Trade of Metal Fabrication

Module 2:	Thermal Processes
Unit 10:	M.I.G/M.A.G. Welding
	Phase 2

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Document Release History

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02/11/06	First draft	
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Module 2 – Thermal Processes

Unit 10 – M.I.G/M.A.G. Welding

Duration – 15 Hours

Learning Outcome:

By the end of this unit each apprentice will be able to:

- List the applications, characteristics and hazards associated with M.I.G/M.A.G.'s welding
- Describe the three methods of filler metal transfers
- Safely set up and operate Metal Active Gas shielded equipment and weld
- Butt and fillet weld in the flat position

Key Learning Points:

Sk Rk	Assembly of M.I.G. welding equipment.
Sc Rk M	Regulation of gas flow and types of shielding used and their applications.
Sk Rk	Regulation of current settings.
Sk Rk	Wire feed regulation - speeds.
Sk Rk	Maintenance and care of plant (water cooled/air cooled).
Sk Rk Rk	M.I.G./M.A.G. principles, techniques and applications.
M Rk	Wire filler sizes and tip sizes.
Rk Sc	Applications and characteristics of the M.I.G./M.A.G. process.
H Rk	Safety standards and procedures - safe work area, P.P.E.
Sc Rk	M.I.G./M.A.G. penetration of weld.
Rk	Properties and strength of M.I.G./M.A.G. weld.
Rk	History and development of the process.
P	Organisation of work area - safe work environment - P.P.E.

Training Resources:

- Fabrication workshop facilities
- Metal inert gas welding plant/shielding gas and equipment
- Safety clothing and equipment
- Handouts
- Overheard transparencies
- Training videos
- Manufacturers data sheets

Key Learning Points Code:

$\boxed{\text{M}}$ = Maths $\boxed{\text{D}}$= Drawing $\boxed{\text{RK}}$ = Related Knowledge $\boxed{\text{Sc}}$ = Science

$\boxed{\text{P}}$ = Personal Skills $\boxed{\text{Sk}}$ = Skill $\boxed{\text{H}}$ = Hazards

Metal Arc Gas-Shielded (MAGS) Welding

Introduction

These semi-automatic and automatic processes have found increasing use in recent years. They have replaced the use of oxyacetylene and manual metal arc processes on certain types of fabrication.

The process is known by different names, such as MIG (metallic inert gas), CO_2 welding (when a carbon dioxide gas shield is employed), metal active gas welding and, in the USA, gas metal-arc welding. In the UK, the most widely accepted name is MAGS (metal arc gas-shielded welding) because this term covers shielding gases other than inert gases, and also gas mixtures.

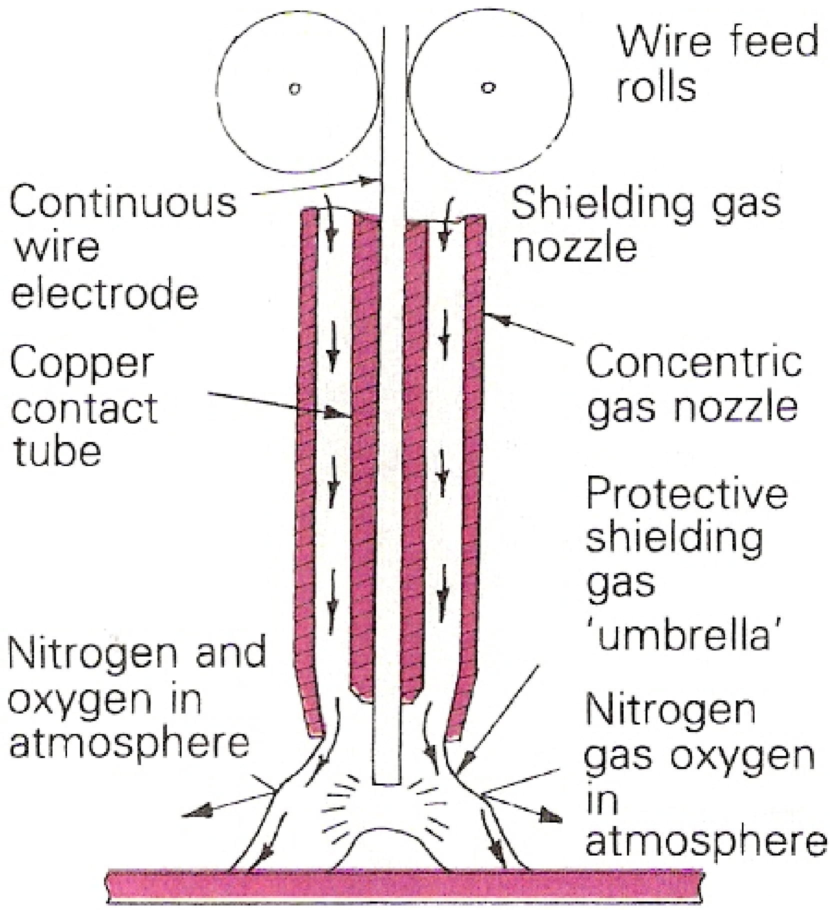


Figure 1 - Diagram of Welding Nozzle and Gas Shield for Metal Arc Gas-Shielded (MAGS) Welding

Because the MAGS process is semi-automatic, it is suitable for full automation on certain types of work and is used quite widely in robot form.

The Process

A continuous consumable wire electrode is fed through a welding gun fitted with a concentric gas nozzle. The arc is struck between the workpiece and the wire, which acts as both electrode and filler. The arc and the weld pool are shielded from atmospheric contamination by passing a suitable gas through the nozzle to form a protective shield around the welding area (Figure 1 to Figure 3).

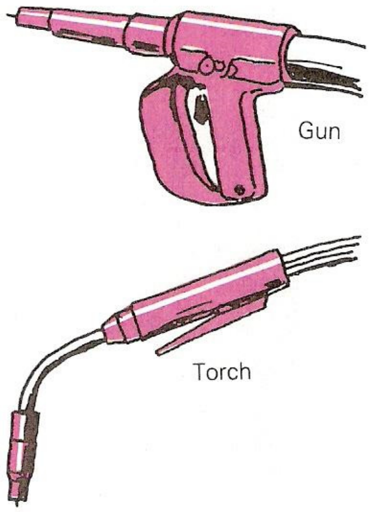


Figure 2 - MAGS Welding Gun and Welding Torch

Some guns can have an outer nozzle attachment for fume extraction. This has to be carefully set so as not to disturb the gas shield.

For non-ferrous metals, pure argon is usually used as the gas shield. Other gases can be used, such as helium or (for copper) nitrogen. For ferrous metals, the gases used include carbon dioxide, argon and oxygen, argon and CO_2.

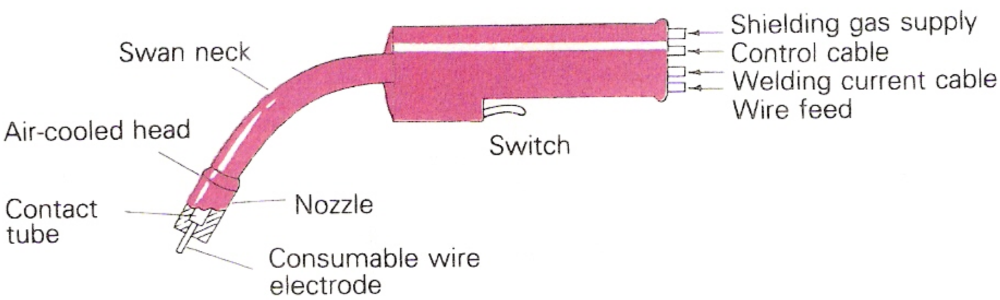


Figure 3 - Air-Cooled Welding Torch

The arc is self-adjusting, which means that any variation in the arc length made by the welder produces a change in the burn-off rate of the electrode, and the arc rapidly returns to its original length.

Figure 4 shows the basic set-up for MAGS welding.

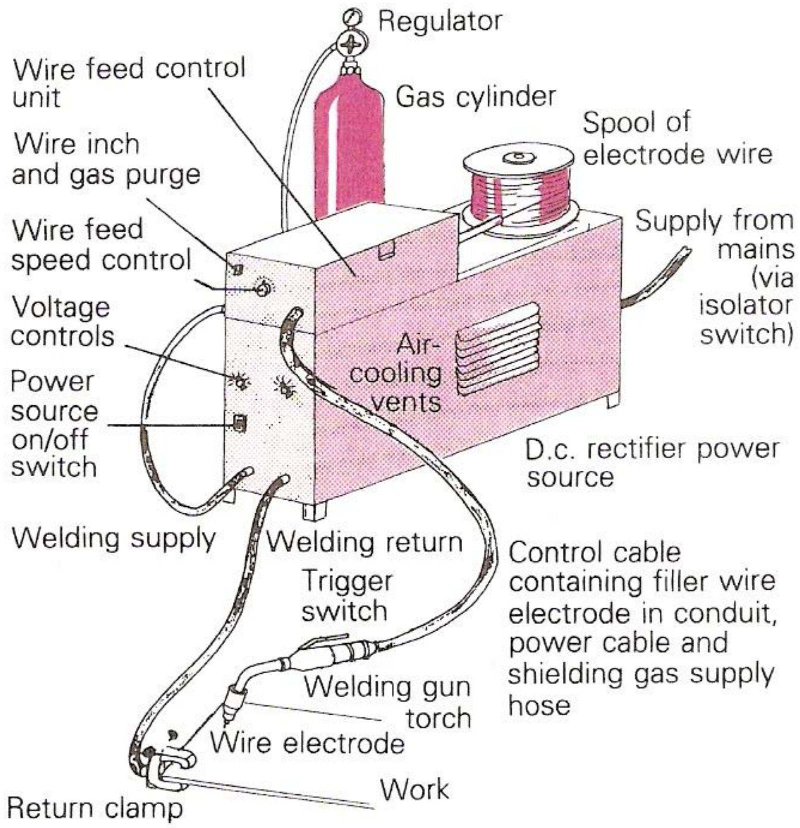


Figure 4 - Basic Set-Up for MAGS Welding

Figure 5 - MAGS Welding a T-Fillet Test Piece

Metal Transfer in MAGS Welding

Figure 6 shows the three main types of metal transfer: spray transfer, pulsed transfer and dip transfer.

