WELDING BASICS SERIES

MAKE SOMETHING BETTER

MMA BASICS

MMA Basics

Also known as:

Electrode Welding

Stick Welding

Please note:

The equipment shown in the following pages are not current models.

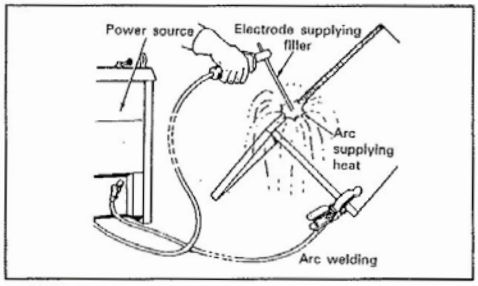
MMA Basics

Manual metal-arc welding (AW1 – AW2)

The manual metal-arc process

When two wires which form part of an electrical circuit are brought together and then pulled slowly apart, an electric spark is produced across their ends.

This spark, or arc as it is called, has a temperature of up to 3600°C. As the arc is confined to a very small area it can melt metal almost instantly.



If one of these wires is connected to the workpiece and the other to a wire rod or electrode, as it is usually called, the heat of the arc melts both the metal of the workpiece and the point of the electrode. The molten metal from the electrode mixes with that from the workpiece and forms the weld. It is important to realize that tiny globules of the molten metal from the electrode are forced through the arc (they do not fall by gravity). If this were not so it would be impossible to use this process for overhead welding.

Always:

- Comply with the prescribed safety precautions and fire prevention procedures.
- Use effective protective equipment and wear the necessary protective clothing.
- Carefully segregate different types and sizes of electrodes. Ensure that they are protected from rain and moisture.
- Place the electrode holder in a safe place when not in use.
- Ensure that all fusion faces and previously deposited weld faces are clean before commencing the next run.
- Switch off power source when not in use.
- Switch off mains supply to power source at the end of the work period.
- Leave the work area in a clean and orderly manner. Ensure that equipment is properly stowed and safe. Ensure freedom from burning or smouldering materials. Return unused tungsten electrodes to store in their original package to ensure correct identification.

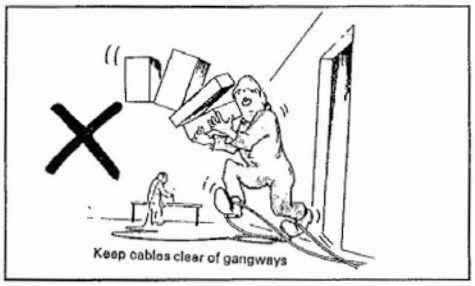
Safety

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.

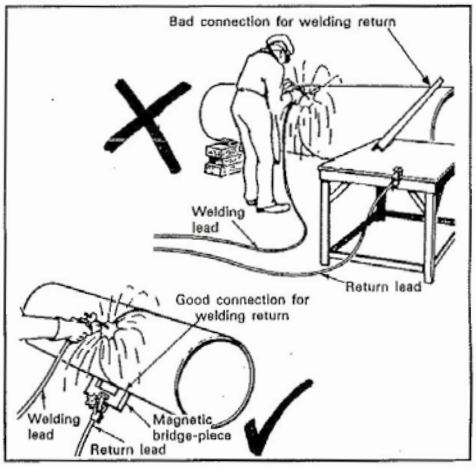
Cables



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.

Leads

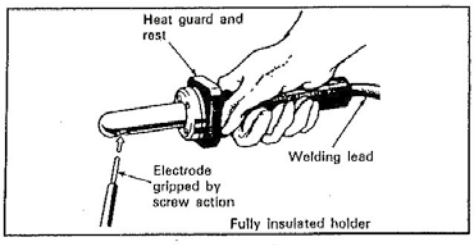


Avoid hazards due to inefficient earthing of electrical equipment and the welding circuit.

- Ensure that only competent persons connect the power source to the appropriate mains supply.
- All welding return leads must be securely connected by bolting or clamping to prevent contact resistance or arcing.
- Welding return leads must have ample current carrying capacity and always be kept as short as possible.
- Do not wrap welding return leads around components, work table, scaffolding, or other metallic objects.
- 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.

MMA Basics

Electrode holders



Use a fully insulated holder when:

- Welding in a confined space.
- There is difficulty of access to the weld because of the proximity of metal parts.
- Welding a steel which may be hardened by accidental 'arcing'.

