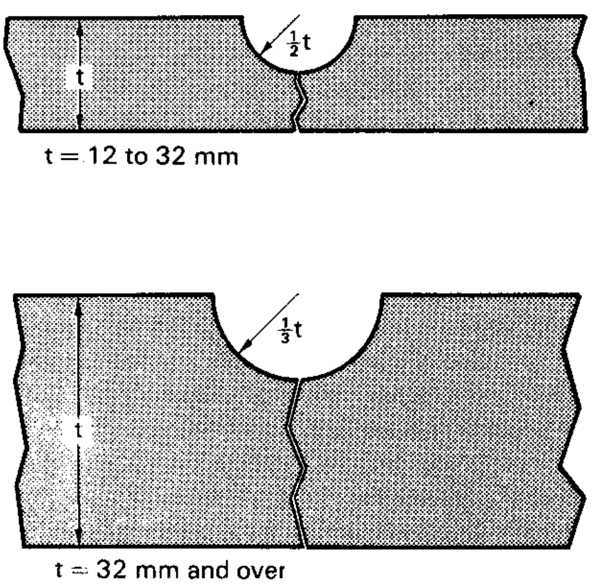
Type (d) is used for the repair of thin section castings where the colour of the deposit is of no account. Pre-heating is not required.

2. Edge preparation

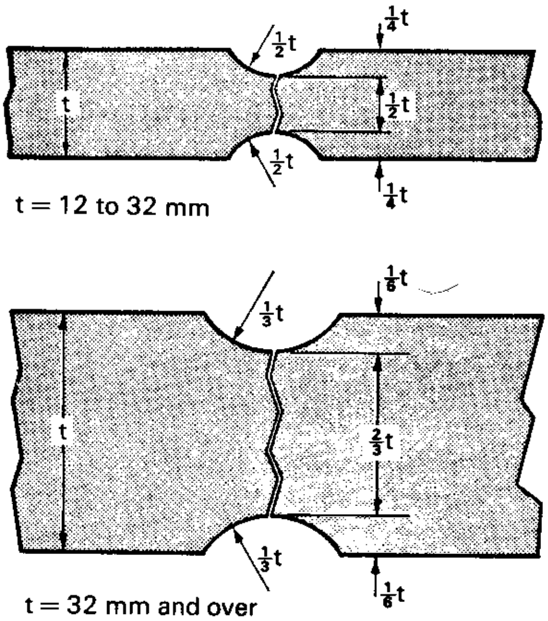
Where access is limited to one side, use a grooved preparation. Preparation which permits welding from both sides is preferable. The weld is not normally made through the full section as the deposited metal is stronger than the grey cast iron.

Mild steel studs may be screwed into the casting to provide basic reinforcement for the welded repair. Where large spaces are left between the main fracture faces, 'butter' the fracture faces to achieve a suitable preparation.

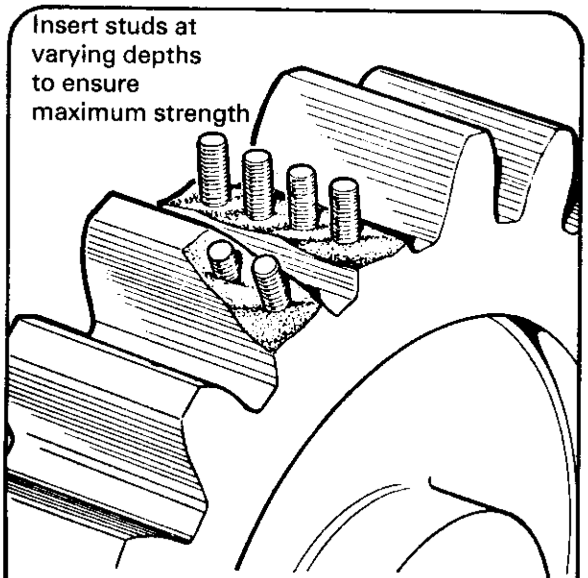
Where mild steel studs are screwed into the fracture faces, stagger the position of the studs. Studs should project from the fracture face for a distance of 3 mm less than the amount of build-up required. Studs should be inserted into the parent metal at varying depths to give maximum strength to the welded repair.



Single-sided joint preparations for welding fractured cast iron

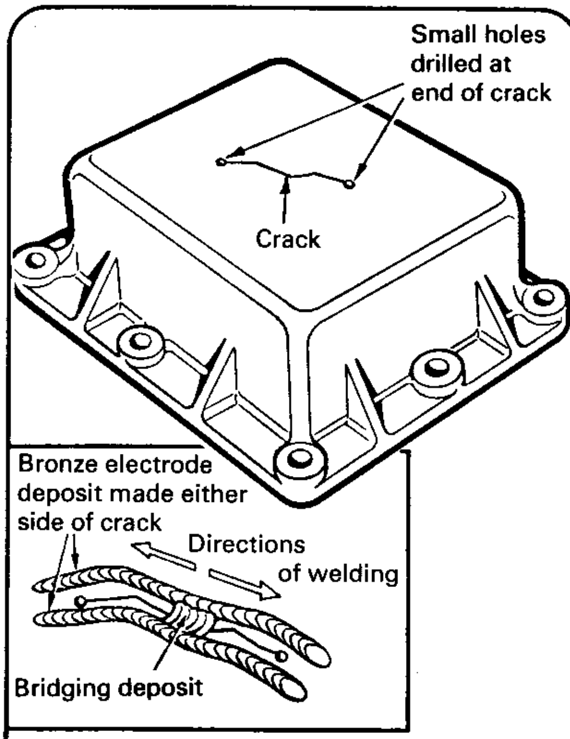


Double-sided joint preparations for welding fractured cast iron



Studding and welding repair of cast iron gear

Note: After repair, castings should be allowed to cool slowly.



Bronze-welding repair of cast iron

Welding procedure for repair of castings

(a) Pre-heated castings (prepared or 'buttered' edges).

1. Deposit up to half the electrode in one run. Long runs may cause transverse cracking.

2. Allow the welding area to cool to the pre-heat temperature between runs.

3. Stagger the runs to balance the heat input.

4. Deposit first on one side, and then on the other side, before the joining runs are made. Join together the metal deposited on the two parts with the final runs.

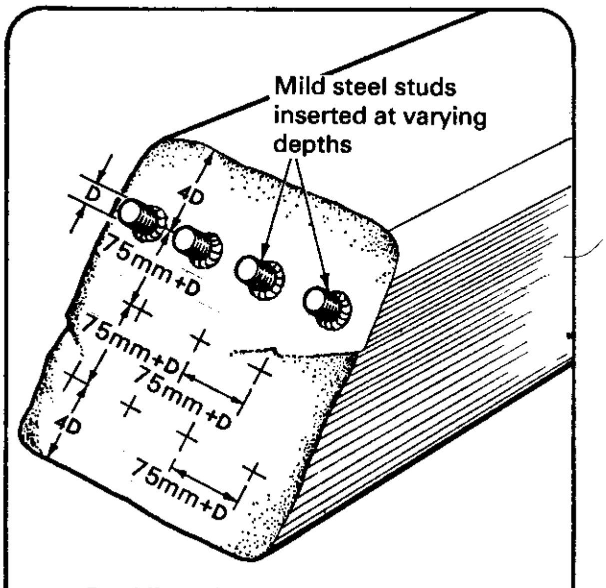
(b) Cold castings (prepared or 'buttered' edges).

1. If pre-heating is not possible, allow the heat to disperse between each run (ie. cool to 'hand heat').

2. Restrict the length of deposit per run to between 50 mm and 75 mm.

3. Do not weave the electrode.

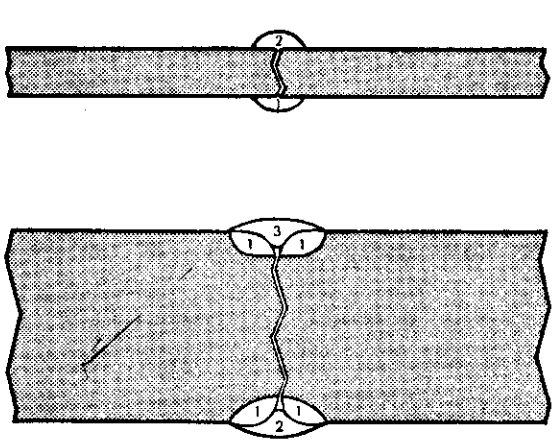
4. Ensure that the casting has cooled to hand heat before depositing the next run.



Studding of cast iron fracture face

(c) Castings (with studded fusion faces).

1. Use electrode with low-carbon mild steel core wire. Full pre-heat (if possible above 100°C. (200°F.)) will be advantageous provided it is uniform.
2. Deposit a light run of weld metal around each stud.
3. Build up the deposit around and between the studs until a level face is obtained.
4. Use small runs. Stagger the deposition to secure balanced heat input.
5. Avoid depositing in the gap between the two parts, as long as possible. The bridging of the gap between the pieces should be completed with the minimum number of runs.
6. Use nickel-iron electrodes for the last three layers of deposit where machinability is required.

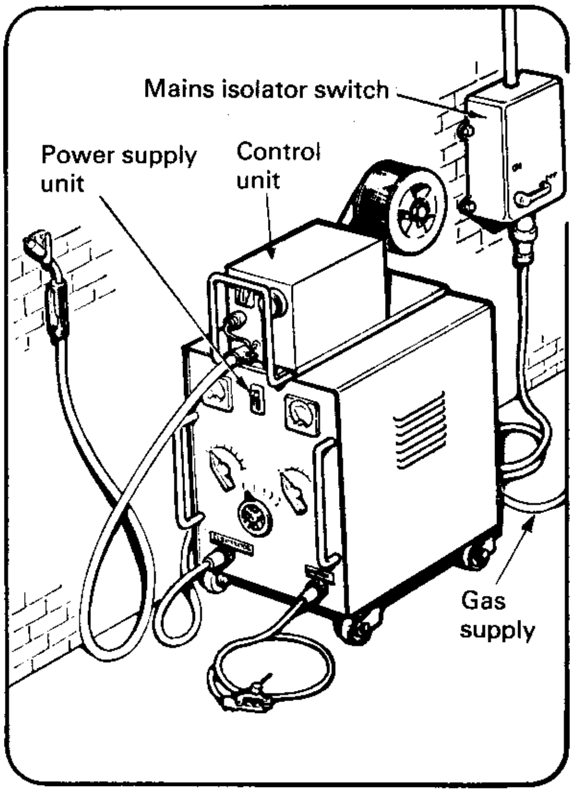

Welding of thin and thick sections of malleable iron

(d) Malleable iron and thin section castings

Malleable iron castings should not be pre-heated. Welding should be done on the surface only, using a bridging technique. The same technique may be used for the repair of thin grey iron castings (as illustrated on previous page).

1. Use electrodes with bronze core wire.
2. Use small size electrode with welding current at lower end of recommended range.
3. Make short runs 50 mm to 75 mm long at the side of the crack or on one part.
4. Repeat until a small run has been made on both sides of the crack extending a little way beyond the ends of the crack (or on the surface of the fracture edges of each part).
5. When the casting has attained an even temperature, make a bridging run across the crack (or between the two 'buttered' edges).

Metal-arc gas shielded welding



General

The essential parts of a **metal-arc gas shielded** system are:

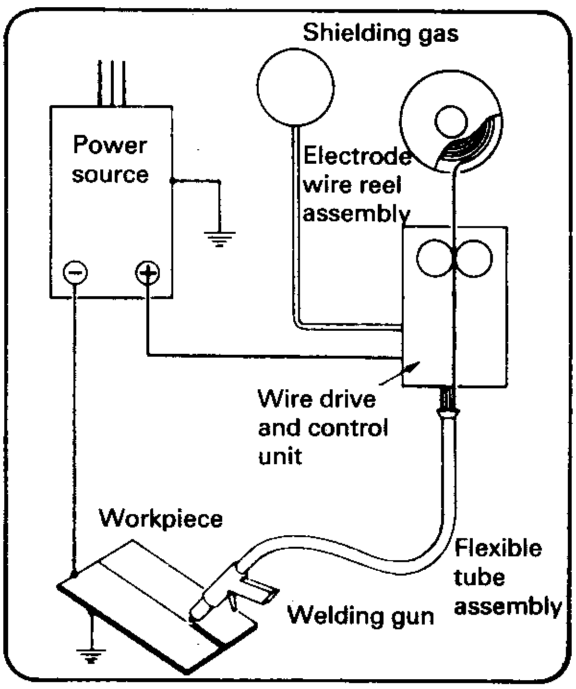
1. Power supply unit.
2. Wire feeder unit.
3. Flexible lead assembly.
4. Welding gun or torch.
5. Gas supply system.

1. Power supply unit
The power supply unit must be of the constant potential type and must be chosen to suit the operating range.

(a) For Spray Transfer the unit should be capable of delivering up to 400 A (for 1·2 mm wire) or 500 A (for 1·6 mm wire or flux cored electrodes). The open-circuit voltage should be high enough to give a satisfactory arc length and voltage at the maximum operating current (see tables for EP's).

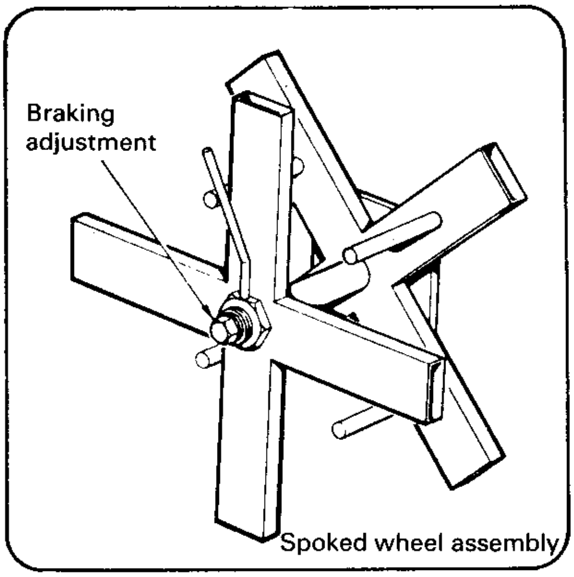
(b) For Dip Transfer the unit for use with the EP's given in this section, should be capable of delivering up to 180 A or 200 A at an operating voltage of 21V. The unit should also be fitted with a tapped or variable inductance.

(c) For Pulse Transfer special power supply units should be used. Seek the advice of the manufacturer.



In addition to the power sources, the equipment is basically as illustrated.

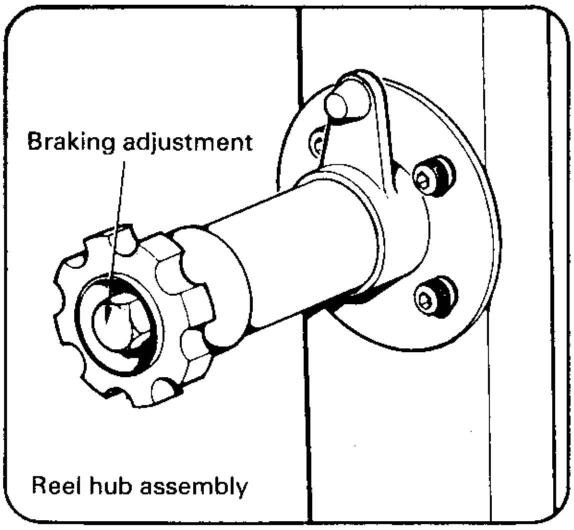
2. Wire feeder unit



Spoked wheel assembly

(a) Electrode wire reel assembly
The electrode wire reel or coil is mounted on to a spindle or spider hub, either horizontally or vertically as required.

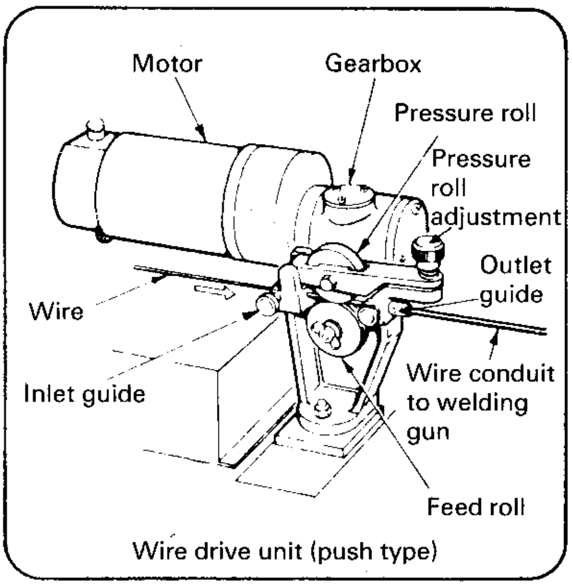
The hub is free to rotate as the wire is drawn off by the wire drive unit.



Reel hub assembly

An adjustable braking device is incorporated in the assembly to prevent overrun of the electrode wire when the motor of the wire drive unit is switched off.

To protect the electrode wire from dust and contamination the reel assembly is usually enclosed by a cover or placed within the control unit cabinet. A cover is essential when using aluminium alloy wires.

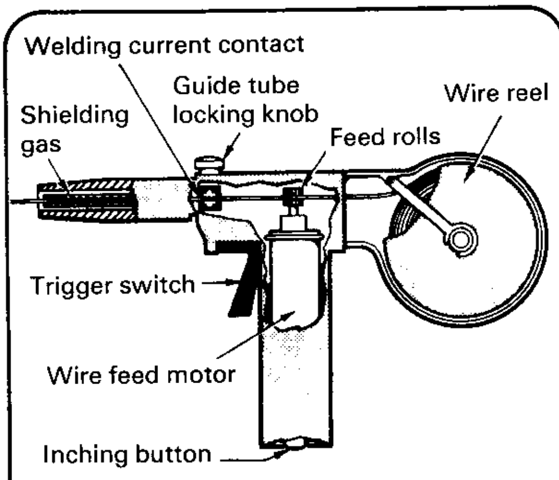


Wire drive unit (push type)

(b) Wire feeder
This may either be a push or a pull type or combined.

(i) Push type
In the push type the mechanism consists of two or more feed rolls where the grip or pressure can be adjusted.

This method of feeding is used for bare soft wire of a diameter not less than 1·2 mm and of not less than 0·6 mm in the case of hard wires.



Reel-on-gun arrangement (pull type)

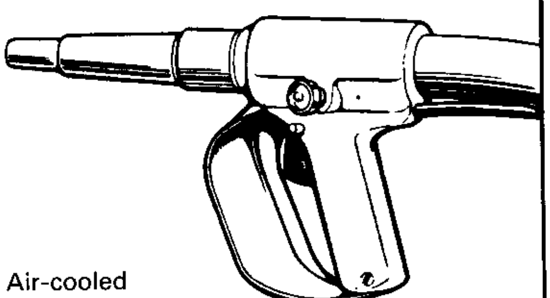
(ii) Pull type

The pull type consists of a drive usually built into the handle of the welding gun. Feed rolls pull wire off a small reel attached to the gun. In the combined method push and pull feed units are used; one is mounted near the electrode wire reel assembly and the other in the welding gun.

(c) Control unit

This unit:

1. Permits setting of the electrode wire feed rate.
2. Starts and stops the feed motor instantaneously.
3. Incorporates gas flow control and water flow control (if used).

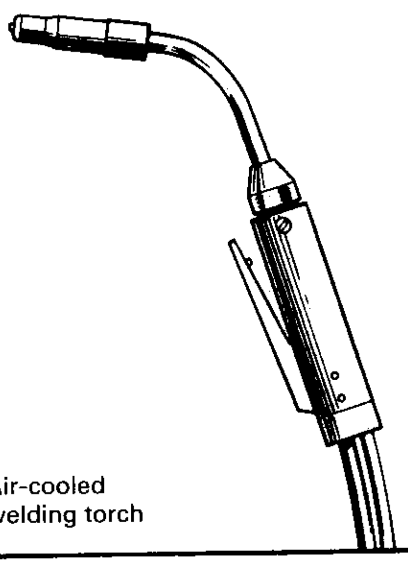

Air-cooled welding gun

3. Flexible lead assembly

This will depend upon the type of equipment used.

It normally contains:

1. Cable for the welding current.
2. Control cable to link the switch on torch gun with the control unit.
3. Hose to convey shielding gas.
4. Conduit to convey electrode wire (except in the case of the reel-on-gun arrangement).
5. Hoses to convey cooling water (if used).
6. Hose to convey air to drive wire feed turbine (if used).


Air-cooled welding torch

4. Welding gun or torch

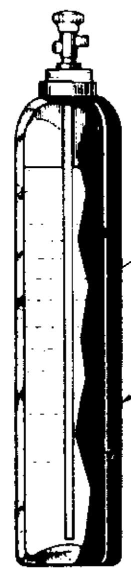
For spray transfer welding with flux cored wires, 1·2 mm diameter or larger, or where a pull feed unit is incorporated, the equipment is generally pistol-shaped, has a trigger-type switch, and is referred to as a welding gun. It can be water-cooled when required for use with currents in excess of 300/400 A.

For dip transfer and pulse transfer welding the electrode holder normally has a curved neck. It is known as a welding torch since it resembles the shape of an oxy-actylene welding nozzle. It incorporates a button or lever-operated switch.

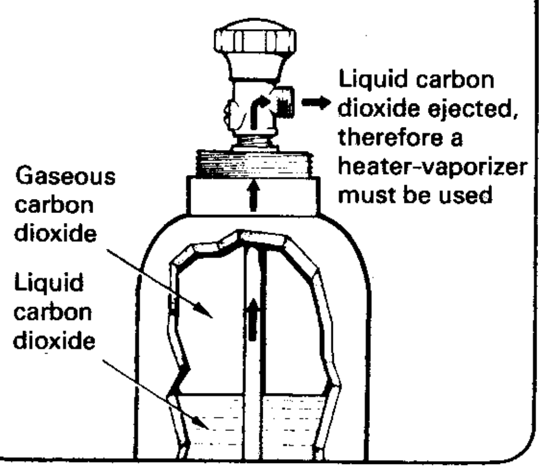
Important	
Cylinder recognition	
Argon	Blue
Argon-oxygen	Blue with black band
Argon-carbon dioxide	Blue with green band

Alternatively cylinders containing mixed gases may be painted with aluminium paint and the name of the mixture stencilled in black.

In addition gas identification labels are attached to the cylinders.



Carbon dioxide cylinder



5. Gas supply system

(a) Shielding gases
(i) Inert gas
Argon of welding grade purity is used as the shielding gas when welding non-ferrous metals.

(ii) Gas mixtures
These mixtures are supplied in steel cylinders. Alternatively, separate gases may be mixed in the proportions required by the use of a gas mixer.

Argon-oxygen mixtures
The addition of small quantities of oxygen to argon makes it more suitable for use when welding steels.

1. About 1–2% of oxygen is added when used for welding stainless steels and 2–5% when used for welding mild steel by spray transfer technique.

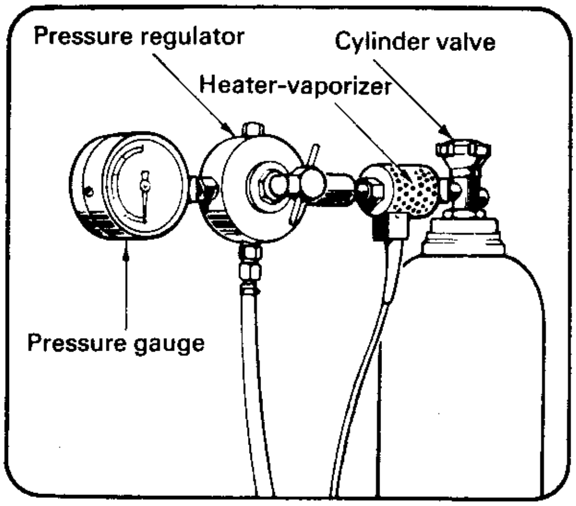
2. For pulse transfer technique, argon mixed with up to 2% of oxygen and up to 5% of carbon dioxide, is used for welding steels.

Argon-carbon dioxide mixtures
Dip and spray transfer welding techniques are possible with a mixed shielding gas of argon and from **5–25% of carbon dioxide.**

Carbon dioxide
Carbon dioxide can be used as a shielding gas for the welding of steel.

It is suitable for dip transfer at low currents and can be used at high currents for spray or free flight transfer. There are two types of internal fittings to the cylinders; one which allows gas, which might contain moisture, to be ejected on opening the valve, and the other called the syphon type which only allows liquid carbon dioxide to be ejected.

Syphon type cylinders should be used, in which the liquid is drawn from the bottom of the cylinder.



(b) Heater-vaporizer unit

To prevent the regulator freezing as liquid carbon dioxide expands into gas, it is necessary to fit an electric heater-vaporizer unit between the cylinder valve and the regulator when using syphon type cylinders.

Assembly of equipment

The initial installation and connection of the power source to the appropriate mains supply should be carried out by a competent person. Ensure that the equipment is adequately earthed.

Equipment varies considerably in the manner of making connections.
The examples chosen illustrate the principles.
Always consult the manufacturer's instruction book!

Electrical connections

Use secondary cables of a suitable size for the maximum welding current, then:

1. Connect one end of the return lead (using a clamp or terminal) to the workpiece.

2. Connect the other end to the negative terminal of the power source.

3. Connect one end of the welding lead to the welding current input terminal on the wire feed and/or control unit.

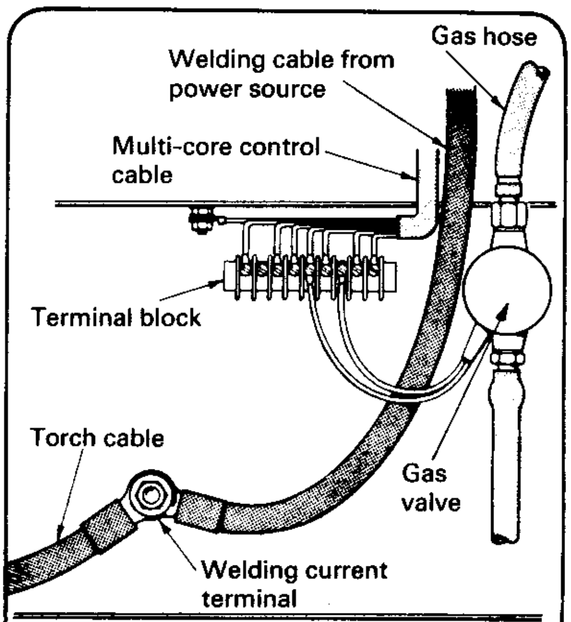
4. Connect the other end to the positive terminal of the power source.

5. Connect one end of the multi-core control cable to the appropriate terminals on the wire feeder control unit.

6. Connect the other end to the appropriate terminals or socket on the power source.

7. Connect the welding cable and the control cable of the flexible tube assembly to the appropriate outlets on the wire feed and/or control unit.

8. If using a heater-vaporizer, connect the lead from the heater to the terminal or socket on the power source or to a separate single phase supply of the correct voltage.



Connection diagram for air-cooled torch/gun

Equipment varies considerably in the control arrangements.
Take care to ensure that water-flow valves are correctly connected.
Always consult the manufacturer's instruction book!

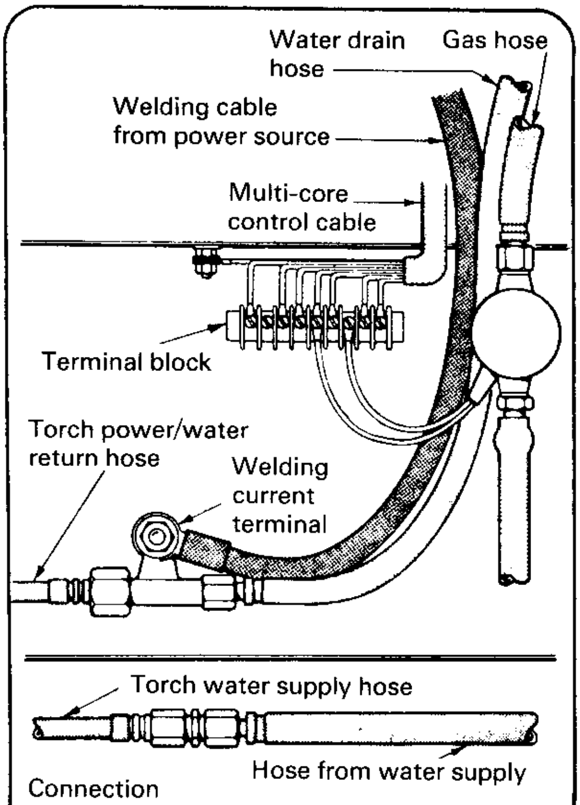
Gas connections

1. Ensure that:
(a) cylinders being used are in an upright position and are securely fastened to a trolley or rigid object to prevent them falling or being knocked over, and
(b) the valve socket is clean, dry and free from dust. This can be done by 'cracking open' the cylinder valve to pass gas to the atmosphere momentarily.

2. If using carbon dioxide from a syphon type cylinder, fit the heater-vaporizer to the cylinder valve before fitting the pressure regulator.

3. Fit the gas pressure regulator (and flowmeter if used) to the heater-vaporizer.

4. Connect the hose to the regulator/flowmeter outlet and to the gas inlet on the control unit.



Connection diagram for water-cooled torch/gun

Water connections

When water-cooled torches are used, water may be taken from the mains or from an independent re-circulating unit.

1. Connect the water supply hose from mains or re-circulating unit to water inlet connection of control unit.

2. Connect water outlet of control unit to water hose in flexible assembly.

3. Connect welding cable/return water hose to power/water connection of control unit.

4. Connect return water outlet to drain or re-circulating unit.

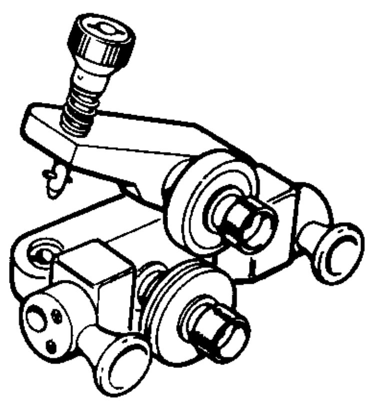
Electrode wire

The electrode wire is usually supplied layer-wound on 300 mm dia. reels. Larger coils are available.

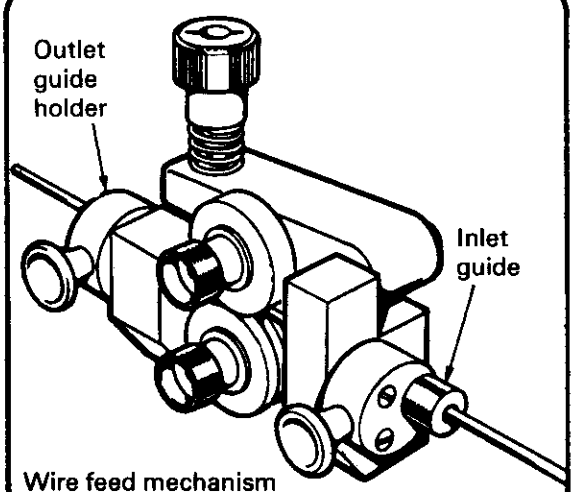
Mild steel and low alloy steel electrode wires are usually coated with a thin layer of copper. This gives a measure of corrosion resistance and improves the electrical contact.

Aluminium and aluminium alloy electrode wires have to be specially processed to reduce the gas content of the material and to give a clean surface to the wire. Two methods are in general use: one in which the oxidized wire surface is mechanically skimmed and the other in which the wire is pickled and chemically cleaned.

It is important that electrode wire should be stored carefully in dry, dust-free conditions. During use it should be protected by a plastic cover or other means. Contaminated wire will cause defective welds.



Wire feed mechanism opened



Wire feed mechanism with wire threaded

Wire feed mechanism

Fitting electrode wire

Equipment varies considerably in the manner of fitting and feeding electrode wire.
The examples chosen illustrate the principles.
Always consult the manufacturer's instruction book!

1. Locate reel of wire on hub or spindle so that wire will be drawn off in the correct direction. Do not release the reel binding at this stage.

2. Loosen braking mechanism so that reel runs freely. Then tighten just sufficient to prevent overrun of spool when wire is drawn off.

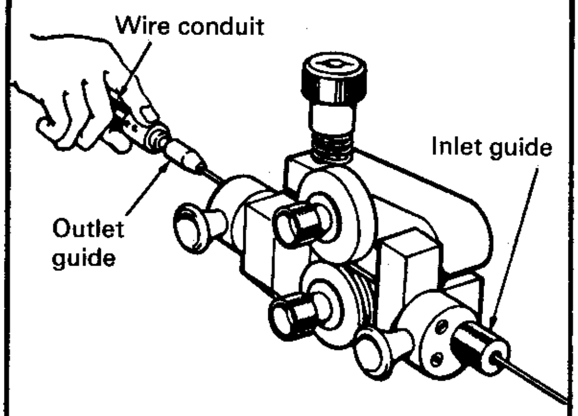
3. Fit correct size inlet guide to wire feed mechanism.

4. Release the end of the wire from the reel binding but do not allow wire to become loose on the reel.

5. Cut off the kinked end of the wire cleanly, making sure that the cut end is not jagged or burred.

6. Thread the wire through the opened wire feed mechanism.

7. Close the wire feed rolls so that the wire is gripped and adjust pressure in accordance with manufacturer's instructions.



Fitting wire conduit

Safety

Do not touch electrode wire when the current is switched on.

With the reel-on-gun assembly, the wire can now be 'inched' through the gun nozzle when the current is switched on.

8. After making sure that all hose assembly connections other than the wire conduit connection have been made fit, the correct size outlet guide to the wire conduit.

9. Thread the outlet guide over the electrode wire protruding from the wire feed mechanism and lock the guide in position.

10. The wire can now be 'inched' through the conduit to the gun/torch contact tube when the current is switched on.

11. Adjust the position of contact tube end/tip and fit gas nozzle.

Operating the equipment

The following applies to all the remaining sections of this manual.

1. The Example Procedures are written for right-handed persons. Unless otherwise stated, adaptations of the procedure for left-handed persons simply involve reversal of direction.

2. In this manual, torch angles (ie. slope and tilt) have either been indicated in the related diagrams or are obvious as described in the text.

3. Two tack lengths are given in the text of the Example Procedures for thin and thick materials respectively. Alternatively, tack lengths can be based on thickness, using the relationship tack length = 2 to 3 x thickness of material (2–3t).

Controls

All equipment will have the controls 1 and 2:

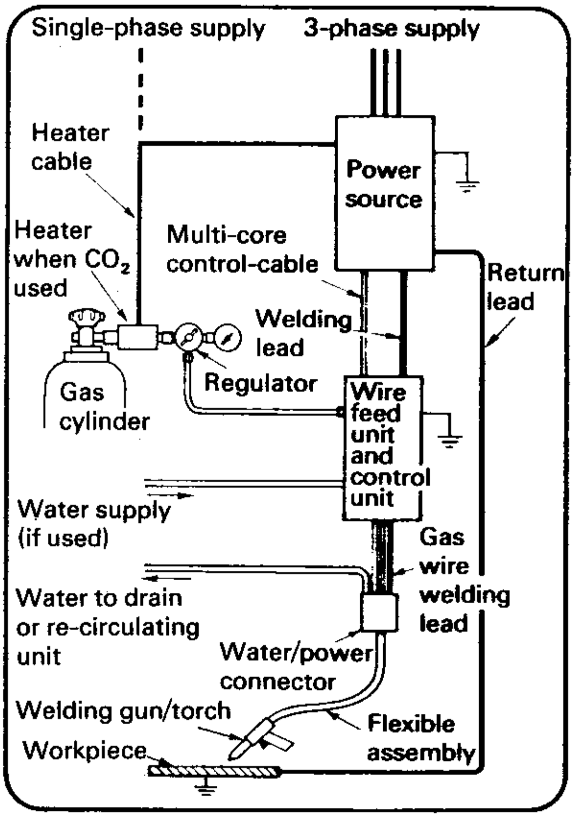
1. Voltage control—governs arc length.

2. Wire feed control—governs welding current.

3. Equipment designed specifically for Dip Transfer welding will have an inductance control. This governs the rate of rise of current during short circuit and therefore it controls the frequency of short-circuiting and the weld profile. It is also used to regulate the amount of spatter.

4. Equipment designed for Pulse Transfer will have a pulse height control. This regulates the maximum voltage of each pulse.

5. Some power sources may be fitted with a pulse frequency control.



General procedure

The following general instructions, which are not repeated in the text, apply to metal-arc gas shielded welding.

Always:

1. Comply with the prescribed safety precautions and fire-prevention procedure.

2. Check that the return lead is firmly connected to workpiece and power source.

3. Check that all connections to wire feed and/or control unit are in good order.

4. Check that gas and water hoses are not 'kinked' or otherwise obstructed.

5. Check that power source is switched on.

6. Check that gas cylinder valve is open and when using carbon dioxide from syphon cylinder, that the heater-vaporizer is switched on five minutes before commencing welding.

7. Check that the regulator pressure is set to 2·1 bar.

8. Check that correct size contact tube/tip is fitted to gun/torch.

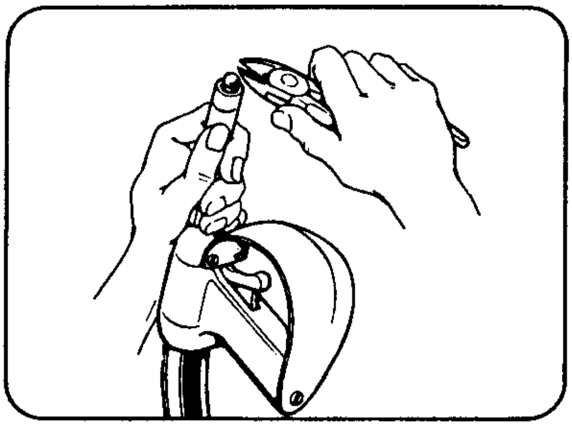
9. Check that correct size gas nozzle is fitted.

10. Check that the electrode wire extension and the relative positions of the exit ends of the contact tube and gas nozzle are correct.

11. Check that the 'burn-off' control (if fitted) is adjusted so that the electrode wire extension is correct after breaking the arc.

12. Check that the gas flow is correctly set (while purging the air from the flexible tube assembly).

13. Check that the water supply is turned on if using a water-cooled gun.

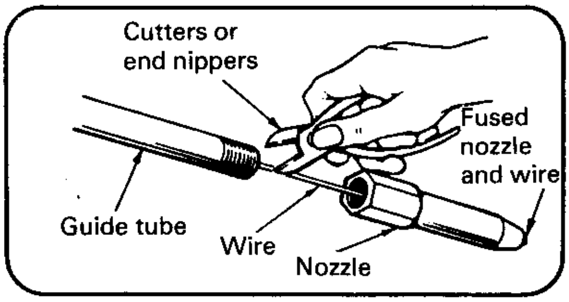


Clearing a 'burn-back'

A 'burn-back is the result of an electrode wire fusing against the contact tube end, do not attempt to clear the burn-back by repeated operation of the control switch on the gun/torch as the feed roll will 'chew' and deform the wire. This situation may result in another burn-back.
1. Release the switch on the welding gun/torch immediately the burn-back occurs.

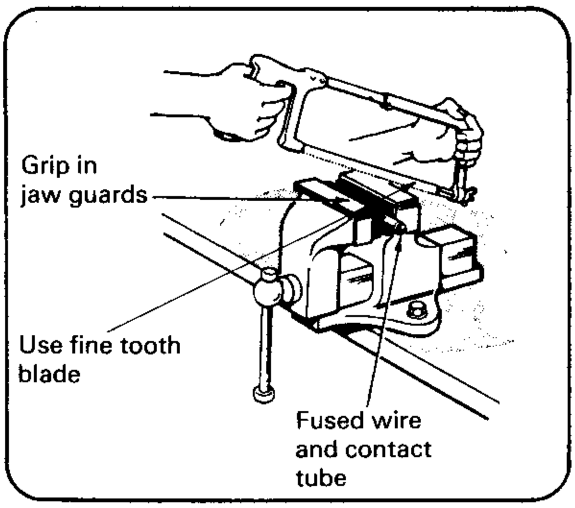
2. Remove gas nozzle and try to free wire from end of contact tube/tip with wire clippers.