In spray transfer, droplets of metal are transferred from the end of the electrode in the form of a fine spray. It is usually used for welding thicker plate in the flat and horizontal/vertical positions.

Spray transfer requires the use of higher welding current and arc voltages. The resulting fluid state of the molten pool prevents it from being used for welding steels in positions other than flat or horizontal/vertical. Aluminium, however, can be welded in all positions using spray transfer.

There are two types of spray transfer. The true spray is obtained when the shielding gas is argon or argon/oxygen mixture. With these gas shields, the droplets in the spray are very fine and never short-circuit the arc. When carbon dioxide or an argon/carbon dioxide mixture is used, a molten ball tends to form at the end of the electrode. This can grow in size until it is bigger than the diameter of the electrode. These large droplets can cause short circuits to occur. This mode is known as globular transfer. With conditions that cause the short circuits to occur very rapidly, the mode becomes short-circuiting or dip transfer.

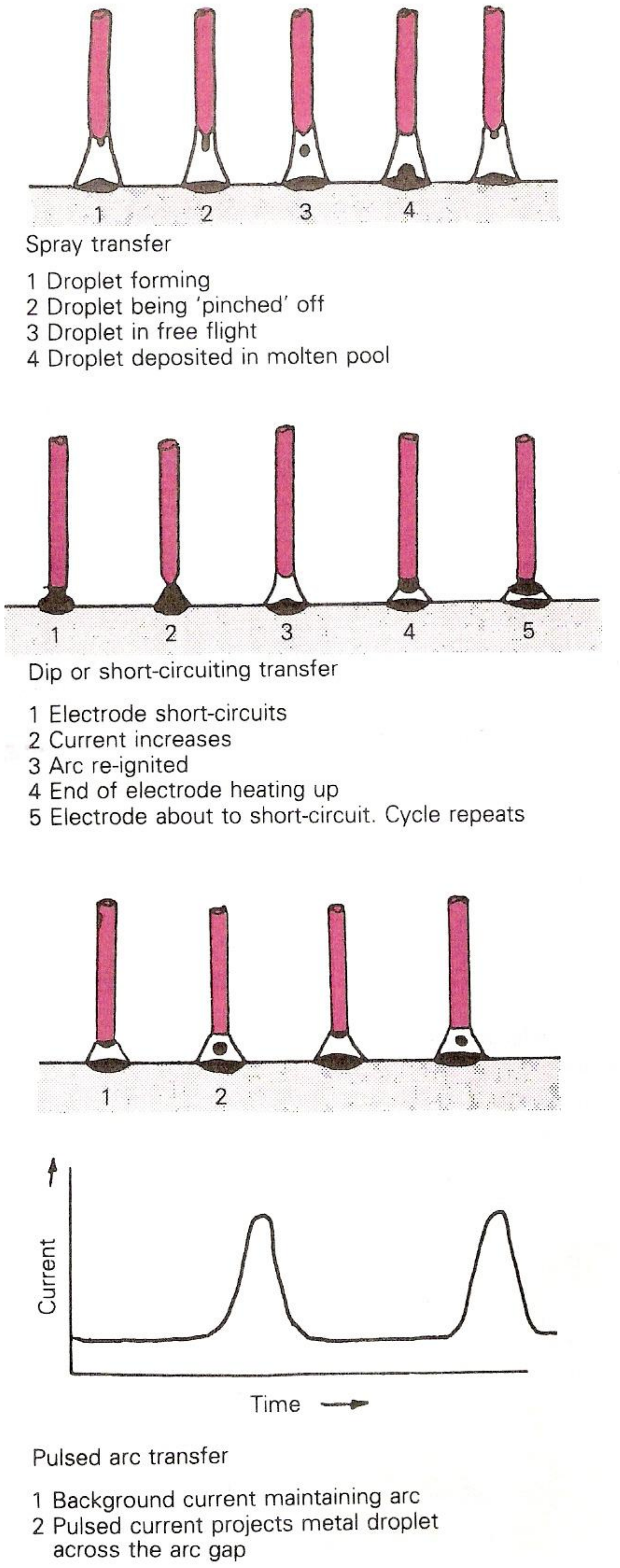


Figure 6 - The Three Types of Metal Transfer used in MAGS Welding

Electrode Wire Size

Generally speaking, the smaller-diameter wires will give greater current density, resulting in a fast burn-off rate and a tendency to give deeper-penetration welds.

Modern MAGS welding machines have an automatic inductance, but older machines may need a manual setting. The inductance is used for dip transfer welding. Increasing the inductance for a given open-circuit voltage produces a hotter arc, which results in quieter welding conditions with less spatter and a smoother weld finish. Decreasing the inductance produces a cooler arc that gives out a distinctive 'crackling' sound and a weld surface with a more pronounced ripple.

On machines that require manual adjustment, high inductance will be needed for thicker materials and low inductance for thin sheet.

Contact Tips and Nozzles

On some torches and guns, the positions of contact tip and nozzle can be adjusted to allow greater visibility of the welding area or accessibility to the particular joint, and/or to improve gas shielding. Table lists the commonly recommended settings.

Always use the correct size of contact tip. A brief spray with silicon 'anti-spatter' solution before use and at regular intervals during use will make it easier to remove spatter from the nozzle and tip. Clean the nozzle and tip regularly.

Mode of metal transfer	Recommended position of control tip
Dip	3–9 mm beyond the end of the nozzle to allow greater visibility/accessibility
Spray (on steels)	6–9 mm within the nozzle to give improved gas shielding
Spray (on aluminium)	9–12 mm within the nozzle to give improved gas shielding
Spray (using flux-cored wire)	9–18 mm within the nozzle to give improved gas shielding and contact tube protection

Table 1 - Contact Tip Positions for MAGS Welding

Welding Speed

Perfection with MAGS welding, as with the other processes discussed in this book, will only come with adequate practice under guidance.

When you are learning MAGS welding, you must pay special attention to obtaining the correct welding speed. Too fast a welding speed can cause excessive spatter and undercut. Shielding gas can get trapped in the quickly solidifying weld metal, causing porosity. Too slow a welding speed may cause excessive penetration.

Wire Extension

The length that the electrode wire extends beyond the contact tip can also affect weld quality. With more wire protruding, the arc current will be reduced, and this will result in less penetration. Wire extension from the contact tip should be approximately:

1. For dip transfer: 3-6 mm
2. For spray transfer: 18-30 mm
3. For flux-cored wire: 30-45 mm

Gases

Since CO_2 and oxygen are not inert gases, the title metallic inert gas is not true when either of these gases is mixed with argon or CO_2 is used on its own. The title metallic active gas (MAG) is sometimes used in these cases.

Argon + 1% or 2% oxygen. The addition of oxygen as a small percentage to argon gives higher arc temperatures and the oxygen acts as a wetting agent to the molten pool, making it more fluid and stabilising the arc.

Helium is nearly always found in mixed gases. Because of the greater arc temperature, mixing it with argon, oxygen or CO_2 controls the pool temperature, increases wetting and stabilises the arc. The higher the helium content the higher the arc voltage and the greater the heat output. It is used in gas mixtures for aluminium, nickel, cupro-nickels, etc., and is particularly applicable to stainless steels with the helium-argon-oxygen or CO_2 mixtures. Helium-argon mixtures are also used for the welding of 9% nickel steels.

Carbon dioxide. Pure CO_2 is the cheapest of the shielding gases and can be used as a shield for welding steel up to 0.4% C and low-alloy steel. Because there is some dissociation of the CO_2 in the arc resulting in carbon monoxide and oxygen being formed, the filler wire is triple deoxidised to prevent porosity, and this adds somewhat to its cost and results in some small areas of slag being present in the finished weld. The droplet rate is less than that with pure argon, the arc voltage drop is higher, and the threshold value for spray transfer much higher than with argon. The forces on the droplets being transferred across the arc are less balanced than with argon-oxygen so that the arc is not as smooth and there is some spatter, the arc conditions being more critical than with argon-oxygen.

Gas flow rate can greatly affect the quality of the weld. Too low a flow rate gives inadequate gas shielding and leads to the inclusion of oxides and nitrides, while too high a rate can introduce a turbulent flow of the CO_2 which occurs at a lower rate than with argon. This affects the efficiency of the shield and leads to a porosity in the weld. The aim should be to achieve an even non-turbulent flow and for this reason spatter should not be allowed to accumulate on the nozzle, which should be directed as nearly as possible at 90° to the weld, again to avoid turbulence.

The torch angle is, in practice, about 70-80° to the line of travel consistent with good visibility and the nozzle is held about 10-18 mm from the work. If the torch is held too close, excess spatter build-up necessitates frequent cleaning, and in deep U or V preparation the angle can be increased to obtain better access. Weaving is generally kept as low as convenient to preserve the efficiency of the gas shield and reduce the tendency to porosity. Wide weld beads can be made up of narrower 'stringer' runs, and tilted fillets compared with HV fillets give equal leg length more easily, with better profile.