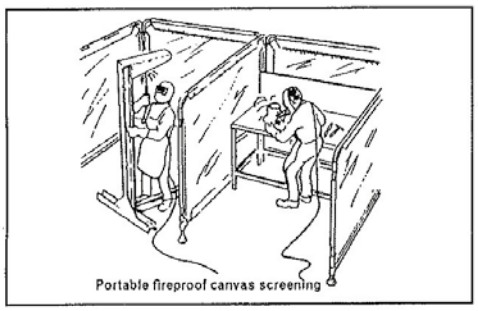
When using a partly insulated holder avoid contact with metal parts causing 'stray flashes'. When the holder (torch or gun) is not being used place it securely on an insulated hook. Do not dip hot electrode holders in water.

Protective equipment

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

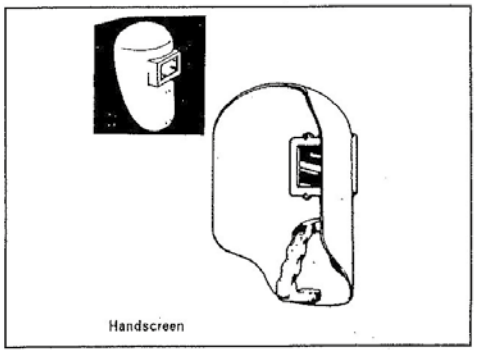
Note: Radiation includes invisible ultra-violet and infra-red rays.

Screening – general



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

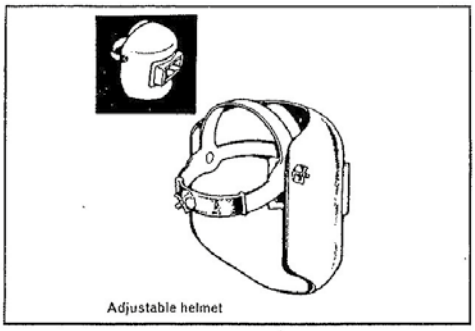
Screening – personal



Manual metal-arc welding (AW1 – AW2)

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 filter

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

Recommended filters for electric welding are:

BS 679 shade	Manual metal-arc welding
8 EW	Up to 100 amps
9 EW	Up to 100 amps
10 EW	100–300 amps
11 EW	100–300 amps
12 EW	Over 300 amps
13 EW	Over 300 amps
14 EW	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.

Protective clothing

With 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.

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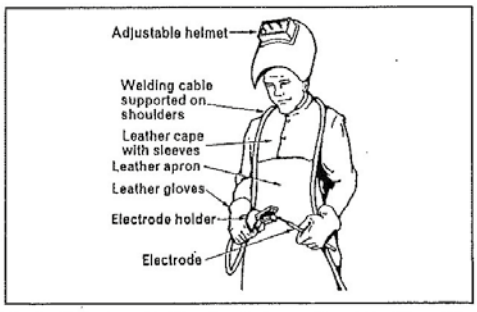


Protect the front of the body from about the throat to the knees with suitable leather cape and apron. If only an apron is worn this must provide full protection. Wear suitable leather gloves to protect the wrists and hands.

First aid

However trivial, minor injuries should be dealt with in a first aid room. This is particularly important for removal of foreign bodies from the eye, and for the treatment of burns caused by hot metal or slag.

Exposure to welding arcs can cause burns to the skin similar to sunburn and also severe irritation to the eye. This condition is known as 'arc eye'. Symptoms become apparent 4 to 8 hours after exposure and include watering eyes, headache and partial loss of vision.

When symptoms occur:

- Use an eye bath to wash eyes with an approved eye lotion.
- Repeat at about four-hourly intervals.
- In the meantime cold compresses, made by soaking cotton wool in cold water (which has been boiled previously), may be applied.
- If going into bright light, dark glasses should be worn.
- Report to the first aid room as soon as possible.

! *SAFETY – If recovery from 'arc eye' is not complete in 36 to 48 hours, medical advice must be sought.*

Manual metal-arc welding (AW1 - AW2)

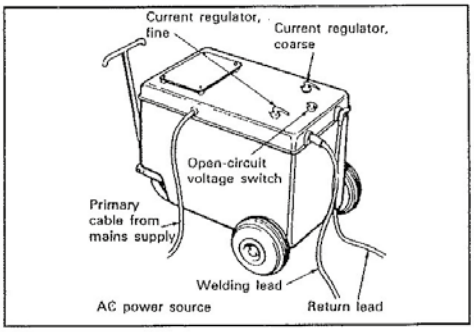
Equipment

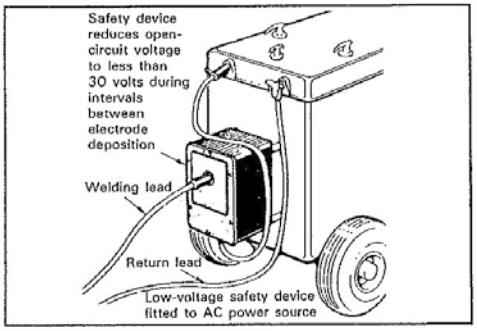
Power sources are classified into two groups. Alternating current (AC) or direct current (DC) according to the output current.