3. If wire is fused tight release the pressure on the electrode wire feed rolls and unscrew contact tube/tip.



4. Clip wire and remove fused portion from contact tube/tip by gripping wire in vice. It may be necessary to file the end of the contact tube/tip, to remove the fused portion of wire, and clean and de-burr it.

5. Where contact tube does not have a screwed tip and wire is fused tight, release the pressure on the electrode wire feed rolls and remove contact tube from torch/gun.



6. Clip wire and remove fused portion from contact tube by gripping wire in vice. In bad cases, it may be necessary to cut off the end of the contact tube with a hacksaw to clear the fused wire.

7. Replace seriously damaged contact tube/tips and contact tubes that have been shortened to below the specified minimum length.

8. Before refitting contact tube or tip, feed sufficient wire through the gun/torch to make sure that the wire scored by the feed roll when the burn-back occurred is discarded.

Closing-down procedure

1. Switch off power source supply current.
2. Close gas cylinder valve.
3. Switch off heater-vaporizer (if used).
4. Turn off water supply (if used).
5. Place torch/gun in a safe place.
6. Cover wire feed and/or control unit to protect from damp and dust.

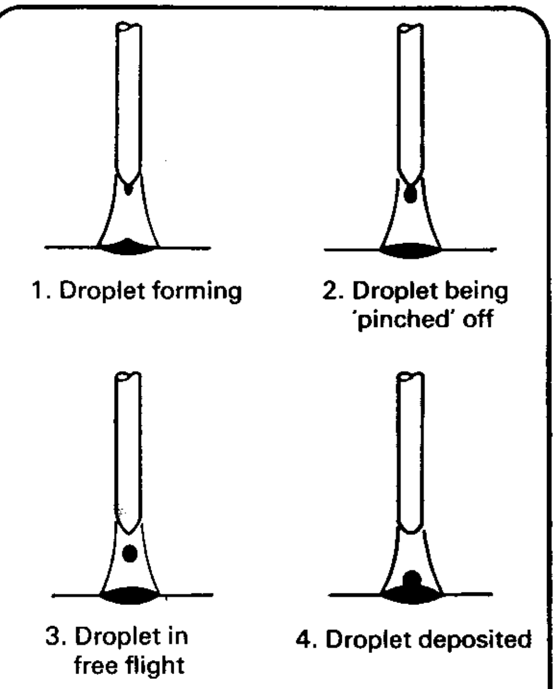
Metal-arc gas shielded welding

Operating ranges

High currents
(240–500 A) are used when good penetration and high deposition rates are required.

Spray transfer
In this range, the molten metal from the end of the electrode is transferred across the arc in the form of small droplets. This mode of metal transfer is called spray or free-flight.

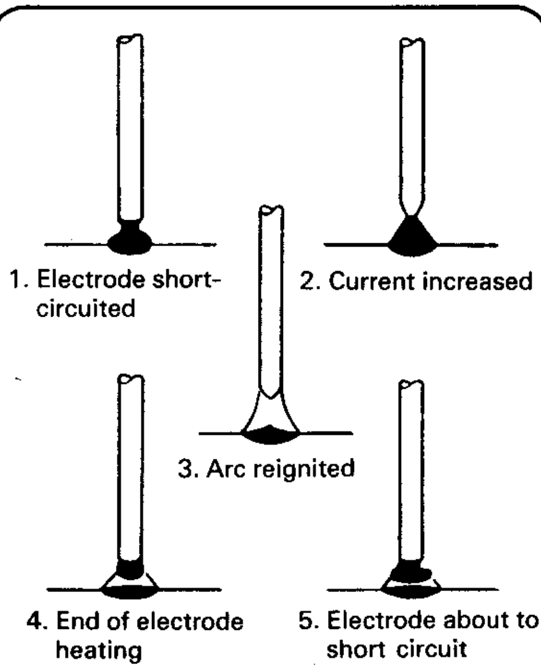
Spray transfer can be used for welding aluminium in any position. It can only be used satisfactorily on other metal when welding in the flat position (all joints) or in the horizontal-vertical position (tee joints only).



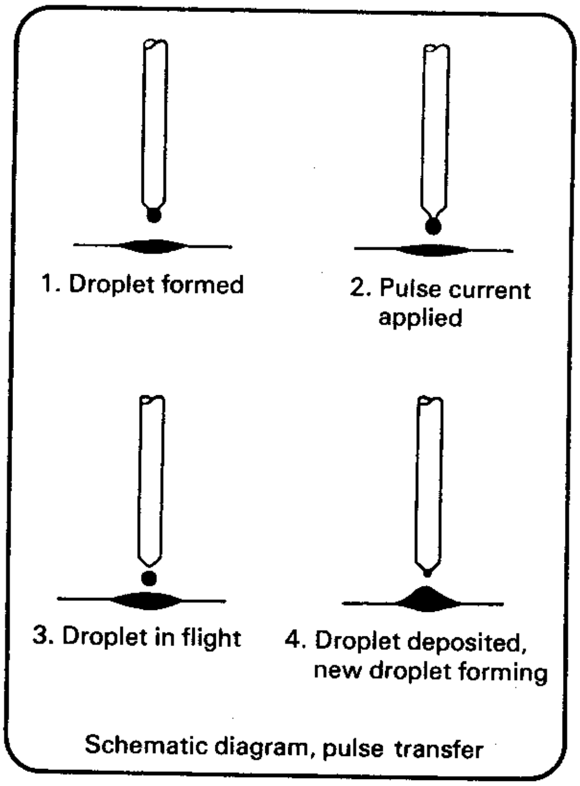
Schematic diagram, spray transfer

Low currents
(80–200 A) must be used for welding in position or for the welding of thin material. The arc must be stabilised by modifying the form of metal transfer. Two systems are in common use.

1. Dip transfer
When the arc length is short (ie. arc voltage is low) the end of the electrode touches the weld pool and the current rises. The end of the electrode melts off and flows into the weld pool. This sequence is repeated automatically 50–200 times per second and is only suitable for use with metals which have a relatively high electrical resistance (eg. steel).



Schematic diagram, dip transfer

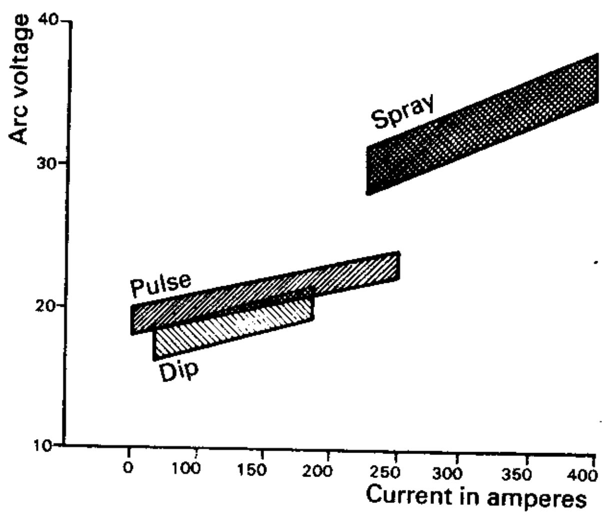


Schematic diagram, pulse transfer

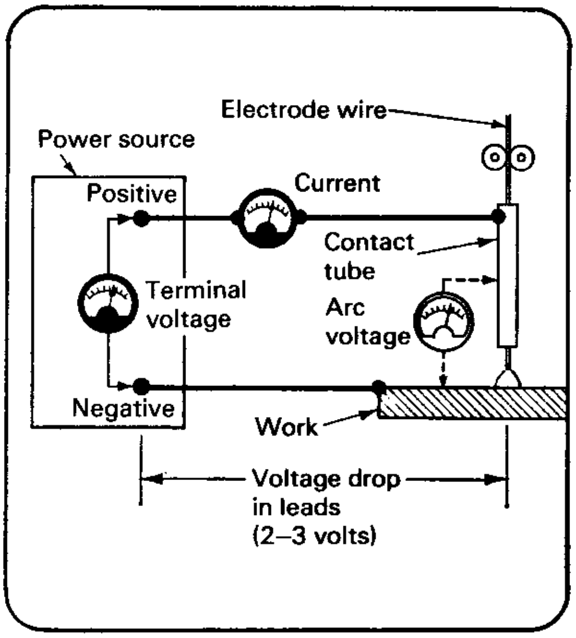
2. Pulse transfer

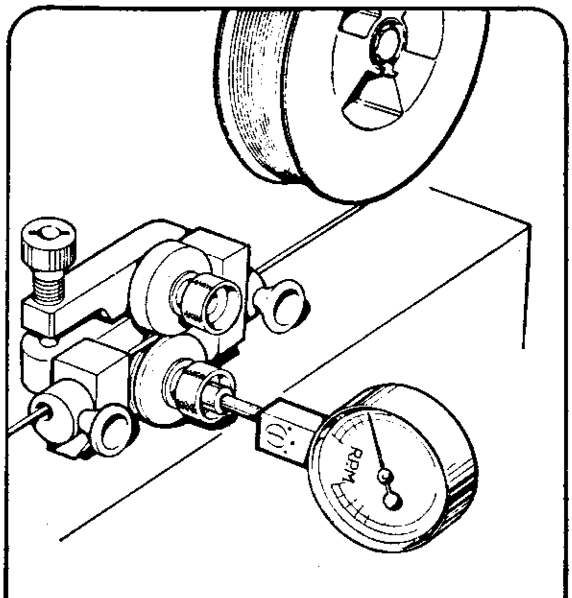
When an arc is operated at low currents, the end of the electrode will melt slowly. If the arc is operated at voltages similar to those used for spray transfer, a large globule will be formed which, in time, would be detached by gravity. A series of short duration, high current pulses (33–100 per second) supplied to the arc will detach droplets from the end of the electrode before they have had sufficient time to become large, thus simulating spray transfer but at low currents. This is known as Pulse Transfer and can be used on most metals.

A graphical illustration showing typical operating ranges for Spray, Dip and Pulse transfer with 1·2 mm diameter wire is provided below.

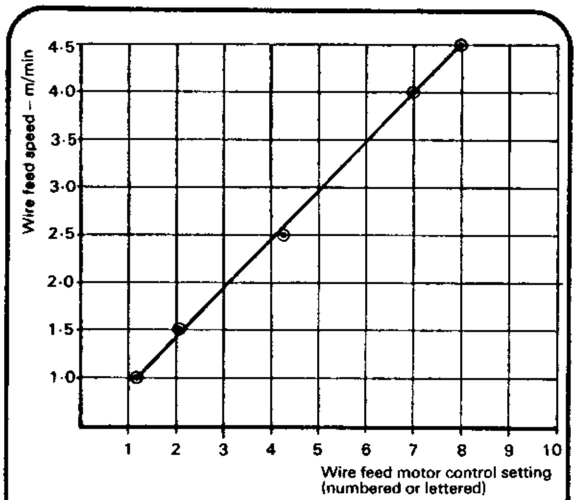


Metal-arc gas shielded welding





Checking wire feed speed with tachometer



Typical calibration chart for wire feed unit

Welding conditions

In the Example Procedures which follow, the electrical conditions quoted are intended as a guide. They are not precise because the actual settings will depend on the composition of the wire, the amount of electrode extension and so on.

Measurements

1. *Voltage* is usually indicated by a voltmeter incorporated in the power source. The meter indicates *terminal voltage.* The actual *arc voltage* will be lower because there is a voltage drop as the welding current flows through the leads. With the correct size cable and with good connections, the voltage drop in the leads is usually about 2 to 3 volts for nominal 3 m lengths.

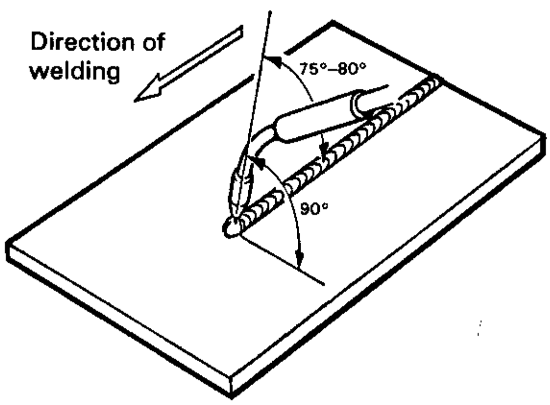
2. *Current* is indicated by an ammeter positioned in the power source.
With *spray conditions* the meter gives the actual welding current.
With *dip and pulse transfer* the indicated reading is a mean value between the highest and the lowest currents experienced in the welding cycle.

3. *Wire feed speed* is not normally metered on commercial equipments. It can be measured by using a tachometer attached to the drive rolls. This will indicate the speed of rotation of the rolls. The wire feed speed can then be calculated.
Wire feed speed = (revolutions per minute) × (circumference of the drive rolls). In the Example Procedures, wire feed speed is quoted in metres per minute (m/min).
Alternatively, the wire can be fed for a carefully determined period of time (say 10 or 20 secs) and the length of wire measured.
Data collected from these measurements can be used to calibrate the wire feed control of the machine on which the measurements were made.

> When measuring wire feed speed, disconnect the welding return lead to prevent stray arcing. Reconnect before welding. Always have the wire feeding and use the correct pressure on the rolls when measuring wire feed.

4. *Inductance* cannot be measured easily. Variable inductances are calibrated with an arbitrary scale, usually marked from 0–10. These numerical settings cannot be transferred from one make of equipment to another.

Metal-arc gas shielded welding



Standard torch angles

Example procedures

Establishing correct welding conditions
Ensure familiarity with the effect each control has on the characteristics of the weld deposit.

Control of arc length—Spray transfer
Example procedure EP/M/1

Material	One piece of mild steel 9 mm thick. Min. size 150 mm x 75 mm
Preparation	Clean surface
Electrode	1·2 mm
Shielding gas	Argon-20% CO_2 or carbon dioxide at 0·9 to 1·0 m^3/hr
Arc type	Spray transfer

1. Set wire feed speed to 8 m/min.
2. Set open circuit voltage to 38 V and deposit a weld run in the flat position, keeping the contact tube-to-plate distance at 20 mm. Note the voltage reading during welding.
3. Reduce open circuit voltage by 2 V and deposit further weld bead, maintaining the same contact tube-to-plate distance. Note the change in arc length and compare the surface profile of the weld beads.
4. Reduce the voltage by steps of 2 V until the electrode just starts to short circuit regularly. Observe the appearance of the weld bead. This voltage represents the lower operating limit for welding with Argon-20% CO_2 shielding gas.

Note: In practice, the lower voltage limit is determined by the level at which there is inadequate fusion at the edges of the weld bead.

5. Repeat the procedure using carbon dioxide shielding.

Material	One piece of mild steel or aluminium 9 mm thick. Min. size 150 mm × 75 mm
Preparation	Clean surface
Electrode	1·2 mm for mild steel 1·6 mm for aluminium
Shielding gas	Mild steel: carbon dioxide or argon-20% CO_2 Aluminium: argon 0·9–1·0 m^3/hr gas flow
Arc type	Spray transfer

Control of current—Spray transfer
Example procedure EP/M/2

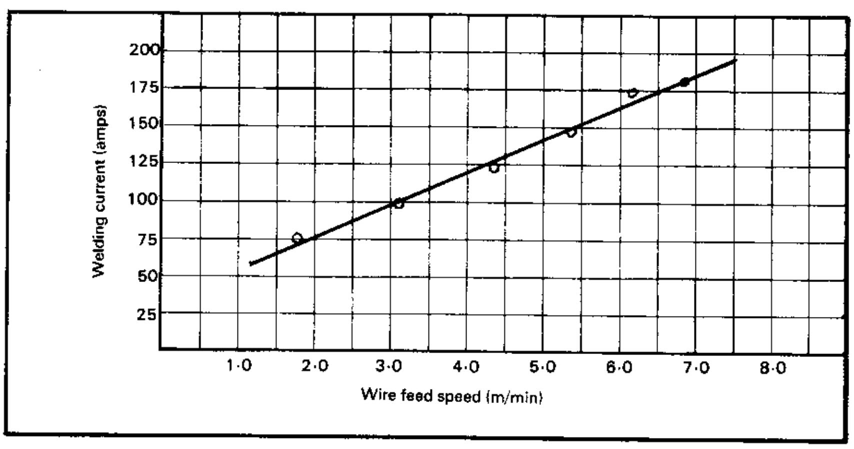
1. Set open circuit (OC) voltage to 35 V for mild steel (28 V for aluminium).

2. Set wire feed speed to 8 m/min for steel (7 m/min for aluminium) and deposit a weld run, noting the current during welding.

3. Reduce the wire feed speed by steps of 0·75 m/min for steel (0·25 m/min for aluminium). Keep contact tube-to-plate distance and travel speed constant. Deposit weld runs noting the current and the appearance of the weld bead.

4. Note the wire feed speed at which the metal transfer becomes unsatisfactory (globular). This is the lowest possible operating limit for spray transfer. Normally, welding currents should be at least 25–50 A higher than this level.

5. Record the results in the form of a *burn-off curve.*



Typical burn-off curve for mild steel electrode

Material	One piece of mild steel 6·5 mm thick. Min. size 150 mm × 75 mm
Preparation	Clean surface
Electrode	1·0 mm or 1·2 mm diameter
Shielding gas	Carbon dioxide 0·5–0·6 m³/hr
Wire feed speed	4·25 m/min
Arc type	Dip transfer

On some equipments the welding current must be switched off before adjusting voltage and/or inductance. Check with manufacturer's handbook.

Some equipments designed for dip transfer welding are not fitted with external inductance control. In these cases consult manufacturer's handbook.

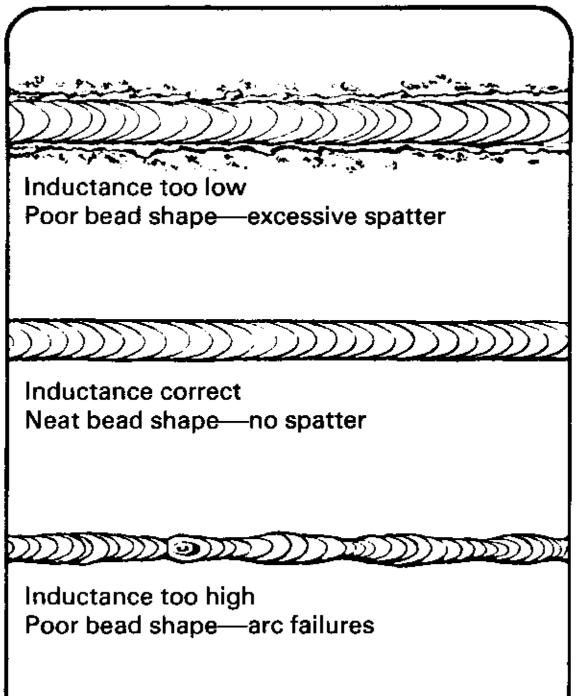
Setting-up for dip transfer welding
Example procedure EP/M/3

The choice of wire diameter will depend on a number of factors related to the type of work, plate thickness and joint configuration.

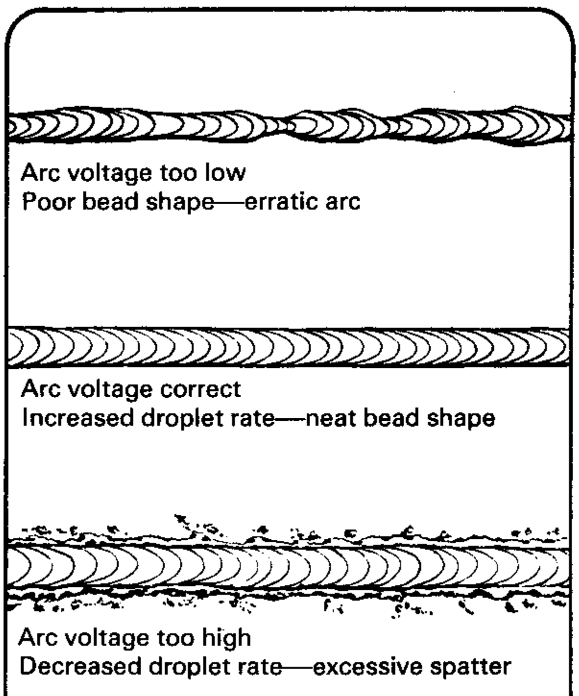
In this Example Procedure, the use of either 1 mm or 1·2 mm diameter wire is suggested since these sizes are frequently employed in practice.

1. Set open-circuit voltage to 22–24 V.
2. Set inductance at mid-point.
3. Set wire feed speed to 4·25 m/min.
4. Deposit weld bead. Adjust voltage to give good fusion at the edges and a smooth weld profile, especially at the toes of the weld.
5. Adjust inductance to give minimum spatter.
6. If electrode stubs into weld pool, increase voltage.
7. Examine weld bead:

If weld bead is too small—increase wire feed speed.
If weld bead is too large—decrease wire feed speed.
If weld bead is 'peaky'—increase voltage.
If there is inadequate fusion at the edges—increase voltage and/or increase inductance.

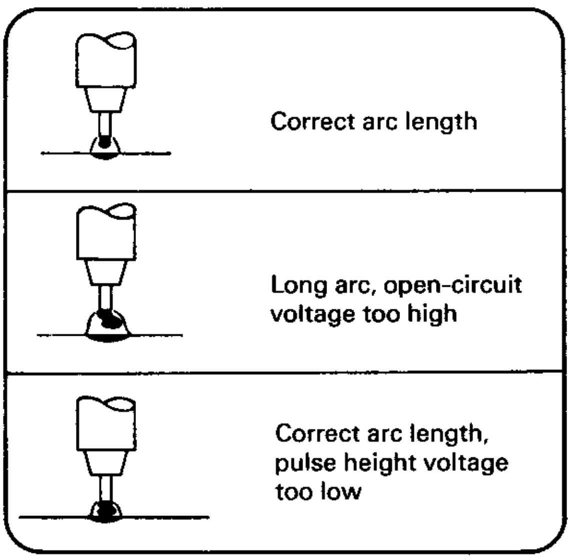


Effect of inductance on weld bead



Effect of arc voltage on weld bead

Material	One piece of mild steel or aluminium 6 mm thick. Min. size 200 mm x 100 mm
Preparation	Clean surface
Electrode	Mild steel: 1·2 mm Aluminium: 1·6 mm
Shielding gas	Mild steel: argon-5% CO_2 at 0·6–0·7 m^3/hr Aluminium: argon at 1·0 m^3/hr
Wire feed speed	Mild steel: 3·75 m/min Aluminium: 2·5 m/min



Setting-up for pulsed arc welding
Example procedure EP/M/4

1. Set wire feed speed.

2. Set pulse amplitude and background voltage controls to a low level.

3. Deposit weld run and increase background voltage until short-circuiting ceases and globular transfer is obtained.

4. Progressively increase pulse height until globular transfer just disappears. Each change in pulse height should be accompanied by a reduction in background voltage to maintain the arc length constant.

5. Increase pulse amplitude by 1 volt (use meter on power source as a guide).

6. Finally, adjust background voltage to give correct arc length.

7. Examine weld bead, paying particular attention to the shape and size of the deposit, the degree of fusion at the edges and the profile at the toes.

If the heat input is too high, ie.:
(a) weld pool is too large
(b) deposit is too heavy
(c) weld pool cannot be controlled in positional welding,
reduce wire feed speed and reduce background voltage to give correct arc length.

If the heat input is too low, ie.:
(a) deposit is too small
(b) weld profile is unsatisfactory
(c) fusion at edges is poor,
increase wire feed speed and increase background voltage to give correct arc length.

Material	One piece of aluminium 6 mm thick. Min. size 200 mm × 100 mm
Preparation	Clean surface
Electrode	1·6 mm
Feed rate	3·25–3·65 m/min
Shielding gas	Argon at 1·0 m^3/hr
Current	110–120 A
Peak voltage	33–34 V
Background voltage	19–21 V

Pulse transfer—Vertical position
Example procedure EP/M/5

1. Hold the plate vertically in a clamp at about chest level.

2. Establish an arc 25 mm from the lower edge.

3. Direct the electrode wire upwards at an angle of 65°–75°.

4. Travel upwards in a straight line. Adjust the speed of travel to give good fusion at the leading edge of the weld pool but without allowing the molten metal to flow downwards.

Visual examination
Examine the completed weld bead.

Excessive convexity and undercut indicate slow travel speed.

Overlap at edges of weld bead indicates fast travel speed or inadequate current.

Material	One piece of mild steel 3·2 mm thick. Min. size 200 mm × 100 mm
Preparation	Clean surface
Electrode	1·0 mm
Feed rate	3·2–3·6 m/min
Shielding gas	Carbon dioxide or argon-20% CO_2 at 0 5–0·6 m^3/hr
Current	125–135 A
DC voltage	24–25 V
Arc voltage	21–22 V

Dip transfer—Vertical position
Example procedure EP/M/6

1. Support the plate as in EP/M/5 and establish a weld pool 25 mm from the top edge.

2. Hold the gun with the electrode pointing upwards at an angle of 55°–65°.

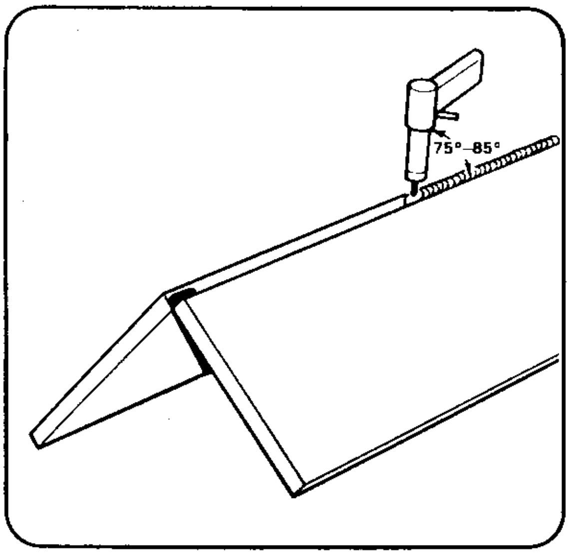
3. Travel down the plate in a straight line, ensuring that the parent material is fused. Adjust travel speed to avoid molten metal running ahead of the arc.

Visual examination
Examine the completed weld as in EP/M/5.

Metal-arc gas shielded welding

Corner joint—Spray transfer—Flat position
Example procedure EP/M/7

Material	Two pieces of aluminium 5 mm thick. Min. size 200 mm x 100 mm
Preparation	Square edge
Assembly	Tack weld both ends to give included angle of 90° no gap. Place on bench with joint-preparation uppermost and line of joint parallel with front of bench
Electrode	1·6 mm
Feed rate	5·6–6·1 m/min
Shielding gas	Argon at 1·0–1·1 m^3/hr
Current	190–215 A
Arc voltage	24 V



1. Establish the arc on the tack weld at the right-hand end of the joint.

2. As soon as pool of molten metal is formed to full depth of joint preparation move the gun progressively leftwards.

3. Point the electrode at the root of the joint at an angle of 75°–85°.

4. Adjust the rate of travel so that the deposit fills the joint.

5. Complete the weld by fusing into the tack weld at the left-hand end of the joint.

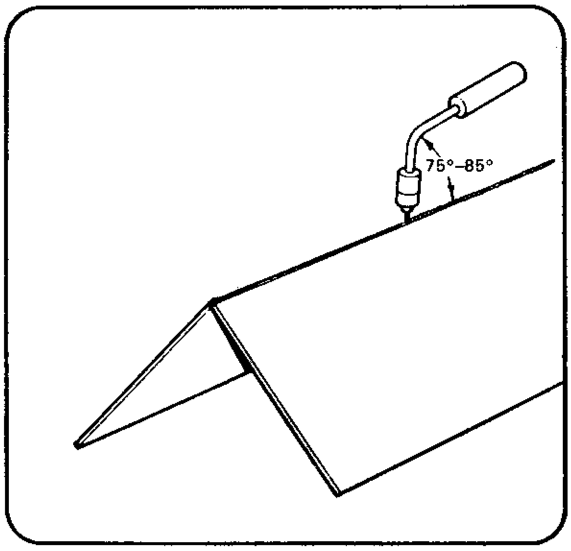
Visual examination

A satisfactory weld will show that the deposited metal has filled the joint without excessive melting away of the top edges of the fusion faces.

There should be signs of penetration to the root on the reverse side of the joint without burn-through.

The above also applies to EP/M/8 and M/9.

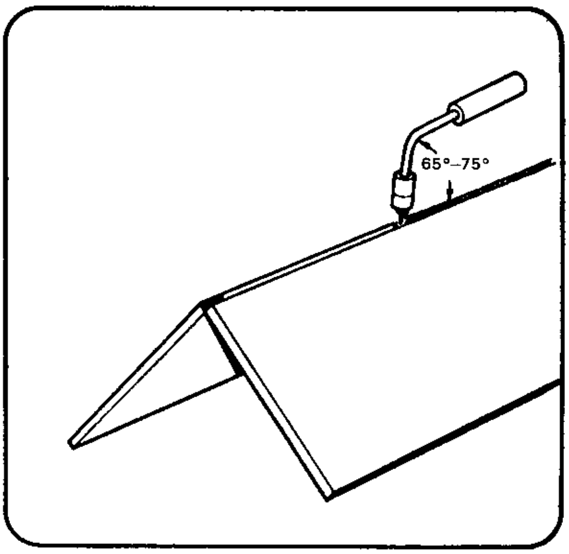
Metal-arc gas shielded welding



Corner joint—Pulse transfer—Flat position
Example procedure EP/M/8

Material	Two pieces of aluminium 2 mm thick. Min. size 150 mm × 100 mm
Preparation	Square edge
Assembly	As for EP/M/7
Electrode	1·6 mm
Feed rate	2·0–2·3 m/min
Shielding gas	Argon at 0·9–1·0 m^3/hr
Current	65–75 A
Peak voltage	33–44 V
Background voltage	17–18 V

1. Proceed as in EP/M/7 except for the amended welding conditions.



Corner joint—Dip transfer—Flat position
Example procedure EP/M/9

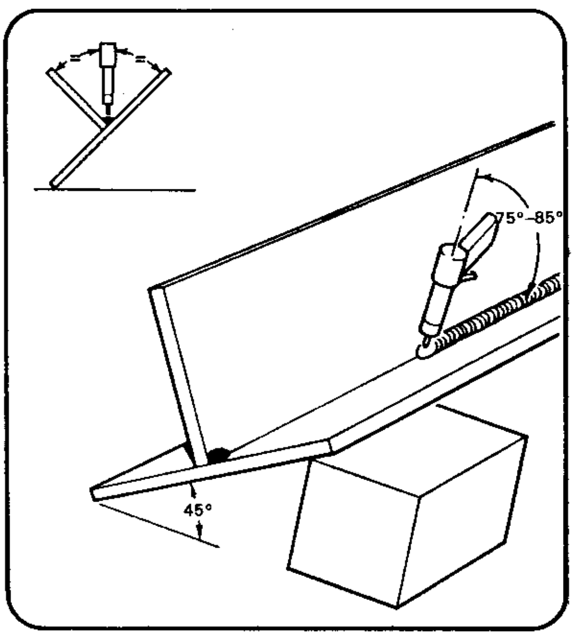
Material	Two pieces of mild steel 3 mm thick. Min. size 150 mm × 100 mm
Preparation	Square edge
Assembly	As for EP/M/7
Electrode	1·2 mm
Feed rate	3·0–3·3 m/min
Shielding gas	Carbon dioxide at 0·9–1·0 m^3/hr
Current	130–150 A
OC voltage	19–21 V
Arc voltage	19–20 V

1. Proceed as in EP/M/7 except for the amended welding conditions and with the electrode pointed at an angle of 65°–75°.

Metal-arc gas shielded welding

T joint—Spray transfer—Flat position
Example procedure EP/M/10

Material	Two pieces of mild steel 10 mm thick. Min. size 200 mm x 100 mm
Preparation	Square edge
Assembly	Tack weld both ends to form an inverted T joint without gap between the two plates. Support the assembly so that the lower plate is inclined transversely at 45°.
Electrode	1·6 mm
Feed rate	5·6–6·4 m/min
Shielding gas	Argon-20% CO_2 at 1·0–1·1 m^3/hr
Current	340–360 A
Arc voltage	33–34 V



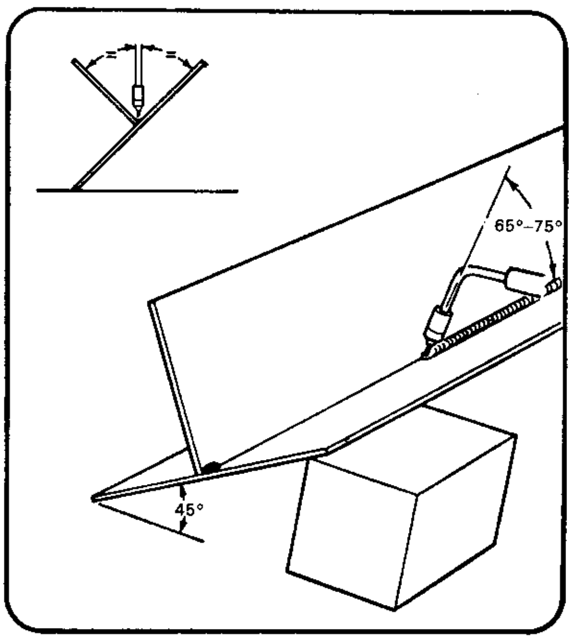
1. Establish the arc at the right-hand end of the joint.
2. When an adequate weld pool is formed, start leftwards movement.
3. Adjust the rate of travel so as to deposit a fillet weld having a leg length of about 5 mm.
4. The electrode should be pointed directly at the root of the joint and at an angle of 75°–85°.
5. A very slight forward and backward reciprocating motion of the welding gun will help to smooth out the weld and give good fusion at the toes.

Visual examination
Examine the weld to check any operating faults. Repeat, welding the other side of the joint after making any necessary corrections to equipment settings, travel speed or electrode angle.
A satisfactory weld should be evenly disposed in the joint, be of uniform leg length and free from undercut at the toes.

Metal-arc gas shielded welding

T joint—Dip transfer—Flat position
Example procedure EP/M/11

Material	Two pieces of mild steel either (a) 1·5 mm or (b) 5 mm thick. Min. size 200 mm × 100 mm
Preparation	Square edge
Assembly	As for EP/M/10
Electrode	(a) 0·8 mm; (b) 1·2 mm
Feed rate	(a) 3·3–3·5 m/min (b) 2·5–2·8 m/min
Shielding gas	Carbon dioxide at 0·7–0·8 m^3/hr
Current	(a) 90–100 A (b) 110–120 A
Arc voltage	(a) 17–18 V (b) 19–20 V
OC voltage	(a) 19–20 V (b) 21–22 V



1. Establish the arc at the right-hand end of the joint.

2. As soon as fusion is established commence the leftwards movement.

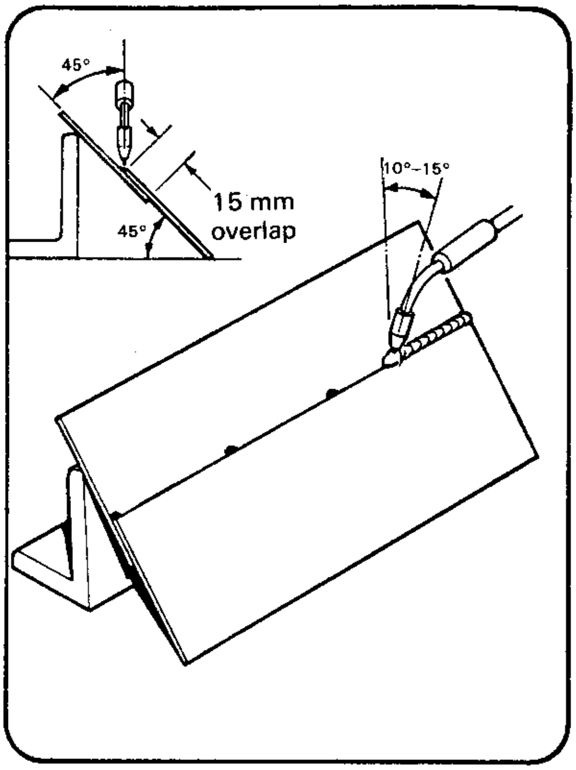
3. Adjust the rate of travel to deposit a fillet weld having a leg length of about:
(a) 2·5 mm
or
(b) 5 mm.

4. The electrode should be held without weaving at an angle of 65°–75° and pointed directly at the root.

Visual examination
Examine the weld to check any operating faults. Repeat, welding the other side of the joint after making any necessary corrections to equipment settings, travel speed or electrode angle.
A satisfactory weld should be evenly disposed in the joint, be of uniform leg length and free from undercut at the toes.

Metal-arc gas shielded welding

Lap joint—Dip transfer—Flat position
Example procedure EP/M/12



Material	Two pieces of mild steel 2 mm thick. Min. size 200 mm x 100 mm
Preparation	Square edge
Electrode	1·0 mm
Feed rate	3·0–3·1 m/min
Shielding gas	Argon-20% CO_2 at 0·8–0·9 m^3/hr
Current	100–110 A
Arc voltage	18–19 V
OC voltage	21–22 V

1. Assemble joint with an overlap of 15 mm.

2. Tack weld at ends and at 65 mm intervals on both sides of sheet.

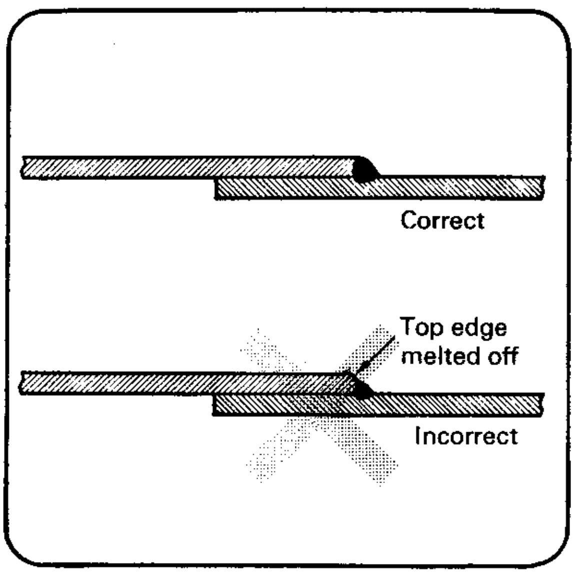
3. Support the assembly so that the weld is deposited in the flat position.

4. Strike arc on tack weld at one end of joint and deposit weld along joint line.

5. Adjust travel speed to prevent burn-through of lower sheet.

6. Arc should be directed slightly away from edge of top sheet.

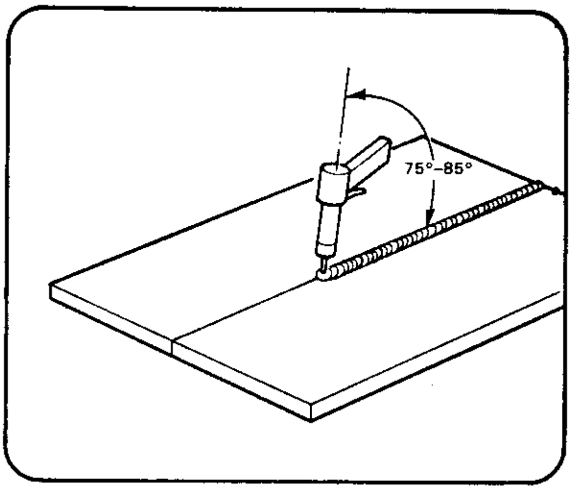
7. Complete weld on opposite side and examine both welds for correct profile.