Mild steel sheet, butt welds, CO_2 shielding, flat, 0.8 mm diameter wire (approximate values).

Thickness (mm)	Gap (mm)	Wire feed (m/minute)	Arc (volts)	Current (A)
1	0	2.8-3.8	16-17	65-80
1.2	0	3.2-4.0	18-19	70-85
1.6	0.5	4.0--4.8	19-20	85-95
2.0	0.8	5.8-7.0	19-20	110--125
2.5	0.8	7.0--8.4	20--21	125-140
3.0	1.5	7.0--8.4	20--21	125-140

Economic Considerations

Although filler wire for the CO_2 process, together with the cost of the shielding gas, is more expensive than conventional electrodes, other factors greatly affect the economic viability of the process. The deposition rate governs the welding speed which in turn governs the labour charge on a given fabrication.

The deposition rate of the filler metal is a direct function of the welding current.

Metal type	Gas shield	Remarks
Carbon and low-alloy steels	CO_2	For dip transfer, and spray transfer Spatter problems. Use deoxidized wire
	Ar–15/20% CO_2	For dip or spray transfer. Minimum spatter
	Ar–5% CO_2	For dip and spray transfer
	Ar–5% O_2	Spray transfer. High impact properties
	Ar–5% CO_2–O_2 2%	For pulsed arc and thin sections
Stainless steels	Ar–1/2% O_2	Spray transfer
	75 He 23.5% Ar 1.5% CO_2	High quality dip transfer. For thin sections and positional work. Good profile
	He 75%–Ar 24%–O_2 1%	
Aluminium and its alloys	Argon	Stable arc with little spatter
	Helium	Hotter arc, less pre-heat, more spatter
	He 75% Ar 25%	Stable arc, high heat input. Good penetration. Recommended for thicknesses above 16 mm

Table 2 - MIG and MAG Processes

Metal arc gas shielded process. Recommended gases and gas mixtures for various metals and alloys.

CO_2 Welding of Mild Steel

There are four controls to enable optimum welding conditions to be achieved: (1) wire feed speed which also controls the welding current, (2) voltage, (3) gas flow.

For a given wire diameter the wire feed rate must be above a certain minimum value to obtain a droplet transfer rate of above about 20 per second, below which transfer is unsatisfactory. With increasing wire feed rate the droplet transfer rate and hence the burn-off increases and the upper limit is usually determined by the capacity of the wire feed unit.

As stated before, the short-circuiting arc is generally used for welding thinner sections, positional welding, tacking and on thicknesses up to 6.5 mm. In positional welding the root run may be made downwards with no weave and subsequent runs upward. The lower heat output of this type of arc reduces distortion on fabrications in thinner sections.