Where input is from the mains the power source must:

- Reduce the mains input voltage to give an output open circuit voltage between 40 and 100 volts.
- Increase the mains input current to give the output currents required for welding.

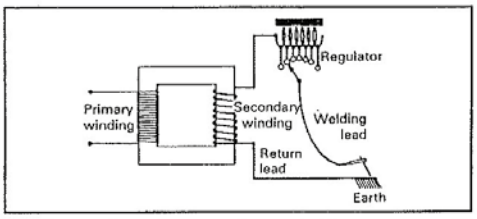
Alternating current (AC) equipment





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.

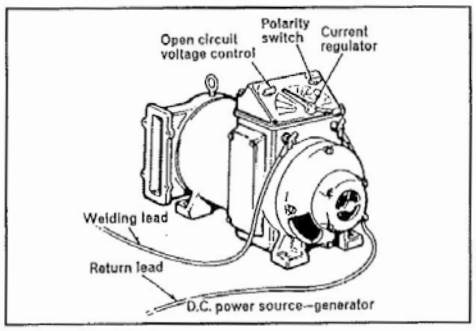


The illustration shows a schematic diagram of an AC welding transformer and regulator.

MMA Basics

Manual metal-arc welding (AW1 – AW2)

Direct current (DC) equipment

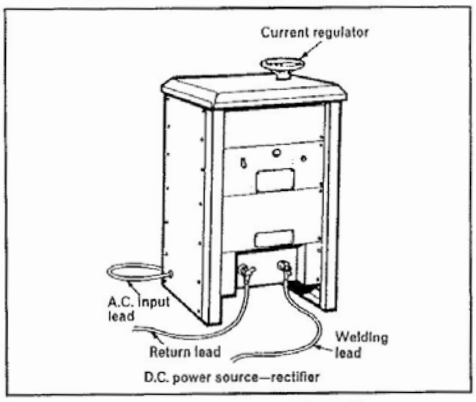


This is classified into two groups – generators and rectifiers.
Generators may be driven by:

- Motor connected to mains supply.
- Petrol or diesel engine.

A rectifier takes AC current from a transformer, via a current regulator.

AC/DC equipment

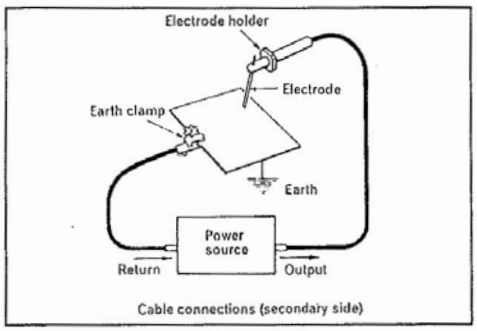


In a single phase transformer and rectifier:

- AC output is taken from the secondary side of the transformer via a current regulator.
- DC output is taken from the rectifier output terminals.

Installation of equipment

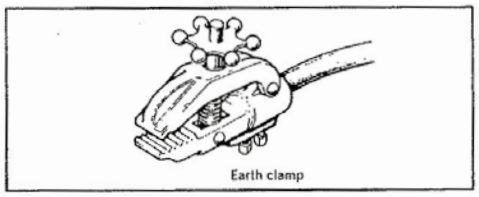
The initial installation and connection of the power source to the appropriate mains supply should be carried out by a competent person. Ensure that the equipment is adequately earthed.



Cable connections (secondary side)

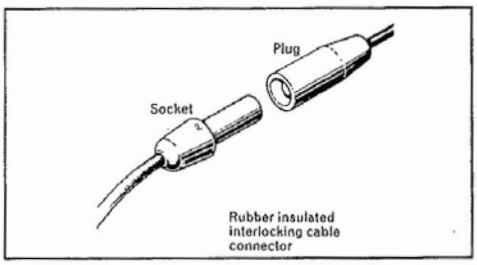
Use secondary cables of a suitable size for the maximum welding current.