Metal-arc gas shielded welding

Close square butt joint—Spray transfer—
Flat position
Example procedure EP/M/13

Material	Two pieces of aluminium alloy 5 mm thick. Min. size 200 mm × 100 mm
Preparation	Square edge
Assembly	Tack weld with three tacks, no gap. The use of stainless steel grooved backing bar is recommended
Electrode	1·6 mm
Feed rate	6·1–7·3 m/min
Shielding gas	Argon at 1·0–1·1 m³/hr
Current	200–235 A
Arc voltage	25–26 V



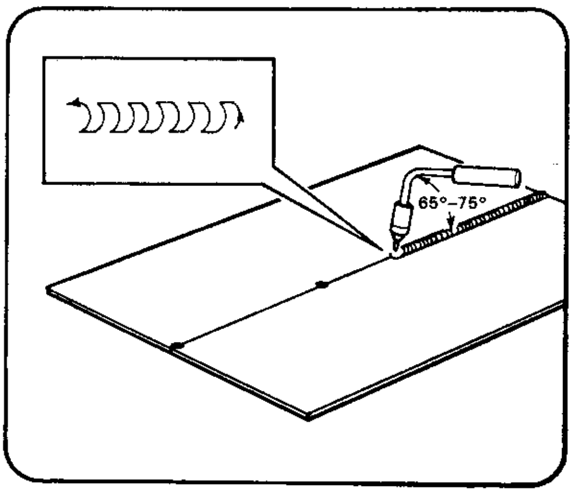
1. Establish the arc on the tack weld at the right-hand end of the joint.
2. When fusion has been obtained to the full depth of the plate, commence the leftwards progression.
3. The electrode should be pointed at an angle of 75°–85° without weaving.
4. Adjust the rate of travel so that the deposited metal is built up just proud of the plate surface and burn-through is avoided.

Visual examination
The weld face should be of even width, free from undercut at the toes. The profile should be slightly convex.
There should be full penetration with a slight penetration bead showing on the reverse side of the joint.

Metal-arc gas shielded welding

Open square butt joint—Dip transfer—
Flat position
Example procedure EP/M/14

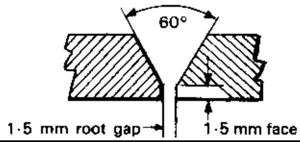
Material	Two pieces of mild steel 1·6 mm thick. Min. size 200 mm × 100 mm
Preparation	Square edge
Assembly	Tack with 1·5 mm gap
Electrode	0·8 mm
Feed rate	3·5–3·9 m/min
Shielding gas	Carbon dioxide at 0·7–0·8 m^3/hr
Current	110–130 A
Arc voltage	18–19 V
OC voltage	21–22 V

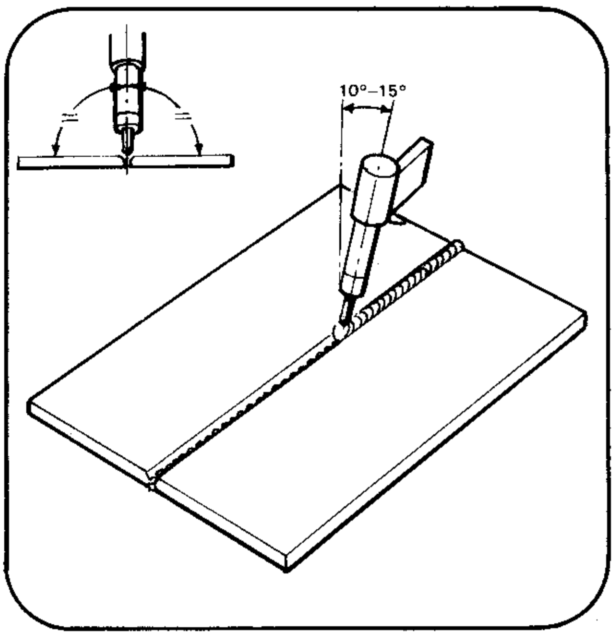


1. Establish the arc at the right-hand end of the joint.
2. Adjust the rate of leftwards travel to secure fusion of the spaced edges of the parent metal while avoiding burn-through.
3. Use a small side-to-side movement to ensure fusion of sheet edges.

Visual examination
The weld face should be of even width, free from undercut at the toes. The profile should be slightly convex.
There should be full penetration with a slight penetration bead showing on the reverse side of the joint

Butt joint—Spray transfer—Flat position
Example procedure EP/M/15

Material	10 mm mild steel 2 off Min. size 200 mm × 100 mm	
Preparation and assembly	Single vee tack with three tack welds in root 	
Location of weld run	**Root**	**Filling passes**
Type of transfer	Dip	Spray
Electrode	0·8 mm	1·6 mm
Feed rate	3·5–3·9 m/min	5·6–6·4 m/min
Shielding gas	Carbon dioxide or argon-20% CO_2 at 0·7–0·8 m^3/hr	Carbon dioxide or argon-20% CO_2 at 1·0–1·1 m^3/hr
Current	120–140 A	340–360 A
Arc voltage	18–19 V	33–34 V

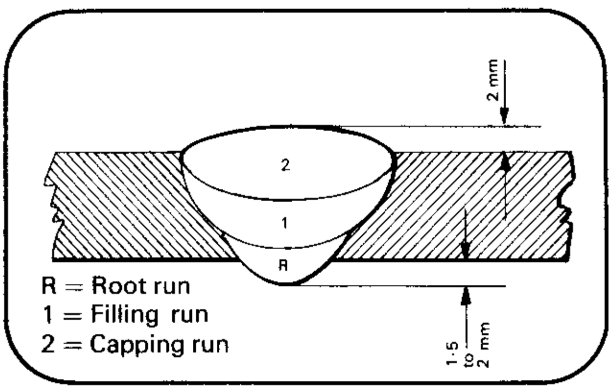


1. Deposit the root run using the procedure given in EP/M/14 for 1·6 mm sheet.

Note: Pulse transfer may be used for the root run as an alternative to dip transfer.

2. Wire brush the surface of the root run, removing any silicate deposits.

3. Deposit a weld run with spray transfer. Adjust the travel speed so that the surface of the weld run is about 2 mm below the surface of the plate. Ensure good fusion into the surface of the root run.



R = Root run
1 = Filling run
2 = Capping run

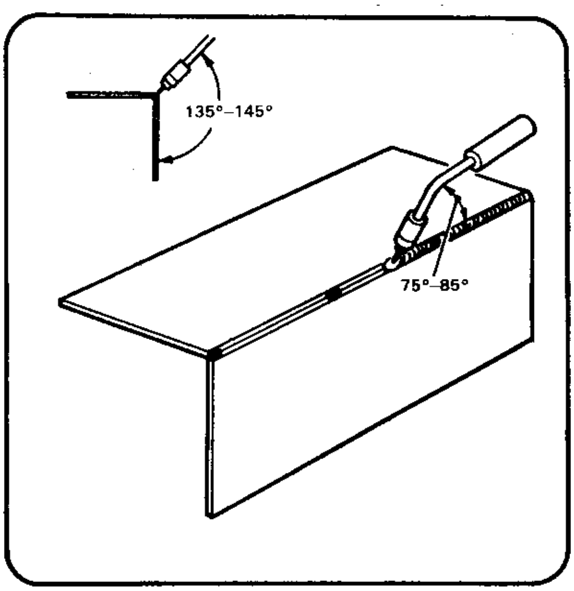
4. Wire brush the surface of the first (filling) run and deposit the second (capping) run. Aim to just overfill the vee preparation so that the finished weld has an excess metal (reinforcement) height of 2 mm.

Visual examination
Examine the completed weld for uniform root penetration and absence of undercut at the toes of the weld on the top surface.

Metal-arc gas shielded welding

Corner joint—Pulse transfer—
Horizontal-vertical position
Example procedure EP/M/16

Material	Two pieces of aluminium 2 mm thick. Min. size 200 mm × 100 mm
Preparation	Square edge
Assembly	Tack weld with three tacks to give included angle of 90°, no gap. Support to form an inverted L with the horizontal sheet pointing away from the welder
Electrode	1·6 mm
Feed rate	2·0–2·3 m/min
Shielding gas	Argon at 0·9–1·0 m³/hr
Current	65–75 A
Peak voltage	33–34 V
Background voltage	18–20 V



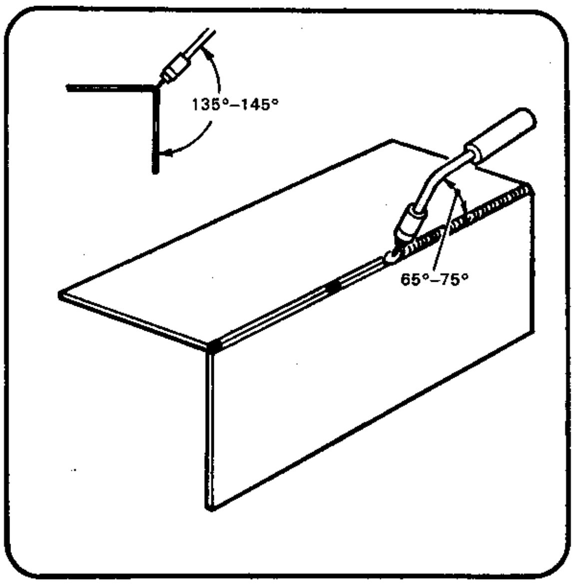
1. Hold the welding torch body so that the electrode wire is pointing to the root of the joint at an angle of 75°–85° and at an angle of 135°–145° to the vertical plate.

2. Establish the arc at the right-hand end of the joint.

3. Adjust the rate of leftwards travel so that the weld metal just fills the joint preparation without excessive burning away at the top edge of the fusion face on the horizontal plate.

**Corner joint—Dip transfer—
Horizontal-vertical position
Example procedure EP/M/17**

Material	Two pieces of mild steel 1·6 mm thick. Min. size 200 mm × 100 mm
Preparation	Square edge and 0·8 mm gap
Assembly	As for EP/M/16
Electrode	0·8 mm
Feed rate	3·0–3·5 m/hr
Shielding gas	Argon-20% CO_2 at 0·7–0·8 m^3/hr
Current	90–100 A
Arc voltage	17–18 V
OC voltage	19–20 V



1. Hold the welding torch body so that the electrode wire is pointing to the root of the joint at an angle of 65°–75° and at an angle of 135°–145° to the vertical plate.

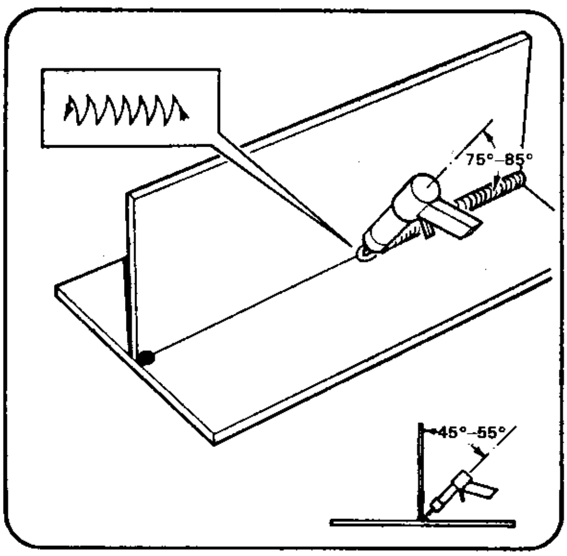
2. Establish the arc at the right-hand end of the joint.

3. Adjust the rate of leftwards travel so that the weld metal just fills the joint preparation without excessive burning away of the top edge of the fusion face on the horizontal plate.

Metal-arc gas shielded welding

T joint—Spray transfer—
Horizontal-vertical position
Example procedure EP/M/18

Material	Two pieces of aluminium alloy 5 mm thick. Min. size 200 mm × 100 mm
Preparation	Square edge
Assembly	Tack weld with three tacks to form an inverted T joint without gap
Electrode	1·6 mm
Feed rate	5·8–6·4 m/min
Shielding gas	Argon at 1·0–1·1 m³/hr
Current	210–230 A
Arc voltage	23–25 V



1. Point the electrode wire at the root of the joint, at an angle of 75°–85° with the welding gun body inclined so that the electrode is at an angle of 45°–55° to the vertical plate.

2. Establish the arc at the right-hand end of the joint.

3. Adjust rate of leftwards progression so as to deposit a fillet weld having a leg length between 5 mm and 6·5 mm.

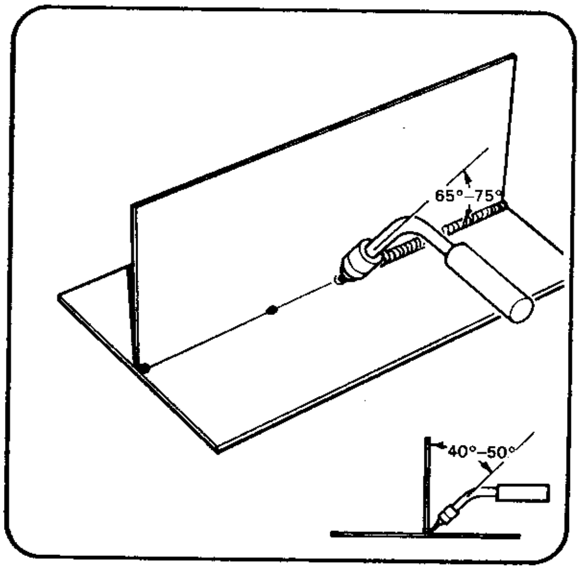
4. A very slight quarter-circle weaving motion from the centre line of the weld, forwards and towards the vertical plate and back, will help to avoid undercut.

Visual examination
A satisfactory weld will have equal leg lengths uniform throughout the length of the weld.
The profile should be slightly convex and free from undercut at the toes.

Metal-arc gas shielded welding

T joint—Dip transfer—Horizontal-vertical position
Example procedure EP/M/19

Material	Two pieces of mild steel 5 mm thick. Min. size 200 mm × 100 mm
Preparation	Square edge
Assembly	As for EP/M/18
Electrode	1·2 mm
Feed rate	3·8–4·1 m/min
Shielding gas	Carbon dioxide at 0·7–0·8 m^3/hr
Current	140–150 A
Arc voltage	20–22 V
OC voltage	25–26 V



1. Point the electrode wire at the root of the joint, at an angle of 65°–75° with the torch body inclined so that the electrode is at an angle of 40°–50° to the vertical plate.

2. Establish the arc at the right-hand end of the joint.

3. Adjust rate of leftwards movement to deposit a fillet weld having a leg length of about 4 mm.

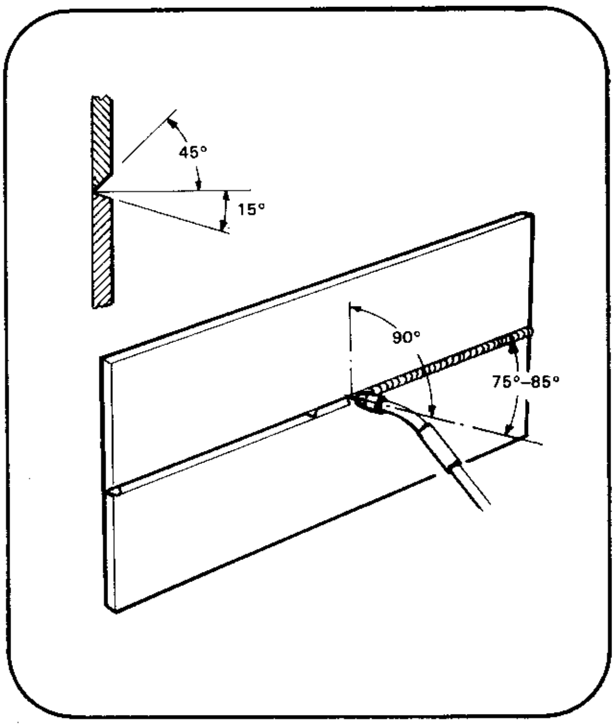
4. A very slight weaving motion as used for EP/M/18 may be used.

Visual examination
A satisfactory weld will have equal leg lengths uniform throughout the length of the weld.
The profile should be slightly convex and free from undercut at the toes.

Metal-arc gas shielded welding

Single V butt joint—Pulse transfer—
Horizontal-vertical position
Example procedure EP/M/20

Material	Two pieces of aluminium alloy 6 mm thick. Min. size 200 mm × 100 mm
Preparation	Lower sheet angle of bevel 15°, upper sheet angle of bevel 45°. No root face
Assembly	Tack weld with three tacks to give included angle of 60°–65°, no gap. Support in a vertical position with line of joint horizontal. Use of stainless steel backing bar optional
Electrode	1·6 mm
Feed rate	3·4–3·7 m/min
Shielding gas	Argon at 1·0–1·1 m^3/hr
Current	100–110 A
Peak voltage	33–34 V
Background voltage	18–20 V



1. Establish the arc at the right-hand end of the joint.

2. The welding gun nozzle should be at right angles to the vertical plates with the electrode wire pointing at the root of the joint at an angle of 75°–85°.

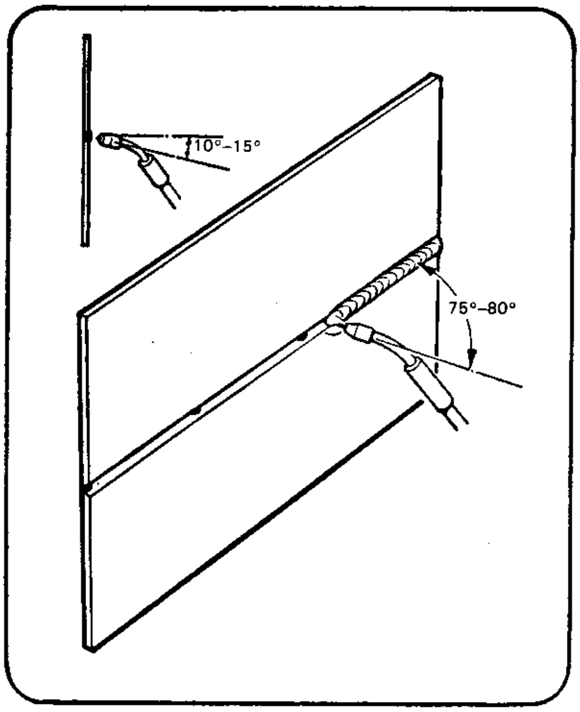
3. Adjust the rate of leftwards travel to secure neat fusion to the outer edges of both fusion faces and ensure that the weld face is not below the parent metal surface.

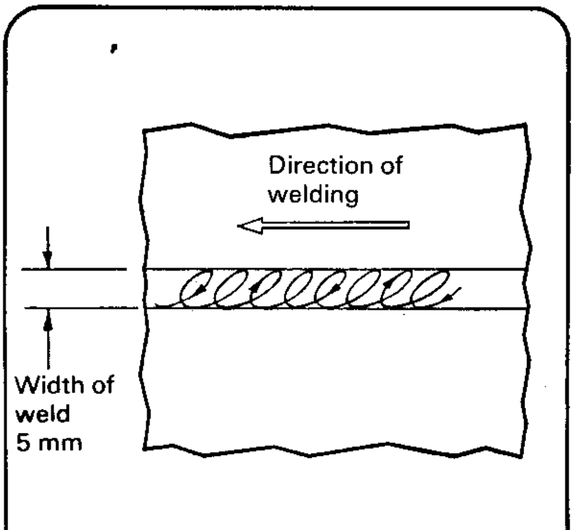
Visual examination
The weld face should be slightly proud of the parent metal surface and without any excessive sagging to the lower toe.
On the reverse side a uniform slight penetration bead should be present.

Metal-arc gas shielded welding

Open square butt joint—Dip transfer—
Horizontal-vertical position
Example procedure EP/M/21

Material	Two pieces of mild steel 3 mm thick. Min. size 200 mm × 100 mm
Preparation	Square edge
Assembly	Tack weld with three tacks so that there is a uniform gap of 1·5–2 mm. Support in vertical position with line of joint horizontal
Electrode	0·8 mm
Feed rate	3·0–3·5 m/hr
Shielding gas	Carbon dioxide at 0·7–0·8 m^3/hr
Current	90–100 A
Arc voltage	17–18 V
OC voltage	19–20 V





Weaving motion in horizontal-vertical butt

1. Establish the arc at the right-hand end of the joint.

2. Hold the torch so that the electrode wire is at right angles to the sheets.

3. Use small weaving motion to ensure fusion of the sheet edges.

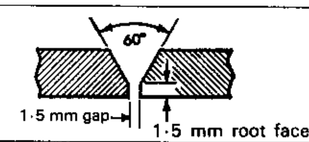
4. Adjust rate of travel to secure fusion without over-penetration.

5. Pay particular attention to torch angles.

Visual examination
Examine complete weld for:
(a) even penetration
(b) uniform profile; the weld must not be offset towards the lower sheet.
The weld face should be slightly proud of the parent metal surface and without any excessive sagging to the lower toe. On the reverse side a uniform slight penetration bead should be present.

Metal-arc gas shielded welding

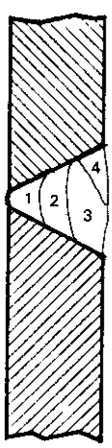
Single V butt joint—Dip or pulse transfer—Horizontal-vertical position
Example procedure EP/M/22

Material	Two pieces of mild steel 10 mm thick Min. size 200 mm × 100 mm			
Preparation				
Type of transfer	Dip		Pulse	
Location of weld run	Root	Filling	Root	Filling
Shielding gas	Carbon dioxide	Carbon dioxide	Argon-5% CO_2	Argon-5% CO_2
Wire diameter, mm	0·8	1	1·2	1·2
Wire feed speed, m/min	4·0–4·5	4·0–4·5	2·5–2·9	3·5–3·9
Welding current	110–130 A	140–160 A	95–100 A	135–145 A
Arc voltage	17–18 V	19–20 V	—	—
Peak voltage	—	—	38–40 V	38–40 V
Background voltage	—	—	20–22 V	23–24 V

1. Strike the arc at the right-hand end of the joint.
2. Deposit the root run. Do not weave but concentrate on achieving penetration and fusion of the root faces.
3. Deposit the second run using a circular weaving motion as in EP/M/21. Adjust travel speed to half fill the vee preparation.
4. Keeping the torch at the angle shown, deposit the third run without weaving. Adjust travel speed to prevent the weld metal running out of the joint.
5. Use a small weaving motion as necessary to fill the joint. If the weld shows a tendency to undercutting at the top edge, adjust the electrode angle.

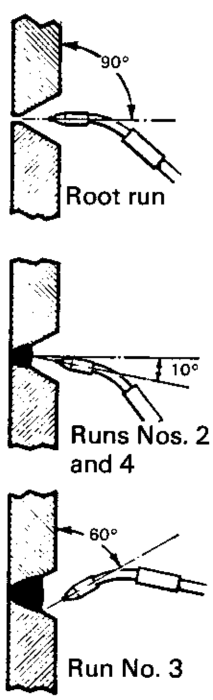
Visual examination

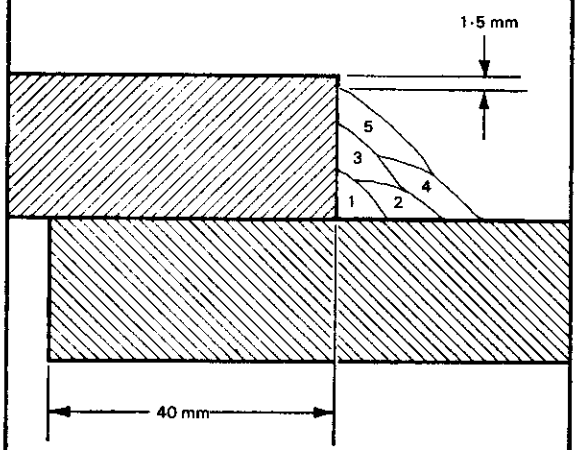
Examine the weld as in EP/M/21. If possible cut a macro test specimen to check for lack of side wall fusion.



Weld sequence for butt joint in the horizontal-vertical position

Vertical section





Welding sequence for horizontal-vertical lap joint

Lap joint, 10 mm plate—Spray and dip transfer—Horizontal-vertical position
Example procedure EP/M/23

Note: The following procedure may be used with either carbon dioxide or argon-20% CO_2 as a shielding gas.

1. Assemble the joint with a 40 mm overlap.
2. Use a dip transfer technique (at 140–160 A) and deposit the root run on one side of the joint.
3. Complete the weld, using a spray transfer technique. Follow the sequence illustrated. The top run (No. 5) should finish 1·5 mm below the edge of the top plate.
4. Reverse the plate and deposit the root run as in 2 above. Complete the joint with either a spray or a dip transfer condition (160–180 A).

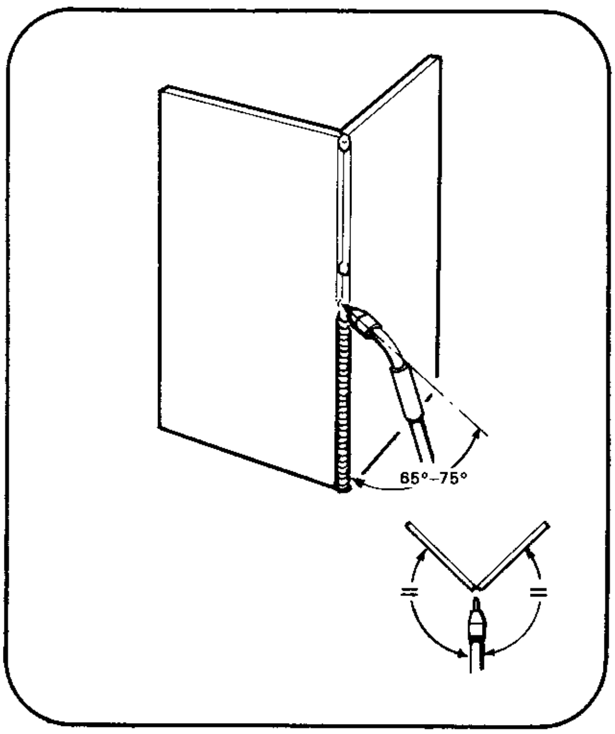
> *Note:* If desired the dip transfer root run may be omitted.

Visual examination
Examine the completed weld. There should be no melting-off of the top edge. The surface of the weld should be smooth and should not show undercutting at the junction of the weld runs.

Metal-arc gas shielded welding

Corner joint—Pulse transfer—Vertical position
Example procedure EP/M/24

Material	Two pieces of aluminium alloy 3 mm thick. Min. size 200 mm x 100 mm
Preparation	Square edge
Assembly	Tack weld with three tacks to give included angle of 90°, no gap. Support assembly with line of joint vertical, about 150 mm above the bench top
Electrode	1·6 mm
Feed rate	3·3–3·7 m/min
Shielding gas	Argon at 1·0–1·1 m^3/hr
Current	100–110 A
Peak voltage	33–34 V
Background voltage	19–21 V



1. Establish the arc at the bottom end of the joint.

2. Direct the electrode wire at the root of the joint, pointing upwards at an angle of 65°–75°.

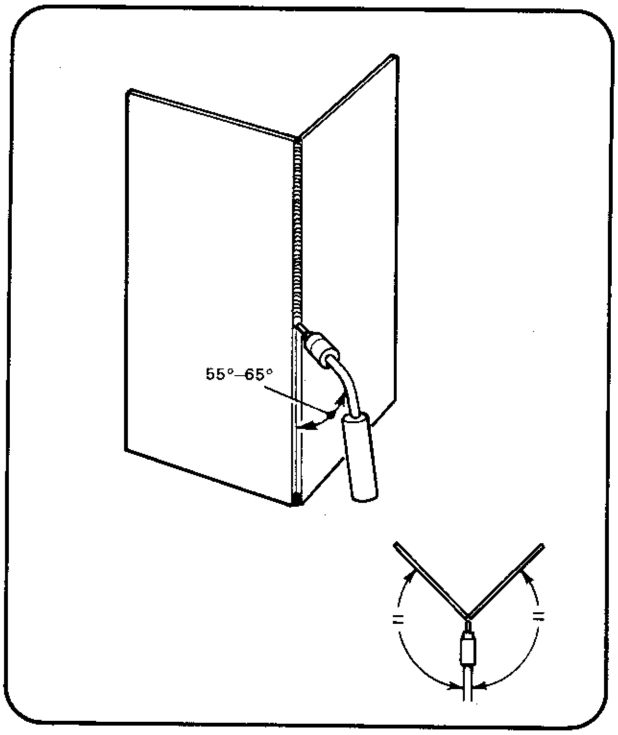
3. Adjust the rate of upwards travel to secure fusion to the outer edges of the fusion faces and produce a slightly convex weld profile.

Visual examination
A satisfactory weld should have a neat even profile which is slightly convex. On the reverse side there should be a slight penetration bead along the full length of the joint.
Too fast a rate of travel may result in failure to secure full penetration.
Too slow a rate of travel may cause excessive penetration and/or excessive weld section.

Metal-arc gas shielded welding

Corner joint—Dip transfer—Vertical position
Example procedure EP/M/25

Material	Two pieces of mild steel 1·5 mm thick. Min. size 200 mm × 100 mm
Preparation	Square edge
Assembly	As for EP/M/24
Electrode	0·8 mm
Feed rate	3·0–3·3 m/min
Shielding gas	Carbon dioxide or argon-20% CO_2 at 0·7–0·8 m^3/hr
Current	80–90 A
Arc voltage	17–18 V
OC voltage	19–20 V



1. Establish the arc at the top end of the joint.

2. Direct the electrode wire at the root of the joint, pointing upwards at an angle of 55°–65°.

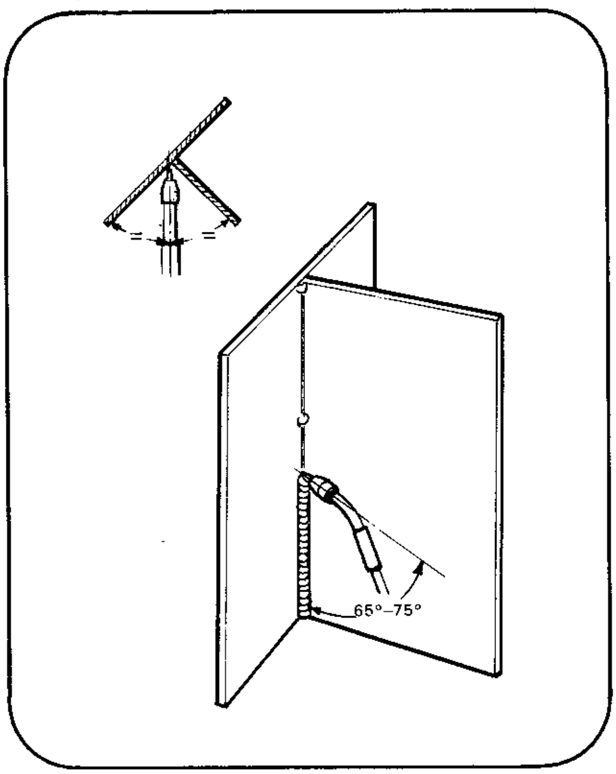
3. Adjust the rate of downwards travel moving the torch at a fairly fast uniform speed co-ordinated with the rate of fusion of parent metal and deposition of filler metal.

Visual examination
A satisfactory weld should show indications of penetration to the root of the joint without any concavity in the weld face profile.

Metal-arc gas shielded welding

T joint—Pulse transfer—Vertical position
Example procedure EP/M/26

Material	Two pieces of aluminium 5 mm thick. Min. size 200 mm × 100 mm
Preparation	Square edge
Assembly	Tack weld with three tacks to form a T joint, no gap. Support assembly with line of joint vertical, about 150 mm above bench top
Electrode	1·6 mm
Feed rate	3·7–4·1 m/min
Shielding gas	Argon at 1·0–1·1 m^3/hr
Current	110–120 A
Peak voltage	33–34 V
Background voltage	19–21 V



1. Establish the arc at the bottom end of the joint.

2. The electrode wire should bisect the angle between the plates and point directly at the root of the joint. The welding gun should be held so that the electrode wire points upwards at an angle of 65°–75°.

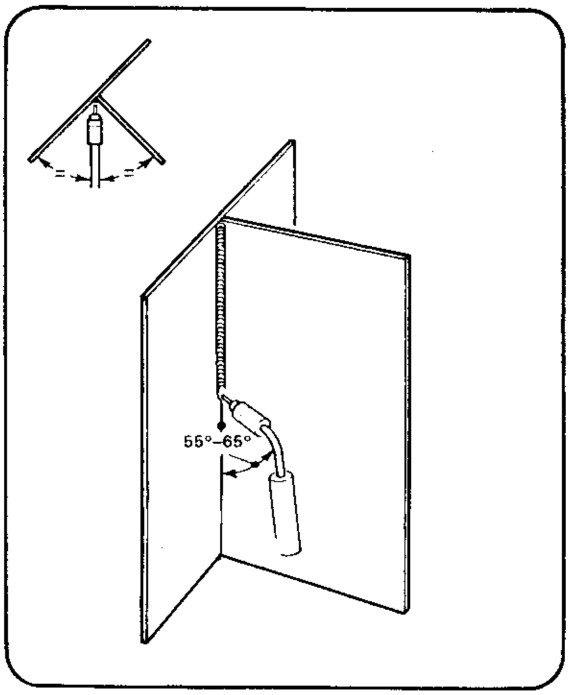
3. Adjust the rate of upwards travel without any weaving motion so as to deposit a fillet weld of leg length between 5 mm and 6·5 mm.

Visual examination
Saw welded assembly transversely and examine the weld.
The weld profile should be slightly convex and have a uniform leg length without undercut at the toes.
There should be no cavity at the root of the joint. Lack of penetration may be caused by too fast a rate of travel while too slow travel may cause undercut.

Metal-arc gas shielded welding

T joint—Dip transfer—Vertical position
Example procedure EP/M/27

Material	Two pieces of mild steel 5 mm thick. Min. size 200 mm × 100 mm
Preparation	Square edge
Assembly	Tack weld with three tacks to form a T joint, no gap. Support assembly with line of joint vertical, about 150 mm above bench top
Electrode	1.2 mm
Feed rate	3·3–3·6 m/min
Shielding gas	Carbon dioxide at 0·7–0·8 m^3/hr
Current	125–135 A
Arc voltage	21–22 V
OC voltage	25–26 V



1. Establish the arc at the top end of the joint.

2. The electrode wire should bisect the angle between the plates and point upwards at an angle of 55°–65°.

3. Direct the electrode at the root of the joint and travel downwards without weaving motion.

4. Adjust the rate of travel to secure a neat fillet weld.

5. Repeat the procedure by welding from the bottom end of the joint, using the sequence as in EP/M/26 (1) and (2) and adjusting the rate of upwards travel to obtain a neat fillet weld.

Visual examination

The weld should be uniform and not excessively concave. The leg lengths should be uniform and not less than 4 mm.

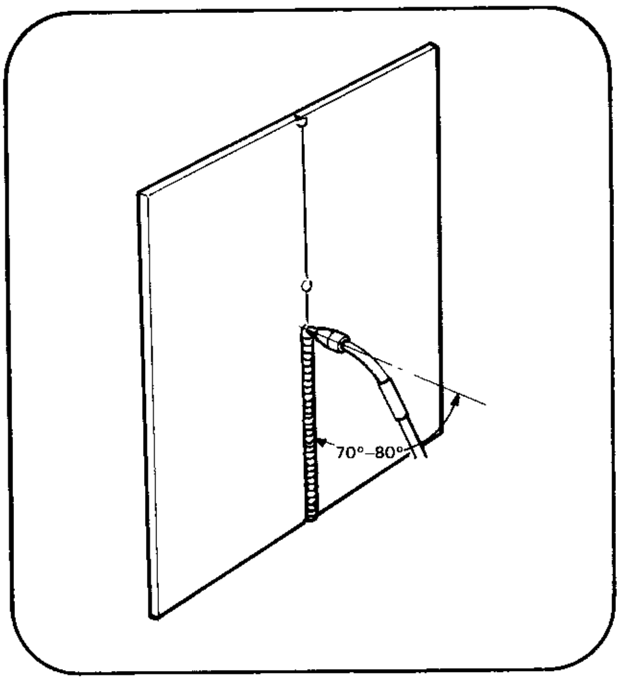
Too fast a rate of travel will give inadequate weld section with excessive concavity.

Too slow a rate of travel may cause undercut at toes and tendency for weld metal to 'sag'.

Metal-arc gas shielded welding

Open square butt joint—Pulse transfer—
Vertical position
Example procedure EP/M/28

Material	Two pieces of aluminium 3 mm thick. Min. size 200 mm × 100 mm
Preparation	Square edge
Assembly	Tack weld with three tacks to give a uniform gap of 0·5 mm. Support assembly with line of joint vertical, about 150 mm above bench top
Electrode	1·6 mm
Feed rate	3·6–3·9 m/min
Shielding gas	Argon at 1·0–1·1 m^3/hr
Current	105–115 A
Peak voltage	33–34 V
Background voltage	20–22 V

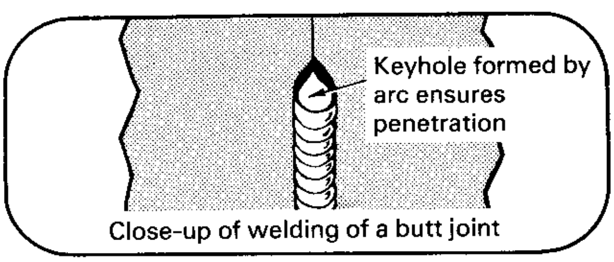


1. Establish the arc at the bottom end of the joint.

2. When fusion to the full thickness of the sheet has been obtained, commence the upwards travel.

3. The electrode wire should be pointed upwards at an angle of 70°–80°.

4. Direct the electrode wire at the gap between the plates to form a pear-shaped melted area (keyhole).



Close-up of welding of a butt joint

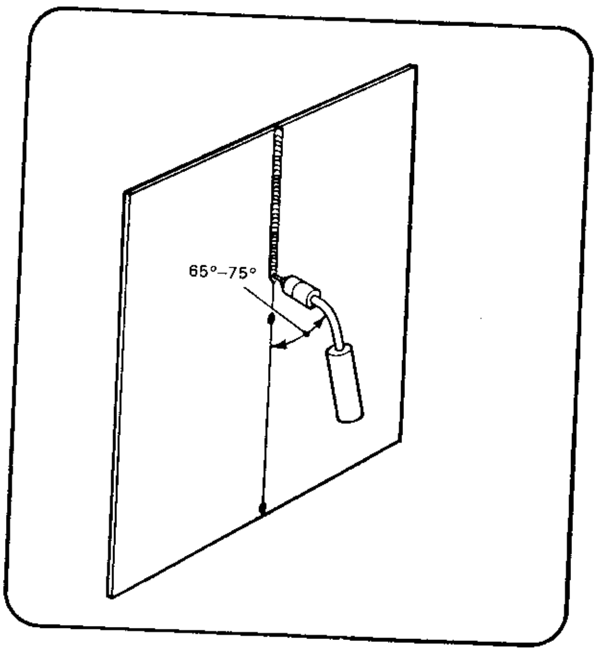
5. Adjust the rate of upwards travel so as to maintain the 'keyhole' ahead of the weld pool with a weld run built up above the plate surfaces behind the weld pool.

Visual examination
A neat weld profile with a uniform (but not excessive) penetration bead should be achieved.

Metal-arc gas shielded welding

Open square butt joint—Dip transfer—
Vertical position
Example procedure EP/M/29

Material	Two pieces of mild steel 1·6 mm thick. Min. size 200 mm × 100 mm
Preparation	Square edge
Assembly	As for EP/M/28
Electrode	0·8 mm
Feed rate	2·5–2·8 m/min
Shielding gas	Carbon dioxide or argon-20% CO_2 at 0·7–0·8 m^3/hr
Current	90–100 A
Arc voltage	17–18 V
OC voltage	19–20 V

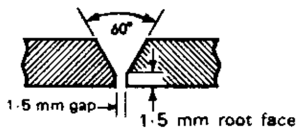


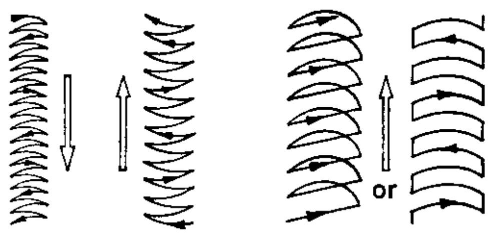
1. Establish the arc at the top end of the joint.

2. The electrode wire should be pointed upwards at an angle of 65°–75°.

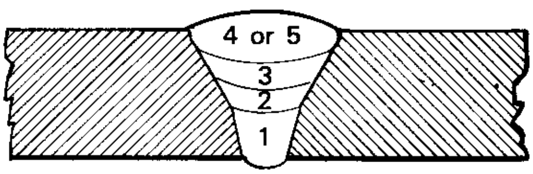
3. Direct the electrode wire at the gap between the plates and adjust the rate of downwards travel to ensure even deposition and control of penetration.

Visual examination
A neat weld profile with a uniform (but not excessive) penetration bead should be achieved.