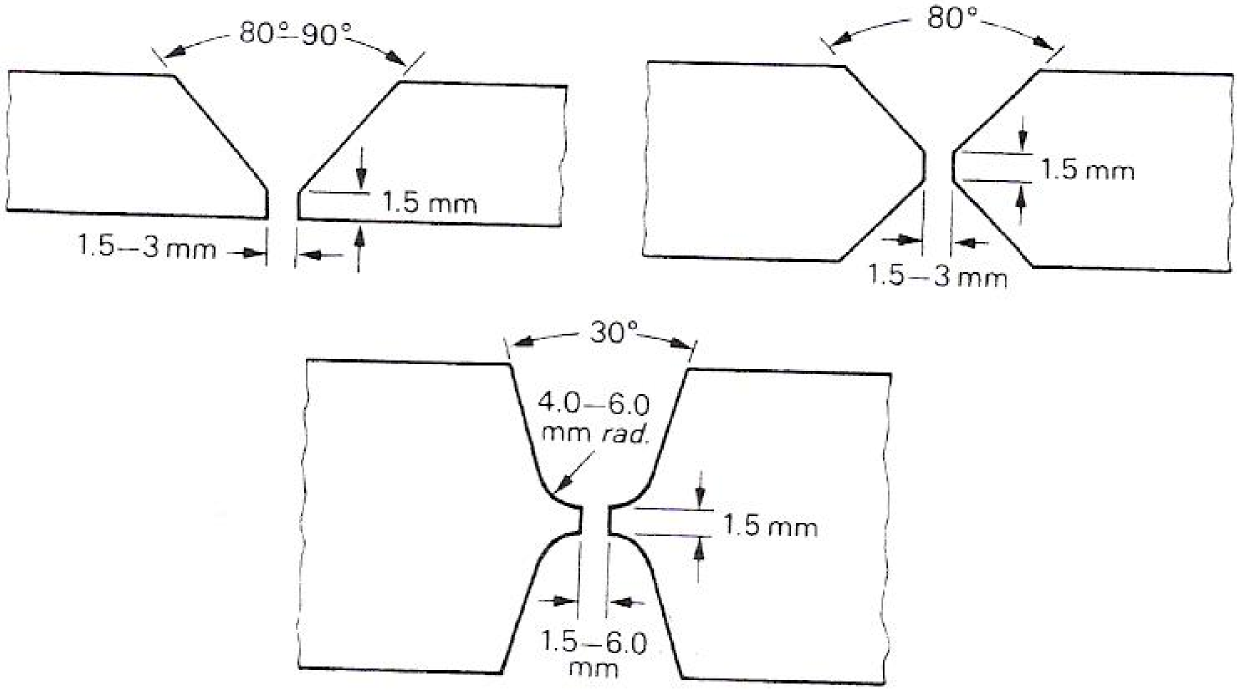


Table 3 - Preparation for Welding of SG Cast Irons

Metal Transfer Forms

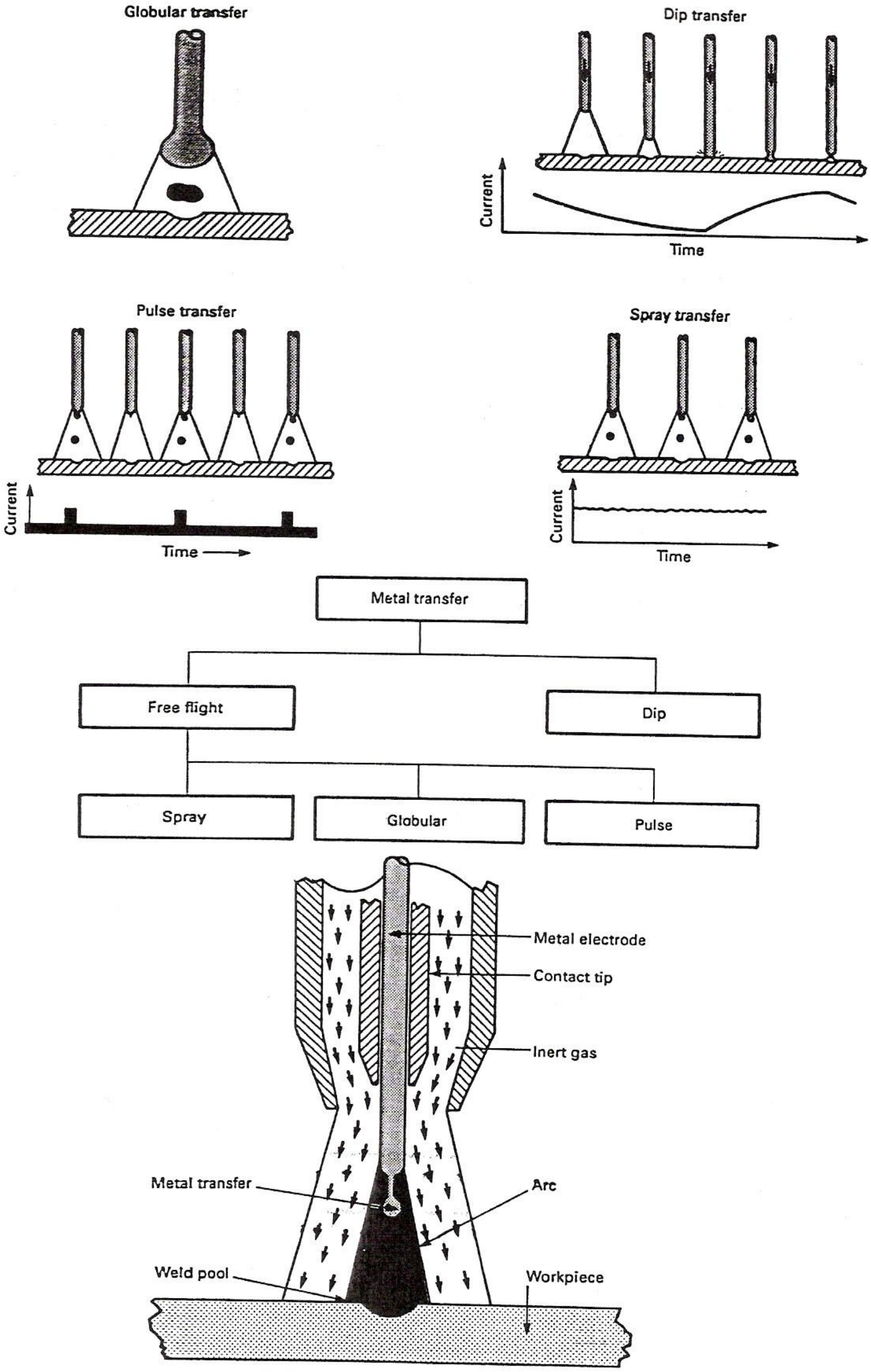


Figure 7 - Metal Transfer Forms

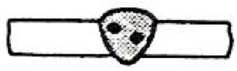
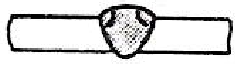
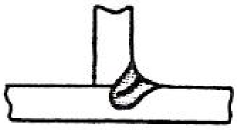
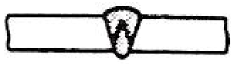
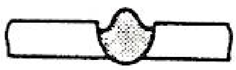
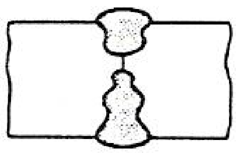
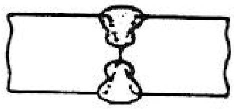
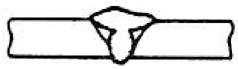
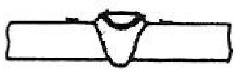
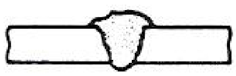
Fault		Cause
Porosity	 	Insufficient Si, Mn in wire Insufficient CO_2 shielding because of Flow rate Frozen value Clogged nozzle Draughts
Cracking	 	Dirty work – grease, paint, scale, rust (i) Weld bead too small (ii) Weld too deep, greater than 1:2:1 (iii) High sulphur, low manganese, slow cooling rate
Undercutting		Travel speed too high Backing bar groove too deep Current too low for speed Torch angle too low
Lack of penetration	 	Current too low – setting wrong Wire feed fluctuating Electrode extension too great Joint preparation too narrow Angle too small, Gap too small
Lack of fusion		Uneven torch manipulation Insufficient indulgence (short circuiting arc) Voltage too low
Slag inclusions		Technique – too wide a weave Current too low Irregular weld shape
Spatter – on work on nozzle in weld		Voltage too high Insufficient inductance Insufficient nozzle cleaning
Irregular weld shape		Excessive electrode extension Wire temper excessive, no straightening rolls Current too high for voltage Travel speed too slow

Table 4 - Weld Defects and Their Causes

CO2	MAG: plain carbon and low-alloy steels.	Low-cost gas. Good fusion characteristics and shielding efficiency, but stability and spatter levels poor. Normally used for dip transfer only.
Argon + 1 to 7% CO_2 + up to 3% CO_2	MIG/MAG: plain carbon and low-alloy steels. Spray transfer.	Low heat input, stable arc. Finger penetration. Spray transfer and dip on thin sections. Low CO_2 levels may be used on stainless steels but carbon pick-up may be a problem.
Argon + 8 to 15% CO_2 + up to 3% CO_2 Argon + 16 to 25% CO_2	MIG/MAG: plain carbon and low-alloy steels. General purpose. MIG/MAG: plain carbon and low-alloy steels. Dip transfer.	Good arc stability for dip and spray pulse. Satisfactory fusion and bead profile. Improved fusion characteristics for dip.
Argon + 1 to 8% O_2	MIG/MAG: dip, spray and pulse, plain carbon and stainless steel.	Low O_2 mixtures suitable for spray and pulse, but surface oxidation and poor weld profile often occur with stainless steel. No carbon pick-up.
Helium + 10 to 20% argon + oxygen + CO_2	MIG: dip transfer, stainless steel.	Good fusion characteristics, high short-circuit frequency. Not suitable for spray pulse transfer.
Argon + 30 to 40% He + CO_2 + O_2	MIG: dip, spray and pulse welding of stainless steels.	Improved performance in spray and pulse transfer. Good bead profile. Restrict CO_2 level for minimum pick-up.
Argon + 30 to 40% He + up to 1% O_2	MIG: dip, spray and pulse welding of stainless steels.	General purpose mixture with low surface oxidation and carbon pick-up. (It has been reported that these low-oxygen mixtures may promote improved fusion and excellent weld integrity for thick-section aluminium alloys).

Tack Weld

A tack is a relatively small temporary MIG/MAG weld that is used instead of a clamp or a self-tapping screw, to tack and hold the panel in place while proceeding to make a permanent weld (Figure 8). Like the clamp or self-tapping screw, the tack weld is always and only a temporary device. The length of the tack weld is determined by the thickness of the metal panel to be welded and is approximately a length of 15 to 30 times the thickness of the metal panel. Tack welds must be done accurately, as they are very important in maintaining proper alignment.

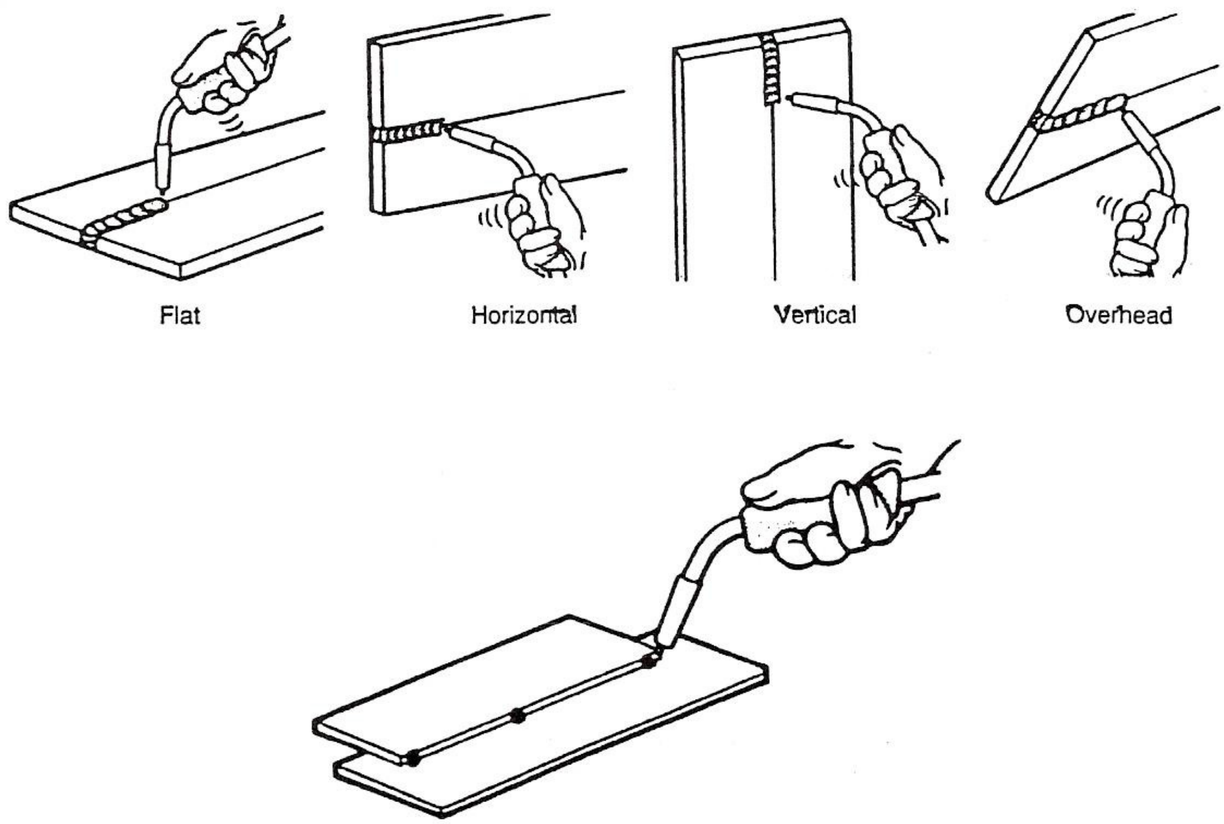


Figure 8 - Typical MIG/MAG Welding Positions and Tack Weld

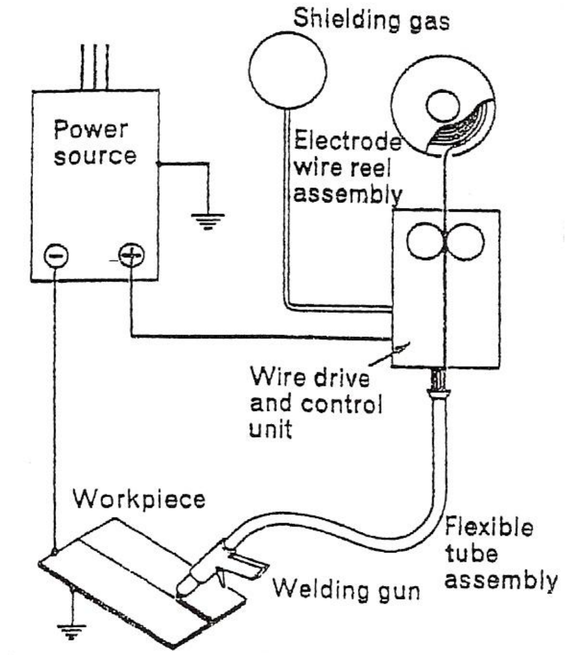
Metal-Arc Gas Shielded Welding

This welding process is a method of welding whereby an electric arc is maintained between a continuously fed consumable wire electrode. The protective gas shield, the wire and cooling water when necessary are fed through a flexible hose connected to the torch or gun at one end and the control unit at the other. This control unit usually houses electronic switches which stop and start the wire feed, the shielding gas flow and the cooling water, in addition to current and voltage control. A contactor switch usually on the gun causes the wire to feed through the copper contact tip in the end of the gun and so allow the arc to be struck.

It is important to note that the wire tip will only arc during the time the wire is feeding out, and increasing the wire speed causes an increase in current. The electrode is fed at a constant speed when selected at the control unit, but as stated above this speed may be varied to increase or decrease the current.