- Connect one end of the welding lead to the electrode holder.
- Connect other end of the welding lead to the output terminal on the power source.



Earth clamp

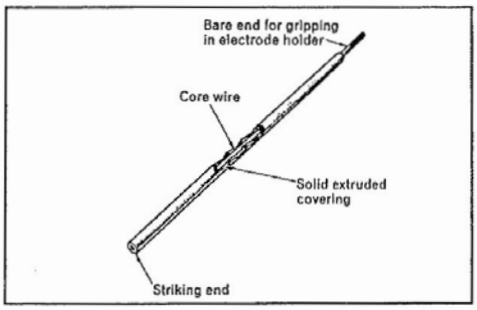
- Connect one end of the return lead to an earth clamp or terminal on the workpiece.
- Connect other end of the return lead to the return terminal on the power source.



Loose joints or bad contacts cause over-heating of cable, electrode holder handle etc, and adversely affect the welding arc.
Make any necessary joints in cables using properly designed cable connectors.
Make sure that good electrical contact is always obtained when connecting cables to power source, electrode holder, and earth clamp.
Pay particular attention to mechanical joints that may work loose, especially when using AC.

MMA Basics

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.

! *IMPORTANT – Electrodes should be stored and used in a dry condition.*
Carefully segregate different types and sizes of electrodes.

Purposes of the electrode covering are:
- To give stability to the arc.
- To provide good arc transfer conditions.
- To control the reactions occurring during welding.
- To protect the molten metal during transfer.
- To provide good welding characteristics.
- To provide a suitable slag protection for the cooling weld.
- To ensure that the deposited metal has satisfactory chemical, physical, and mechanical properties.

The size of the electrode is designated by the diameter of the core wire. The range of sizes is:

Continental	American	British
1.5 mm	1/16"	16 swg
2.0 mm		14 swg
2.5 mm	3/32"	12 swg
3.25 mm	1/8"	10 swg
4.0 mm	5/32"	8 swg
5.0 mm	3/16"	6 swg
6.0 mm		4 swg
6.3 mm	1/4"	1/4"
8.0 mm	5/16"	5/16"
10.0 mm	3/8"	3/8"

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.

Manual metal-arc welding (AW1 – AW2)

Electrodes are described by a code number eg,

E4321 R 1 3

Mechanical properties
Type of covering
Position of welding
Electrical requirements

When selecting an electrode, check that:
- Mechanical properties correspond to specification.
- 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.
- 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

- Electrode can be used with power supply available.

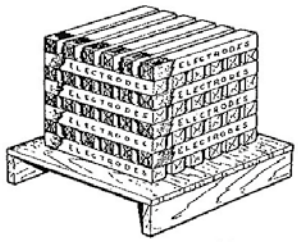
Code	Direct current, recommended electrode polarity	Alternating current, minimum open circuit voltage, V
0	Polarity as recommended by manufacturer	Not suitable for use on AC
1	+ or –	50
2	–	50
3	+	50
4	+ or –	70
5	–	70
6	+	70
7	+ or –	90
8	–	90
9	+	90

MMA Basics

Manual metal-arc welding (AW1 - AW2)

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 → Indicates 130% efficiency

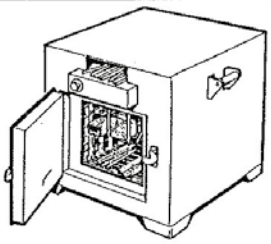
Storage of electrodes
The efficiency of an electrode is impaired if the covering becomes damp.


Storage under heated conditions

- Keep electrodes in unopened packets in a dry store.
- Place packages on a duckboard or pallet, not directly on the floor.
- Store so that air can circulate around and through the stack.
- Do not allow packages to be in contact with walls or other surfaces down which moisture can run.
- The temperature of the store should be about 5°C (10°F) higher than the outside shade temperature to prevent condensation of moisture.
- Free air circulation in the store is as important as heating. Avoid wide fluctuations in the store temperature.
- Where electrodes cannot be stored in ideal conditions place a moisture-absorbent material (eg, silica-gel) inside each storage container.

Drying electrodes
Water in electrode covering is a potential source of hydrogen in the deposited metal and thus may cause:
- Porosity in the weld.
- Cracking in the heat-affected zone.