Material	Two pieces of mild steel 10 mm thick. Min. size 250 mm × 100 mm
Preparation	
Electrode	1 mm
Shielding gas	Carbon dioxide or argon-20% CO_2 at 0·7–0·9 m^3/hr



Weaving patterns for vertical butt weld, showing direction of torch



Butt joint—Dip transfer—Vertical position
Example procedure EP/M/30

1. Assemble joint with a 2·5 mm gap between the edges.

Deposit a 25 mm long tack at one end. Correct gap if necessary and tack at other end of joint.

2. With the plate in the vertical position, deposit the root run vertically down on the first side, using a dip transfer technique (110–130 A).

3. Good fusion at the root faces must be achieved. A small weaving motion may be used to facilitate control of the weld pool.

4. Visually examine the surface of the root run. There should be good fusion at the edges and the weld surface should be as near flat as possible. If the profile is peaky, voltage and/or inductance should be increased slightly.

5. Wire brush the surface of the root run.

6. Increase the current to 140–160 A, readjusting voltage and inductance as required. Deposit the second run over the root run, using a weaving technique. Start at the bottom of the joint and travel vertically up.

Note: When weaving, the arc should be allowed to dwell at the edges, but should be traversed rapidly across the face of the weld.

7. Fill the join, using vertical-up 4 or 5 runs according to the sequence illustrated.

8. Particular care must be exercised when depositing the finishing (capping passes) to avoid undercut at the edges.

Visual examination
Section the completed weld. Use a side-bend test to locate any lack of side wall or inter-run fusion.

Metal-arc gas shielded welding

Welding stainless steel

The welding of stainless (corrosion resistant) and heat-resistant steels containing chromium (17–25%) and nickel (8–20%) requires careful control to ensure that the finished weld will behave satisfactorily in service.

Before welding these steels, obtain the following information:
1. Correct electrode wire composition; this will depend on
(a) tendency to cracking
(b) properties required.

2. Maximum weld run size; large weld runs may crack.

3. Sequence of welding, required to minimize distortion; it is more difficult to avoid distortion in austenitic steels by comparison with mild steel.

4. Special precautions, eg. interpass grinding may be required to remove oxide on surface of deposit; correct grade and type of grinding wheel; slippage in fixtures.

Note: (i) Electrode wires are available in standard sizes:
0·8, 1·0, 1·2 and 1·6 mm diameter.

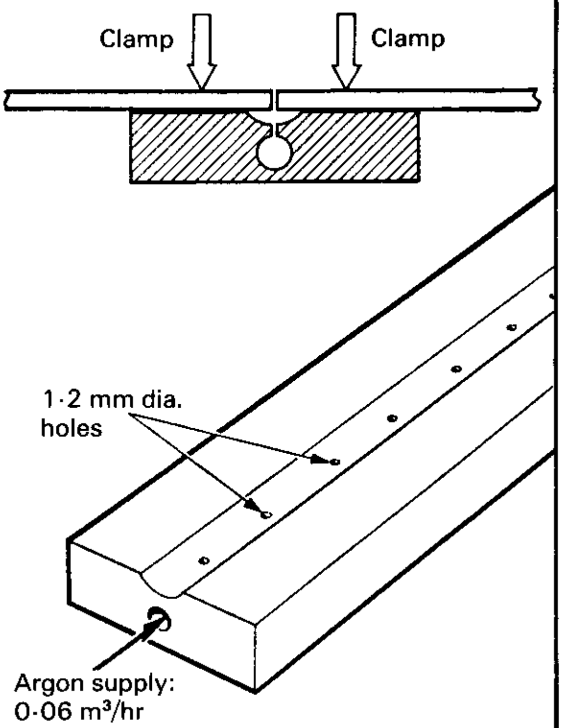
Seek guidance from the electrode manufacturer on the most suitable composition for the steel being used.

(ii) The shielding gas for austenitic steels should generally be argon-2% oxygen.

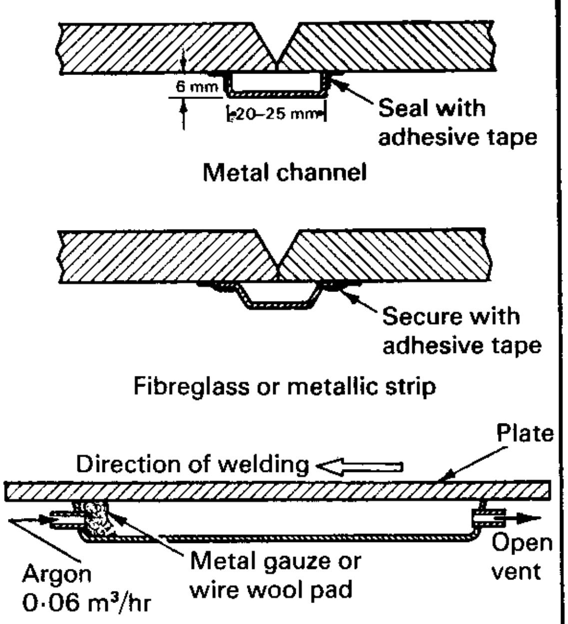
Other gases may be used, but these are confined to specific applications where a particular requirement has to be satisfied. Do not use gases containing carbon dioxide without expert confirmation that they are suitable.

Recommended flow rates:
Spray transfer: 1·0–1·2 m^3/hr.
Pulse transfer: 0·8–0·9 m^3/hr.

Metal-arc gas shielded welding



Backing bar with facility for back purging



Method of providing local back purge for a butt joint in steel plate

Welding procedures (ie. assembly and tacking), torch angles and sequences are identical with those suggested in the example procedures for mild steel.

When welding austenitic steels:

1. Keep electrode extension constant,
   for spray transfer: 19 mm extension.
   for pulse transfer: 13–16 mm extension.
2. Use large tacks.
3. Do not use pre-heat in an attempt to avoid cracking.
4. Do not deposit large weld runs; these may crack. Small stringer beads are preferred.
5. Always use a stainless steel brush when cleaning the weld area. A mild steel brush will leave a layer of steel on the surface which will rust in service.
6. When depositing a butt weld from one side only, prevent oxidation of the underside of the root run by using a gas purge.
   The purging gas can be carried to the underside of the weld by means of a backing bar with holes or a section which will confine the gas to the joint area.
7. Always fill the crater at the end of a run to avoid cracking.

Spray transfer can be used:
flat position—all joints; horizontal-vertical position—tee and lap only.

Pulse transfer can be used for all joints in all positions.

Preparation for welding

Cleanliness and correct alignment of the joint edges are essential.

1. Machine prepare or guillotine the edges wherever possible. Remove any burr before welding.
2. Degrease thoroughly after machining.
3. Brush edges with stainless steel wire brush just prior to welding.
4. On tee and lap joints, grind along the joint line if the surface is pitted or heavily oxidised.
5. Avoid excessive handling of the electrode wire.

Typical welding conditions

1. Flat position

Material thickness mm	1·6	3·0	6·0–10·0	
Preparation for butt joint	Square edge	Square edge	Single vee, 70° included angle	
Transfer type	Pulse	Pulse	Pulse (Root)	Spray (Filling)
Electrode dia. mm	1·2	1·2	1·2	1·6
Feed rate m/min	2·3	3·1	3·8	3·5–4·2
Current A	90	120	150	260–300
Arc voltage	—	—	—	26–28
Peak voltage	36–37	36–37	36–37	—
Background voltage	19	21	21–22	—

2. Vertical position

Material thickness mm	up to 5	5 and above
Electrode dia. mm	1·2	1·2
Feed rate m/min	2·0–2·5	3·1–3·8
Current A	80–100	120–150
Peak voltage	37–38	37–38
Background voltage	19–21	22–24

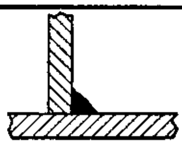
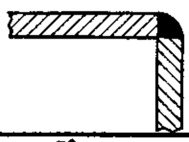
Use pulse welding for all joints to be welded in the vertical positions.

Welding should be started at the bottom of the joint and traversed upwards.

Use only a very small weave to ensure fusion at the edges of the weld.

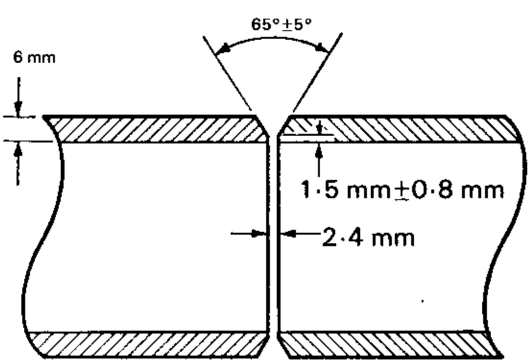
3. Horizontal-vertical position

Type of transfer	Spray		Pulse	
Material thickness mm	5 and above		up to 5	5 and above
Electrode dia. mm	1·2	1·6	1·2	1·2
Feed rate m/min	4·6–6·6	3·3–3·8	2·0–3·1	3·6–4·6
Current A	180–260	240–280	80–120	140–180
Arc voltage	24–26	26–28	—	—
Peak voltage	—	—	36–37	36–37
Background voltage	—	—	19–22	23–25

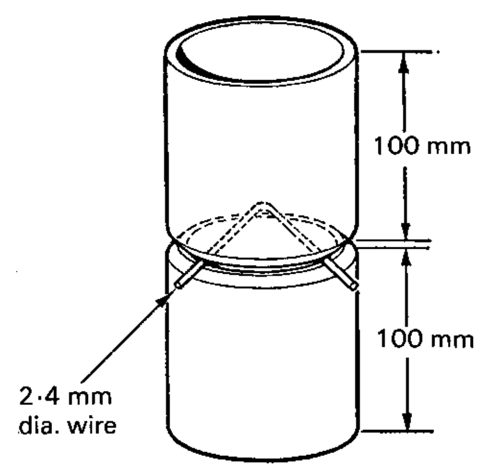
Type of joint		Spray transfer	Pulse transfer
Close square tee		Yes	Yes
Close corner		Yes	Yes
Close corner		No	Yes
Lap		Yes	Yes
Butt		No	Yes

Welding austenitic steels—horizontal-vertical position

Spray transfer can only be used for a limited number of joints in the horizontal-vertical position. Pulse transfer can be used for all joints.



Edge preparation for butt weld in pipe



Use of bent wire or suitable spacer to set root gap

Pipe welding

Good pipe welding requires a high degree of skill. Backing bars or strips are only used occasionally and it is therefore important that the welder should learn to exercise a considerable degree of control over penetration in the root run.

Attention must be paid, at all times, to the following points:

1. Prepared edge must be free from cutting defects.

2. Thickness of root face must be as uniform as possible.

3. Sections of pipe must be aligned correctly to minimize the effect of pipe ovality at the joint.

Note: Pipe showing excessive ovality should not be used for training.

4. Root gaps must be uniform at all parts of the joints.

> When welding a pipe, adopt a comfortable position which allows ease of manipulation and control of rotator speed.

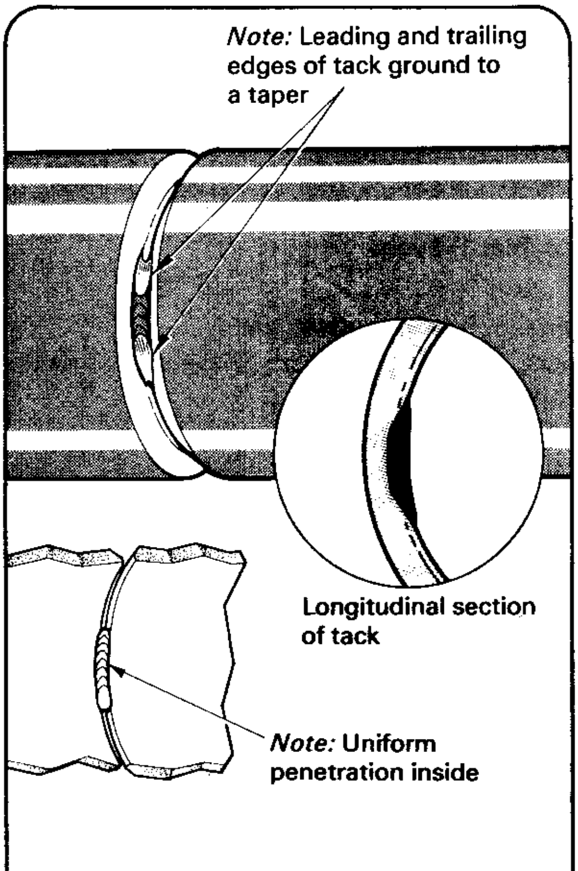
Butt weld in pipe, 6 mm wall thickness
Example procedure EP/M/31

Material	Mild steel pipe; two pieces 100 mm long × 75 mm dia. 6 mm wall thickness
Preparation	Single vee, included angle 65°±5°; root face 1·5 mm±0·8 mm
Electrode	0·8 mm or 1 mm diameter, mild steel (solid wire)
Shielding gas	Carbon dioxide at 0·7–0·8 m³/hr
Arc type	Dip transfer

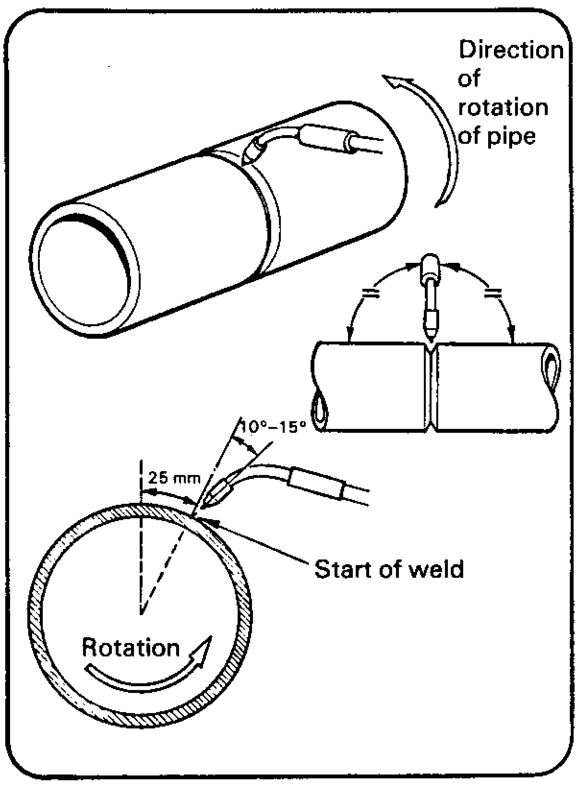
Establishing welding conditions
1. Set open circuit voltage to 21–24 V and establish welding conditions on a piece of scrap plate.

Welding current should be 120 A.

Metal-arc gas shielded welding



Taper grinding of tacks



Assembly

2. Ensure that weld area is free from surface imperfections, rust, scale or grease.
3. Tack-weld pipes together. Use four equally spaced 13 mm long tacks.
Note: Tacks must be fully penetrated and fused into the root of the joint.
4. Check that root gap is 2·4 mm and is uniform.
5. Taper grind both ends of all tacks.
6. Position tacked assembly in rotator.
Note: Connect welding return lead on to the actual pipe weldment.

Welding procedure—Root run

7. Use the welding conditions established at 1.
8. Inititate arc on one sidewall of the weld preparation at the position indicated. Move the arc until it is directed into the root of the joint.
9. Start the pipe rotating and adjust speed of rotation to obtain complete root fusion.
10. Keeping the contact tip-to-work distance between 9 mm and 13 mm, deposit the root run.
Note: Deposit thickness should be about 2·5 mm to 3 mm.
11. Terminate the root run by welding over the ground surface of the tack and running the arc towards the edge of the joint preparation.
12. Grind stop-start junction smooth.
13. Inspect penetration bead and surface of weld.

Excessive penetration can result from
either (a) speed of rotation too slow;
or (b) gap too large (can be overcome by *slight* weaving motion),
or (c) contact tube-to-work distance too short,
or (d) torch angle too steep.

Inadequate penetration can result from
either (a) speed of rotation too fast,
or (b) gap too small,
or (c) contact tube-to-work distance too long,
or (d) torch angle too shallow.

'Peaky' weld profile with inadequate fusion at edges can result from
either (a) voltage too low,
or (b) insufficient inductance.

Welding procedure—Capping pass

14. Increase welding current to 150 amp. and establish correct voltage and inductance settings on scrap material.

15. Using the torch angles shown previously, commence welding the capping pass.

16. Adjust speed of rotation to ensure that the joint is filled in one pass. A slight weaving motion can be used to ensure complete interpass and sidewall fusion.

Note: Height of reinforcement should be not more than 1·6 mm.

Examination of completed weld

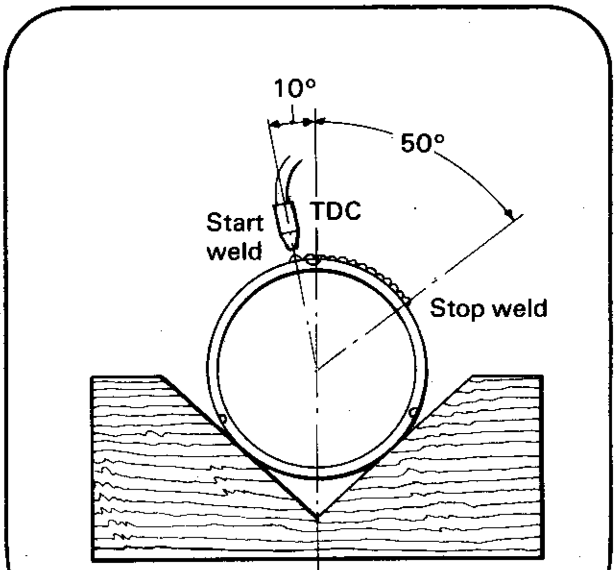
Inspect completed weld, paying particular attention to:

(a) uniformity of surface
(b) absence of undercut
(c) smooth profile at stop and start.

Side-bend test specimens should be cut from the weld to locate any lack of sidewall or root fusion.

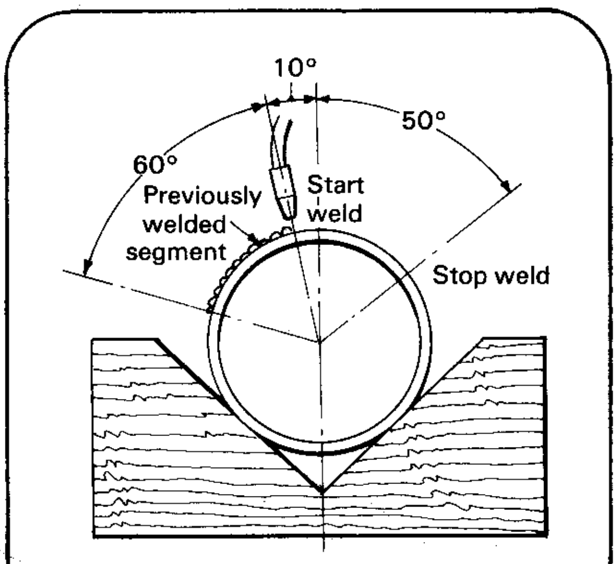
Mild steel pipe—Segmentally welded
Example procedure EP/M/32

1. Use the material specified for EP/M/31.
2. Tack the pipe and support the assembly on two vee blocks.
3. Strike the arc at 10° from Top Dead Centre (TDC) and deposit the root run. Use a small weaving motion to achieve fusion of the root faces. Adjust travel speed to control root penetration.
4. When a segment equivalent to 60° has been welded, terminate the weld run. Avoid the formation of a crater.



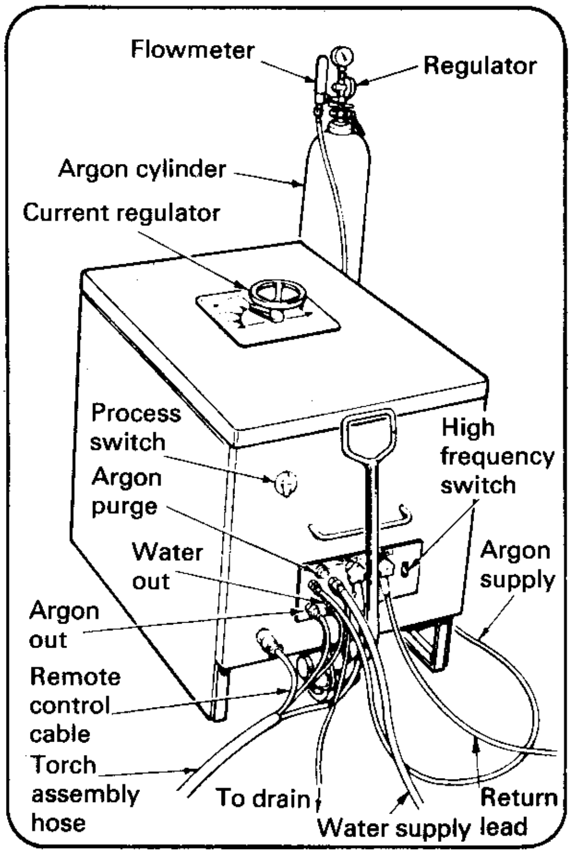
Welding first segment

5. Move the pipe until the end of the segment is at 10° before TDC.
6. Strike the arc on the end of the previous weld run and establish a weld pool.
7. Weld a further 60° segment.
8. Continue welding in segments until the root run has been completed.
9. Move the pipe until the mid-point of one of the segments is at TDC.
10. Strike the arc and deposit the second (filling) run. Use a side-to-side weaving position to fill the preparation and to achieve fusion of the pipe edges.
11. Complete the filling run in 60° segments.



Welding second segment

Tungsten-arc gas shielded welding



Typical AC power supply unit

Equipment

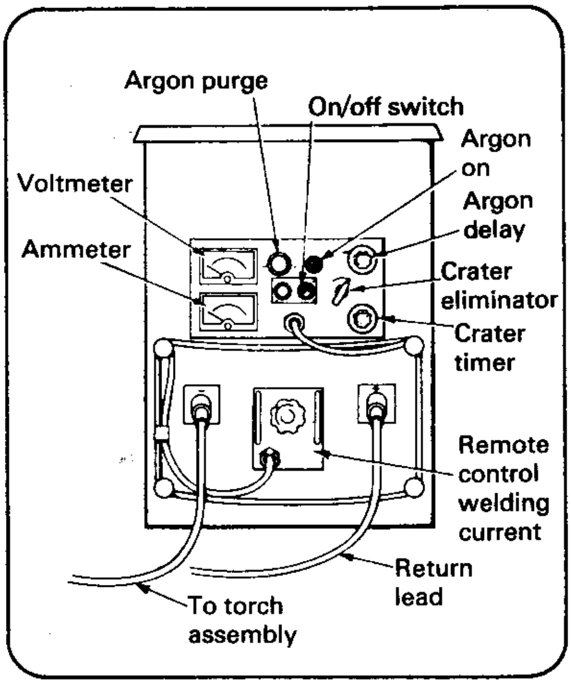
Power supply unit
A drooping characteristic (constant current) power supply unit should be used.

The open-circuit voltage should be between 50 V and 100 V.

In the Example procedures which follow, currents from 50 A to 250 A may be required.

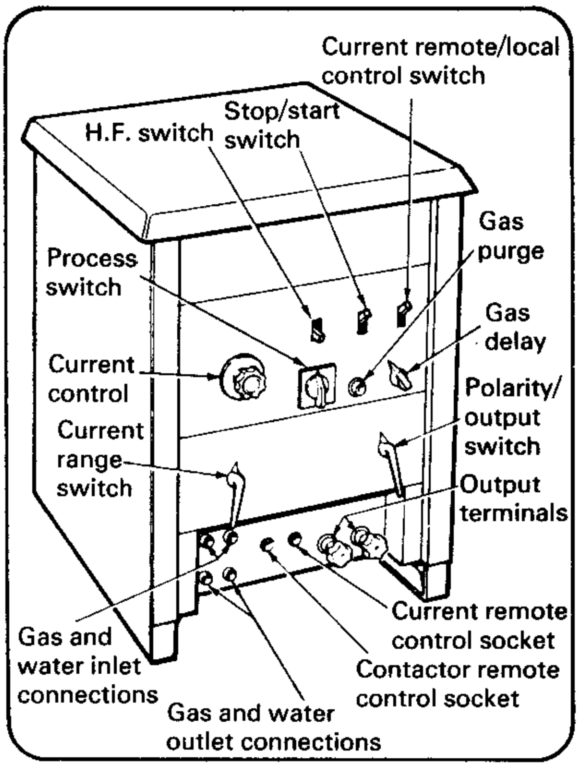
If possible, a power unit fitted with remote control of current should be chosen.

An alternating current (AC) unit will be required for the welding of aluminium and aluminium alloys.



Typical DC power supply unit

A direct current (DC) unit will be needed for the welding of stainless steel, mild steel, copper, titanium and nickel alloys.



Combined AC/DC units are also available.

Note: Power supply units used for manual metal-arc welding can be adapted for tungsten-arc gas shielded welding if additional features are added to the circuit. In general it is better to use a power unit specifically designed for the latter process.

Control unit

The control unit should provide on/off switching for:

Welding current
Shielding gas flow
Water flow (if appropriate)

Controls will normally be incorporated in the power supply unit. If possible, use a foot-switch connected to the control unit; it is an advantage if this is fitted with a current control device.

Arc initiation system
A peak starter or high frequency unit will initiate the arc without the need to touch the tungsten electrode onto the work.

This gives longer electrode life and better welds.

With most equipment, this is incorporated in the power supply unit.

Suppressor
A capacitor bank, often called a suppressor is needed when welding with AC to suppress the DC component which is produced in the welding circuit.

Crater eliminator
A crater eliminator is an automatic device which gradually reduces the welding current at the end of a run, preventing the formation of a crater.

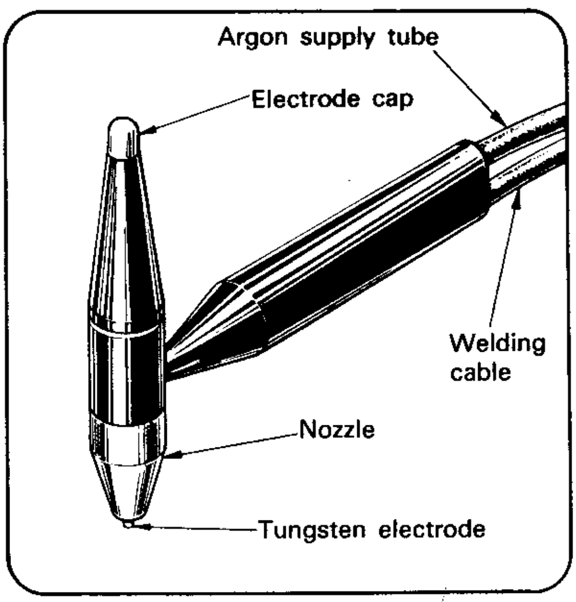
The device is available only on a limited range of welding sets. In other cases the same effect can be obtained by use of the remote foot control.

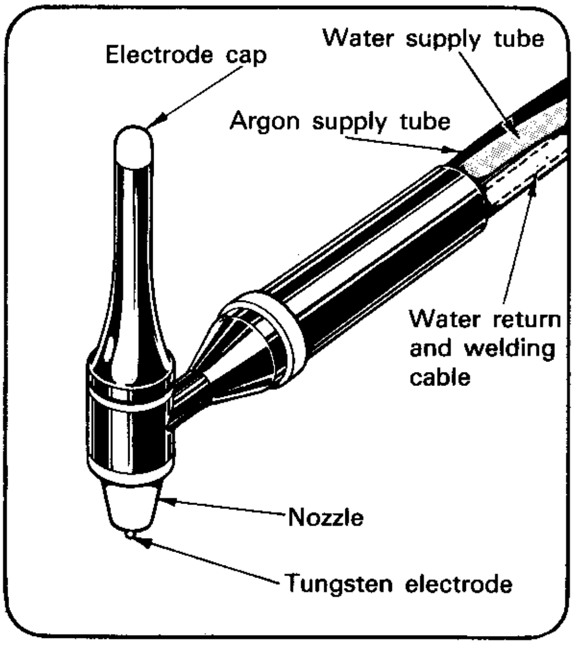
The device, which is not suitable for AC, is usually fitted to DC or combined AC/DC units as an optional extra.

Welding torch
The welding torch can be air-cooled or water-cooled.

Air-cooled torches
These vary from the pencil torches used for welding at currents of less than 50 A to general purpose torches for use with currents up to 150 A.

Torches are usually supplied with a hose assembly containing PVC tubing to convey the gas and an insulated cable for the welding current.





Water-cooled torches
These are made in various sizes, depending upon the maximum welding current to be used.

The hose assembly contains:
1. Gas supply tube.

2. Water supply tube.

3. Water return tube containing the welding cable.

4. Usually a fuse unit or water-flow switch to cut off current supply if water flow ceases.

In some types, a remote-control cable is included with a switch in the torch handle.

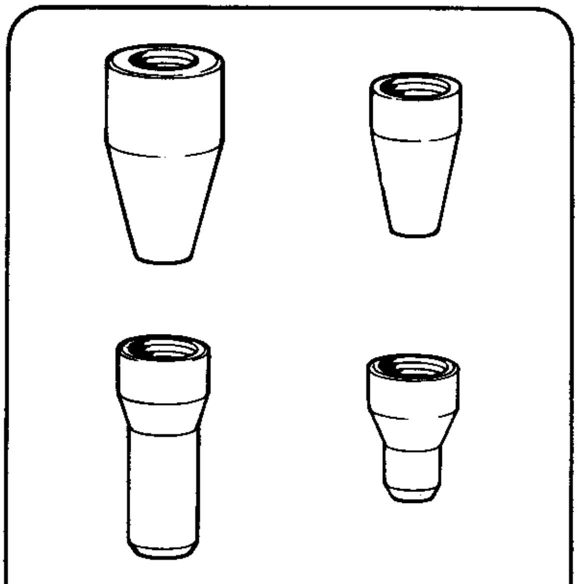
Gas nozzles
The standard ceramic nozzles are 6·5 mm bore for air-cooled torches and 10 mm bore for water-cooled torches.

A 'gas lens' may be fitted to some torches within the shield to improve the gas coverage and enabling the electrode to stick out, thus giving a better view of the arc.

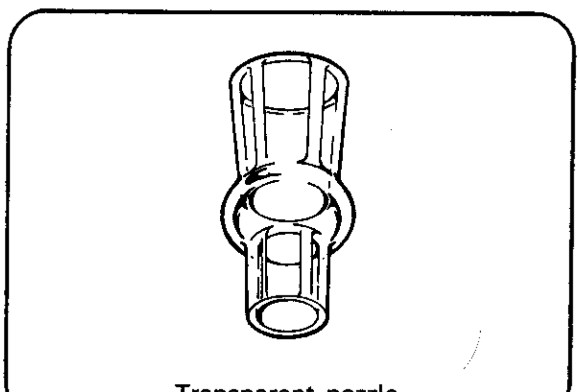
Transparent nozzles may be used to obtain a better view of the arc.

Gas nozzles, by their nature, are not strong, and the ageing effect of repeated heating and cooling may make them fragile.

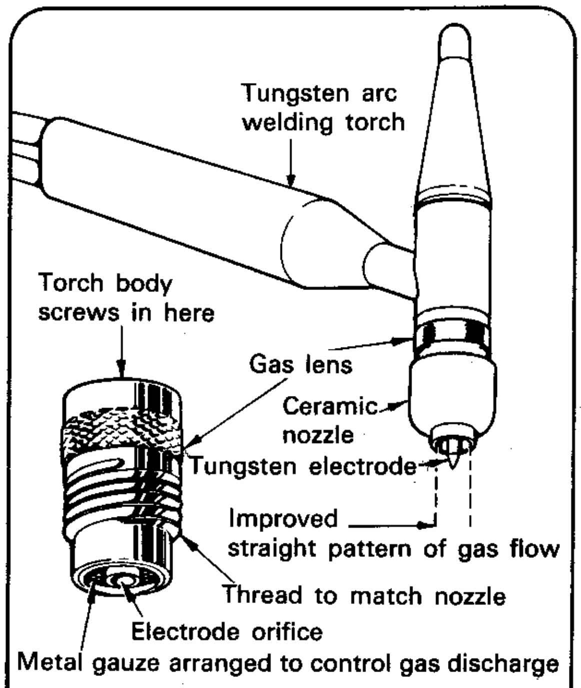
Take care not to drop the torch, nor to bring the nozzle into sharp contact with other objects.



Ceramic nozzles



Transparent nozzle



Gas lens fixed between torch and nozzle to give improved flow of inert gas and more economy

Shielding gas

Welding grade argon is used as the shielding gas in practically all applications.

Argon is supplied in steel cylinders painted blue. The usual size is 8·5 m³ charged at a pressure of 172 bars.

Gas supply system

Shielding gas can be supplied from an individual cylinder

or

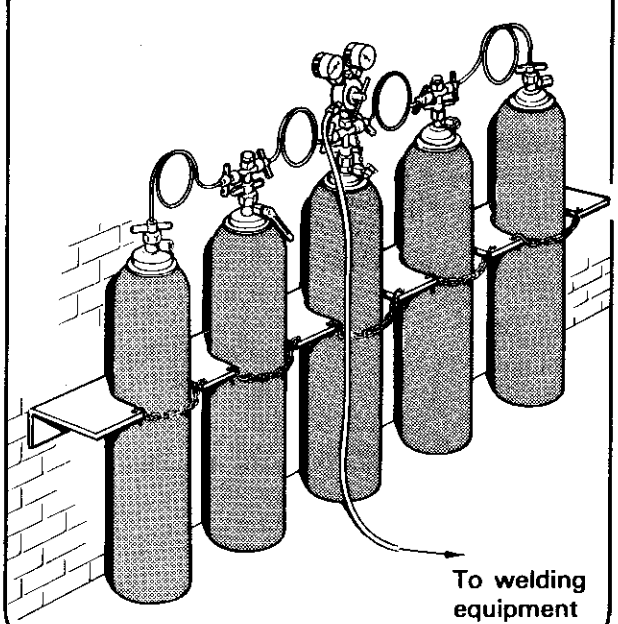
manifold cylinders

or

bulk storage tank.

In all cases the gas supply pressure must be reduced to the working pressure by means of a regulator.

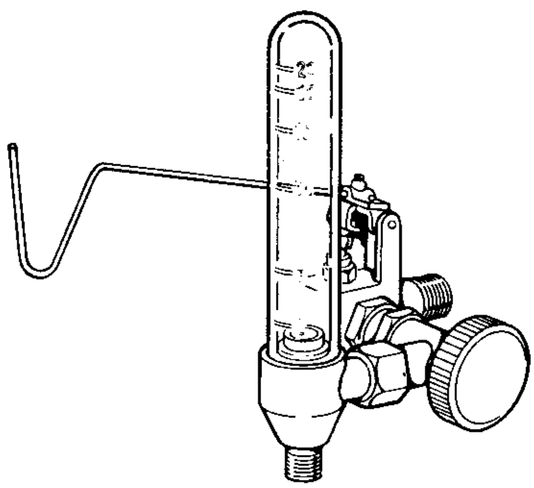
Manifold cylinders



The gas flow is controlled by a valve and measured by a flow gauge.

In some units the flow gauge may be a bobbin-type meter.

In others, a dial gauge may be used.

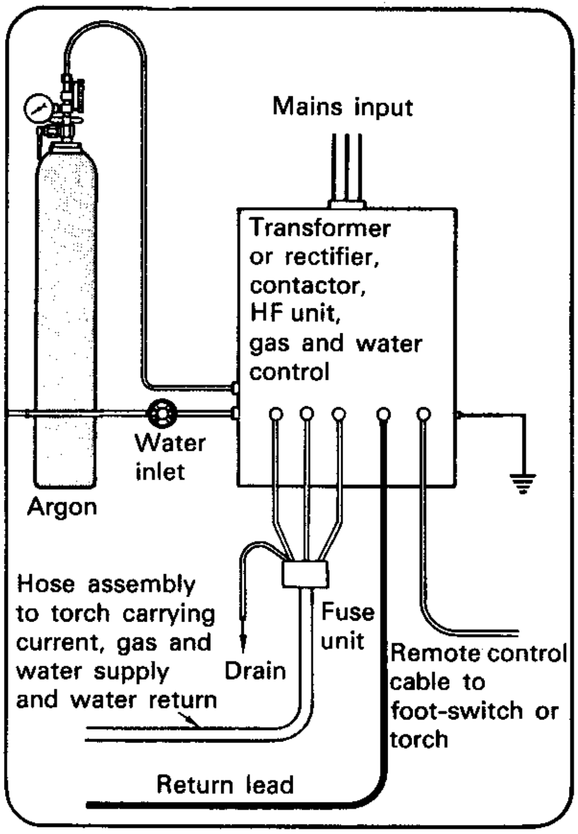


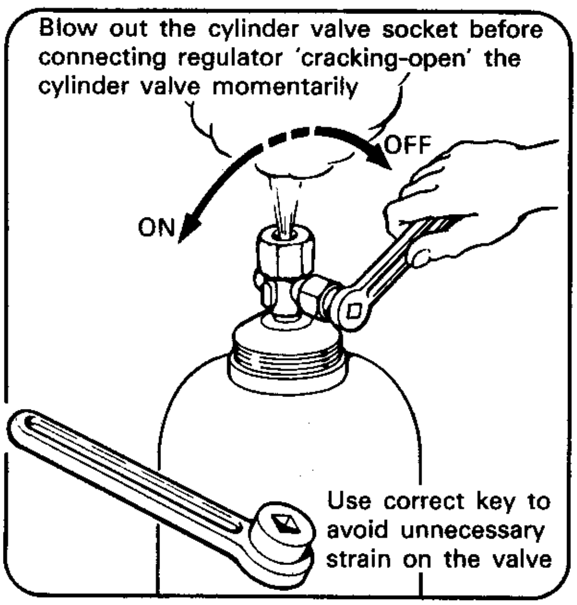
Gas economiser and flowmeter

Caution

Cylinder pressure should never be allowed to fall below 2 bars since atmospheric contamination may then occur.
Make sure that valves on used cylinders are closed to avoid contamination of the small amount of gas remaining in the cylinders.

Equipment vary considerably in the manner of making connections. The examples chosen illustrate the principles. Always read the manufacturer's instruction book!





Assembly of equipment

1. Select secondary cables of a size suitable for the maximum welding current.

2. Connect the bench (or work) to a convenient earthing point which would be capable of carrying the full welding current.

3. Connect the bench (or work) to the welding return (or positive) socket of the power supply unit.

4. Connect the torch lead to the electrode (or negative) outlet of the power supply unit.

5. Connect the foot-switch (and remote current control if used) to the appropriate outlets on the power supply unit.

6. Make appropriate gas connections.

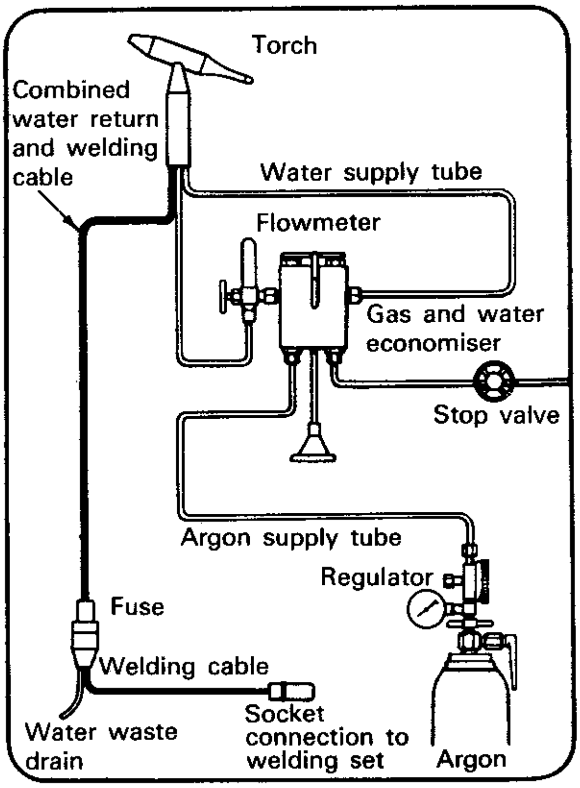
(a) Make sure that cylinder valve socket is clean, dry and free from dust before fitting regulator.