Ancillary Equipment

In addition to the power source the equipment is as illustrated:

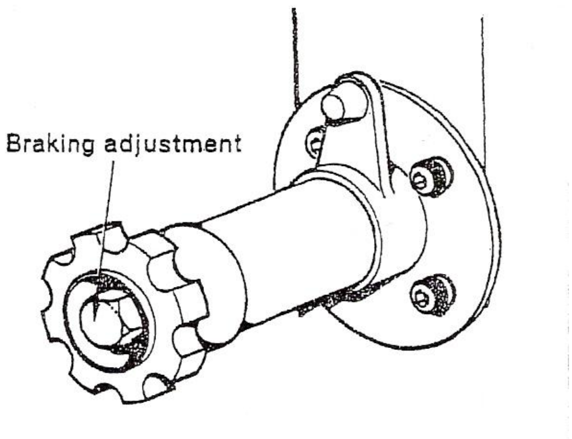


Electrode Wire Reel Assembly

The electrode wire reel or coll 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.

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 stopped.

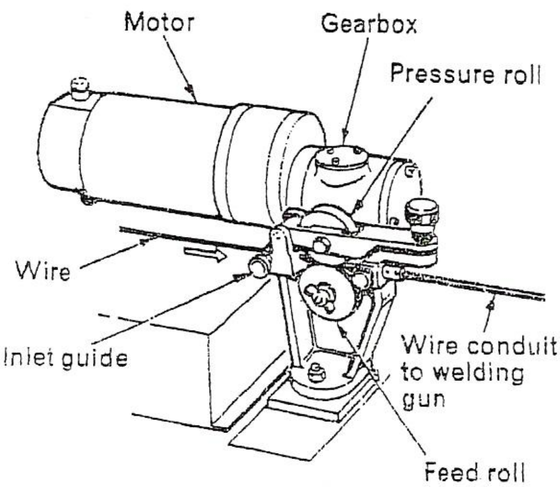


Wire reel spindle

Electrode Wire Drive Unit

This may either be a push or a pull type or combined.

In the push type the mechanism consists of two or more feed rolls where the grip or pressure can be adjusted.



Wire drive unit (push type)

Horizontal/Vertical Position

Open Square Butt Joint – Pulse Transfer

Example Procedure EP79

1. Direct the electrode wire at the gap between the sheets to form a pear-shaped melted area (keyhole).

2. 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 sheet surfaces behind the weld pool.

Visual Examination

A neat weld profile with a uniform (but not excessive) penetration bead should be achieved.

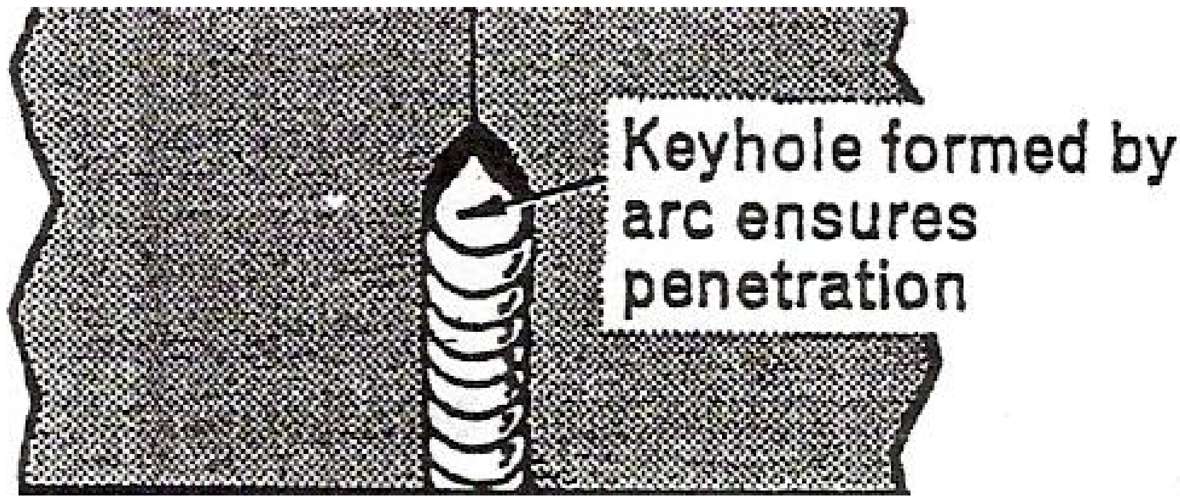


Figure 9 - Close-up of Welding of a Butt Joint

Open Square Butt Joint – Dip Transfer

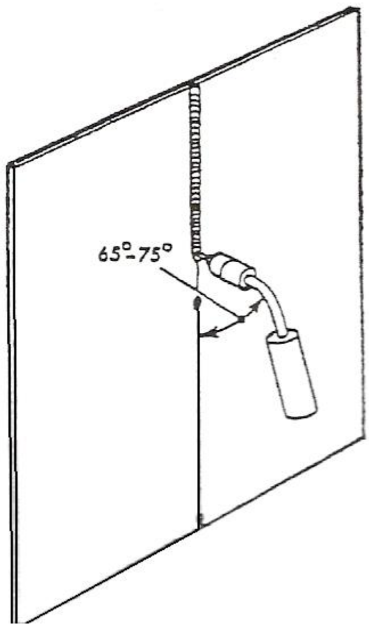
Example Procedure EP80

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 sheets and adjust the rate of downwards travel to ensure even deposition and control of penetration.

Visual Examination

As in EP80.

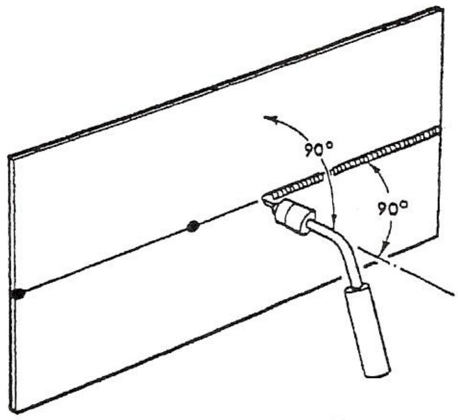
Material	5 mm or 6mm mild steel.
Preparation	(a) square edge. (b) bevel to 30° on each plate. No root face.
Electrode	(a) 0.8 mm (b) 1.2 mm
Feed Rate	(a) 100-110 in./min. (b) 120-130 in./min.
Current	(a) 90-100 amperes (b) 120-140 amperes
O.C. Voltage	(a) 19-20 volts (b) 22-24 volts
Arc Voltage	(a) 17-18 volts (b) 19-21 volts



Example ProcedureEP14

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. Adjust rate of travel to secure fusion without over-penetration.

Material	3 mm MS plate
Preparation	square edge.
Electrode	0.8 mm
Feed Rate	130-140 in./min.
Carbon Dioxide	25-30 ft.^{3}/hr.
Current	90-100 amperes
O.C. Voltage	19-20 volts
Arc Voltage	17-18 volts



Flat Position

Corner Joint – Spray Transfer

Example Procedure EP62

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.

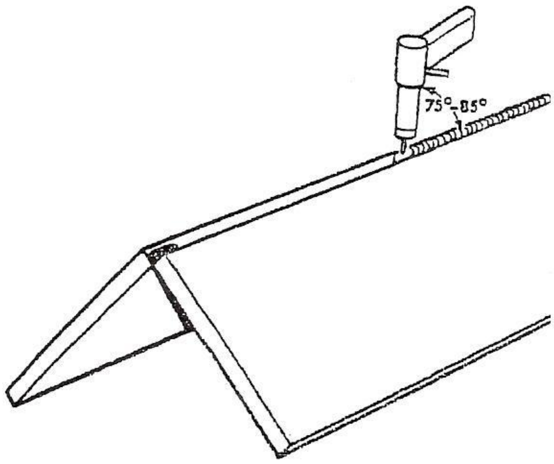
Visual Examination

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 EP63 and EP64.

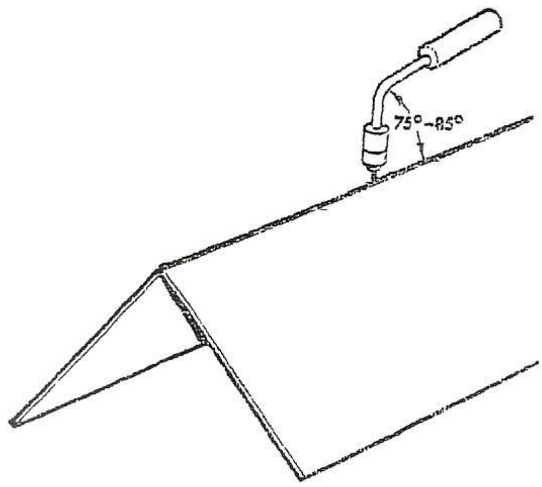
Material	3/16″ (5.0 mm) aluminium alloy, 2 off, min. 4" (10.0 cm) x 8" (20.0 cm)
Preparation	square edge
Assembly	Tack weld both ends to give included angle of 90°, no gap. Place on bench with joint-preparation upper-most and line of joint parallel with front of bench.
Electrode	1/16″ (1.6 mm)
Feed Rate	220-240 in./min.
Argon	35-40 ft.³/hr.
Current	190-215 amperes
Arc Voltage	24 volts



Corner Joint – Pulse Transfer

Example Procedure EP63

Material	14 s.w.g. (2.0 mm) aluminium alloy, 2 off, min. 4" (10.0 cm) x 6" (15.0 cm)
Preparation	square edge
Assembly	as for EP62
Electrode	1/16″ (1.6 mm)
Feed Rate	80-90 in./min.
Argon	35-45 ft.³/hr.
Current	65-75 amperes
Peak Voltage	33-34 volts
Arc Voltage	17-18 volts



Close Square Butt Joint – Spray Transfer

Example Procedure EP67

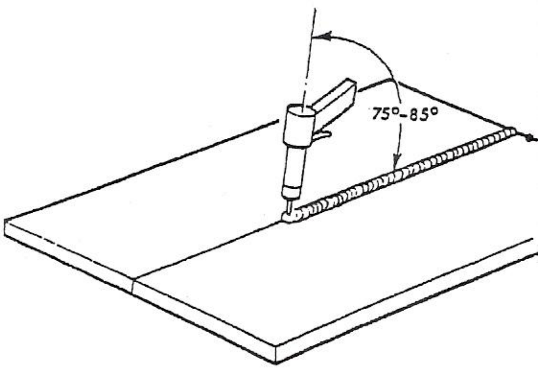
1. Establish the arc on the tack weld at the right-hand end of the joint.
2. When fusion has been obtained to the full depth of the plate commence the leftwards progression.
3. The electrode should be pointed at an angle of 75°-85° without weaving.
4. Adjust the rate of travel so that the deposited metal 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.