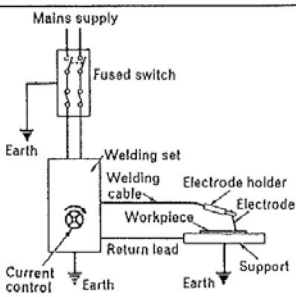
Indications of electrodes affected by moisture are:
- White layer on covering.
- Swelling of covering during welding.
- Distintegration of covering during welding.
- Excessive spatter.
- Excessive rusting of the core wire.


Electrode drying oven

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.*

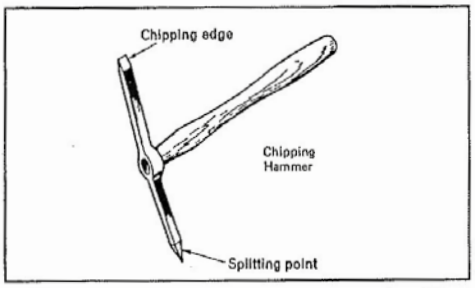
Operating the equipment



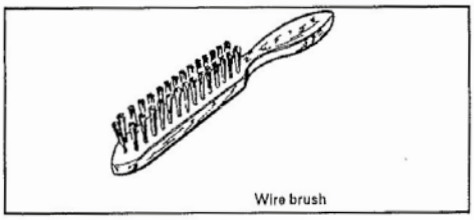
Manual metal-arc welding circuit diagram

Always:
- Comply with the prescribed safety precautions and fire prevention procedure.
- Check that the return earth lead is firmly connected to bench or workpiece and to power source.
- Check that the welding lead is connected to power source and that the connection to the electrode holder is tight and sound.
- Check that the power source is switched on.
- Use effective protective equipment and wear the necessary protective clothing.
- Concentrate on watching the welding operation.
- Have full control of the movements of the electrode and hold it steady.
- Hold the electrode holder with just sufficient grip to give control - tight gripping will cause muscle fatigue.
- Position yourself to avoid stretching and the risk of over-balancing.
- Support the arm holding the electrode holder by keeping it near the body, but do not restrict freedom of movement.

MMA Basics



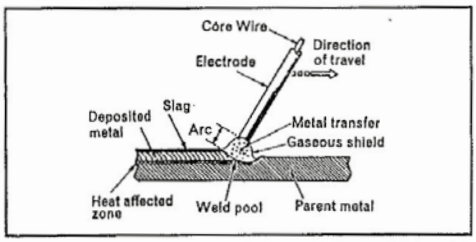
- Check that portable screens are in position. Warn unscreened observers before the arc is struck.
- Ensure that the welding screen is in front of the eyes before striking the arc; keep it there until the arc is broken.
- Place the electrode holder in a safe place when not in use.



- Ensure that all slag and spatter is cleaned off fusion faces and previously deposited metal before starting the next run, using chipping hammer and wire brush.
- Use goggles when chipping off hot slag.
- Switch off power source when not in use.
- Switch off mains supply to power source at end of work period.
- Leave the work area in a tidy and orderly manner and ensure that equipment is properly stowed.

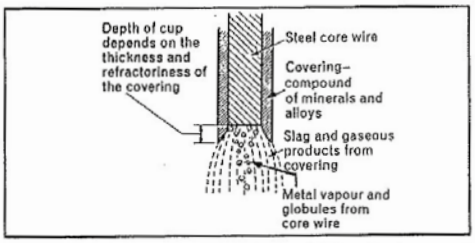
The welding arc

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.

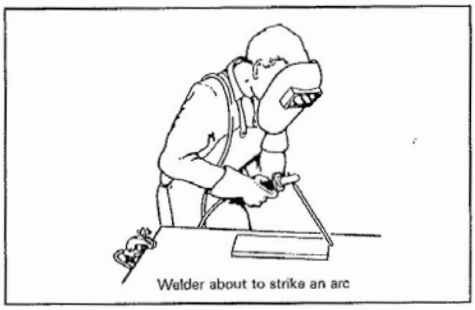
The arc voltage depends upon:

- The type of electrode used.
- 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 and molten metal is transferred across the arc gap to fuse with the workpiece.

Striking the arc

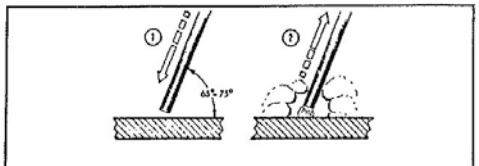
Material	One piece of low carbon steel 10 mm thick. Minimum size 150 mm x 300 mm
Preparation	Clean surface
Electrode	4 mm Rutile
Current	To suit electrode



- Ensure that there is good electrical contact between the plate and the bench. The plate should be in the flat position.
- Using gloved hand, insert the grip end of the electrode in the electrode holder.