(b) Screw regulator into valve socket (right-hand thread) until just home. Then give a sharp blow with one hand on the spanner shaft to ensure a gas-tight sealing.

(c) Follow manufacturer's instructions for making hose connections between regulator, flow gauge and valve, on/off control and torch.

Caution

Use two spanners and take care when tightening male and female connectors. An uneven twist with a single spanner may cause strain, distortion or breakage of slender connectors.



7. Make water connections as appropriate.

When water-cooled torches are used, water may be taken from the mains or from an independent re-circulating unit. If mains pressure is high, a water-pressure regulator must be used to reduce the pressure.

(i) Connect the water supply hose from mains or water re-circulating unit to water supply tube of the torch assembly, or to the water inlet on composite power source, and then to the torch assembly.

(ii) Connect water return tube of the torch assembly to drain, or to water re-circulating unit.

(iii) Check water flow.

Selecting electrical conditions

Type of current

Use AC for welding aluminium, magnesium, alloys based on these metals, and aluminium bronze.

Use DC for welding steels, stainless steels, copper, copper alloys, nickel, nickel alloys, titanium and other reactive metals.

Current level

Select a welding current which will give:
(a) good fusion of the parent metal
(b) adequate penetration.

The correct current level will depend on:
(a) material being welded
(b) thickness to be welded
(c) type of joint
(d) position of welding
(e) electrode extension
(f) type of electrode holder.

Note: Current levels suggested in the Example Procedures are intended only as a guide. Small adjustments may be made to suit the above factors.

Electrodes

Plain tungsten electrodes can be used but those containing a percentage of thorium or zirconium give better arc striking and arc stability.

Thoriated tungsten electrodes should be used for DC welding. They may contain either 1% or 2% Thorium. When welding at low currents, a 2% thoriated electrode should be used to give better striking of the arc. Zirconiated tungsten electrodes should be used for AC welding. They are particularly suitable for the welding of aluminium, magnesium, and alloys containing substantial amounts of either of these elements.

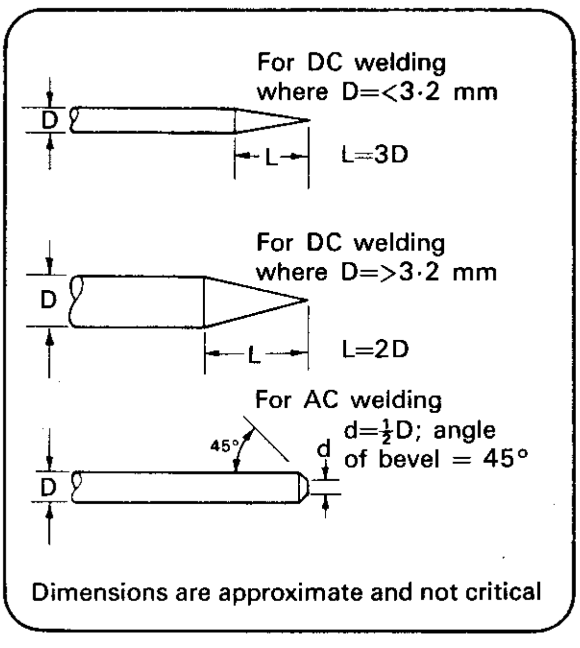
Electrodes are usually supplied in 150 mm lengths in sizes ranging from 1·2 mm to 5 mm diameter. There is a maximum and minimum current for each size of electrode. At high currents, the end of the electrode becomes overheated and melts off, whilst at low currents the arc may be unstable.

If the electrode is overheating, change to the next larger size of electrode.

If the arc is unstable, change to the next smaller size of electrode.

Maximum recommended currents for electrodes

Electrode type	**Thoriated tungsten**	**Zirconiated tungsten**
Diameter mm	**Amps (DC)**	**Amps (AC)**
1·2	70	40
1·6	145	55
2·4	240	90
3·2	380	150
4	440	210
5	500	275



Preparation of electrode ends

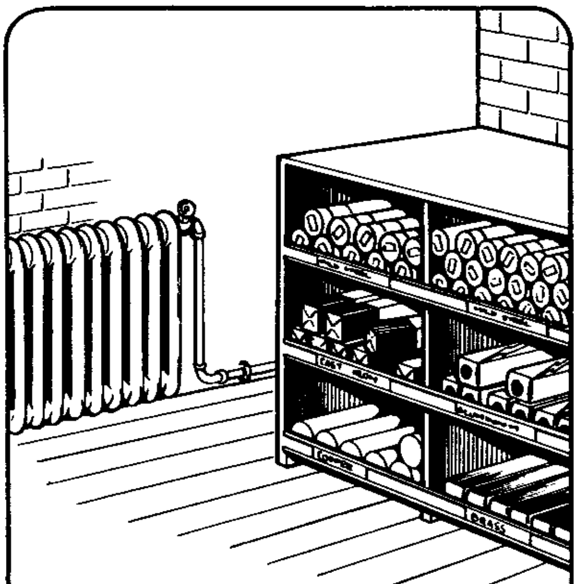
1. The working tip of the electrode should be ground to provide a point.

For this purpose a silicon carbide wheel, (grade O to M60) should be kept and *not used for other work.* Always ensure that grinding marks run along the taper and not circumferentially round the tip.

2. For DC welding a sharp point is desirable. The length of taper for the electrode sizes up to 3·2 mm should be about three times the diameter. For electrode sizes over 3·2 mm it should be about twice the diameter.

3. For AC welding a 'balled' point is desirable. The end should be pre-chamfered at an angle of about 45° leaving a blunt point of a diameter about half that of the electrode diameter. Before use an arc should be struck on scrap parent metal to 'ball' the end of the electrode.

For important work, the cleaned filler rod should not be touched with the bare hands, as perspiration causes significant contamination.
Wear clean, flexible, soft leather or fire-proofed cotton gloves, as it is essential that one should have precise control of the manipulation of the filler rod.


Store in clean dry conditions

Filler wires

Always use filler wires designed specifically for tungsten-arc gas shielded welding. The compositions of suitable filler materials are specified in BS 2901.

Recommended filler wires for metals referred to in the example procedures are given below.

Filler wire is supplied either (a) in cut lengths (filler rods) or (b) in coil form in the following diameters:
0·6; 0·8; 1·6; 2·4; 3·2; 4·8 mm.

Handling and storage (Rod and wire)

1. Handle filler rods with care.

2. Store under clean dry conditions to prevent deterioration.

3. Do not mix different types of filler rod. Ensure that packages and their labels make for easy and correct selection.

4. Where it is not practicable to store filler rods under heated conditions, an absorbent (such as silica-gel) for moisture may be used in the storage area.

5. When welding, wear lightweight cotton gloves to prevent moisture from the hands being transferred to the filler rod or wire.

Preparing the filler rod for use
1. Ensure the rod is free from contamination such as rust, scale, oil, grease and moisture.

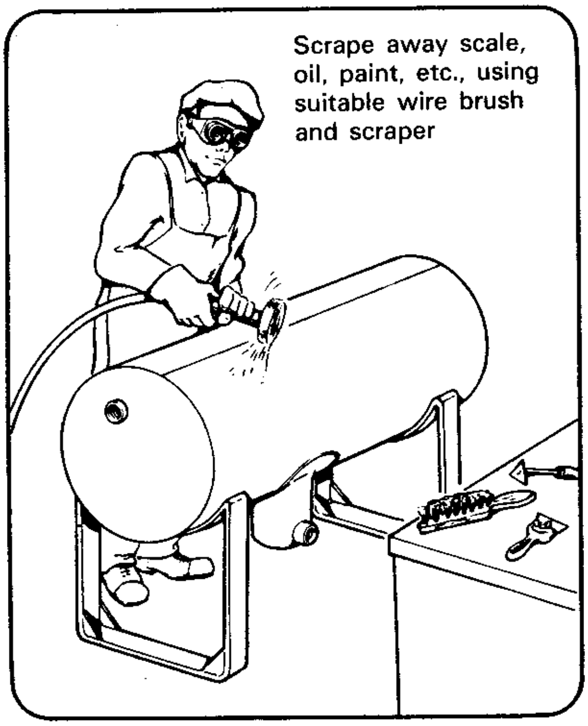
2. Just prior to welding, clean the filler rod surface with wire wool.

Use stainless steel wool on stainless steel and aluminium filler rods.

3. Ensure the rod is reasonably straight to assist manipulation during welding.

Safety

1. **Always** place a hot filler rod where it cannot be accidentally touched or handled.
2. **Always** position the filler rod to avoid personal injury whilst welding—bend filler rod end to prevent injury to the eyes and to facilitate identification of the hot end.
3. Take care to avoid fire hazards by keeping hot filler rods away from combustible materials.

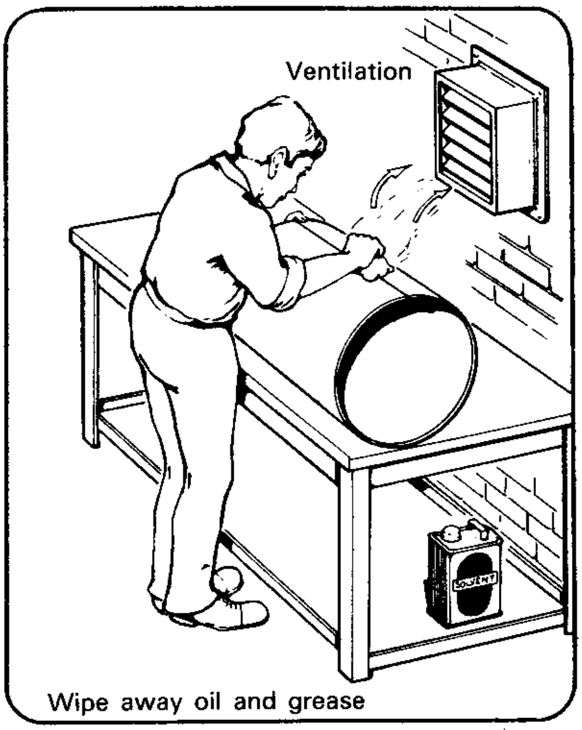


Parent metal preparation

Surface conditions

The surface of the parent metal must be clean in the vicinity of the fusion faces. For lap and fillet welds remove any contamination which is present on the surfaces of the parent metal in contact with each other. Ensure that no moisture is trapped in between abutting surfaces either on fusion faces or in their vicinity as this may cause hydrogen gas or steam to be generated, thus producing tubular cavities or worm holes in the weld. Avoid disturbance of the shroud which may otherwise lead to atmospheric contamination, and a resultant faulty weld.

The surface oxide of aluminium and its alloys should be removed by stainless steel wire brushing or by stainless steel wire wool immediately before welding, a new oxidized surface forms rapidly on the fusion faces, and the object of the brushing is to ensure that the oxide layer formed is uniform, thin, and uncontaminated.



Safety

Degreasing must be done in a place away from arc-welding activities. Make sure that degreased parent metal is thoroughly free from traces of the degreasing agent. Special care is necessary when degreasing has been done with fluids such as trichlorethylene or perchlorethylene. When these substances are brought into contact with the arc zone their vapours decompose to form a toxic gas.

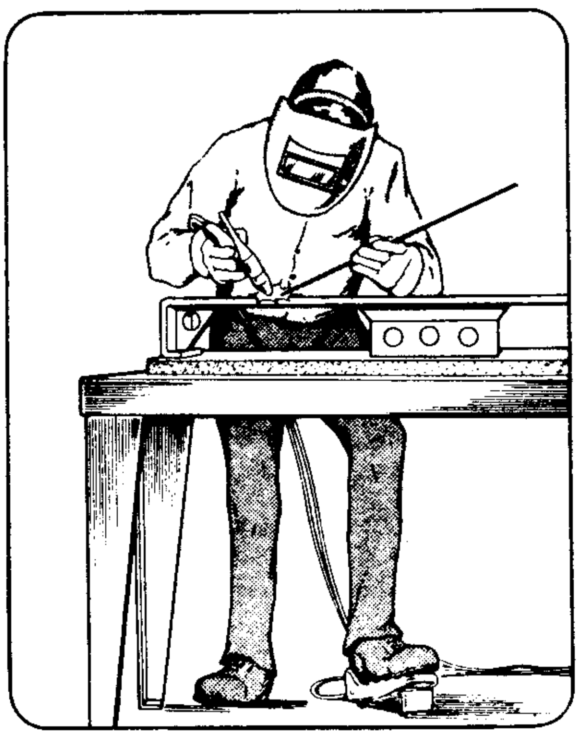
General procedure

The following general instructions which are not repeated later in the text apply to tungsten-arc gas shielded welding.

> Equipment, particularly composite power sources, vary considerably in their control arrangements.
> **Always** consult the manufacturer's instruction book!

Always—

1. Comply with the prescribed safety precautions and fire prevention procedure.
2. Check that return lead is firmly connected to bench and power source.
3. Check that all connections to torch hose assembly are in good order.
4. Check that argon and water hoses are not 'kinked' or otherwise obstructed.
5. Check that power source is switched on.
6. Check that argon cylinder valve is open.
7. Check that regulator, if not of pre-set type, is set to 2 bars pressures.
8. Check that correct size gas nozzle is fitted to torch.
9. Check that the tungsten electrode is of the correct type and size, that it is in a clean and properly prepared condition.



10. Check that the electrode extension is correct for the work to be done.

11. Check that the argon flow is correctly set. The flow rate should be checked with the torch removed from the hook on the gas economizer, or with the gas purge button depressed.

12. Check that water supply is turned on and that the flow to drain is correct (when using water-cooled torch).

13. Check that crater eliminator controls are correctly set.

14. Use effective protective equipment and any necessary protective clothing.

15. Acquire the habit of supporting and relaxing the body so as to be free from tension and able to concentrate on observation of the welding operation.

16. Hold the torch with just sufficient grip at the point of balance to give full control. Tight gripping or ill balance will cause muscle fatigue.

17. Take up a position that will enable the weld run to be completed without having to stretch unduly, if possible with the shoulder line parallel with the longitudinal axis of the joint (except in vertical welding).

18. Warn any persons in the vicinity when about to strike the arc.

19. Ensure that any screens required are in position.

20. Keep the welding screen in front of the eyes until the arc is broken.

21. Follow closing-down procedure at the end of the work period or when there is a long interruption namely:

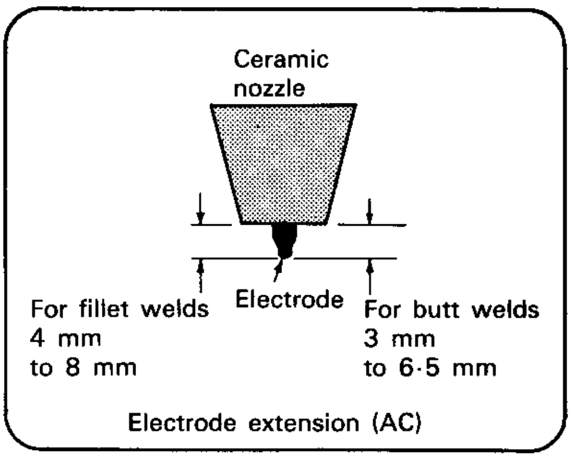
(a) Switch off power source.
(b) Close argon cylinder valve.
(c) Turn off water supply (if used).
(d) Switch off power supply to power source and to separate high frequency unit (if used).
(e) Remove tungsten electrode from torch and store carefully.
(f) Place torch in a safe place.
(g) Collect any unused filler rod and store carefully.

Welding conditions

To avoid repetition, certain common conditions that apply to all example procedures are given below.

Leftwards welding
For the welding of all materials, the 'leftwards' welding technique is used to ensure effective gas shrouding, ie. the electrode is pointed in the direction of welding. With the torch held in the right hand, welding proceeds from right to left, with the torch held in the left hand, welding proceeds from left to right.

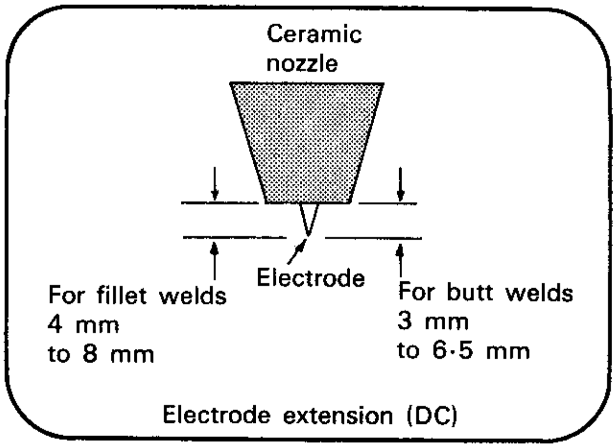
Welding of aluminium
1. Use commercially pure 99·5% aluminium parent metal.
2. Use a filler rod of a type complying with BS 2901, G.I.B.*
3. Use AC welding equipment.
4. Use zirconiated tungsten electrode.
5. Use 12·5 mm bore gas nozzle.



6. Use an electrode extension as shown in diagram, unless otherwise stipulated.
7. Arc length to be about the same as the diameter of the electrode used, subject to a maximum of 6 mm.

*If aluminium alloy parent metal is used, a filler rod of the appropriate composition must be used and somewhat lower welding currents may be necessary.

Welding of stainless steel
(see also note below)
1. Use austenitic stabilized corrosion-resistant steel parent metal.
2. Use a filler rod of a type complying with BS 2901, 1970, Part 2, 347s96.
3. Use DC welding equipment.
4. Use thoriated tungsten electrode.
5. Use 10 mm bore gas nozzle.
6. Use electrode extension as shown in diagram, unless otherwise stipulated.
7. Ensure arc length 1·5 mm when not using filler rod and up to 3 mm when using filler rod.



Note: Mild steel may be used as a substitute for stainless steel for *initial training purposes.* Rimmed and semi-killed steels, which have not been fully de-oxidized during manufacture, cannot be welded without some porosity occurring.

Mild steel *used for training purposes* must be of a quality that will obviate cracking and porosity. The use of welding quality killed or fully de-oxidized steel, low in carbon and sulphur contents, is recommended. The carbon content should be less than 0·12% and the sulphur content be less than 0·04%.

The requirements if mild steel is used instead of stainless steel are:
1. Use a filler rod of a type complying with BS 2901, 1970, Part 1, A15 or A16.

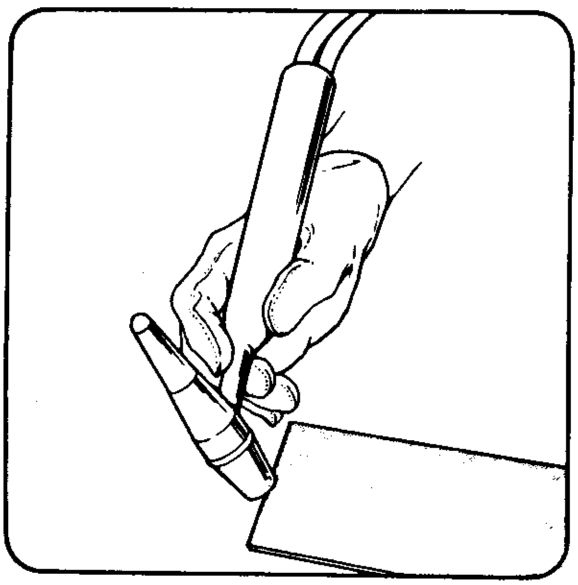
2. Increase the argon flow to 0·33 m^3/hr.

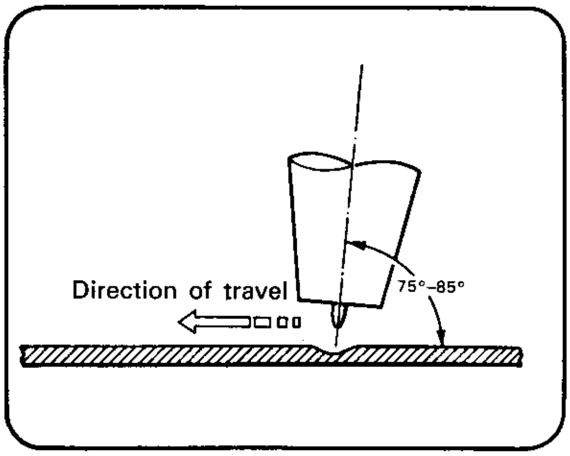
3. Increase the welding current by about 15 amperes over the values recommended for the stainless steel welding exercises.

Tungsten-arc gas shielded welding

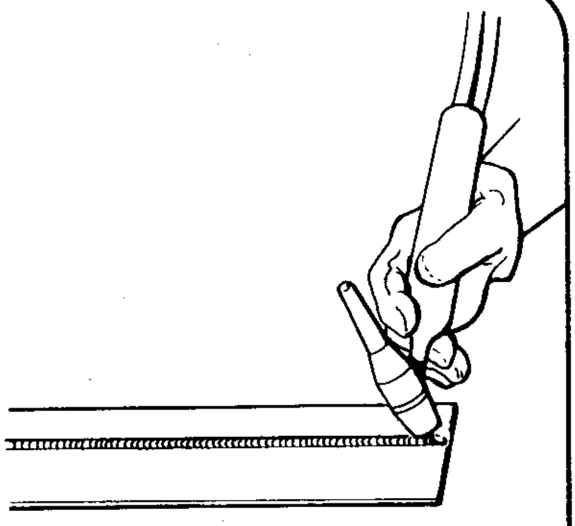
Example procedures
Fusion without filler metal—Flat position
Example procedure EP/T/1

Material	One piece of stainless steel 1·5 mm thick. Min. size 100 mm x 150 mm
Preparation	Clean surface
Assembly	Support sheet in flat position, with air space below, long axis to be parallel to bench front
Electrode	1·6 mm
Argon	0·11 to 0·22 m^3/hr
Current	50–70 A





1. Hold torch between the forefinger and thumb of the right hand with the torch handle lying on top of the hand and with the hose assembly supported by the forearm.
2. With the torch body inclined backwards, so that the electrode is pointing at an angle of 75°–85°, lower the torch until the electrode end is about 25 mm away from the sheet surface at the right-hand end.
3. With welding current switched on, allow argon to flow (to purge the hose assembly of air) and switch on the high frequency starter.
4. With welding screen in position, lower the torch until the electrode end is in close proximity to the sheet.
5. A train of sparks will pass from the electrode, an arc will be established and the high frequency starter will cease to operate.
6. Lower the torch until a short arc length of about 1·5 mm is obtained.
7. As soon as a small pool of molten metal is formed, where the arc is established, gently move the torch in a leftwards direction.
8. Synchronize the rate of travel with the progressive formation of the molten metal pool.
9. The molten pool should be perfectly clean and tranquil without trace of scum or oxide.
10. Observe the width of the fused and re-solidified metal. This will be uniform if the speed of leftwards travel is maintained correctly.



Cool weld in argon shroud

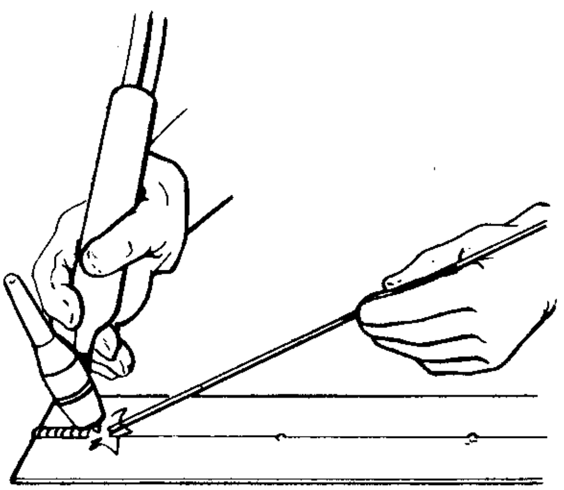
11. As the torch approaches the left-hand edge of the sheet, switch off the welding current.

12. Keep the torch in position over the crater with the argon flowing for 10–15 seconds. This allows weld and tungsten electrode to cool in the protective argon shroud.

Repeat the procedure until the techniques of establishing, maintaining, and breaking the arc are mastered.

Visual examination
The underside of the sheet should show that there has been near penetration of the sheet. If a burn through has occurred it will be the result of excessive concentration of heat, either by the use of too high a welding current or too slow a rate of travel.

If the fused metal is not bright and clean after gentle wire brushing, or if the electrode end is discoloured, the argon flow should be checked for possible blockage or leakage or false flow meter reading. Too long an arc length may be another possible cause.



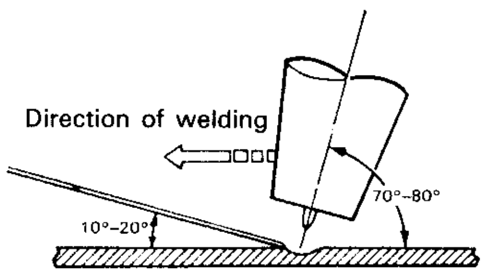
Fusion with filler metal

Fusion with filler metal
When using the leftwards method and a filler rod, the arc is directed towards the unwelded portion of the joint, and the filler rod is directed towards the welded portion of the joint.

Sometimes in the handling of the filler rod, the tungsten electrode may become contaminated by accidental contact with the filler rod end. If so, the arc should be broken immediately, the electrode removed and replaced or ground to remove the contamination and the end re-prepared.

Fusion with filler metal—Flat position
Example procedure EP/T/2

Material	One piece of stainless steel 2 mm thick. Min. size 100 mm × 150 mm
Preparation	Clean surface
Assembly	Support sheet in flat position, long axis parallel to bench front
Electrode	2·4 mm
Argon	0·22–0·33 m³/hr
Current	110–125 A
Filler rod	2·4 mm



Keep the filler rod end always within the argon shroud and resting on the parent metal

1. Establish small pool of molten metal near right-hand edge of sheet, holding torch vertical.
2. Decrease the electrode angle to 70°–80°.
3. Hold filler rod in left hand, between the fingers and thumb, pointing at the front edge of the molten pool and at an angle of 10°–20°.
4. Allow the arc heat to melt a little metal from the end of the filler rod and start the leftwards movement of the torch.
5. Always keep the filler rod end *within the argon shroud,* making contact with the weld pool but not with the electrode when adding filler metal.
6. Steady addition of filler metal gives even deposition. The rate of travel leftwards should be co-ordinated with melting of filler rod to control size of bead and extent of penetration.

Repeat the procedure until separate straight runs of even shape and width can be produced at will with a consistent arc length of less than 3 mm. Do not allow parent metal to become overheated.

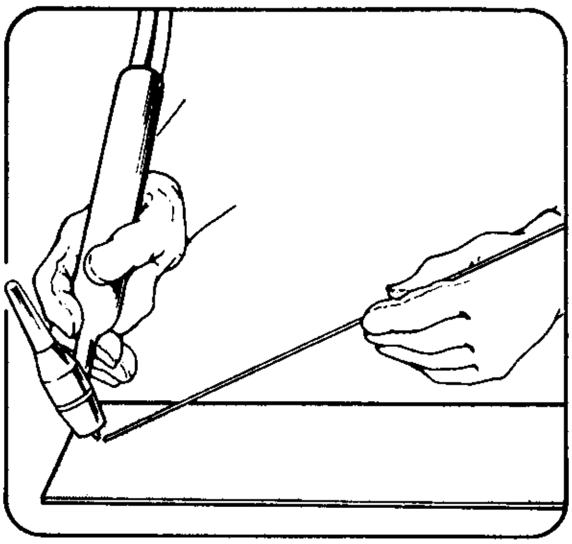
Fusion with filler metal (Aluminium)

Having mastered the basic skills using DC equipment for the welding of stainless steel (or mild steel), practice should be obtained using AC equipment for the welding of aluminium.

It will be necessary to make adjustments to the rate of torch travel and the rate of filler metal feed. There will be observable differences in arc characteristics.

Fusion with filler metal—Flat position
Example procedure EP/T/3

Material	One piece of aluminium 1·5 mm thick. Min. size 100 mm x 150 mm
Preparation	Surface cleaned immediately before welding
Assembly	As for EP/T/2
Electrode	2·4 mm
Argon	0·22–0·33 m^3/hr
Current	50–75 A
Filler rod	2·4 mm



1. Commence welding at the right-hand edge of the sheet.

2. The torch and filler rod should be held in the same manner as for EP/T/2 taking great care that the filler rod end is kept within the argon shroud.

3. The weld pool will not be so clear as when welding corrosion-resistant steel but the slight oxide film will be disintegrated and removed so that it causes no difficulty in observing the weld pool.

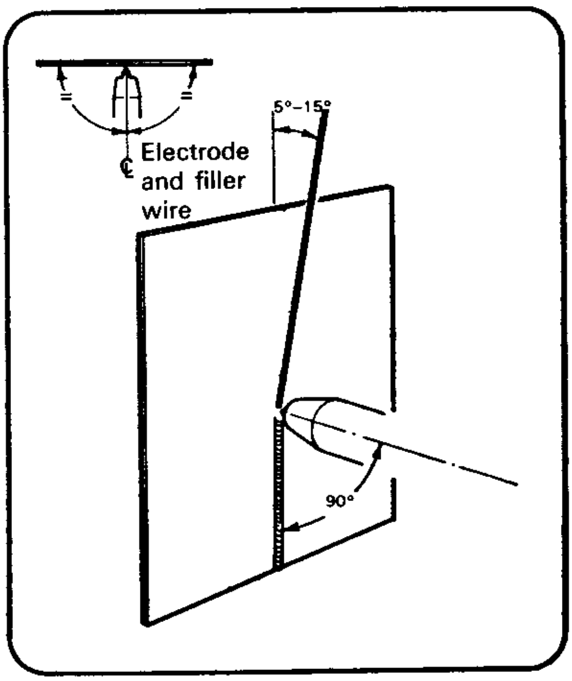
4. Co-ordinate the leftwards movement and the addition of filler metal to build up a reinforcement bead of even height and width.

Visual examination
Examine deposited beads and note any variations in width or height of run or depth of fusion into parent metal. These may be caused by variations in arc length, rate of travel, rate of addition of filler metal. Assess causes and take appropriate corrective action.
The reverse side of the sheet should indicate traces of penetration without any burn-through.

Tungsten-arc gas shielded welding

Fusion with filler metal—Vertical position
Example procedure EP/T/4

Material	One piece of stainless steel 1·5 mm thick. Min. size 100 mm × 150 mm
Preparation	Clean surface
Assembly	Support in a vertical position with bottom end 150 mm above bench top
Electrode	1·6 mm
Argon	0·16–0·22 m³/hr
Current	55–70 A
Filler rod	1·6 mm



1. Hold the torch body so that the axis of the electrode is at right angles to the surface of the sheets.

2. The filler rod is fed in from above the arc at an angle of 5°–10° to the sheet. The rod may be cranked to avoid heat discomfort.

3. Establish the arc at the bottom end of the weld.

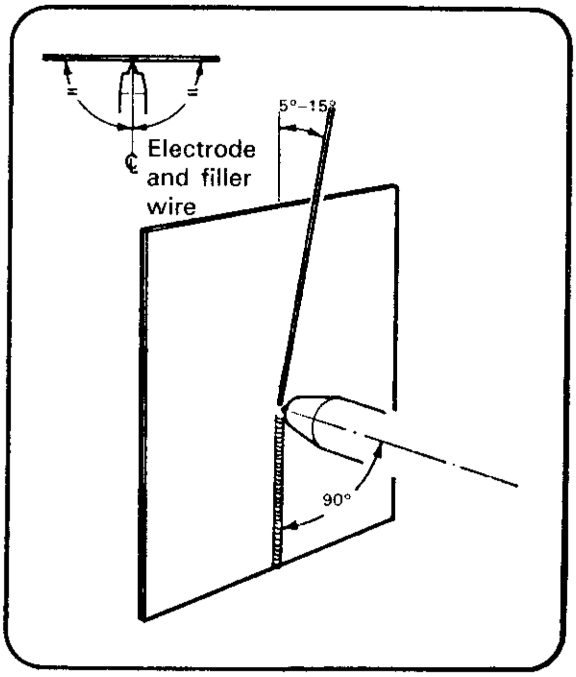
4. Move the torch gradually upwards, adding filler metal frequently but in small amounts to avoid contamination of the electrode end.

Visual examination
The deposited metal should be proud of the parent metal surface along the full length of the joint, without excessive convexity.
The weld metal should be free from tungsten inclusions.
The reverse side should have a reasonably uniform penetration bead and there should be freedom from burn-through.

Tungsten-arc gas shielded welding

Fusion with filler metal—Vertical position
Example procedure EP/T/5

Material	One piece of aluminium 3 mm thick. Min. size 100 mm x 150 mm
Preparation	Clean surface
Assembly	As EP/T/4
Electrode	5 mm
Argon	0·22–0·33 m^3/hr
Current	120–150 A
Filler rod	4·8 mm



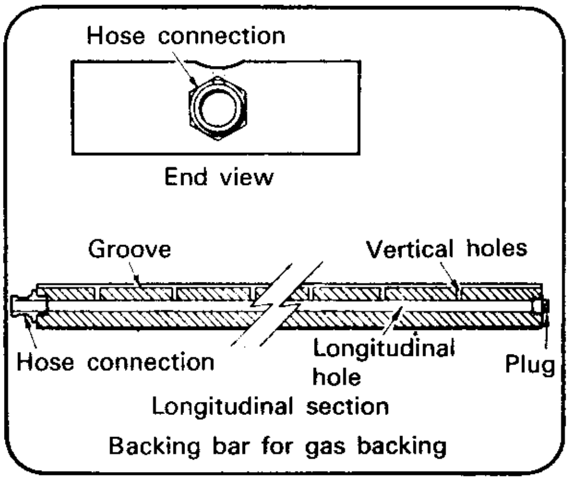
1. Hold the torch body so that the axis of the electrode is at right angles to the surface of the sheets.

2. The filler rod is fed in from above the arc at an angle of 5°–10° to the sheet. The rod may be cranked to avoid heat discomfort.

3. Establish the arc at the bottom end of the weld.

4. Move the torch gradually upwards, adding filler metal frequently but in small amounts to avoid contamination of the electrode end.

Visual examination
The deposited metal should be proud of the parent metal surface along the full length of the joint, without excessive convexity.
The weld metal should be free from tungsten inclusions.
The reverse side should have a reasonably uniform penetration bead and there should be freedom from burn-through.



Backing bar for gas backing

Backing bars

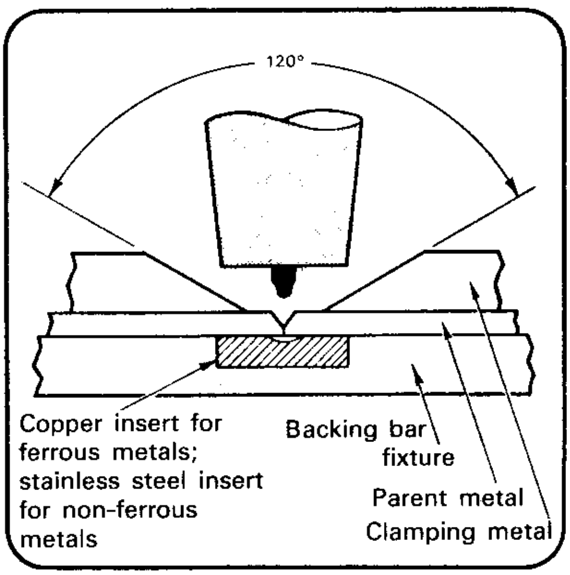
It will be found helpful to use a recessed backing bar when welding butt joints. This will control the penetration bead and enable higher welding currents to be used.

The backing bar should be made of copper when welding ferrous materials and preferably of stainless steel when welding non-ferrous materials. It should be provided with a longitudinal groove of suitable dimensions, eg. of a depth one-third of the thickness of the parent metal, semi-circular in form, having a radius of 6·5 mm.

For many parent metals, including stainless steel but not aluminium, it is desirable to have an argon backing. Small vertical holes, communicating with a longitudinal supply hole, should be drilled at about 25 mm intervals along the groove in the backing bar to permit an evenly distributed supply of argon to the underside of the joint at a flow rate of about 0·11 m^3/hr.

It is essential that adequate means should be provided for holding the underside of the parent metal in firm contact with the backing bar.

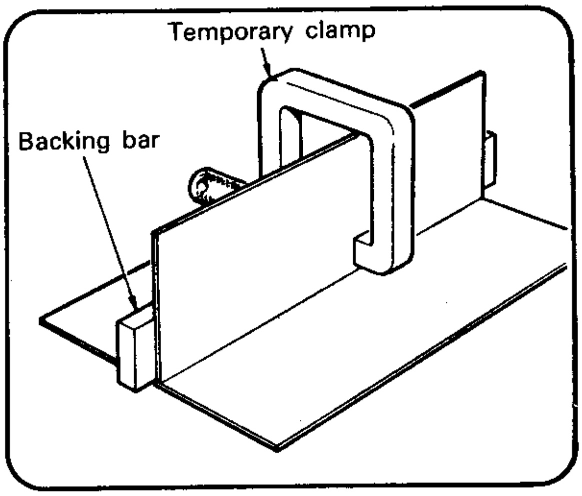
The backing bar may be incorporated as an insert in a jig, holding-down, or backing bar fixture.



Take care to ensure that the assembled joint does not lift away from the backing bar during welding, or burn-through may occur. Lack of such care makes the welding more difficult.

The use of a backing bar with argon backing is advantageous when welding butt joints in stainless steel and other ferrous materials. It prevents oxidation of the penetration bead and gives the bead a neat and uniform appearance.

Provided the sheets are closely abutted, tacked in true alignment, and the correct welding technique is used, a backing bar is not necessary when welding aluminium or aluminium alloy sheet between 1·5 mm and 3 mm thickness.



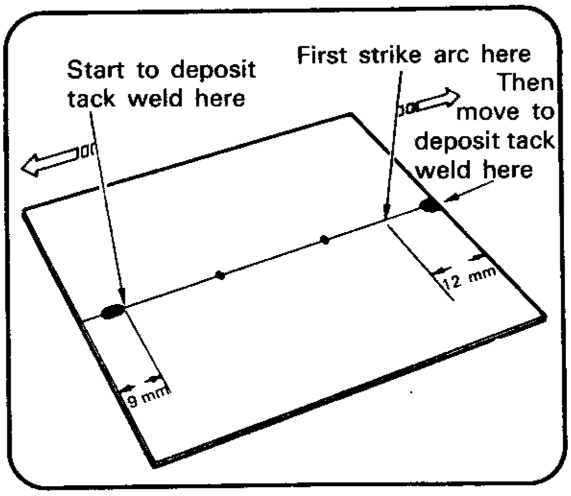
Tack welds

Allowance must be made for the possibility of loss of argon shrouding when tack welding the ends of joints. Supporting the joint in close contact with a backing bar extending beyond the end of the joint will help to prevent this loss. The argon flow rate should be increased by about 0·06 m^3/hr and the electrode extension restricted to 4·5 mm.

For tack welding T joints a longer electrode extension may be necessary.

For materials up to 3 mm thickness, tack welds should be at a pitch of 25 mm plus 8 t (t = sheet thickness). These distances may be doubled for fillet-welded T joints.

End tack welds should be of a length equal to four times the thickness of the sheet. Intermediate spot tack welds should fuse the full thickness of the sheet over a distance not less than twice the thickness of the sheet.



Tack welding procedure

1. Set the appropriate conditions for welding the material used but with increased argon flow.

2. Strike the arc at about 12 mm from the right-hand end of the joint.

3. Quickly move the torch back so that electrode is pointing at the end of the joint at an angle of 65°–75°.

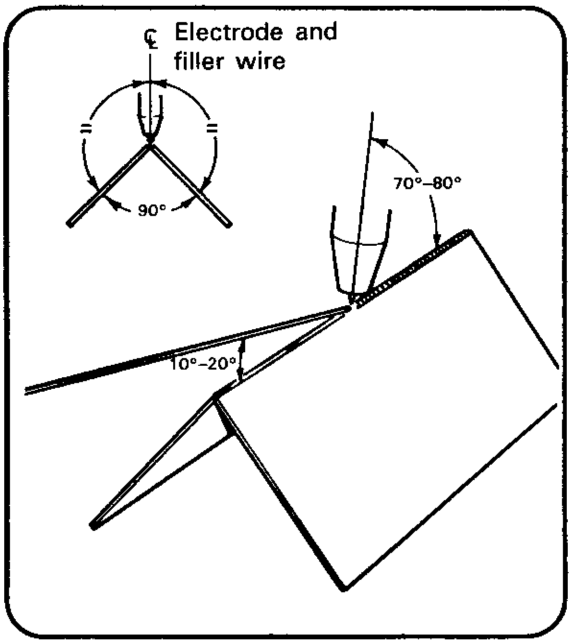
4. As soon as fusion is established, melt sufficient filler metal to make a weld of the required length.