Material	3/16" (5.0 mm) aluminium alloy, 2 off, min. 4" (10.0 cm) x 6" (15.0 cm)
Preparation	square edge
Assembly	Tack weld with three tacks, no gap. The use of a stainless steel grooved backing bar is recommended.
Electrode	1/16″ (1.6 mm)
Feed Rate	240-290 in./min.
Argon	35-45 ft.³/hr.
Current	200-235 amperes
Arc Voltage	25-26 volts



Open Square Butt Joint – Dip Transfer

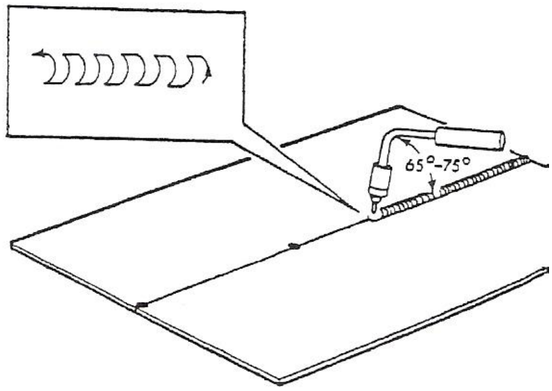
Example Procedure EP68

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.

Visual Examination

As for EP67.

Material	Either (a) 16 s.w.g. (1.5 mm) or (b) 3/16" (5.0 mm) mild steel, 2 off, min. 4" (10.0 cm) x 8" (20.0 cm)
Preparation	square edge and 1/16" gap
Assembly	Tack weld with three tacks
Electrode	(a) 1/32″ (0.8 mm) (b) 3/64″ (1.2 mm)
Feed Rate	(a) 130-140 in./min. (b) 100-110 in./min.
Carbon Dioxide	25-30 ft.^{3}/hr.
Current	(a) 90-100 amperes (b) 110-120 amperes
O.C. Voltage	(a) 19-20 volts (b) 21-22 volts
Arc Voltage	(a) 17-18 volts (b) 19-20 volts



T Joint – Spray Transfer

Example Procedure EP65

1. The electrode should be painted directly at the root of the joint and at an angle of 75°-85°.
2. 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, of uniform leg length and free from undercut at the toes.

The above also applies to EP66.

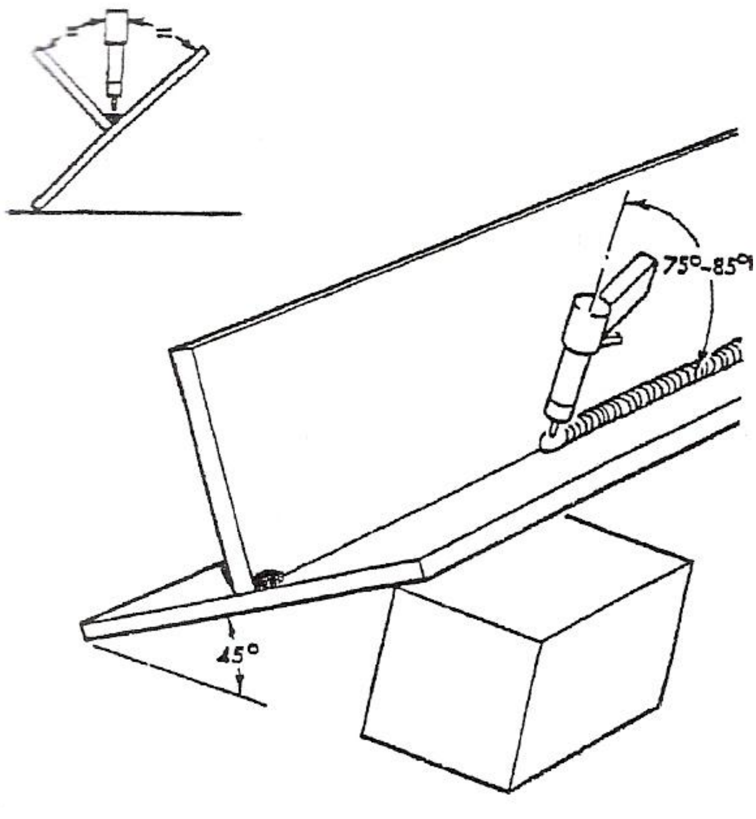


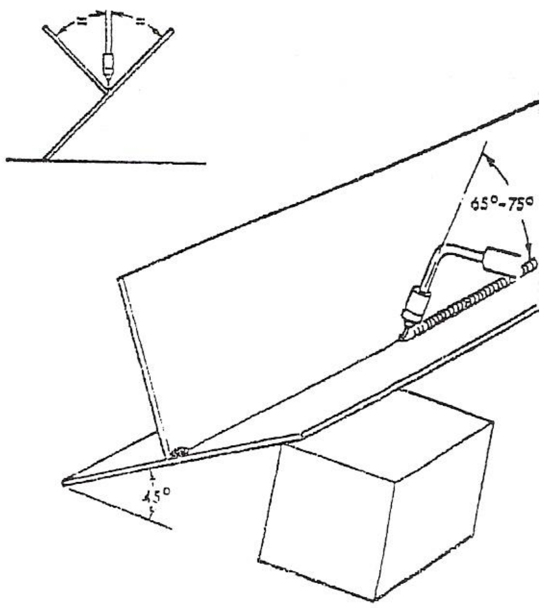
Figure 10 - T Joint - Spray Transfer

T Joint – Dip Transfer

Example Procedure EP66

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 3/32" (2.5 mm).
4. The electrode should be held without weaving at an angle of 65°-75° and painted directly at the root.

Material	Either (a) 16 s.w.g. (1.5 mm) or (b) 3/16" (5.0 mm) mild steel, 2 off, min. 4" (10.0 cm) x 8" (20.0 cm)
Preparation	square edge and 1/16" gap
Assembly	As for EP65
Electrode	(a) 1/32″ (0.8 mm) (b) 3/64″ (1.2 mm)
Feed Rate	(a) 130-140 in./min. (b) 100-110 in./min.
Carbon Dioxide	25-30 ft.³/hr.
Current	(a) 90-100 amperes (b) 110-120 amperes
Arc Voltage	(a) 17-18 volts (b) 19-20 volts
O.C. Voltage	(a) 19-20 volts (b) 21-22 volts



Shielding Gas

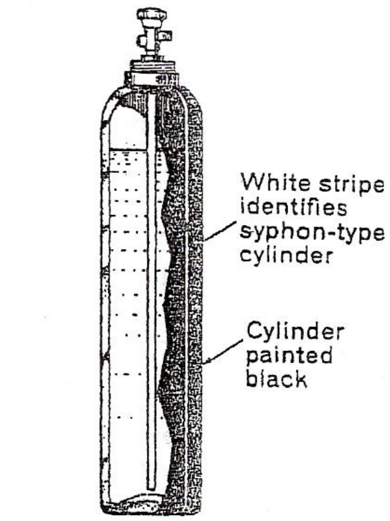
Important!

CYLINDER RECOGNITION

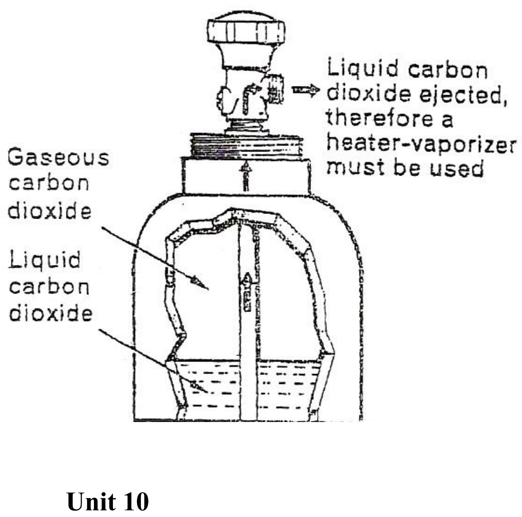
Argon	**Blue**
Argon-Oxygen	**Blue with black band**
Argon-Carbon Dioxide	**Blue with green band**

ALTERNATIVELY cylinders containing mixed gases may be painted with aluminium paint and the name of the mixture stencil1ed in black.

In addition gas identification labels are attached to the cylinders.



Carbon dioxide cylinder



Inert Gas

Argon of welding grade purity is used as the shielding gas when welding non-ferrous metals.