MMA Basics

Manual metal-arc welding (AW1 – AW2)



Striking the arc

- Point the electrode downwards, and away from the body at an angle of 65° to 75° to the plate surface.
- 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.
- 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).
- 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.
- After a few seconds break the arc by withdrawing the electrode end smartly from the plate.
- Repeat until skill in establishing the arc is attained.

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.

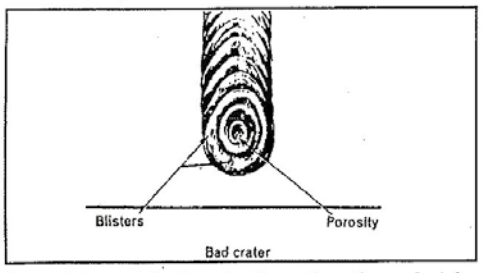
If the electrode is not freed immediately open the electrode holder jaws and move the holder away (or switch off the welding current) and remove the electrode with a chisel.

Breaking the arc

A simple withdrawal of the electrode end will break the arc.

Before breaking the arc:

- Pause with the electrode held in position long enough to build up the weld pool.
- Move the electrode quickly sideways and away from the plate surface.

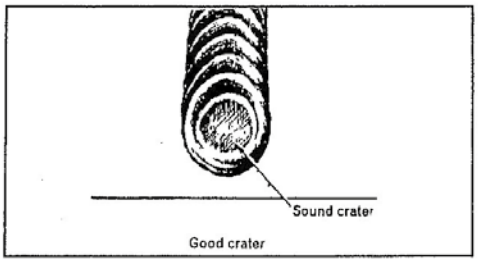


Bad crater

One will learn later how to strengthen the end of the weld run. The above procedure will avoid the formation of:

- Cavities.
- Blisters.
- Porosity or fine cracks in the crater.

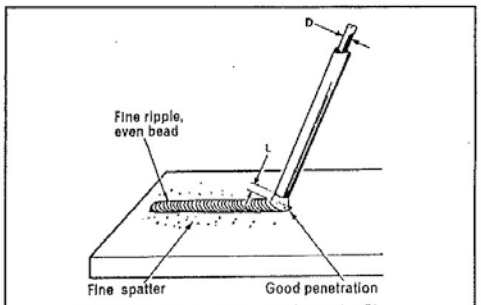
These result from premature or hasty breaking of the arc.



Good crater

Deposition in flat position

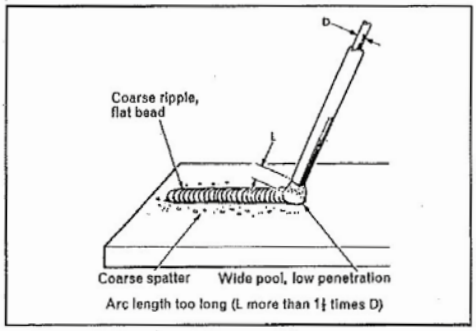
Material	One piece of low carbon steel 10 mm thick. Minimum size 150 mm x 300 mm
Preparation	Clean surface
Electrode	4 mm Rutile
Current	To suit electrode



Visible arc length (L approximately equal to D)

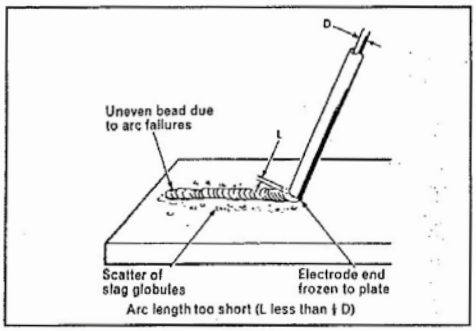
- Establish the arc at the left hand edge.
- Move the electrode holder progressively towards the plate to maintain the arc.
- Combine this with a progressive movement along the plate at a rate of about 150 mm per minute.
- The direction of deposition should be either from left to right or from the starting point towards the person.

MMA Basics



Arc length too long (L more than 1½ times D)

- 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.
- 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).
- Watch the arc length and keep it as constant as possible.
- 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 420 mm of electrode ie, the run length per electrode.



Arc length too short (L less than ½ D)

If the arc length is correct the electrode metal will be deposited in a stream of small particles.
If it is too long the arc will be noisy; deposition will be erratic; large globules of metal will be ejected; excessive spatter will result.
If too short, it will be difficult to maintain the arc; freezing of the electrode end in the weld pool may occur.