5. Make sure the sheets are tightly abutted and re-strike the arc at about 9 mm from the left-hand end of the joint, with the electrode vertical.

6. As soon as fusion is established make a weld of the required length.

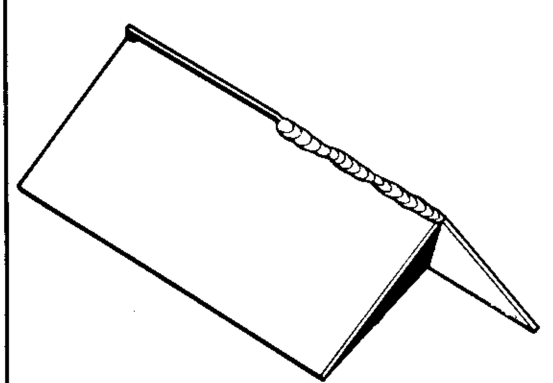
7. Make intermediate spot tack welds, depositing a small bead with filler metal at the appropriate intervals.

Take care that the fusion faces are closely abutted and the joint correctly aligned.



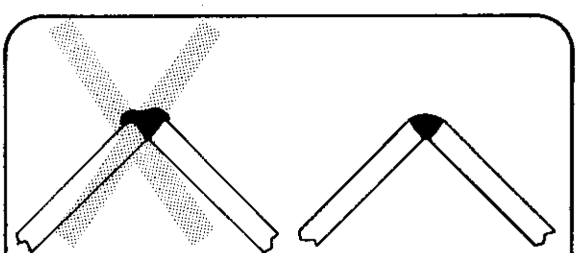
Corner joint—Flat position
Example procedure EP/T/6

Material	Two pieces of stainless steel 3 mm thick. Min. size 50 mm x 200 mm
Preparation	Square edge
Assembly	Tack weld with five tacks to give included angle of 90° without gap at the root
Electrode	2·4 mm
Argon	0·22–0·33 m^3/hr
Current	110–125 A
Filler rod	2·4 mm



Bad fit-up on a corner joint will lead to incorrect weld profile

1. Establish the arc on the tack weld at the right-hand end of the joint.
2. As soon as a small pool of molten metal is formed add filler metal.
3. Point the electrode at the root of the joint at an angle of 70°–80°.
4. Move the torch progressively leftwards, co-ordinated with the melting of filler metal to just fill the joint.
5. Keep arc length short.
6. Adjust the rate of travel to avoid excessive melting away of the top edges of the fusion faces or excessive fusion through the root.
7. When the tack weld at the left-hand end of the joint is reached, move the torch so that the electrode is perpendicular.
8. After fusing the tack weld and building up the weld section, break the arc in the correct manner.

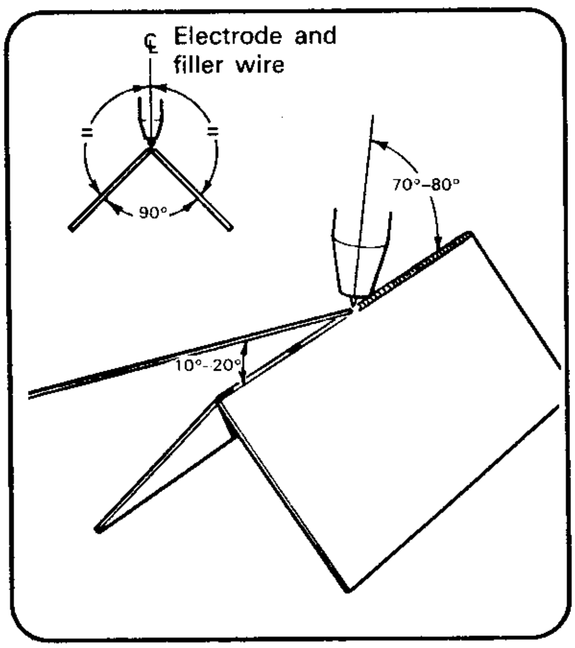


Incorrect profile   Correct profile

Visual examination
With correct speed of travel a full weld with a slightly convex profile will result.
The underside of the joint should show fusion to the root or even a slight penetration bead.

Corner joint—Flat position
Example procedure EP/T/7

Material	Two pieces of aluminium 1·5 mm thick. Min. size 100 mm × 150 mm
Preparation	As for EP/T/6
Assembly	As for EP/T/6
Electrode	2·4 mm
Argon	0·33–0·44 m^3/hr
Current	65–85 A
Filler rod	2·4 mm



1. Establish the arc on the tack weld at the right-hand end of the joint.

2. As soon as a small pool of molten metal is formed, add filler metal.

3. Point the electrode at the root of the joint at an angle of 70°–80°.

4. Move the torch progressively leftwards, co-ordinated with the melting of filler metal to just fill the joint.

5. Keep arc length short.

6. Adjust rate of travel to avoid excessive melting away of the top edges of the fusion faces or excessive fusion through the root.

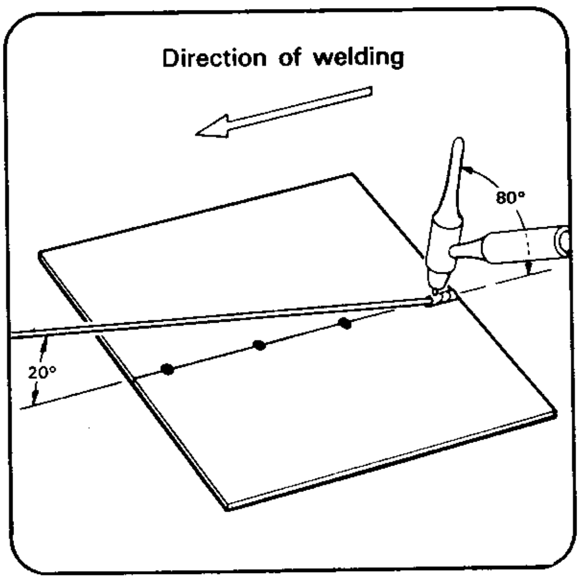
7. When the tack weld at the left-hand end of the joint is reached, move the torch so that the electrode is perpendicular.

8. After fusing the tack weld and building up the weld section, break the arc in the correct manner.

Visual examination (as for EP/T/6)
With correct speed of travel a full weld with a slightly convex profile will result.
The underside of the joint should show fusion to the root or even a slight penetration bead.

Close square butt joint—Flat position
Example procedure EP/T/8

Material	Two pieces of stainless steel 1·5 mm thick. Min. size 100 mm × 150 mm
Preparation	Square edge
Assembly	Use grooved backing bar, preferably with argon backing
Electrode	1·6 mm
Argon	0·22–0·33 m^3/hr
Current	50–70 A
Filler rod	1·6 mm



1. Assemble and tack joint.
2. Strike the arc on the first tack and move quickly to right-hand end of joint, maintain the torch at an angle of 80° slope and 95° tilt from the line of the weld.
3. Maintain the arc stationary until the joint is fused through the thickness of the plate.
4. Move the filler rod towards the weld area at 10°–20° slope 90° tilt. Introduce the tip of the filler rod into the leading edge of the weld pool and allow a short length of filler to melt into the pool.
5. Withdraw the filler slightly. **Do not allow the tip to come outside the gas shield.**
6. Move the torch slowly forward to the leading edge of the weld pool and move the filler rod out a similar distance.
7. The pool will become elongated and the previous leading edge should form part of the main pool.
8. Allow the leading edge to fuse and when a small depression appears in the base, add more filler rod.
9. Maintain the small depression in the base by moving the torch forward and feeding the filler rod into the main pool. Continue this action along the joint, adjusting the additions of filler rod to allow the weld to be reinforced sufficiently.

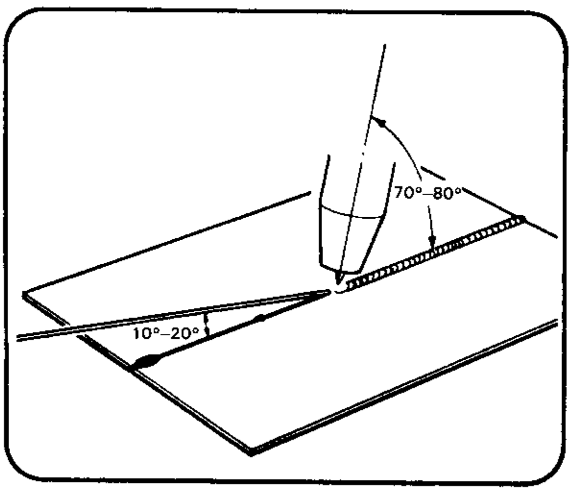
Visual examination
Examine the completed weld for adequate penetration, freedom from undercut, cold lap, excessive reinforcement (and possible porosity).

Faults in butt welds

Lack of penetration	Intermittent penetration	Excessive penetration	Undercut	Cold lap	Excessive reinforcement
Rate of travel too fast. Filler rod fed in too quickly. Current too low. Torch angle of slope incorrect.	Variations in speed of travel. Variations in torch angle of slope. Incorrect feed of filler rod.	Rate of travel too slow. Current too high.	Variations in angle of torch and/or filler rod. Current too high. Incorrect feed-in and/or deposition of filler rod.	Incorrect feed-in of filler rod. Excessive or fast deposit. Current too low.	Excessive deposition of filler rod. Current too low.

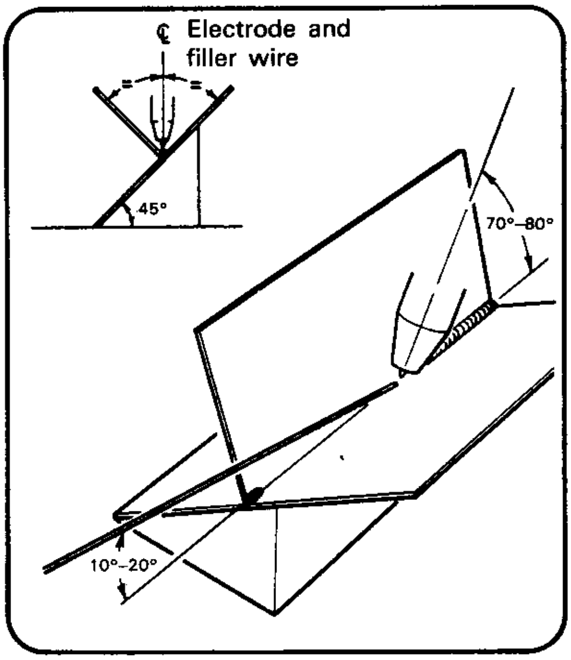
Close square butt joint—Flat position
Example procedure EP/T/9

Material	Two pieces of aluminium 1·5 mm thick. Min. size 100 mm × 150 mm
Preparation	Square edge
Assembly	Tack weld with five tacks, no gap. Support in flat position with air space below
Electrode	2·4 mm
Argon	0·33–0·42 m^3/hr
Current	70–85 A
Filler rod	2·4 mm



1. Establish the arc at the right-hand end of the joint, with the electrode held at an angle of 70°–80°.
2. Immediately fusion to the root of the joint is obtained, add filler metal to prevent excessive fusion of parent metal.
3. Commence leftwards movement without weaving of torch.
4. Co-ordinate addition of filler metal and rate of travel so as to maintain fusion to the root and build up the weld to a slightly convex profile.
5. Add filler metal immediately if excessive penetration seems imminent.

Visual examination (as for EP/T/8)



Material	Two pieces of stainless steel 1·5 mm thick. Min. size 150 mm × 100 mm
Preparation	As for EP/T/10
Assembly	As for EP/T/10
Electrode	1·6 mm
Argon	0·1–0·2 m^3/hr
Current	50–70 A
Filler rod	1·6 mm

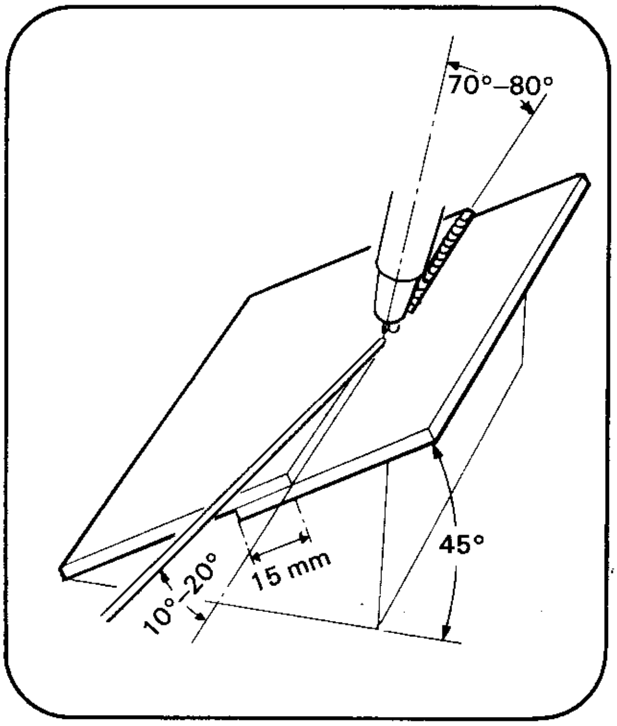
T joint—Flat position
Example procedure EP/T/10

Material	Two pieces of aluminium 3 mm thick. Min. size 50 mm × 200 mm
Preparation	Square edge
Assembly	Tack weld both ends to form an inverted T joint, adding a spot tack centrally, no gap. Support the assembly so that the lower sheet is inclined at 45° transversely
Electrode	3·2 mm
Argon	0·3–0·4 m^3/hr
Current	125–140 A
Filler rod	3·2 mm

1. Establish the arc at the right-hand end of the joint.
2. Point the electrode directly at the root of the joint at an angle of 70°–80°.
3. Point the filler rod directly at the root of the joint at an angle of 10°–20° and in line with the joint.
4. As soon as a small pool of molten metal is formed, add filler metal and commence the progressive leftward movement without weaving the torch.
5. Adjust the rate of travel and addition of filler metal so as to produce a fillet weld of between 3 mm and 5 mm leg length.

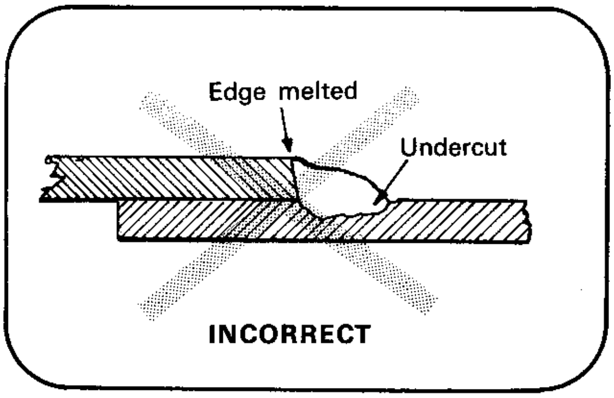
T joint—Flat position
Example procedure EP/T/11

1. As for EP/T/10 except for the amended welding conditions.



Lap joint—Flat position
Example procedure EP/T/12

Material	Two pieces of stainless steel 2·5 mm thick. Min. size 100 mm x 150 mm
Assembly	Place the sheets on the bench with an overlap of 15 mm. Tack at four points. Turn over and tack other side of joint.
Electrode	2·4 mm
Argon	0·1–0·2 m^3/hr
Current	100–110 A
Filler rod	2·4 mm



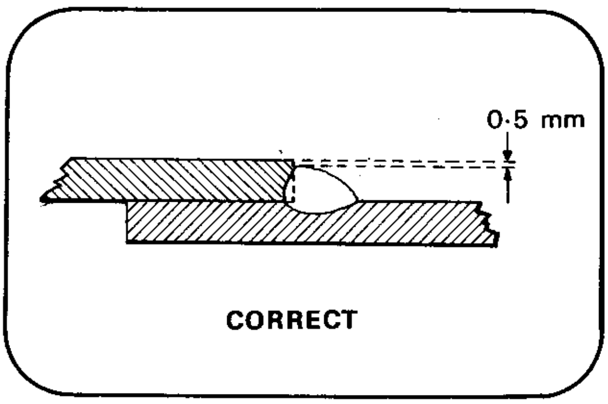
1. Strike arc on tack at end of joint.

2. As soon as the molten pool has been formed move forward, depositing a fillet weld along the joint with a leg length of about 2 mm.

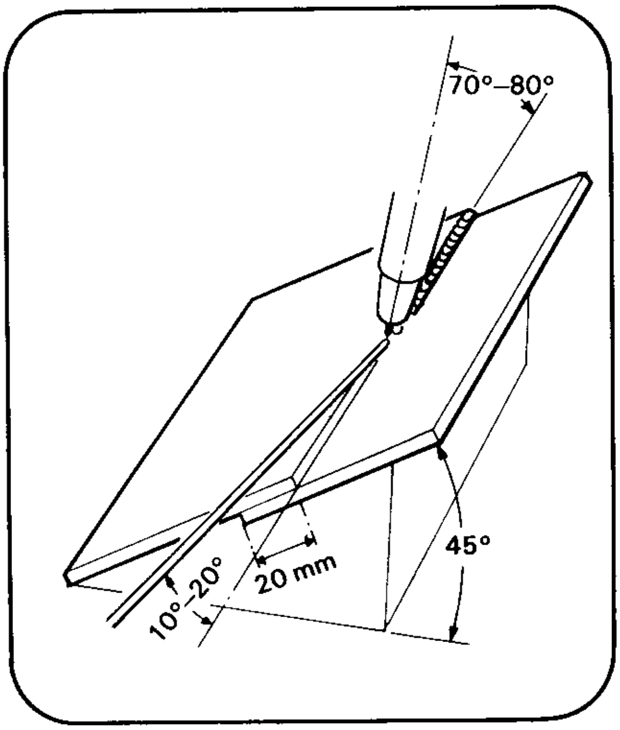
3. Do not melt the top edge. If the plate edge becomes too hot, direct the arc towards the lower plate.

4. When the first side has been welded, turn the plates over and examine the tack welds on opposite side. If these are cracked, grind out and re-tack.

5. Deposit weld on second side.



Visual examination
Examine the top edges of the joint for melting or loss of leg length.
Check for undercut.



Lap joint—Flat position
Example procedure EP/T/13

Material	Two pieces of aluminium 5 mm thick. Min. size 150 mm x 200 mm
Assembly	As for EP/T/12 except that overlap should be 20 mm
Electrode	3·2 mm
Argon	0·3–0·4 m^3/hr
Current	125–140 A
Filler rod	3·2 mm

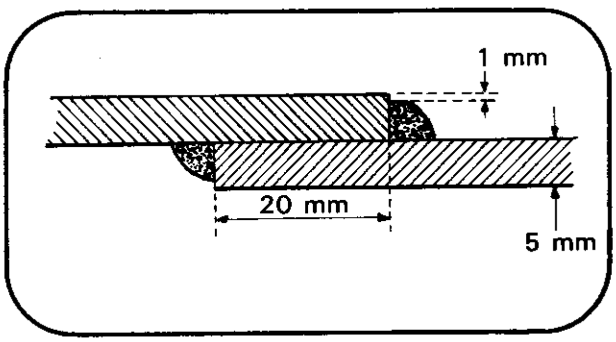
1. Strike arc on tack at end of joint.

2. As soon as the molten pool has been formed move forward, depositing a fillet weld along the joint with a leg length of about 4 mm.

3. Do not melt the top edge. If the plate edge becomes too hot direct the arc towards the lower plate.

4. When the first side has been welded, turn the plates over and examine the tack welds on opposite side. If these are cracked, grind out and re-tack.

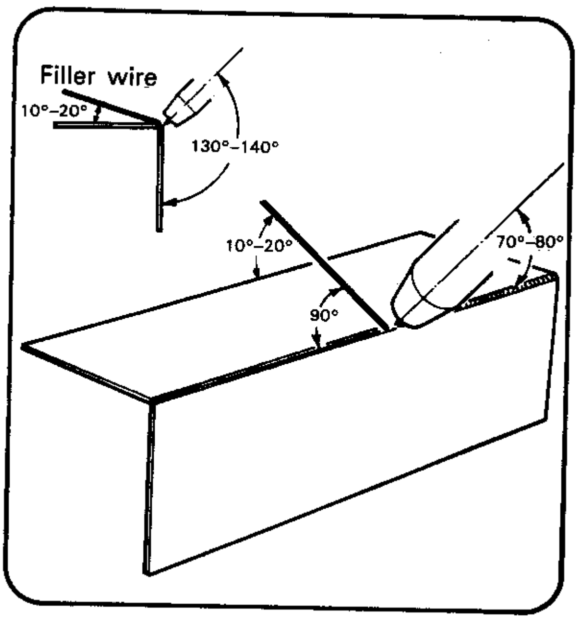
5. Deposit weld on second side.



Visual examination
Examine the top edges of the joint for melting or loss of leg length.
Check for undercut.

Depositing straight runs in the horizontal-vertical position

When welding joints that are in the horizontal-vertical position, the arm holding the torch should be placed below the hose assembly which is then looped so that the portion of the assembly near the torch handle is resting on the forearm. Supporting the hose assembly in this manner prevents drag on the torch handle.



Corner joint—Horizontal-vertical position
Example procedure EP/T/14

Material	Two pieces of aluminium 3 mm thick. Min. size 100 mm × 200 mm
Preparation	Square edge
Assembly	Tack weld with seven tacks to give included angle of 90°; no gap. Support to form an inverted L with the horizontal sheet pointing away from the welder.
Electrode	2·4 mm
Argon	0·3–0·4 m³/hr
Current	55–70 A
Filler rod	2·4 mm

1. Point the electrode at the root of the joint, at an angle of 70°–80° and with the torch tilted so that the electrode is at an angle of 130°–140° to the vertical plate.

2. Hold the filler rod at right angles to the joint and at an angle of 10°–20° to the horizontal plate.

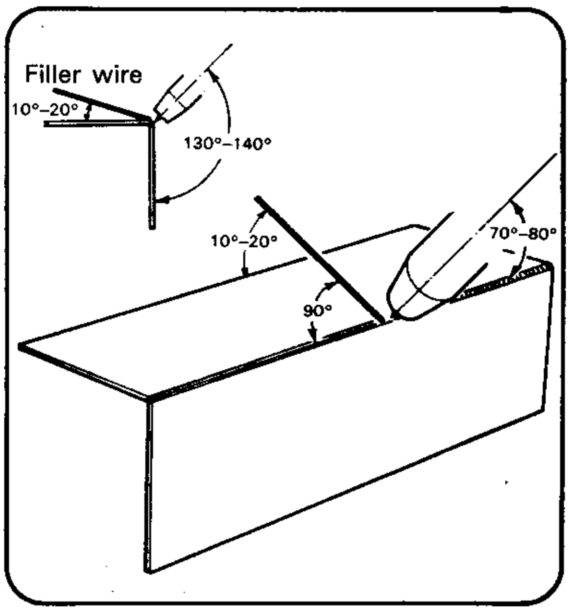
3. Immediately fusion to the root of the joint at the right-hand end is obtained, commence leftwards movement adding filler metal to the top edge of the weld pool.

4. Co-ordinate the addition of filler metal and the rate of travel so as to secure full section weld without burn-through. Take care when welding material thinner than 1·5 mm.

Visual examination
Good preparation of the edges and alignment of joint, also correct adjustment of welding current and rate of travel, should produce a neat uniform weld which on the reverse side has either a small uniform penetration bead or an indication that fusion to the root has been obtained consistently.

Corner joint—Horizontal-vertical position
Example procedure EP/T/15

Material	Two pieces of stainless steel 1·6 mm thick. Min. size 100 mm × 200 mm
Preparation	As for EP/T/14
Assembly	As for EP/T/14
Electrode	1·6 mm
Argon	0·1–0·25 m^3/hr
Current	45–55 A
Filler rod	1·6 mm



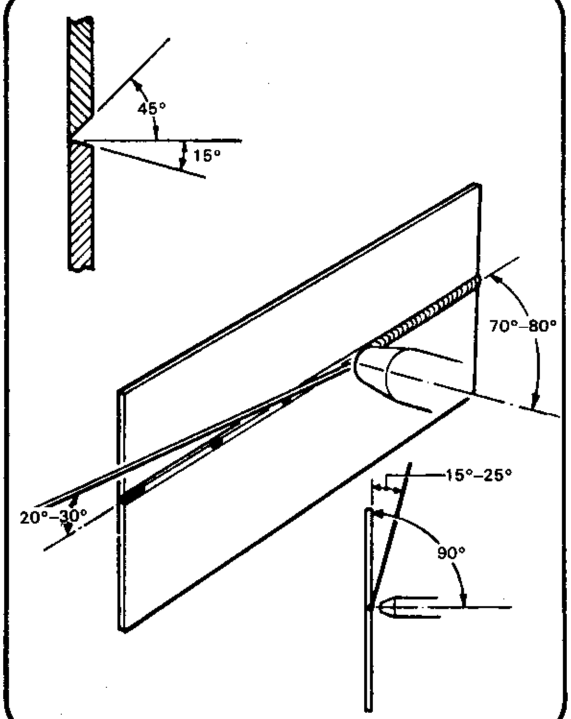
1. Point the electrode at the root of the joint at an angle of 70°–80° and with the torch tilted so that the electrode is at an angle of 130°–140° to the vertical plate.

2. Hold the filler rod at right angles to the joint and at an angle of 10°–20° to the horizontal plate.

3. Immediately fusion to the root of the joint at the right-hand end is obtained, commence leftwards movement adding filler metal to the top edge of the weld pool.

4. Co-ordinate the addition of filler metal and the rate of travel so as to secure full section weld without burn-through. Take care when welding material thinner than 1·5 mm.

Visual examination
Good preparation of edges and alignment of joint, also correct adjustment of welding current and rate of travel, should produce a neat uniform weld which on the reverse side has either a small uniform penetration bead or an indication that fusion to the root has been obtained consistently.



Single V butt joint—
Horizontal-vertical position
Example procedure EP/T/16

Material	Two pieces of stainless steel 3 mm thick. Min. size 100 mm x 200 mm
Preparation	Lower sheet, angle of bevel 15°, upper sheet, angle of bevel 45°, no root face
Assembly	Tack weld with five tacks to give an included angle of 60°–65°; no gap. Support in a vertical position with line of joint horizontal. The use of a grooved backing bar with argon backing is recommended
Electrode	2·4 mm
Argon	0·2–0·3 m³/hr
Current	100–200 A
Filler rod	2·4 mm

1. Establish the arc at the right-hand end of the joint.

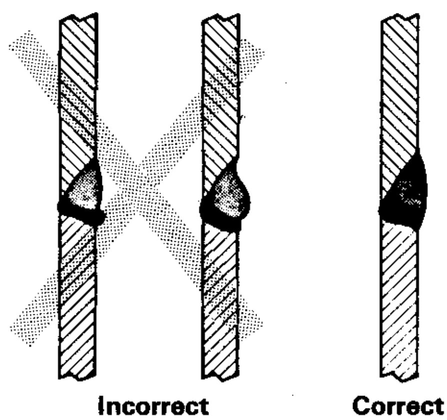
2. The torch body should be at right angles to the vertical plates with the electrode pointing at the root of the joint at an angle of 70°–80°.

3. The filler rod should be held so that it is at an angle of 15°–25° to the vertical plates and at an angle of 20°–30° to the horizontal line of the joint.

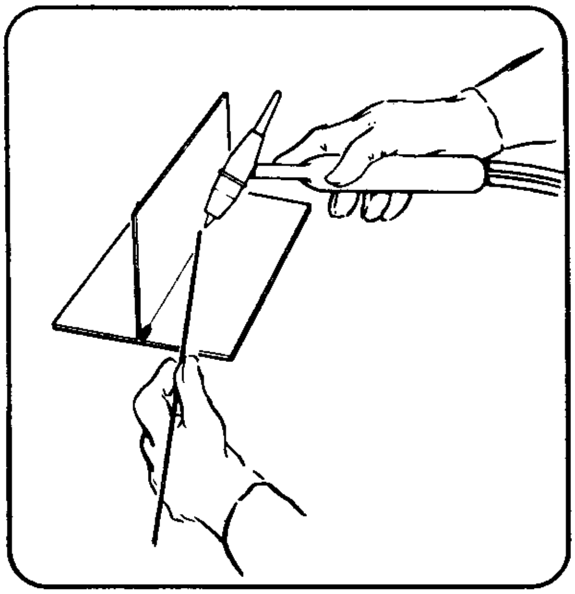
4. Add filler metal by inserting the filler rod end in the weld pool, in a fairly rapid reciprocating motion, fusing a small quantity at a time.

5. Adjust rate of travel to secure neat fusion to outer edges of the fusion faces and ensure that face of weld is not below the level of the parent metal surface.

Visual examination
The weld face should be just proud of the parent metal surface and should be reasonably free from 'sagging' caused by molten metal falling.
A slight and uniform penetration bead should be visible on the reverse side with freedom from burn-through.

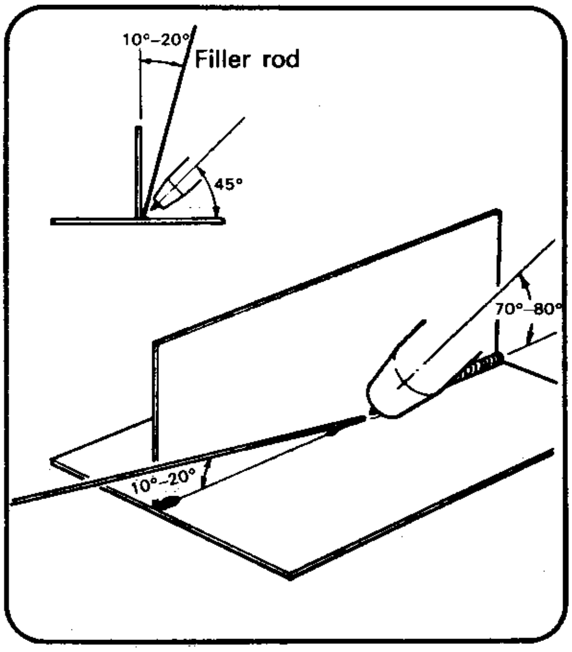


Incorrect and correct profiles horizontal-vertical butt joint



T joint—Horizontal-vertical position
Example procedure EP/T/17

Material	Two pieces of stainless steel 1·5 mm thick. Min. size 100 mm × 150 mm
Assembly	Tack weld both ends to form an inverted T joint, adding a spot tack centrally, no gap
Electrode	1·6 mm
Argon	0·1–0·2 m³/hr
Current	50–70 A
Filler rod	1·6 mm



1. The torch body should be inclined so that the electrode is at 45° to both the vertical and the horizontal plates.

2. The filler rod should be held so that it is at an angle of 10°–20° to both the vertical and the horizontal plates.

3. Establish the arc at the right-hand end of the joint, and as soon as fusion starts bring the filler rod end into contact with the leading edge of the weld pool.

4. Move torch slowly and uniformly leftwards without weaving.

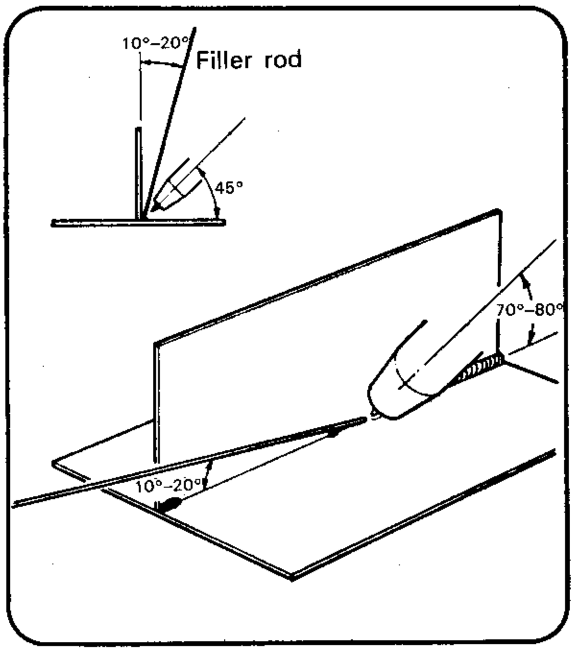
5. Regulate the rate of travel and the addition of filler metal to give a fillet weld of between 2·5 mm and 3·5 mm leg length.

Visual examination
The weld should be equally disposed between the vertical and horizontal plates and of uniform leg length, without undercut in the vertical plate. Undercut may be caused by too fast a rate of travel, too high a welding current or too shallow an angle of electrode to the horizontal plate.

Tungsten-arc gas shielded welding

T joint—Horizontal-vertical position
Example procedure EP/T/18

Material	Two pieces of aluminium 5 mm thick. Min. size 50 mm × 200 mm
Preparation	As for EP/T/17
Assembly	As for EP/T/17
Electrode	3·2 mm
Argon	0·3–0·4 m^3/hr
Current	140–160 A
Filler rod	3·2 mm



1. The torch body should be inclined so that the electrode is at 45° to both the vertical and the horizontal plates.

2. The filler rod should be held so that it is at an angle of 10°–20° to both the vertical and the horizontal plates.

3. Establish the arc at the right-hand end of the joint, and as soon as fusion starts bring the filler rod end into contact with the leading edge of the weld pool.

4. Move torch slowly and uniformly leftwards without weaving.

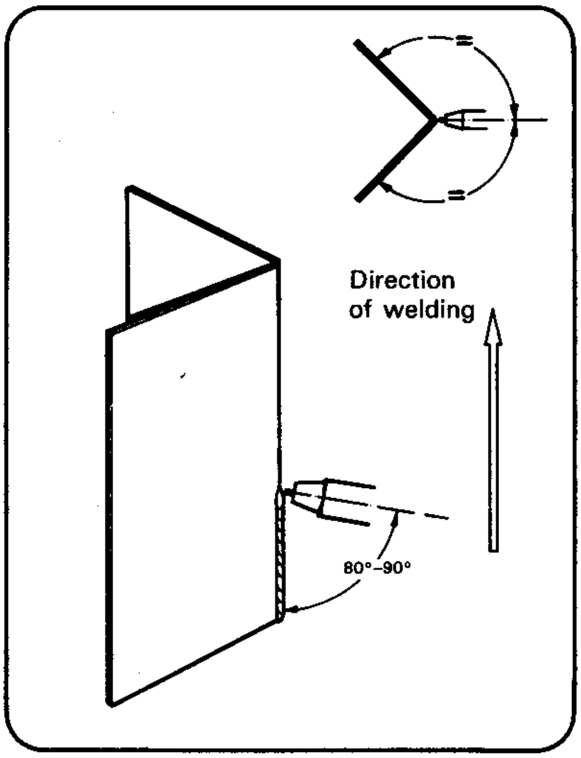
5. Regulate the rate of travel and the addition of filler metal to give a fillet weld of between 4 mm and 6 mm leg length.

Visual examination
The weld should be equally disposed between the vertical and horizontal plates and of uniform leg length, without undercut in the vertical plate. Undercut may be caused by too fast a rate of travel, too high a welding current or too shallow an angle of electrode to the horizontal plate.

Tungsten-arc gas shielded welding

Close corner weld without filler—
Vertical position
Example procedure EP/T/19

Material	Two pieces of stainless steel 1·5 mm thick. Min. size 50 mm × 100 mm
Assembly	Tack the joint. Stand the plate on end with the corner towards the welder supporting the plates so that they will not fall or move during welding.
Electrode	1·6 mm
Argon	0·15–0·2 m³/hr
Current	60–70 A



1. Ensure that the welding operation can be carried out free from restriction and that heat is not being conducted away from the base.

2. Strike the arc at the point of the tack weld.

3. Establish the arc and move to the lower end of the joint.

4. With the torch pointed directly at the centre of the joint, hold it at an angle of 80°–90° slope with equal angles of tilt as illustrated.

5. Proceed to melt the edges of the plate.

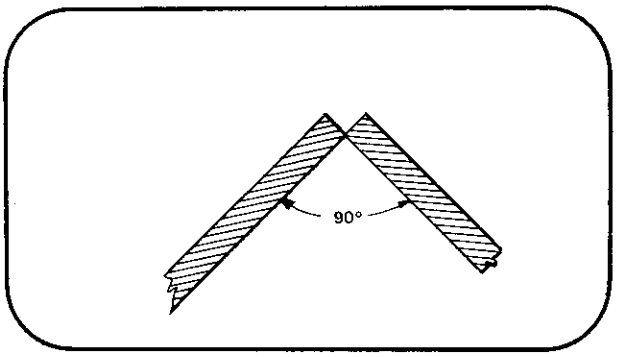
6. Manipulate the torch slightly to flow the molten edges together.

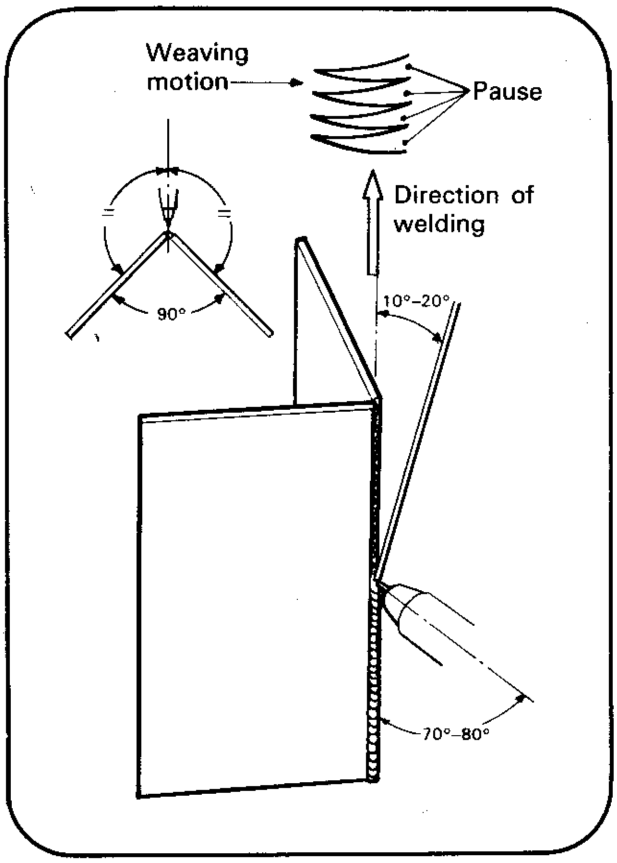
7. As soon as a weld pool has been established hold the torch steady and advance up the joint ensuring the edges are fusing in advance of the molten pool. When approximately 6·5 mm from the top of the weld change the torch angle until it is at 90° (slope) and reduce current to fill the crater at the end of the run. Allow the termination of the weld to cool off in the argon shield after the arc has been extinguished.

Visual examination
Weld should be of uniform profile and correct width with adequate root penetration.
Absence of overlap along the toes of the weld.

Close corner weld with filler—
Vertical position
Example procedure EP/T/20

Material	Two pieces of aluminium 5 mm thick. Min. size 50 mm x 200 mm
Assembly	Tack the joint with the edges touching. Stand plate on end and support.
Electrode	3·2 mm
Argon	0·3–0·4 m^3/hr
Current	140–150 A
Filler rod	3·2 mm





1. Ensure that the welding operation can be carried out free from restriction and that heat is not being conducted away from the base.

2. Strike the arc at the point of the lowest tack weld and melt a weld pool.

3. Add filler and commence to move up the joint, ensuring that the edges of the plates at the root are fused and that penetration is achieved.

4. Deposit a root run which has a thickness of 2 to 3 mm.

5. Establish a weld pool at the base of the joint by melting the surface of the root.

6. Point the torch to the right-hand edge and melt the joint face. As soon as fusion is achieved point the torch at the other edge; melt and add filler metal to the weld pool.