Argon-Oxygen Mixtures

The addition of small quantities of oxygen to argon makes it more suitable for use when welding steels.

1. About 1 % of oxygen is added when used for welding stainless steels and up to 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 with small percentages of other gases, is used for welding steels.

Argon-Carbon Dioxide Mixtures

Dip and spray transfer welding techniques are possible with a mixed shielding gas of 80% argon and 20% carbon dioxide. The spray transfer can be further improved by the inclusion of up to 2% of oxygen.

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.

Carbon Dioxide

Carbon dioxide is used as a shielding gas for mild steel welding, and is cheaper than argon-rich gases. It is more suitable for dip transfer at low currents but can be used at high currents for a form of 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.

Safety Precautions

SAFETY

The protective clothing and protective equipment as used for manual metal-arc welding are applicable. The amounts of ultra-violet and infra-red radiation, as well as the visible light radiation, are however more intense and full precautions must be exercised.

SAFETY PRECAUTION!

Cheek that there is good ventilation of the working area to prevent the build-up of harmful concentration of gases. Remember that carbon dioxide is heavier than air.

Other Safety Precautions

Always:

1. Use effective protective equipment and any necessary protective clothing.
2. Have full control of the torch/gun and hold it steady. Concentrate on watching the welding operation.
3. Support the flexible hose assembly so that drag on the torch/gun is reduced.
4. Hold the torch/gun with just sufficient grip at the point of balance to give control. Otherwise it will cause muscle fatigue. Position yourself to avoid over-balancing.
5. Warn any bystanders when about to strike the arc.
6. Ensure that any portable screens required are in position.
7. Ensure protection from radiation reflected from bright surfaces. Screen or temporarily cover polished surfaces in the vicinity.
8. Keep the welding screen in front of the eyes until the arc is broken.
9. Follow closing down procedure at the end of the work period or when there is a long interruption.

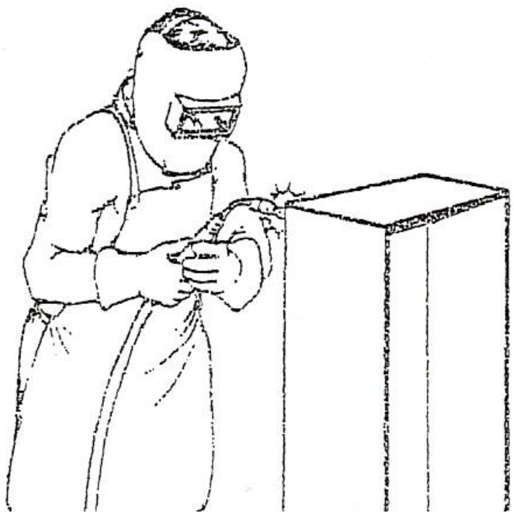


Figure 11 - Safety Precautions

Safety Precautions (T.A.G.S. and M.A.G.S.)

The safety precautions to be observed with these processes are similar for other metal arc processes with certain modifications.

In confined spaces gas shields, if allowed to escape, may displace oxygen and cause suffocation. Degreasing agents such as trichloroethylene and carbon tetrachloride decompose around the arc to form poisonous compounds. Local fume extraction should be used when employing very high current densities or flux core electrode wire, and filter breathing pads to prevent inhaling oxide dust. Correct grades of screen glass should be used as ultra violet light is greater when welding aluminium with an argon shield compared with other processes. Remember to chalk HOT on materials after welding, especially aluminium. Use light gloves when T.A.G.S. welding to avoid burning through radiation and H.F. burns between the fingers. Adequate protective clothing should always be worn.

Power Sources

Transformer-rectifiers are normally used for metal-arc gas shielded welding. A.C. equipment is suitable for welding with gas shielded flux cored electrodes. Motor generator power sources of suitable design may be used in certain circumstances.

Three forms of metal transfer across the arc are in common use. Power sources are available which make it possible to select the appropriate circuit arrangement for each type of transfer.

Direct current using either a rectifier or generator is used in the M.A.G.S. welding system with the polarity of the electrode being positive. The power source characteristic is a ″flat″ power source as shown at Figure 12 for a constant potential machine.

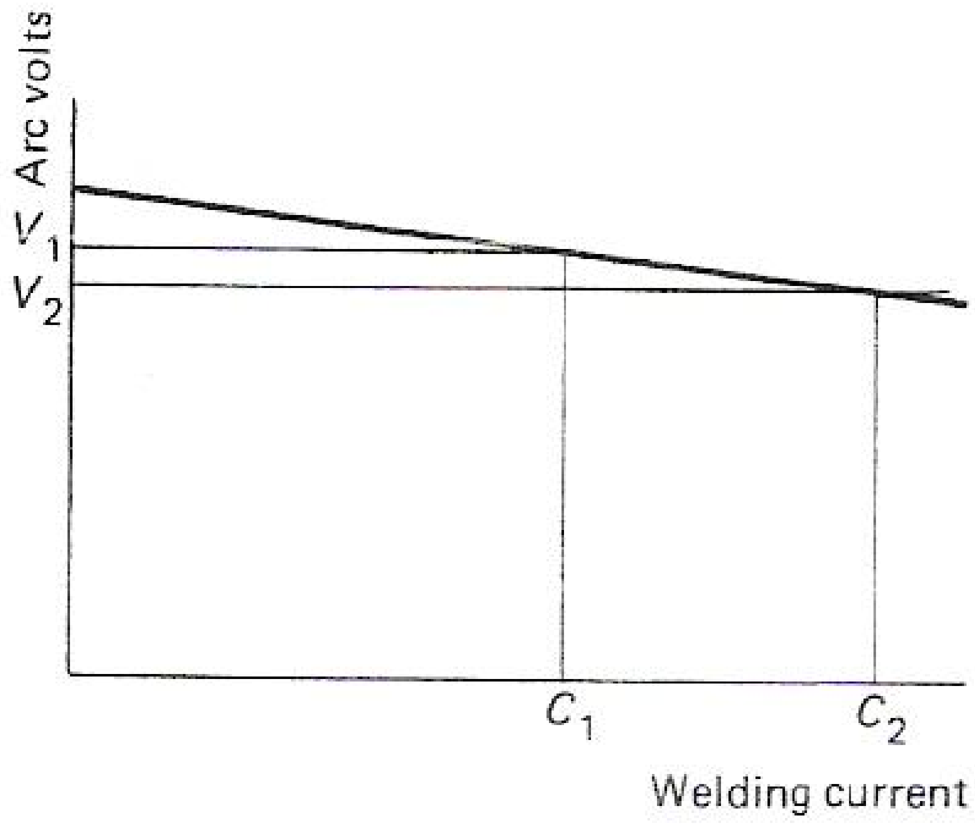
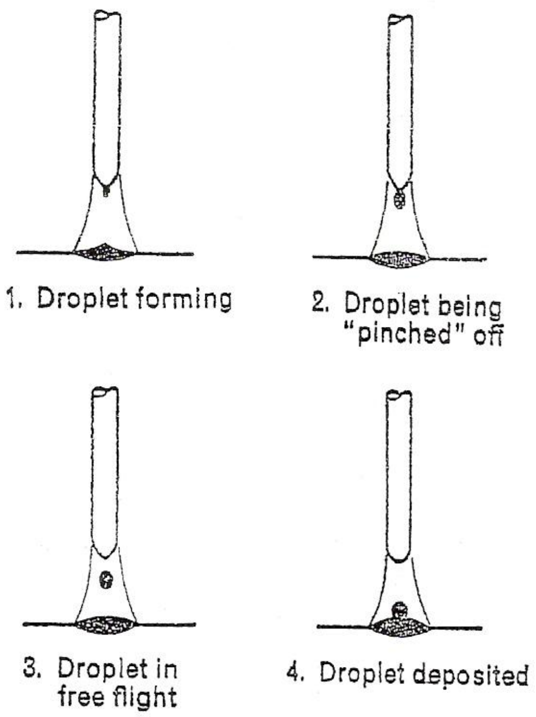


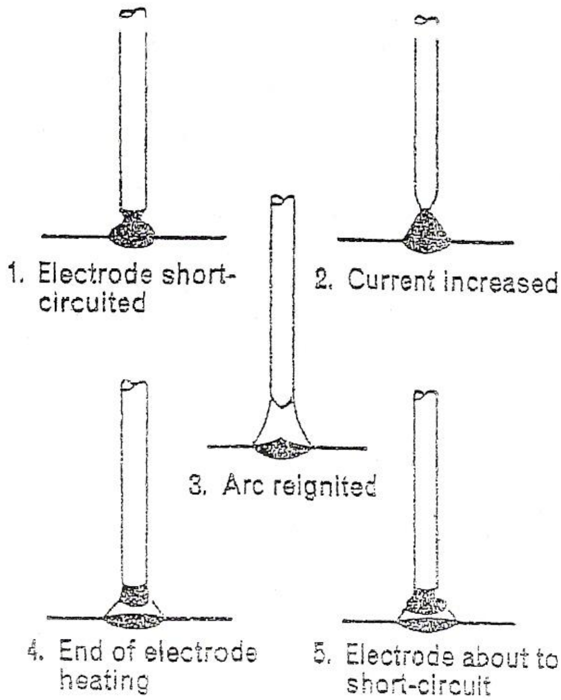
Figure 12 - Power Source

Modes of Metal Transfer

The mode of metal transfer from the tip of the electrode to plate may be influenced by current density, type of parent metal and electrode, gas shield, etc. The two basic modes are dip and spray transfer.