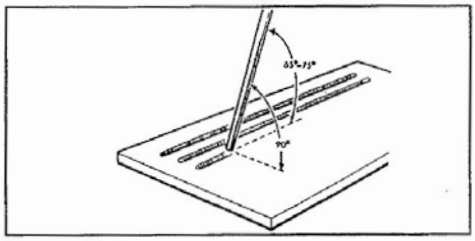
Manual metal-arc welding (AW1 – AW2)

Slag

While 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:

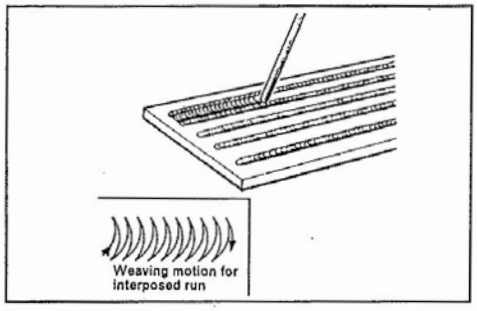
- The electrode end is directed at the correct angle to the plate surface.
- The correct welding conditions and techniques are used.

Depositing straight runs



- Establish the arc at the left hand edge.
- Move the electrode end in a straight line along the plate.
- Develop a sense of direction with the welding screen in position.
- Weld first on one side of the plate and then on the other side to keep it fairly level.
- The plate may be water (or air) cooled between runs provided it is allowed to dry off.
- Leave a space of about 12 mm between the parallel runs.
- Use different rates of travel to see the effect of the change in speed on the shape of the weld bead.
- Use welding currents about 20% lower and higher to see the effect of the change in current on the appearance of the weld bead.

Weaving



Material – Use the plates from previous examples on which separate parallel runs have been deposited.

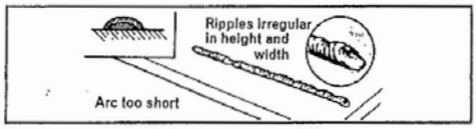
- Using the same welding conditions as for the deposition of the separate runs establish the arc between two previous deposits.
- Practise increasing the width of the deposit by using a transverse weaving motion of the electrode.
- The weaving motion should be slow and in a slightly curved path.

MMA Basics

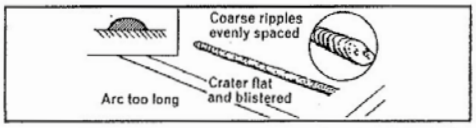
- Pause slightly at each side to control the slag and ensure side fusion into previous deposit.
- The deposit width should be equal to four or five times the diameter of the electrode core wire. Do not try to exceed this width or difficulty may be found in controlling slag.

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.

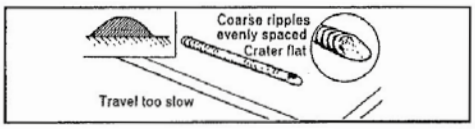
Effect of variation in procedure



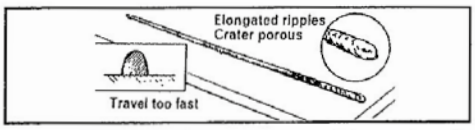
Too short an arc length will cause irregular piling of the weld metal.



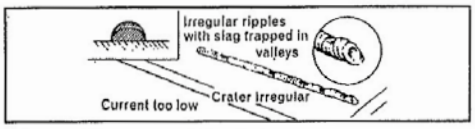
Too long an arc length will cause the deposit to be coarse rippled and flatter than normal.



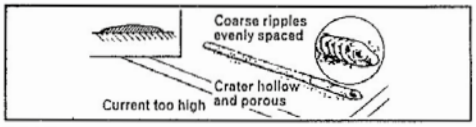
A slow rate of travel gives a wider, thicker deposit, shorter than normal length; too slow a rate of travel may allow the slag to flood the weld pool causing difficulty in controlling deposition.



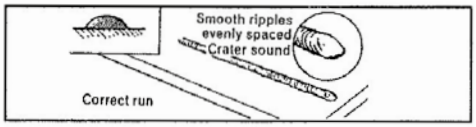
A fast rate of travel gives a narrower, thinner deposit, longer than normal length; too fast a rate of travel may prevent adequate interfusion with the parent metal.



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.



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.



With the correct arc length, rate of travel, angle of electrode, welding conditions and technique, the deposited metal will be regular in thickness and width, with a neat finely rippled surface, free from porosity or any slag entrapment.