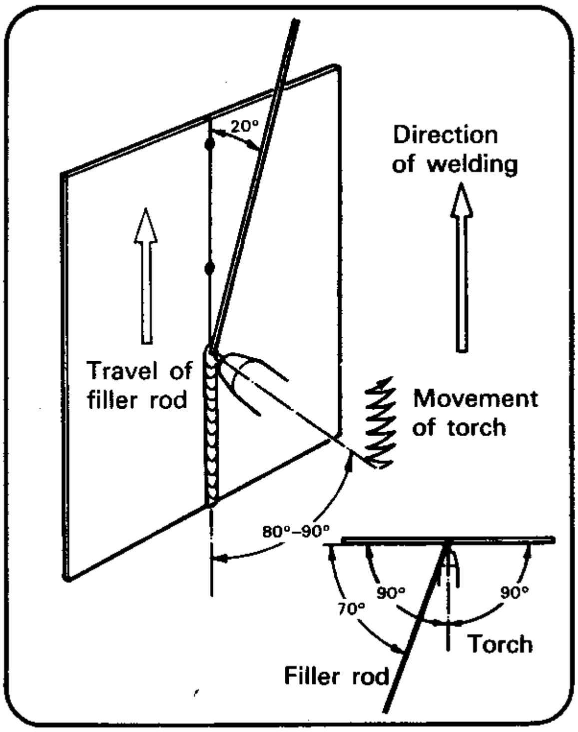
7. Move up the joint weaving the electrode from side-to-side and adding filler metal to give a flat surface. Pause momentarily at the end of each weaving motion to ensure edge melting.

Visual examination
Weld should be of uniform profile and correct width with adequate root penetration.
Absence of overlap along the toes of the weld.

Tungsten-arc gas shielded welding

Close square butt weld—Vertical position
Example procedure EP/T/21

Material	Two pieces of stainless steel 2·4 mm thick. Min. size 150 mm × 150 mm
Assembly	Cut with square edges. Tack weld leaving no gap. Secure in vertical position.
Electrode	3·2 mm
Argon	0·2–0·25 m^3/hr
Current	90–125 A
Filler rod	2·4 mm



1. Strike the arc on the first tack weld and move to the lower end of the joint.

2. Establish a weld pool, holding the torch at an angle of 90° (slope) and 90° (tilt) from the line of the weld.

3. Alter the torch angle to 80°–90° (slope) and move the torch slowly up the joint to a point where the leading edge of the pool was previously established. Manipulate the torch to ensure fusion through the material.

4. Introduce the filler rod into the top edge of the weld pool at an angle of 20°–30° (slope) and 70° (tilt).

5. Repeat the upwards movement of the torch fusing the side walls into the main pool and ensure full penetration.

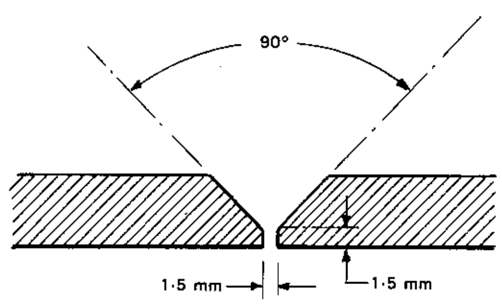
6. At approximately 6·5 mm from the end manipulate the torch at angle of 90° (slope) and ensure that the crater is filled at the termination of the weld. Allow this area to cool off in the argon shield after the arc has been extinguished.

Visual examination
Weld should be of uniform profile and correct width adequate root penetration.
Absence of undercutting along the toes of the weld.

Butt joint—Vertical position
Example procedure EP/T/22

Note: The procedure for this joint is similar to that used for EP/T/20.

Material	Two pieces of aluminium 5 mm thick. Min. size 100 mm × 200 mm
Assembly	Prepare one long edge of each plate with a 45° bevel leaving a 1·5 mm root face. Tack weld the plates to give a 1·5 mm root gap. Wire brush thoroughly.
Electrode	3·2 mm
Argon	0·3–0·4 m^3/hr
Current	(a) Root run 120–120 A (b) Capping run 140–150 A
Filler rod	3·2 mm



Joint preparation

1. Support the plates in the vertical position so that there is complete freedom of movement.

2. Strike the arc at the point of the lowest tack weld.

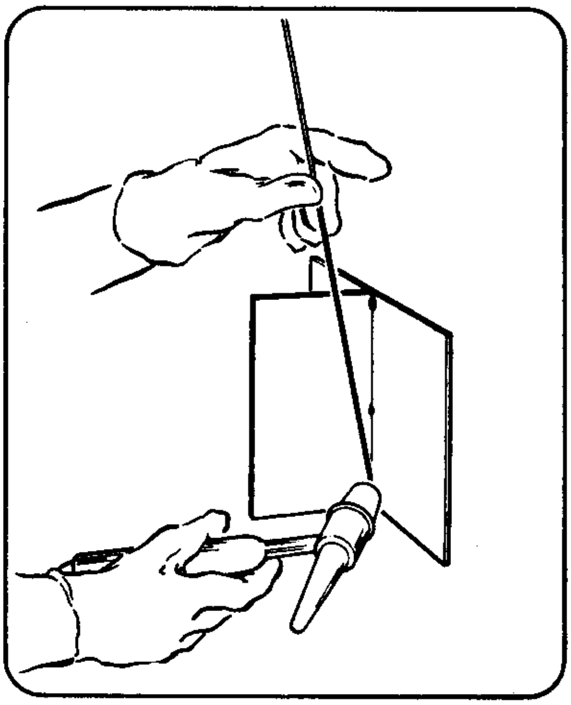
3. Establish a weld pool and move up the joint, ensuring that the root faces are fused into the weld. Add filler metal as needed; the weld run should fill half the thickness of the joint.

4. When the root run has been deposited, wire brush the joint and start the capping run by establishing a weld pool at the base of the joint.

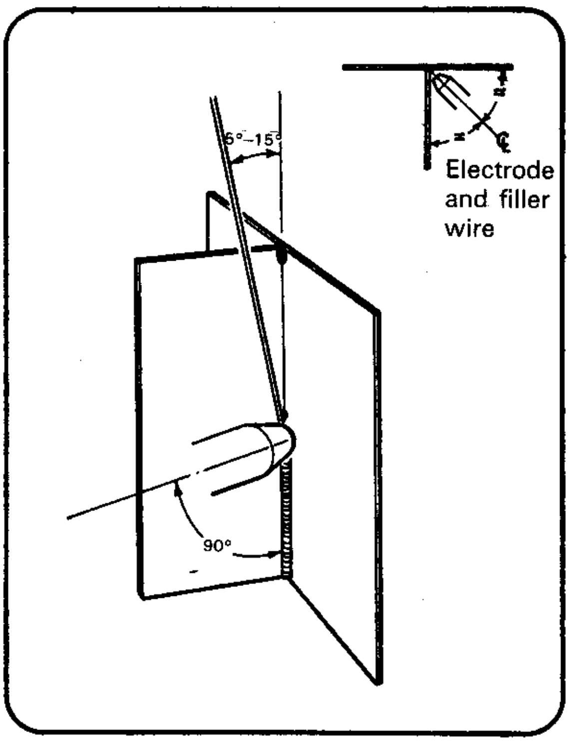
5. Fill the joint, using a side-to-side weaving motion. Pause momentarily at the edges of the joint to achieve fusion of the parent metal. Ensure that the surface of the root run is fused. Add sufficient filler metal to fill the joint.

Visual examination
The penetration bead should be uniform in size along the length of the joint and should be free from oxide inclusion.
The surface of the weld should be uniform and free of undercut.

T joint—Vertical position
Example procedure EP/T/23



Material	Two pieces of stainless steel 3 mm thick. Min. size 100 mm × 200 mm
Preparation	Square edge
Assembly	Tack weld both ends to form a T joint, adding spot tack centrally; no gap. Support assembly with line of joint vertical, about 150 mm above bench top
Electrode	2·4 mm
Argon	0·2–0·3 m³/hr
Current	100–200 A
Filler rod	2·4 mm



1. Hold the torch body so that the axis of the electrode bisects the angle between the two plates and is at right angles to the joint.

2. The filler rod is fed in from above the arc at an angle of 5°–15° to the line of the joint. The rod may be cranked to avoid heat discomfort.

3. Establish the arc on the tack weld at the bottom end of the joint and form a small weld pool.

4. Add a small quantity of filler metal to build up the weld section and start upwards movement.

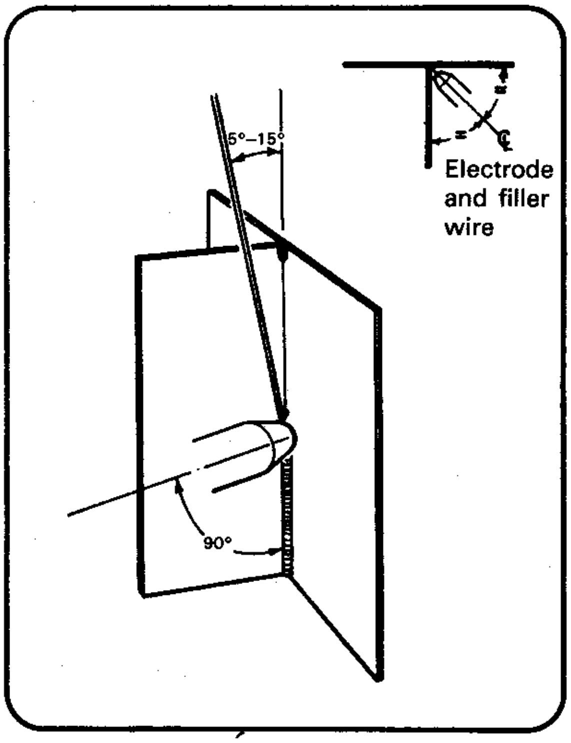
5. Only a small quantity of filler metal should be melted each time to avoid contamination of the electrode end.

6. Adjust rate of travel to secure neat fusion without undercut at either toe of the weld.

Visual examination
The weld should be equally disposed between the two plates and reasonably uniform in leg length. The leg length should be between 3·5 mm and 6·5 mm.
The weld metal should be free from tungsten inclusions and have a uniform profile without excessive 'sagging'.
There should be no undercut at the toes of the weld.

T joint—Vertical position
Example procedure EP/T/24

Material	Two pieces of aluminium 3 mm thick. Min. size 100 mm × 200 mm
Preparation	As for EP/T/23
Assembly	As for EP/T/23
Electrode	3·2 mm
Argon	0·3–0·4 m^3/hr
Current	110–130 A
Filler rod	3·2 mm



1. Hold the torch body so that the axis of the electrode bisects the angle between the two plates and is at right angles to the joint.

2. The filler rod is fed in from above the arc at an angle of 5°–15° to the line of the joint. The rod may be cranked to avoid heat discomfort.

3. Establish the arc on the tack weld at the bottom end of the joint and form a small weld pool.

4. Add a small quantity of filler metal to build up the weld section and start upwards movement.

5. Only a small quantity of filler metal should be melted each time to avoid contamination of the electrode end.

6. Adjust rate of travel to secure neat fusion without undercut at either toe of the weld.

Visual examination
The weld should be equally disposed between the two plates and reasonably uniform in leg length.
The leg length should be between 3·5 mm and 6·5 mm.
The weld metal should be free from tungsten inclusions and have a uniform profile without excessive 'sagging'.
There should be no undercut at the toes of the weld.

Pipe welding

Normally, joints in pipes and tubes cannot be welded from the inside of the bore. When the weld is made from the outside, great care must be exercised in controlling the penetration which must be uniform around the circumference of the pipe. The underbead must be smooth and blend into the pipe surface. It is also important that the bore of the pipe must not be restricted by the presence of a large penetration bead. A maximum bead size will often be specified on the Procedure sheet.

During the welding of example butt joints the pipe may be:
either
Rolled ie. continuously revolved or rotated.
or
Turned through 90° after each quarter section of the circumference has been welded.

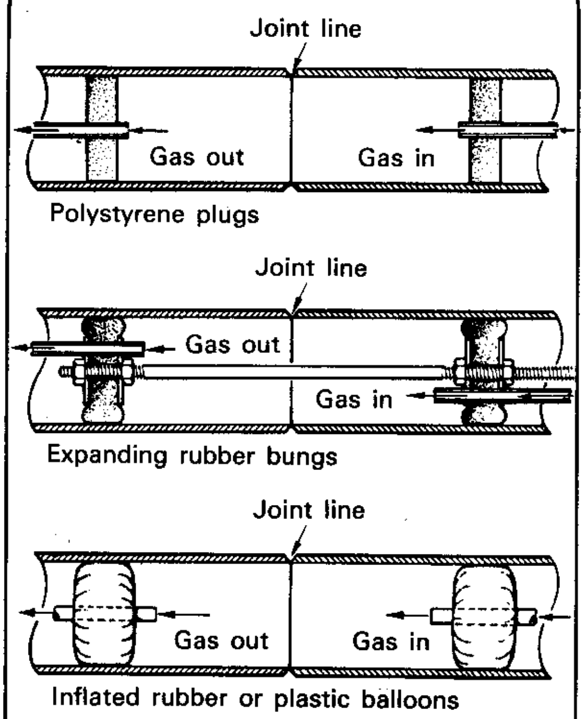
In both cases the aim is to do as much welding as possible in the flat position.

Gas backing

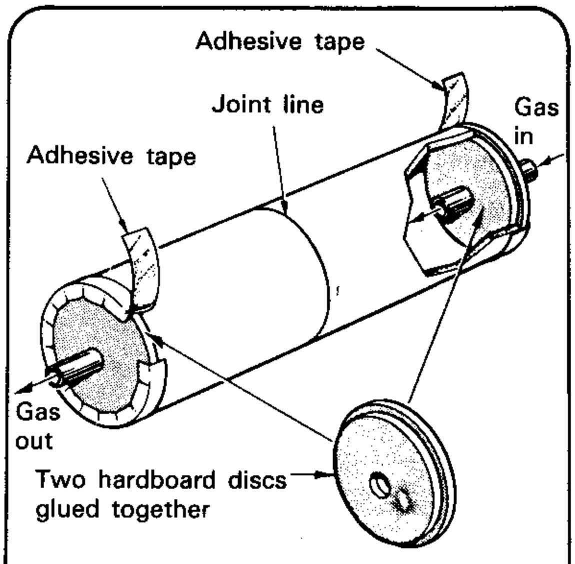
When welding pipes with the tungsten-arc gas shielded process, protect the underside of the weld from oxidation by filling the pipe bore with argon or any other suitable non-oxidising gas.

In practice, the gas backing is confined to the joint area by inserting suitable dams or plugs in the pipe. These are removed after welding and should be positioned at a suitable distance from the joint line to avoid damage by the heat produced during welding.

In training, when short lengths of pipe are used, block the ends of the pipe with discs made from hardboard or similar material. If the pipes are longer than 150 mm the discs can be held in place by adhesive tape. With shorter lengths, secure the discs by means of a bolt.



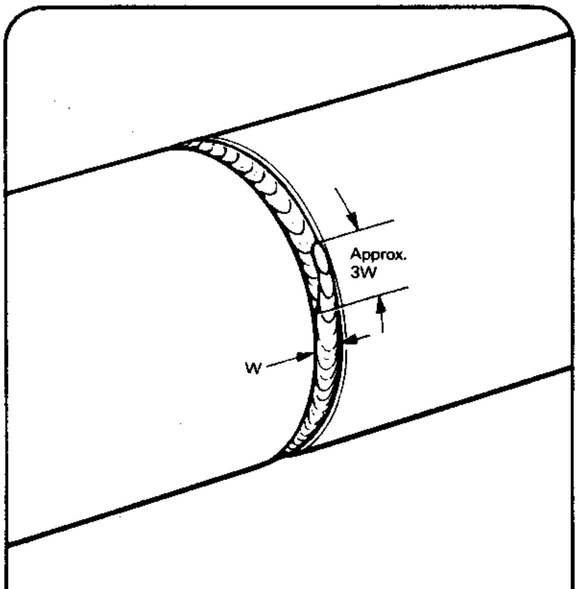
Methods of localising gas backing



Method used in training for blocking ends of pipe

Preparation for welding pipe butt joints
Before welding ensure that:

1. the pipe ends have been correctly prepared and are free from cutting or machining defects,
2. the pipe edges are clean and free from dust, oil or grease, paint or heavy oxide,
3. the root face is uniform around the circumference of the pipe,
4. the bores of the two pipes match; pipe showing excessive ovality may need to be machined or swaged to match the diameter. Good fit-up and alignment is essential,
5. when assembled, the root gap is uniform at all points around the circumference.



Correct finish of weld bead to avoid cracks

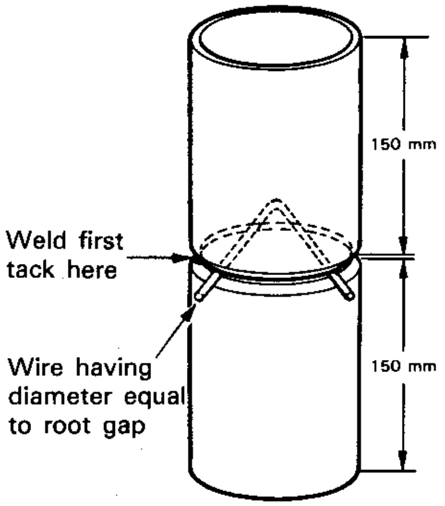
Termination of weld run
In the welding of pipe butt joints it is important to use the correct procedure for terminating the weld bead in order to avoid the production of crater cracks.

At the end of the weld run an overlap of approximately three times the width of the weld bead should be made.

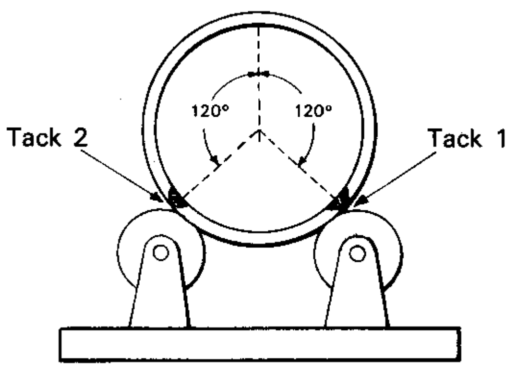
As the overlapping run is made the size of the weld pool is reduced by rapidly increasing the speed of travel with all runs except the capping run; the diminishing weld pool can be directed off to one side of the joint so that the actual point of termination is on the face of the edge preparation.

Tacking butt joints prior to welding
Example procedure EP/T/25

> *Note:* This procedure should be followed in assembling the pipes used in example procedures EP/T/26, 27 and 28.
> Use the welding conditions appropriate to each example procedure.



Use of bent wire or spacer to set root gap



Tacking positions for butt weld in pipe

1. Place one length of pipe, 150 mm long, on the bench, with the pipe axis vertical and with the prepared end uppermost.

2. Place a piece of bent wire on the end of the pipe. The diameter of the wire should be equal to the root gap required.

3. Place second piece of pipe in position. Check that the bores are in alignment.

4. With the joint in the horizontal-vertical position, strike an arc in the root of the joint, using the current specified for the main weld.

5. As soon as the weld pool has penetrated through the root face, add a small amount of filler rod. Do not traverse the torch. Switch off the current and allow the weld pool to solidify.

6. Check that the root gap is still uniform.

7. Support the assembly on rolls with the tack weld at the bottom. Fit end discs and supply argon at a rate of about 0·1 m^3/hr. Estimate the volume of the bore between the dams and allow the gas to flow for a length of time sufficient to supply six times the pipe volume.

8. Deposit a 10 mm long tack weld at a distance of one third of the pipe circumference from the first tack weld. Ensure full penetration through the wall or root face thickness. Make filler rod additions as required. Fill the crater at the end of the weld.

9. Rotate the pipe. Re-melt the first tack weld and extend its length to 10 mm.

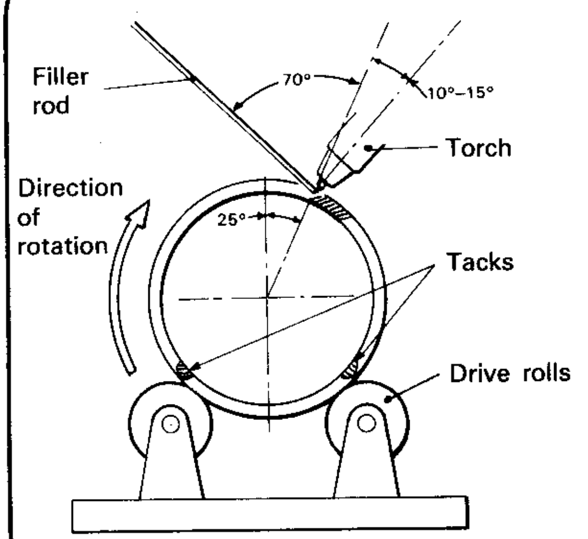
10. Remove the wire spacer from the joint.

Visual examination
The root gap in the joint should be uniform. The tack welds should show uniform penetration and should not contain cracks.

Butt joint—Rolled during welding—
Aluminium pipe
Example procedure EP/T/26

Material	Aluminium pipe 60 mm outside dia. 3·2 mm wall thickness
Assembly	Prepare the edges square and tack the joint as in EP/T/25. Locate the tacked assembly on the rolls or in a rotator with the untacked segment of the joint at the top
Electrode	3·2 mm
Argon	0·2–0·3 m^3/hr
Current	120–140 A
Filler rod	3·2 mm

1. Strike the arc at a point on the joint line about 25° after top dead centre (see illustration—note position of tack weld).
2. As soon as a weld pool has been formed and full penetration through the pipe wall has been achieved, rotate the pipe. The direction of rotation should be such that welding is carried out in an upwards direction.
3. Adjust the speed of rotation to give uniform penetration, with the torch held stationary. Add sufficient filler metal to produce a reinforcement of about 1·6 mm.
4. Continue the rotation until the joint has been welded round the complete circumference. Adjust the speed of rotation, if necessary, to maintain uniform penetration.
5. At the join-up, with the start of the weld, fuse the previously deposited weld for a distance of 6·5 mm.
6. Stop the rotation; fill the crater by the addition of a small amount of filler rod and switch off the current. Allow the weld to solidify under the protection of the shielding gas.

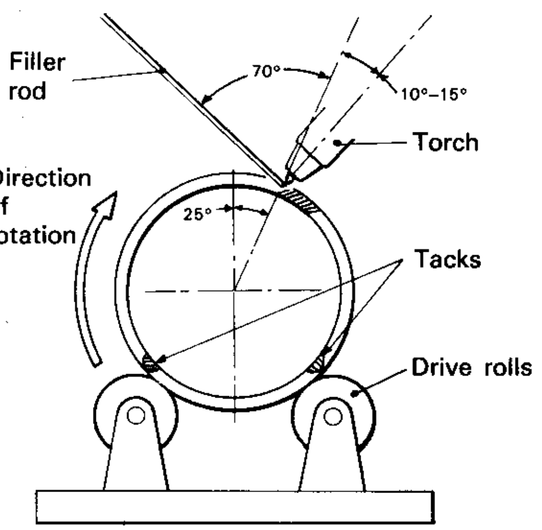


Butt weld in pipe

Visual examination
Examine the completed weld for uniformity of the penetration bead.
If possible, cut sections and carry out bend tests to detect any lack of fusion or oxide inclusions. Inadequate penetration can result from insufficient current or a high speed of rotation. The presence of oxide inclusions indicates that the joint was not cleaned correctly before welding.

Butt joint—Rolled during welding—
Stainless steel pipe
Example procedure EP/T/27

Material	Stainless steel pipe 60 mm outside dia. 3·2 mm wall thickness
Assembly	Prepare the edges square and tack the joint as in EP/T/25. Locate the tacked assembly on the rolls or in a rotator with the untacked segment of the joint at the top.
Electrode	2·4 mm
Argon	0·1–0·2 m³/hr
Current	90–110 A
Filler rod	2·4 mm



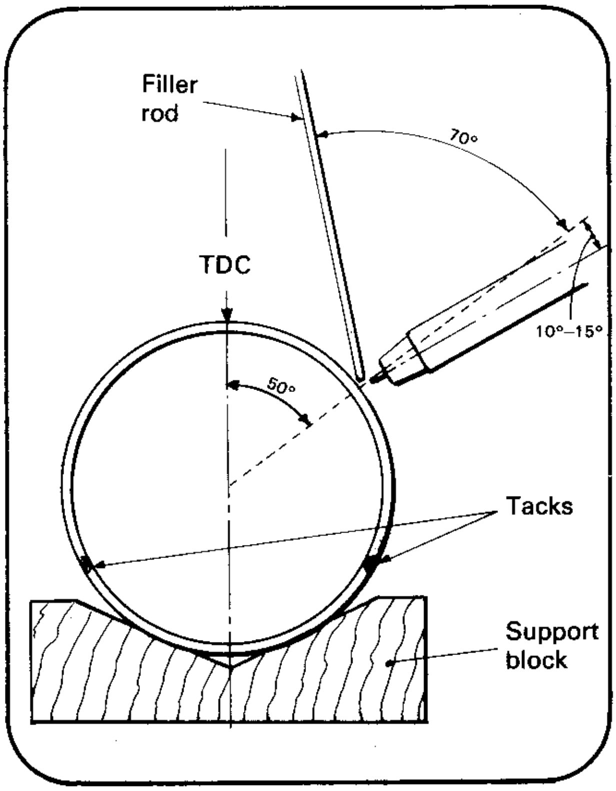
Butt weld in pipe

1. Strike the arc, at a point on the joint line, about 25° after top dead centre (see illustration—note position of tack welds).
2. As soon as a weld pool has been formed and full penetration through the pipe wall has been achieved, rotate the pipe. The direction of rotation should be such that welding is carried out in an upwards direction.
3. Adjust the speed of rotation to give uniform penetration, with the torch held stationary. Add sufficient filler metal to produce a reinforcement of about 1·6 mm.
4. Continue the rotation until the joint has been welded round the complete circumference. Adjust the speed of rotation, if necessary, to maintain uniform penetration.
5. At the join-up, with the start of the weld, fuse the previously deposited weld for a distance of 6·5 mm.
6. Stop the rotation; fill the crater by gradually reducing the current. Allow the weld to solidify under the protection of the shielding gas.

Visual examination
As for EP/T/26.

Butt joint—Segmentally welded—
Aluminium pipe
Example procedure EP/T/28

Material	Aluminium pipe 60 mm outside dia., 3·2 mm wall thickness
Assembly	Prepare the edges square and tack the joint as in EP/T/25
Electrode	3·2 mm
Argon	0·2–0·3 m³/hr
Current	120–140 A
Filler rod	3·2 mm



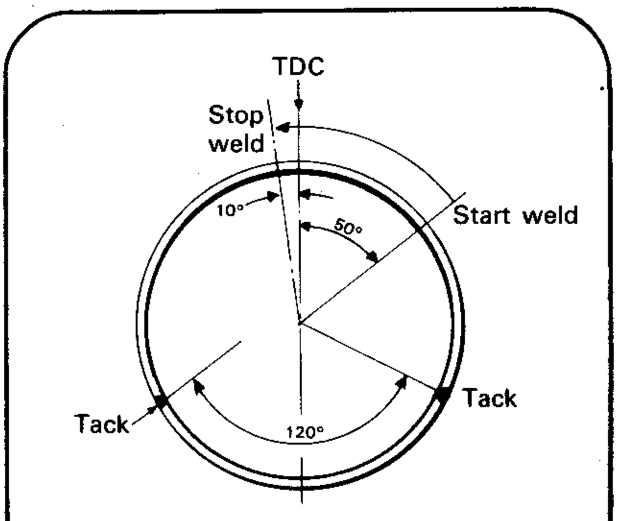
1. Locate the tacked pipe assembly on the bench and ensure that it is supported and will not move during welding. The untacked segment should be at the top.

2. Strike the arc at a point on the joint line, about 50° around the circumference from top dead centre (TDC).

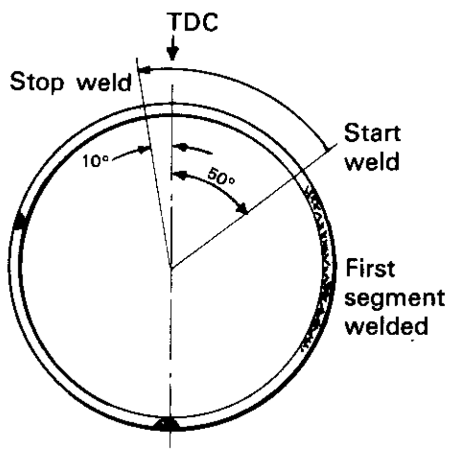
3. As soon as a weld pool has been established and penetration has been achieved, move along the joint line towards TDC. Add filler as necessary. Adjust the speed of travel to achieve full penetration of the wall thickness.

4. Continue welding past TDC until a total segment equal to 60° of the circumference has been welded.

5. Finish the weld run, filling the crater by addition of filler metal.



Welding first segment



Welding second segment

6. Turn the pipe so that the end of the weld is in the position used for the start of the weld (see illustration).

7. Strike the arc on the filled crater and form a weld pool. Complete a further 60° segment as above.

8. Continue welding, segment by segment until the complete circumference has been welded.

9. At the joint-up with the start of the weld, fuse the previously deposited metal for a distance of 6 mm.

Visual examination
Examine the completed weld for uniformity of the penetration bead.
If possible, cut sections and carry out bend tests to detect any lack of fusion or oxide inclusions. Inadequate penetration can result from insufficient current or a high speed of rotation. The presence of oxide inclusions indicates that the joint was not cleaned correctly before welding.

Phase tests

1. General

The sixteen phase tests (including tests for 'Alternatives' in the Training Specification) have been devised to measure the progress of trainees who are taking the General Welding and Cutting Module F10.

It is emphasised that these tests are merely examples and that alternative tests of items of production with similar skill demands can be used.

The tests have been arranged to coincide with the intermediate and final stages based on the skill elements given in the Training Specification.

Trainees should reach a satisfactory performance in each of the aspects of welding and cutting which are contained in the Module F10 Training Specification.

The phase tests must be completed satisfactorily before the trainee can proceed to any of the Stage III Modules F21 to 25.

2. Assessment

Each phase test shows a simple example of an engineering production item and a time is to be given for its completion.

The items to be assessed are detailed in the panel headed 'Assessment'. Where an alternative phase test is selected, it must include a similar number and type of skill elements. It is recommended that in half of the tests, the dimensions should be given in the metric system.

Before commencing the test, the trainee should be given time to study the drawing and to record the sequence of operations required to produce the work.

On completion of the test, it should be examined by the trainee's supervisor, or other competent person, who will determine whether it is satisfactory in ALL of the following elements:

(a) Dimensional accuracy
All dimensions must lie within the given range. Freedom from distortion and the use of correct Set-ups should be considered. Economy in plate usage should be assessed in the cutting processes.

(b) Quality
This assessment appertains to weld appearance; absence of gaps, undercutting and surface defects; also quality of edge preparation in the case of cutting.

Where examination of the weld is called for, the assessment should include root penetration; absence of slag inclusions; degree of fusion; freedom from cavities and other defects.

(c) Time
A time should be set (usually by the supervisor) for the satisfactory completion of the job. The results of the phase tests must be entered in the trainee's log book and signed by his supervisor.

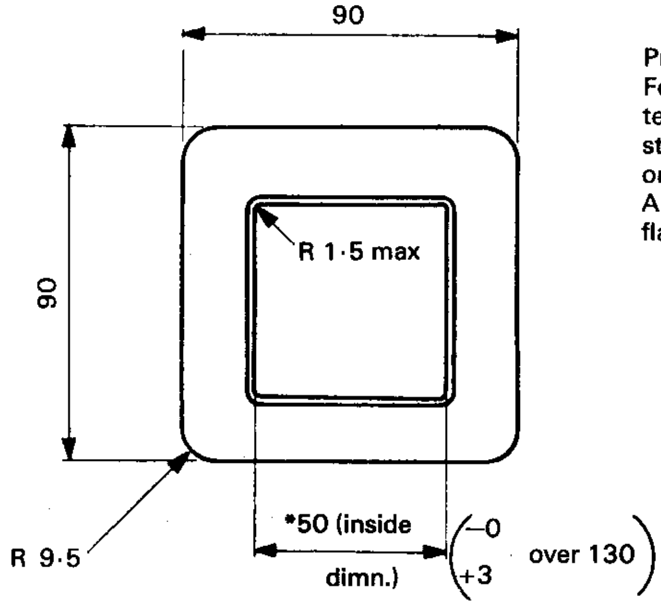
Note: Phase test drawings are according to British Standard 308 using symbols for indicating welds as in BS 499 Part 2.

PHASE TEST No. 1 – BASE FOR ADJUSTABLE STAND

OXY-ACETYLENE WELDING PHASE TEST 'A'

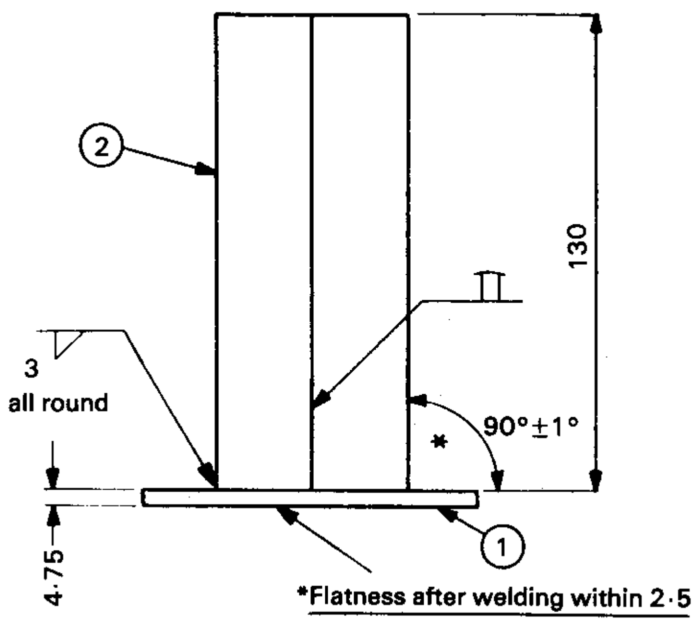
Open square butt and fillet welds

All dimensions in mm
1st angle projection



Procedure:
For the purpose of this phase test, the welds must be stopped and restarted at least once.
All welds can be made in the flat position.

ITEM	No. OFF	MATERIAL
1	1	90×90×4·75
2	1	210×130×1·5
		MILD STEEL



Note:
As an alternative to a folded construction two rolled formed channels may be used.

ASSESSMENT

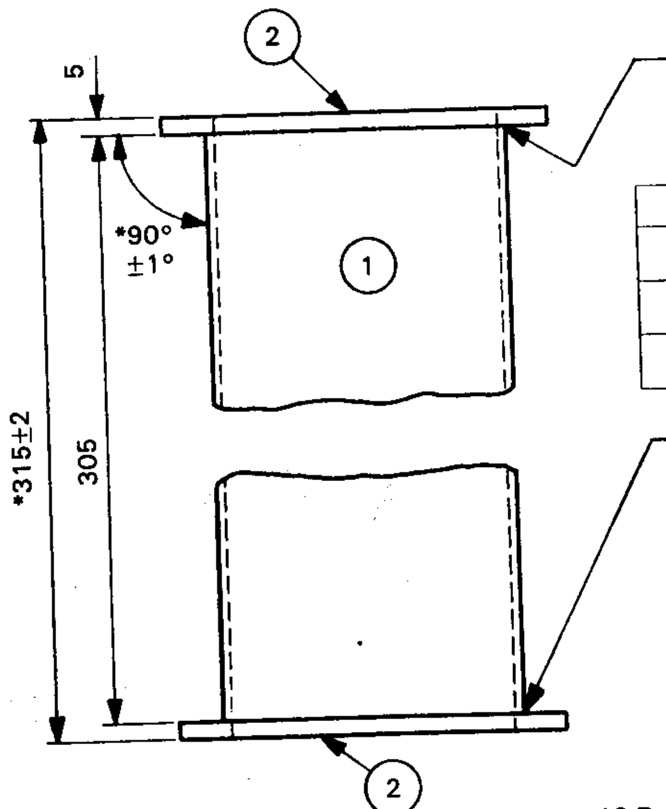
	ITEM	TOLERANCE		ITEM	FINISH
ACCURACY	1. All dims. marked thus *	As indicated on the drawing	QUALITY	2. Welds generally	(a) Appearance, including even ripple and join-up (b) Leg length (c) Even penetration

Time – To Be Given

PHASE TEST No. 2 – MAKE-UP PIECE FOR DUCTING

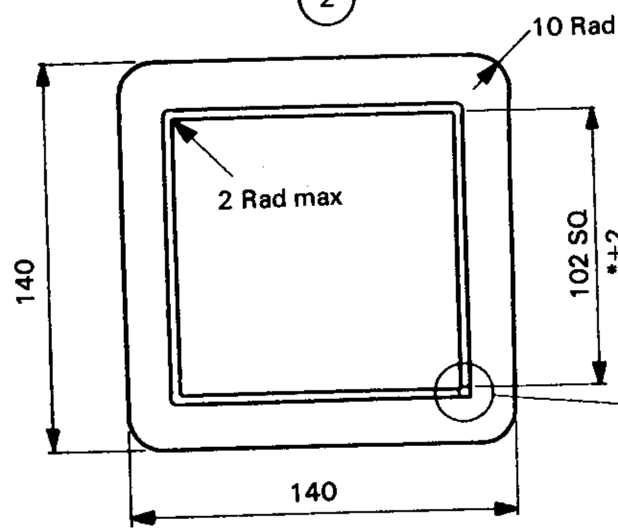
OXY-ACETYLENE WELDING PHASE TEST 'B'

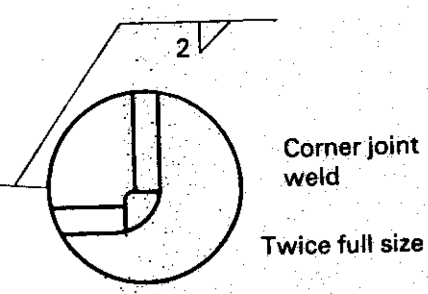
Corner joint in the vertical position	1st angle projection	All dimensions in mm



ITEM	No. OFF	MATERIAL
1	1	305×410×2 (or 16 SWG)
2	2	140×140×5
		MILD STEEL

Procedure:
1. For the purpose of this phase test, the welds must be stopped and restarted at least once in their length.
2. The corner joint weld must be made in the vertical position. No sealing run to be deposited: but the external weld should have a slightly convex profile.
3. The fillet welds may be made in any position.





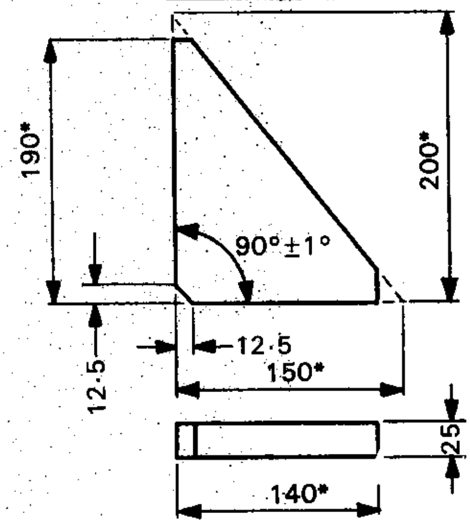
ASSESSMENT

	ITEM	TOLERANCE		ITEM	FINISH
ACCURACY	1. All dims. marked thus*	As indicated on the drawing	QUALITY	2. Welds generally	(a) Appearance, including even ripple and join-up (b) Leg length (c) Even penetration (d) Convex profile

Time – To Be Given

PHASE TEST No. 3 – GUSSET PLATE

OXY-FUEL GAS CUTTING PHASE TEST 'A'



Using a straight edge and single support, cut from stock plate.