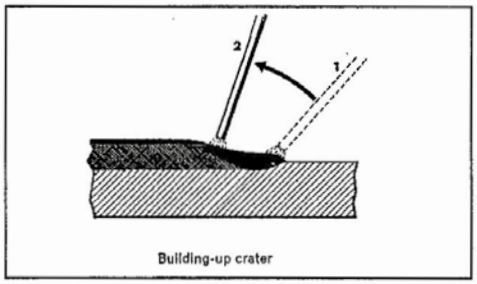
Stopping and re-starting

An incorrectly finished weld or uneven join-up in a weld run can make a local notch effect which may cause the weld to fail under load. Take care to build up craters at the end of runs and to make smooth joins in runs.

Building up crater

Material	One piece of low carbon steel 10 mm thick. Minimum size 150 mm x 300 mm
Electrode	As selected
Current*	As selected

*At this stage the trainee should be able to assess whether or not the current selected is correct for the conditions.



- Welding conditions as for previous examples.
- Pause at the end of the run and shorten the arc length slightly.
- Move the arc slowly backwards until over the centre of weld pool.

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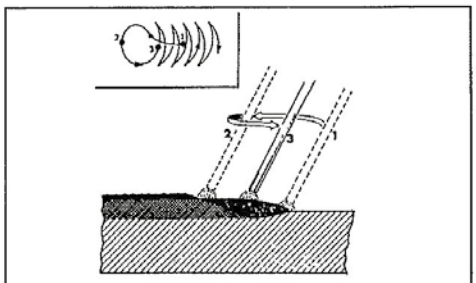
- At the same time increase the angle of the electrode until it is at right angles to the plate surface. (As positions 1 and 2 in illustration).
- Maintain the very short arc until the crater is built up with deposited metal and then break the arc.

Re-starting runs



Restarting with new electrode

- Welding conditions as for previous examples.
- After depositing one electrode break the arc after only a slight pause over the weld pool.
- With a new electrode, re-strike the arc at the leading edge of the deposit crater.
- Move the arc slowly back over the crater in a loop movement to the back edge of the crater. (As positions 1, 2 and 3 in illustration).
- Resume weaving motion in the correct direction of travel and at the normal rate.

Tack welds

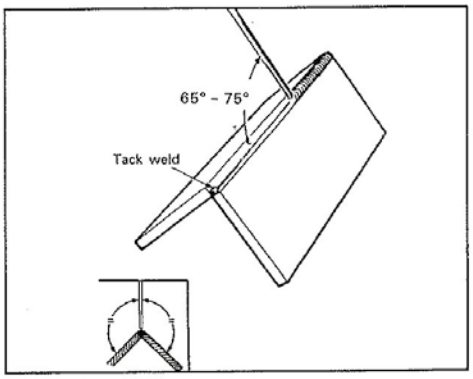
A tack weld is a short weld used to help assembly and to maintain the position of parts during welding.
Tack welds should be between three and four times the plate thickness, up to a maximum length of 35 mm at the ends of the joint.
For intermediate tack welds the length should be between two and three 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)

Material	Two pieces of low carbon steel 5 mm thick. Approximate size 150 mm x 50 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	To suit electrode



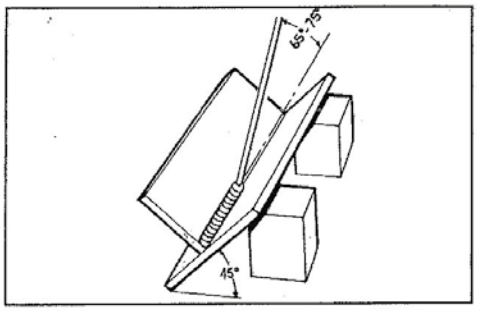
- Deposit the corner weld in one run.
- Hold the electrode, without weaving, at an angle of 65° to 75° to the line of the joint.
- Adjust the rate of travel so as to secure a full section weld without undue melting away of the top edge of the fusion faces.

MMA Basics

Manual metal-arc welding (AW1 – AW2)

T-joint (flat position)

Material	Two pieces of low carbon steel 5 mm thick. Approximate size 150 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	4 mm Rutile
Current	To suit electrode



- Deposit a fillet weld with the 4 mm electrode.
- Hold the electrode at an angle of 65° to 75° to the line of the joint, without weaving.
- Adjust the rate of travel so that a weld of equal leg length is deposited.
- After the joint has cooled sufficiently to be handled, weld the other side using the same technique but with a slightly faster rate of travel to deposit same size of weld.

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ANY QUESTIONS? CONTACT US!

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