All dimensions in mm

1st angle projection

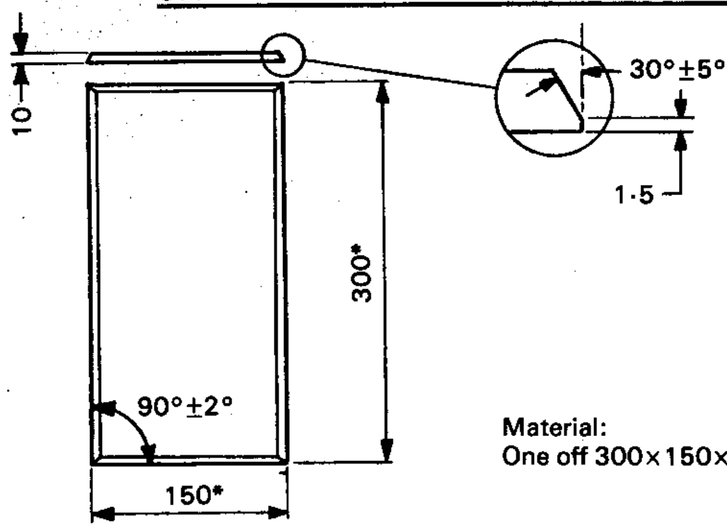
ITEM	No. OFF	MATERIAL
1	1	200 × 150 × 25
		MILD STEEL

ASSESSMENT					
ACCURACY	ITEM	TOLERANCE	QUALITY	ITEM	FINISH
	1. All dims. marked thus *	± 3		3. Profile of cuts	(a) Squareness (b) Clean finish
	2. 90° angle	As marked on the drawing		4. Marking out	(a) Max. use of stock plate

Time – To Be Given

PHASE TEST No. 4 – BEDPLATE END COVER

OXY-FUEL GAS CUTTING AND BEVELLING PHASE TEST 'B'



All dimensions in mm

Procedure:

1. Cut out profile
2. Bevel as shown, using two straight edges to give 30° angle of bevel with 1·5 mm root face.

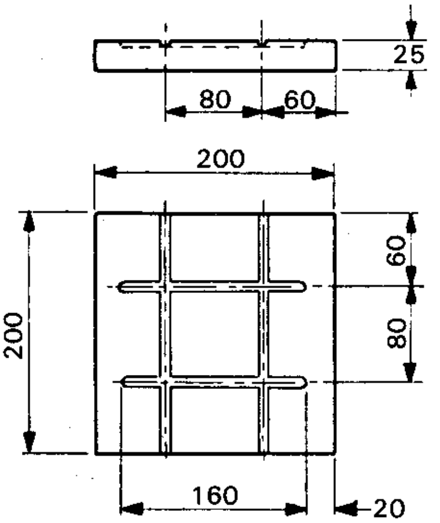
Material:
One off 300×150×10 mm mild steel

ASSESSMENT					
ACCURACY	ITEM	TOLERANCE	QUALITY	ITEM	FINISH
	1. All dims. marked thus *	±3 mm		2. Profile of cuts and bevels	(a) Clean finish
				3. Marking out	(a) Max. use of stock plate

Time – To Be Given

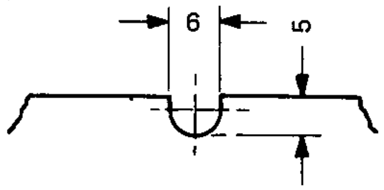
PHASE TEST No. 5 – GROOVED FURNACE PLATE

OXY-FUEL GAS GOUGING PHASE TEST 'C'



3rd angle projection
All dimensions in mm

Material:
One off mild steel 200×200×25



Profile of groove. Full size

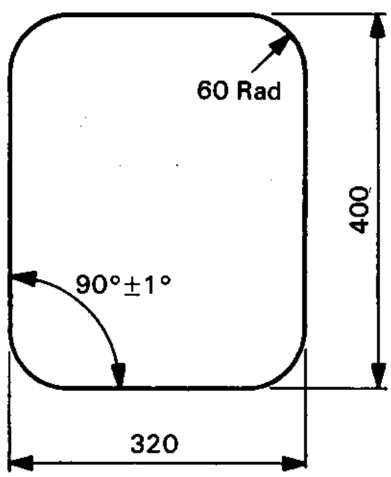
ASSESSMENT

	ITEM	TOLERANCE		ITEM	FINISH
ACCURACY	1. All dims.	±3 mm	QUALITY	2. Profile of cutting and gouged grooves 3. Marking out	(a) Squareness (b) Clean finish (a) Max. use of stock plate

Time – To Be Given

PHASE TEST No. 6 – MOTOR MOUNTING PAD

ARC CUTTING PHASE TEST 'A'



Free hand cutting

Material:
One off 400×320×10 mm mild steel

All dimensions in mm

Note:
Any of the arc cutting processes may be used

ASSESSMENT

	ITEM	TOLERANCE		ITEM	FINISH
ACCURACY	1. All dims.	±3 mm	QUALITY	2. Profile of cuts 3. Marking out	(a) Squareness (b) Clean finish (a) Max. use of stock plate

Time – To Be Given

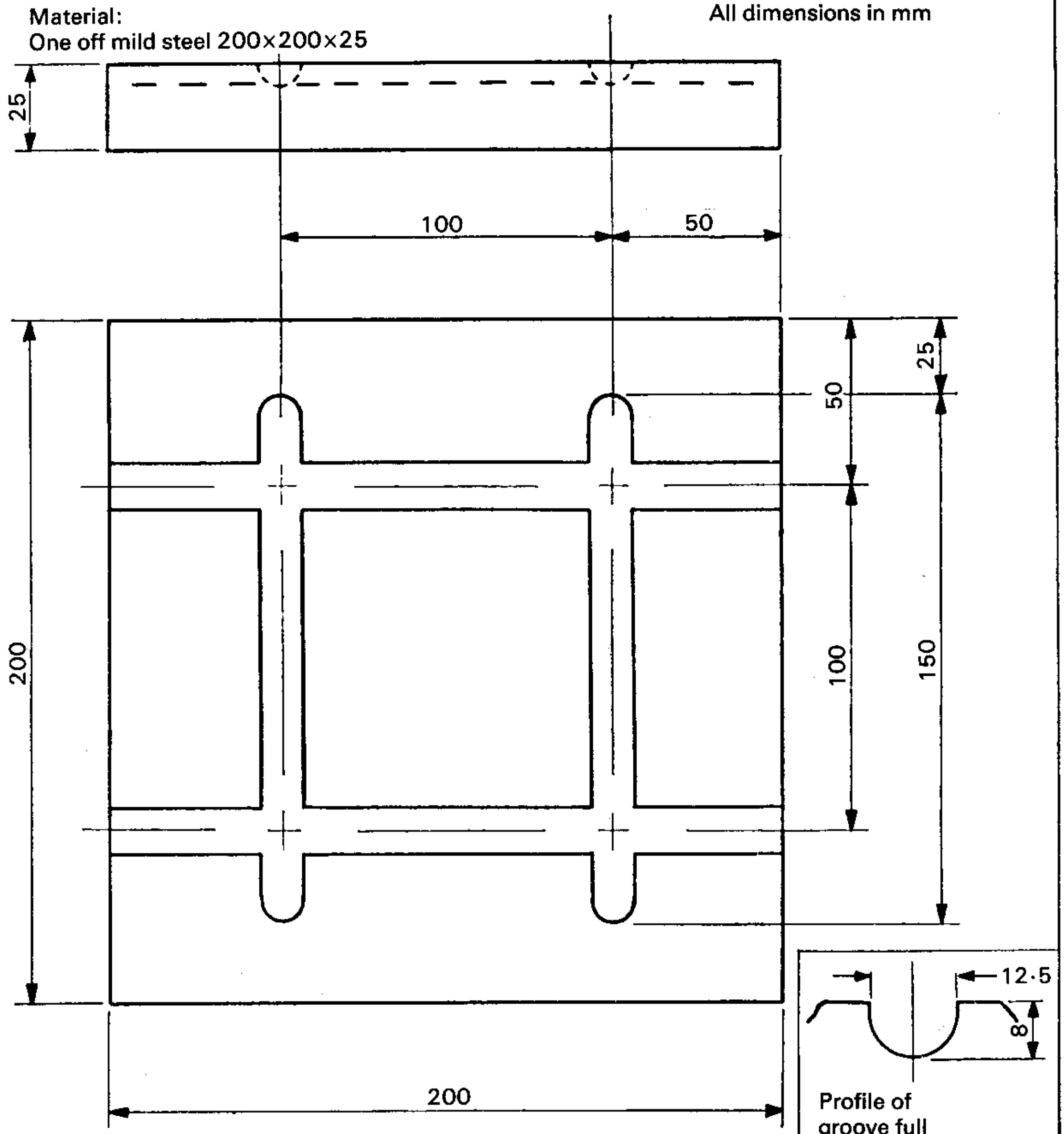
PHASE TEST No. 7 – GROOVED FURNACE PLATE

ARC GOUGING PHASE TEST 'B'

Note:
Any of the arc cutting processes may be used.

Material:
One off mild steel 200×200×25

All dimensions in mm



Profile of groove full size

ASSESSMENT

ACCURACY	ITEM	TOLERANCE	QUALITY	ITEM	FINISH
	1. All dims.	±3 mm		2. Profile of cutting and gouged grooves	(a) Squareness (b) Clean finish
				3. Marking out	(a) Max. use of stock plate

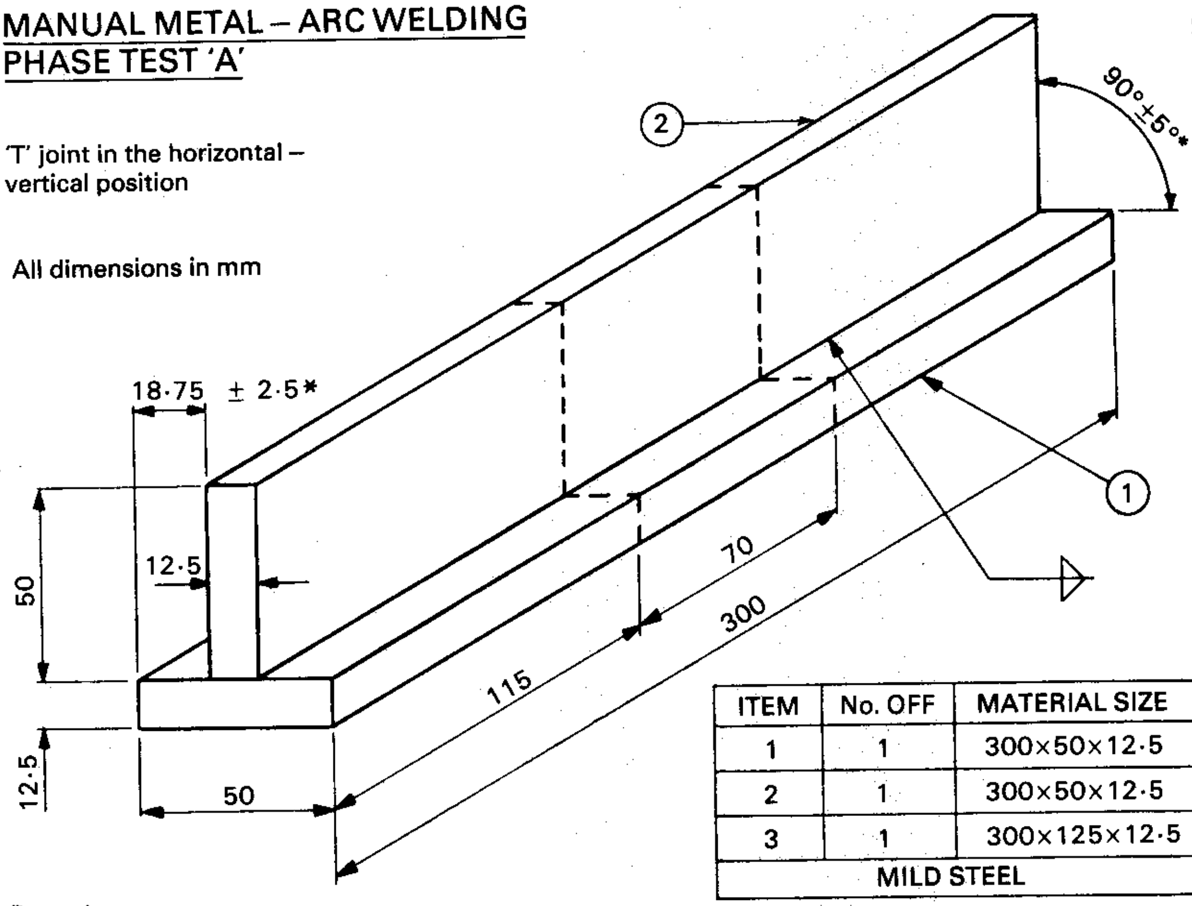
Time – To Be Given

PHASE TEST No. 8 – PUMP STOOL

MANUAL METAL – ARC WELDING
PHASE TEST 'A'

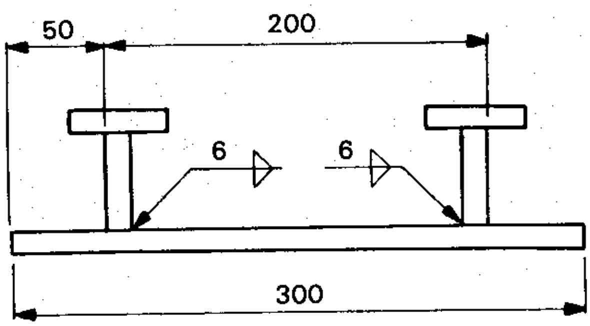
'T' joint in the horizontal – vertical position

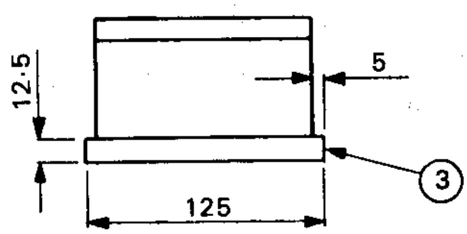
All dimensions in mm



ITEM	No. OFF	MATERIAL SIZE
1	1	300×50×12·5
2	1	300×50×12·5
3	1	300×125×12·5
MILD STEEL		

Procedure:
For the purpose of this phase test, the welds must be stopped and restarted with a new electrode in the middle of each weld length.
After welding item 1 to item 2, the centre 70 is to be cut out, as shown, for macro examination and fracture of the weld.
The remaining two pieces are then welded to item 3 below.





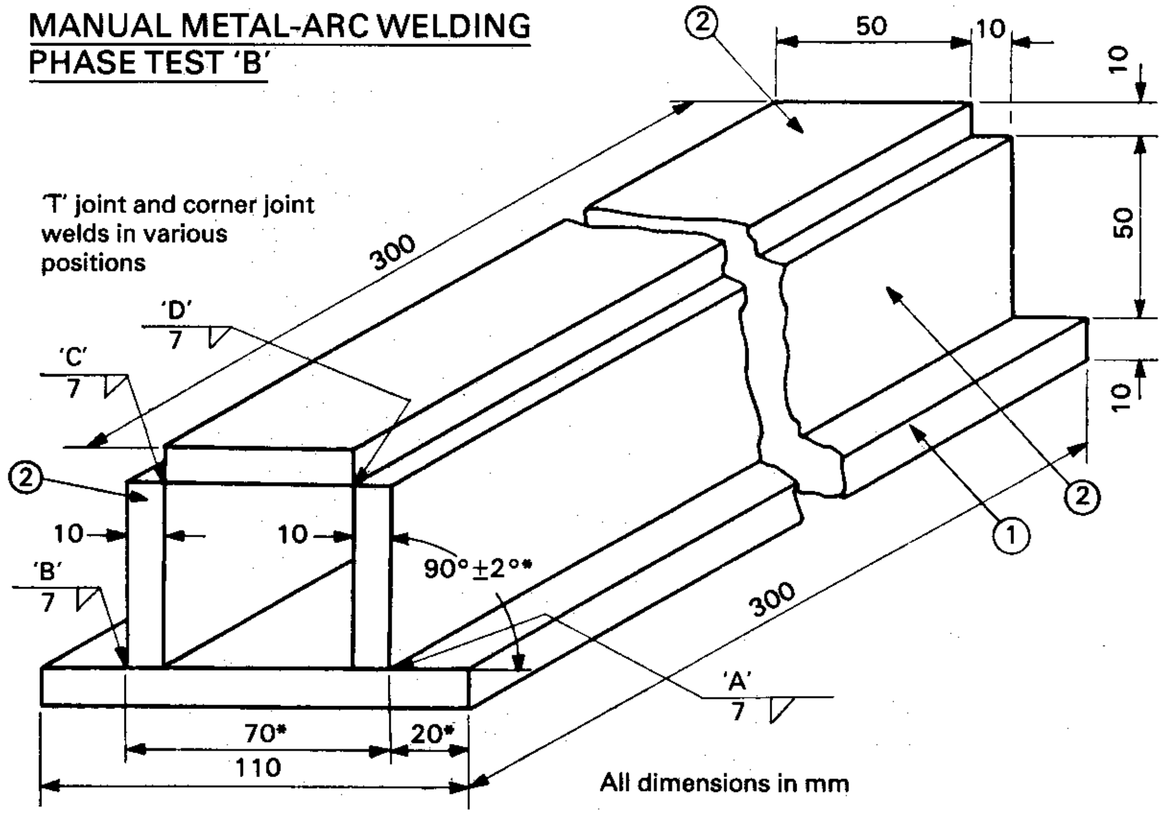
ASSESSMENT

	ITEM	TOLERANCE		ITEM	FINISH
ACCURACY	1. All dims marked thus *	As indicated on the drawing	QUALITY	2. Welds generally	(a) Appearance, including even ripple and join-up (b) Leg length (c) Lack of undercut
				3. Section test-piece	(a) Penetration (b) Free from defects

Time – To Be Given

PHASE TEST No. 9 – GUIDE COLUMN

MANUAL METAL-ARC WELDING
PHASE TEST 'B'



Procedure:
For the purpose of this phase test, after tack welding the assembly:
Weld 'A' is to be made in the flat position,
Welds 'B' and 'C' are to be made in the horizontal-vertical position,
Weld 'D' in the vertical position.
All welds must be stopped and restarted at least once.

ITEM	No. OFF	MATERIAL SIZE
1	1	110×10×300 mm
2	3	50×10×300 mm
		MILD STEEL

ASSESSMENT

	ITEM	TOLERANCE		ITEM	FINISH
ACCURACY	1. All dims. marked thus *	±2 mm or as marked on the drawing	QUALITY	2. Welds generally	(a) Appearance, including even ripple and join-up (b) Leg length (c) Lack of undercut

Time – To Be Given

PHASE TEST No. 10 – EXPERIMENTAL COOLER COVER

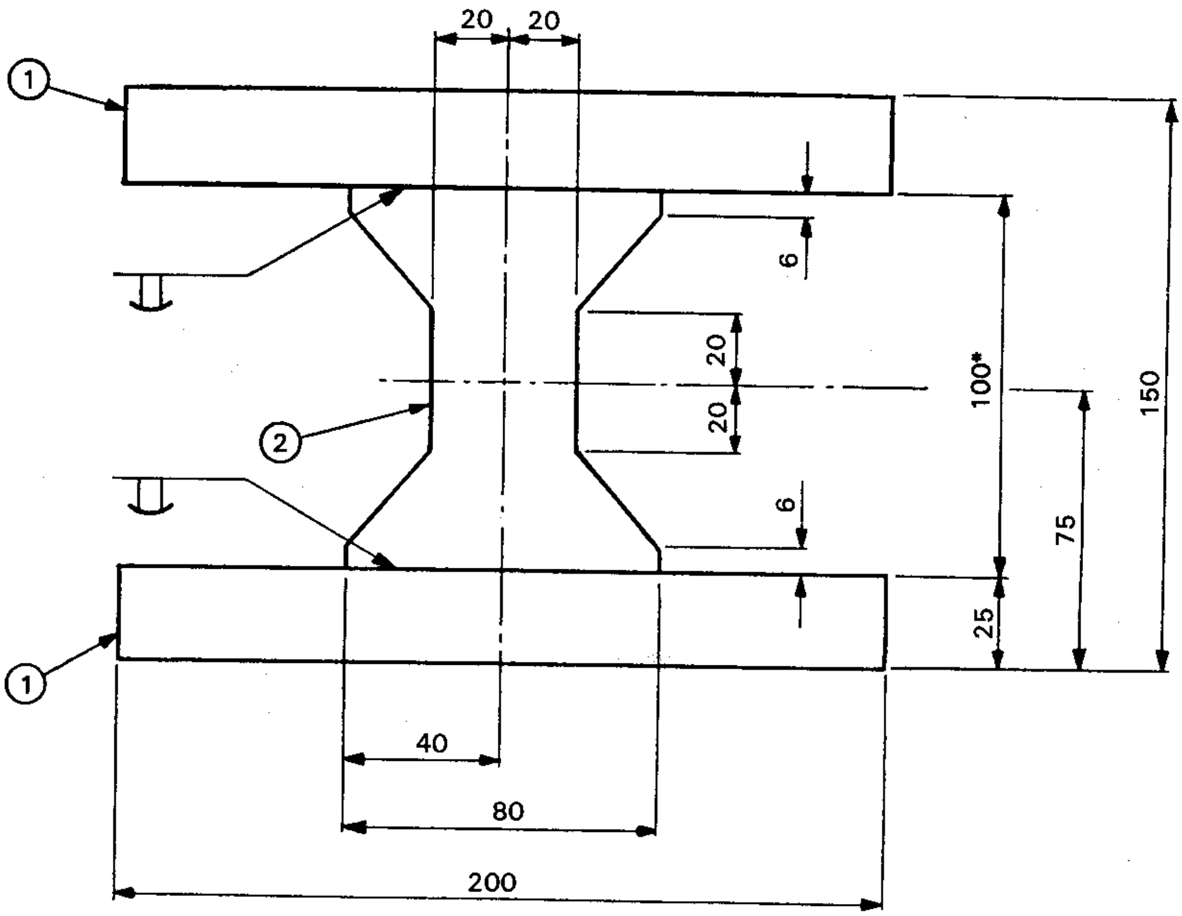
METAL-ARC GAS SHIELDED WELD PHASE TEST 'A'

Close square butt welded in the flat position, using an appropriate backing bar

ITEM	No. OFF	MATERIAL SIZE
1	2	200×25×5
2	1	100×80×5
ALUMINIUM PLATE		

Procedure:
For the purpose of this phase test, both welds must be stopped and restarted at least once.

All dimensions in mm



ASSESSMENT

	ITEM	TOLERANCE		ITEM	FINISH
ACCURACY	1. All dims. marked thus * 2. Flatness	±1·5 mm Within 2·5 all over	QUALITY	3. Welds	(a) Appearance, including even ripple and squareness of ends of weld (b) Even penetration

Time – To Be Given

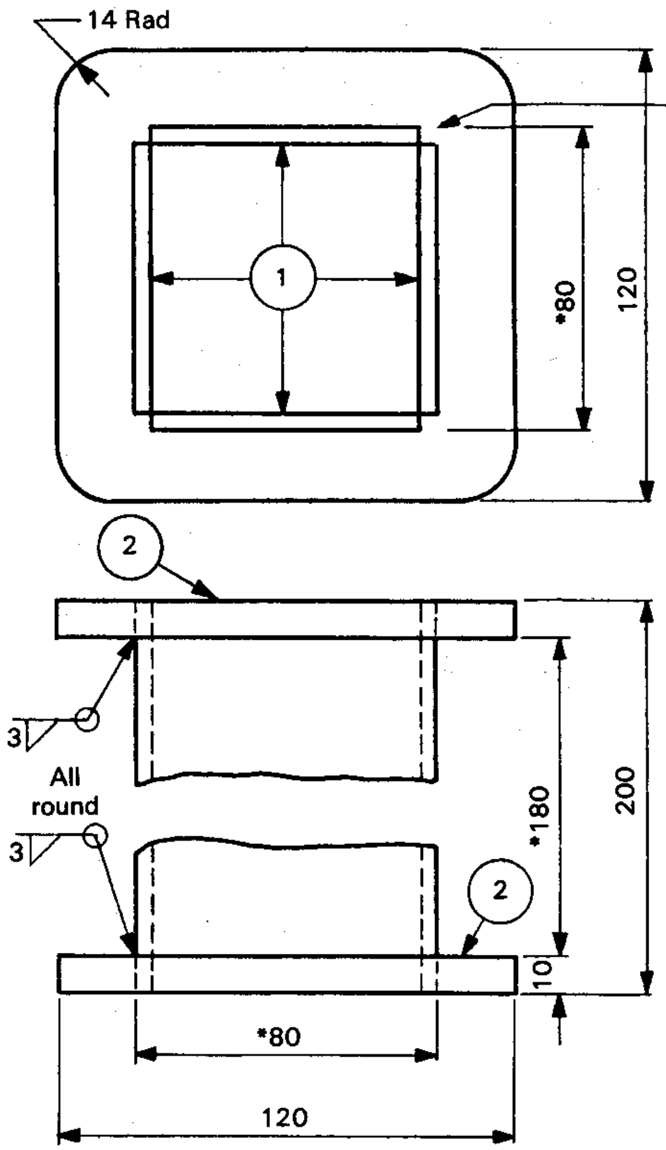
PHASE TEST No. 11 – OIL FILTER BOX

METAL-ARC GAS SHIELDED WELDING PHASE TEST 'B'

Corner joints welded in the vertical position.
Either dip or pulsed transfer welding techniques can be used.

3rd angle projection

All dimensions in mm



ITEM	No. OFF	MATERIAL SIZE
1	4	200×74×3
2	2	120×120×10
		MILD STEEL

Procedure:

1. For the purpose of this phase test all the welds must be stopped and restarted at least once in their length.
2. The corner joint welds must be made in the vertical position, without sealing runs, but the external weld should have a slightly convex profile.
3. The fillet welds may be made in any position.

ASSESSMENT

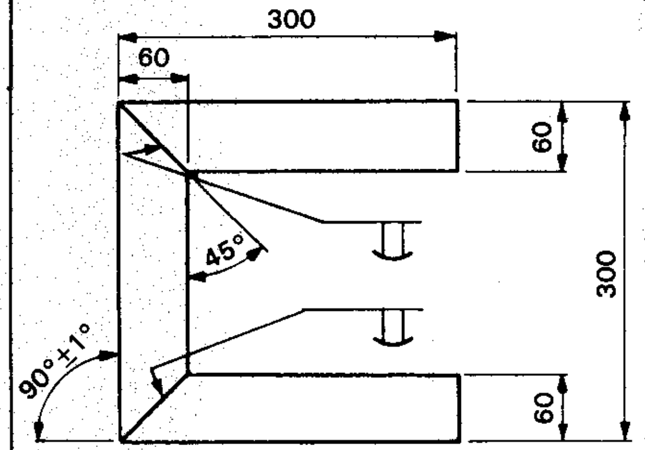
	ITEM	TOLERANCE		ITEM	FINISH
ACCURACY	1. All dims. marked thus *	±2 mm	QUALITY	3. Welds	(a) Appearance, including even ripple and join-up
	2. Flatness of flanges (item 2)	Within 2 mm all over			(b) Leg length (c) Even penetration (d) Convex profile

Time – To Be Given

PHASE TEST No. 12 – FILTER COVER PIECE

TUNGSTEN-ARC GAS SHIELDED WELDING PHASE TEST 'A'

Close square butt joint, welded in the flat position



Material:
Three off 300×60×1·5 mm aluminium strip.

Note:
Stock material of similar dimensions may be used.

A suitable backing bar should be used and both welds can be made in the flat position.

All dimensions in mm

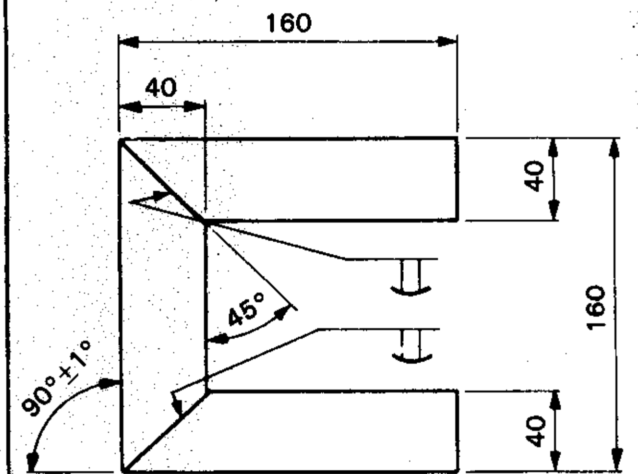
ASSESSMENT

ACCURACY ITEM	TOLERANCE	QUALITY ITEM	FINISH
1. All dims.	To be within ±2 mm	3. Welds	(a) Appearance, including even ripple and squareness of ends of weld
2. Flatness	Within 3 mm all over		(b) Even penetration

Time – To Be Given

PHASE TEST No. 13 – SPACING PIECE

TUNGSTEN-ARC GAS SHIELDED WELDING PHASE TEST 'B'



Material:
Three off 160×40×1·5 mm stainless steel.

Procedure:
A suitable backing bar should be used and both welds can be made in the flat position. For the purpose of this phase test, the welds must be stopped and restarted at least once.

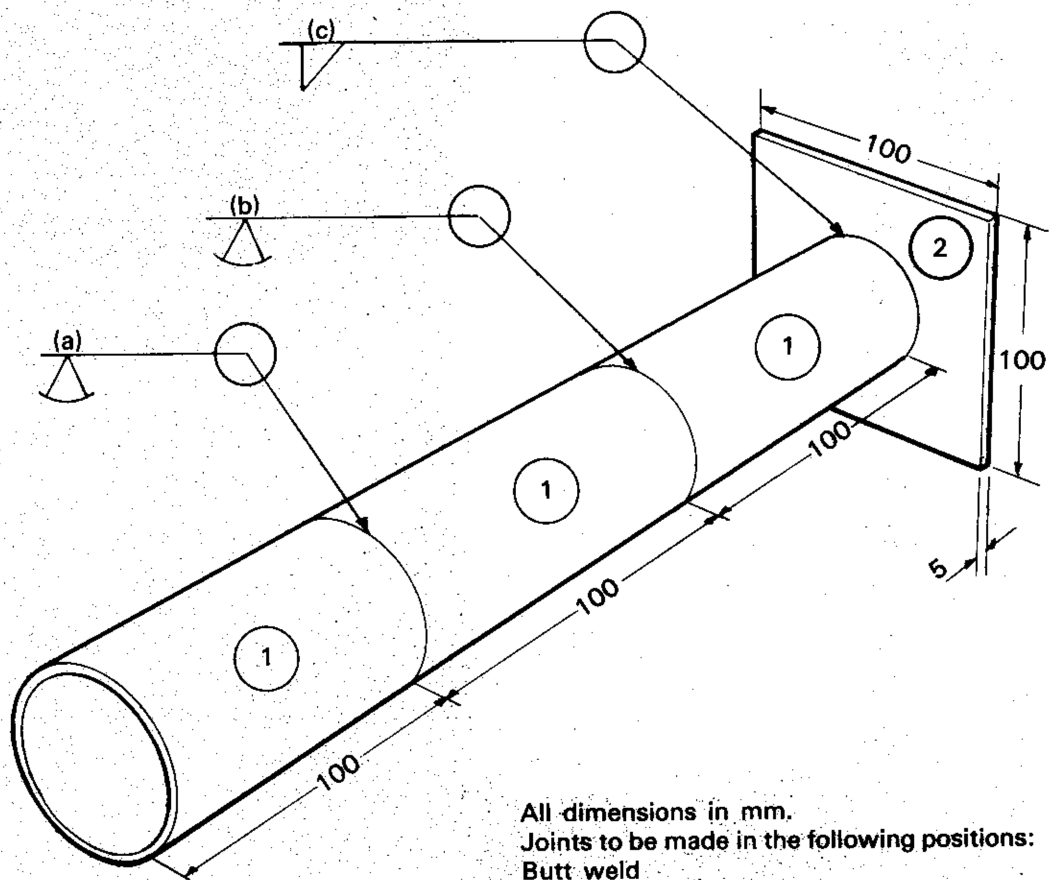
All dimensions in mm

ASSESSMENT

ACCURACY ITEM	TOLERANCE	QUALITY ITEM	FINISH
1. All dims.	To be within ±2 mm	3. Welds	(a) Appearance, including even ripple and squareness of ends of weld
2. Flatness	Within 3 mm all over		(b) Even penetration

Time – To Be Given

PHASE TEST No. 14 – BUTT WELDS



All dimensions in mm.
Joints to be made in the following positions:
Butt weld
(a) – rotated
(b) – fixed for segmental welding
(c) – horizontal-vertical

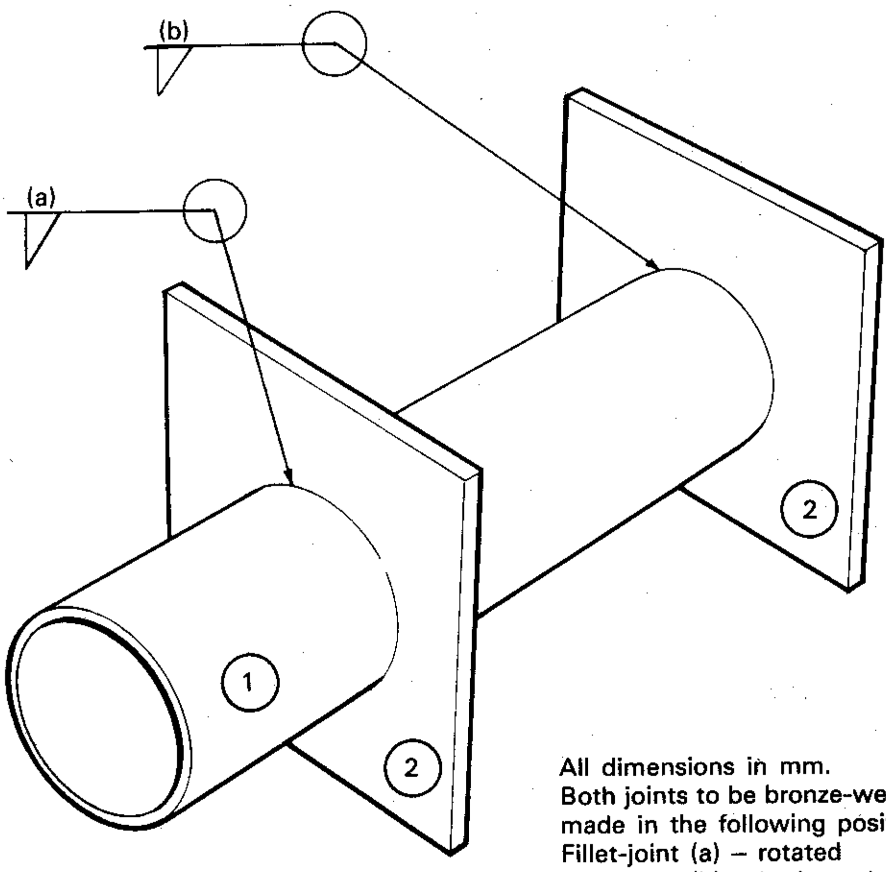
MATERIAL – MILD STEEL			
ITEM	No.OFF		
1	3	100×60 O/D.	Heavy grade steel pipe
2	1	100×100×5	Plate

ASSESSMENT

	ITEM	TOLERANCE		ITEM	FINISH
ACCURACY	1.	Length ± 1 mm	QUALITY	All welds	(a) Appearance (b) Uniformity of size (c) Penetration Root penetration not to exceed 2 mm and to be free from root concavity (d) Absence of gaps
	2.	Flatness ± 1 mm Sides ± 1 mm Plate to be at 90° to ℄ of pipe bore			

Time – To Be Given

PHASE TEST No. 15 – FILLET WELDS



All dimensions in mm.
Both joints to be bronze-welded and made in the following positions:
Fillet-joint (a) – rotated
Fillet-joint (b) – horizontal-vertical.

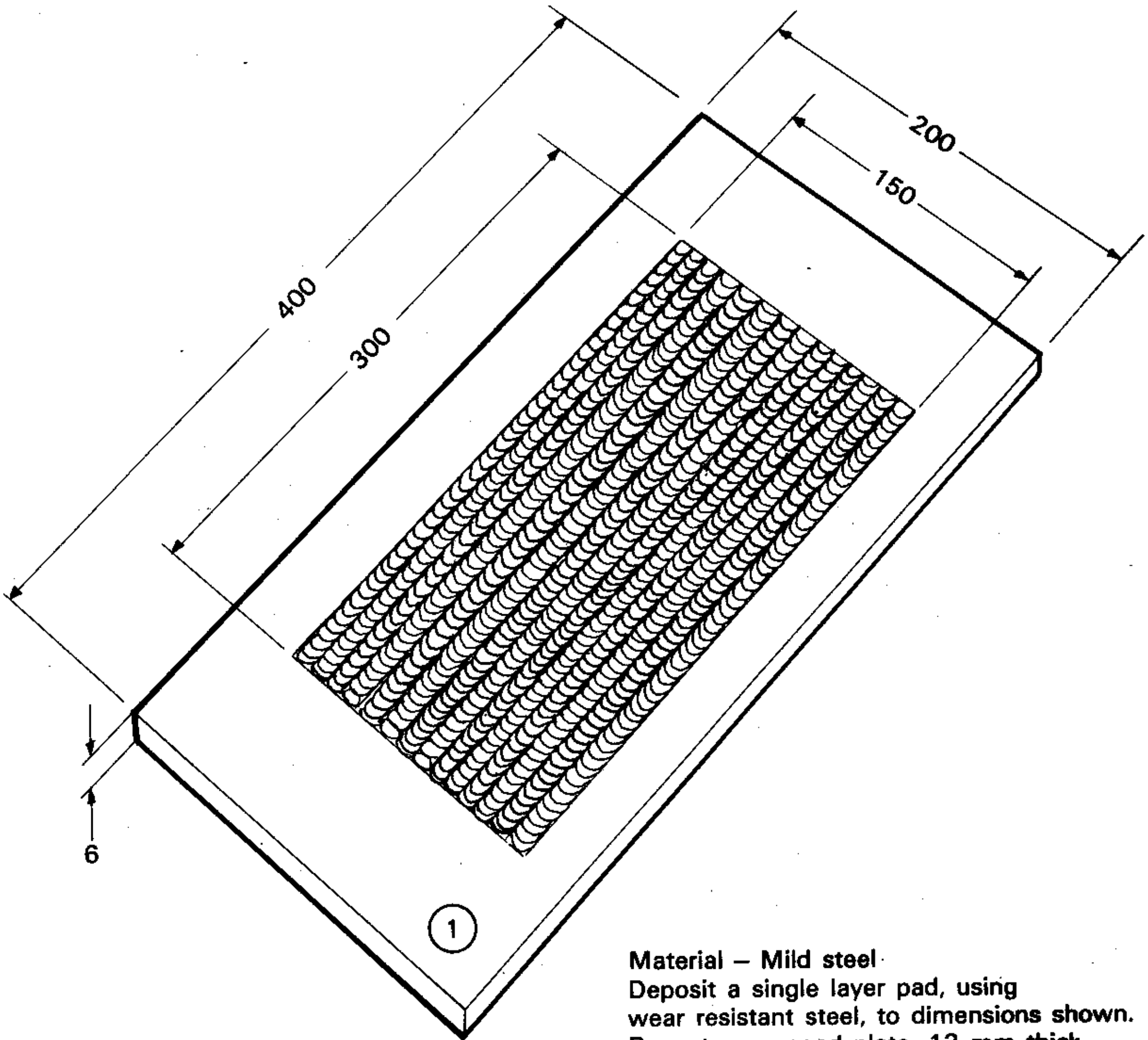
MATERIAL – MILD STEEL		
ITEM	No. OFF	
1	1	200×60 nb Tube
2	2	120×120×5 Plate

ASSESSMENT

	ITEM	TOLERANCE		ITEM	FINISH
ACCURACY	1.	Length ± 2 mm	QUALITY	Both welds	(a) Appearance (b) Uniformity and size (c) Bending (d) Absence of porosity
	2.	Hole central within 1 mm			

Time – To Be Given

PHASE TEST No. 16 – HARD FACING (PAD WELD)



Material – Mild steel
Deposit a single layer pad, using wear resistant steel, to dimensions shown.
Repeat on second plate, 13 mm thick, other dimensions as shown.
Assessment as below.
All dimensions in mm.

ASSESSMENT

	ITEM	TOLERANCE		ITEM	FINISH
ACCURACY	All dimensions	± 3 mm	QUALITY	All welds	(a) Uniform deposition (b) Freedom from craters and slag inclusions (c) Freedom from porosity (d) Freedom from cracks Maintain flatness.

Time – To Be Given