Schematic diagram, spray-transfer



Schematic diagram, dip-transfer

Spray Transfer

For this type of transfer a power source giving an output of about 400 amperes with an open-circuit voltage within the range 25-50 volts may be used.

With high current density, and particularly when using an aluminium or aluminium alloy electrode wire, the metal transfer is in the form of tiny drops when using argon shielding.

Spray transfer can be used for aluminium in any position, with appropriate reduction in welding current.

This mode of transfer can only be used satisfactorily on other metals when welding in the flat position.

Even, when using the smallest diameter wire, the minimum current is in the order of 160 amperes.

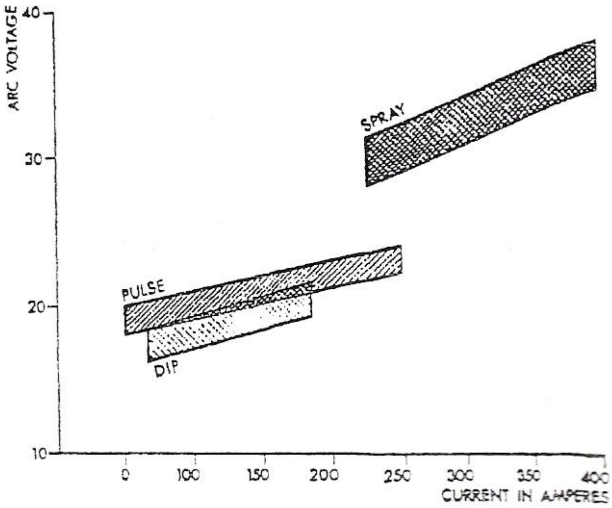
For welding in position or for the welding of thin materials dip or pulsed transfer is used.

Dip Transfer

For this type of transfer a power source giving an output of about 200 amperes with open circuit voltage tappings from 15-30 volts is appropriate. Inductance control must be incorporated. When the arc length is short (i.e. arc voltage is low) the end of the electrode wire touches the weld pool and the current rises.

If the rate at which the current rises is controlled, the end of the electrode is melted off and flows into the weld pool. This is known as Dip Transfer and is only applicable to materials having a relatively high electrical resistance, e.g. steel.

Pulse Transfer



For this type of transfer the high current pulses may be obtained from a single phase rectifier connected to a rectifier power source as used for dip transfer.

With pulse transfer the welding current alternates between high and low levels. A high current density detaches droplets of metal and a low current density maintains the arc. By this means a form of controlled spray transfer is obtained at low current values.

Typical operating ranges are shown for Spray, Dip and Pulse Transfer for 3/64″ (1.25 mm) dia. Mild steel wire.

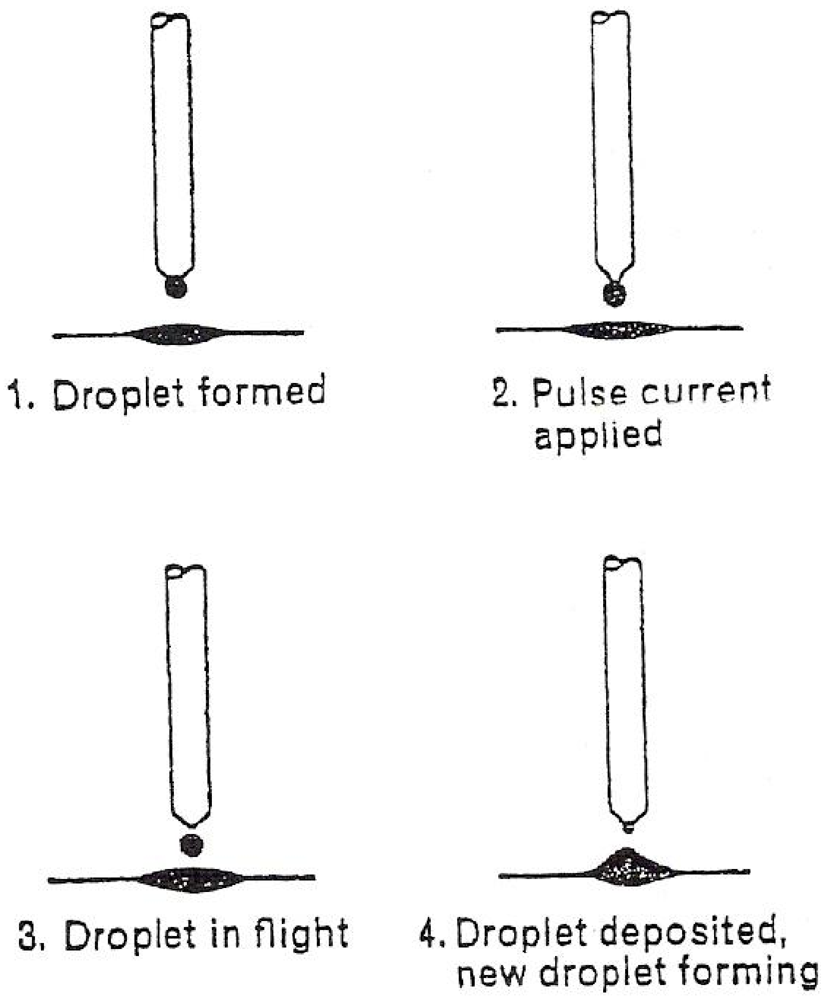


Figure 13 - Schematic Diagram, Pulse-Transfer

Types of M.A.G.S. Transfer

There are several types of torch but they may be divided into the gas-cooled and water-cooled types. The drive may be by electric motor with the wire spool on the hand-held gun, by air motor, or simply by a wire-feed push gun. A gas-cooled light-duty swan-neck torch is shown in Fig. 19.5.

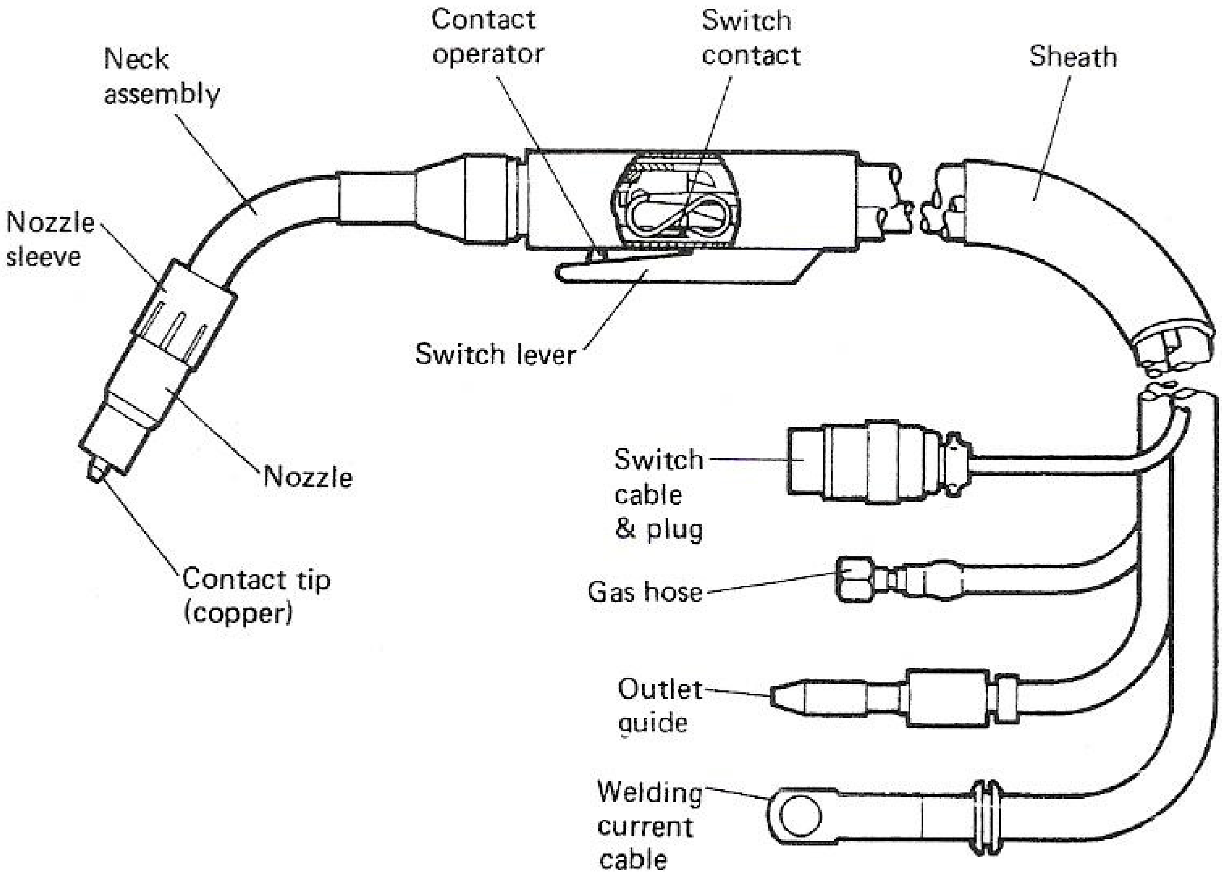


Figure 14 - Light-Duty Swan-Neck Torch

Operating the Equipment

Controls

All equipment will have the following controls:

1. Voltage control - governs arc length.
2. Wire feed control - governs welding current.

Equipment designed specifically for Dip Transfer welding will have an additional control:

3. 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.

Equipment designed for Pulse Transfer will have additional controls:

4. Pulse height control. This regulates the maximum voltage of each pulse.
5. Pulse frequency control. This may be fitted on some power sources.

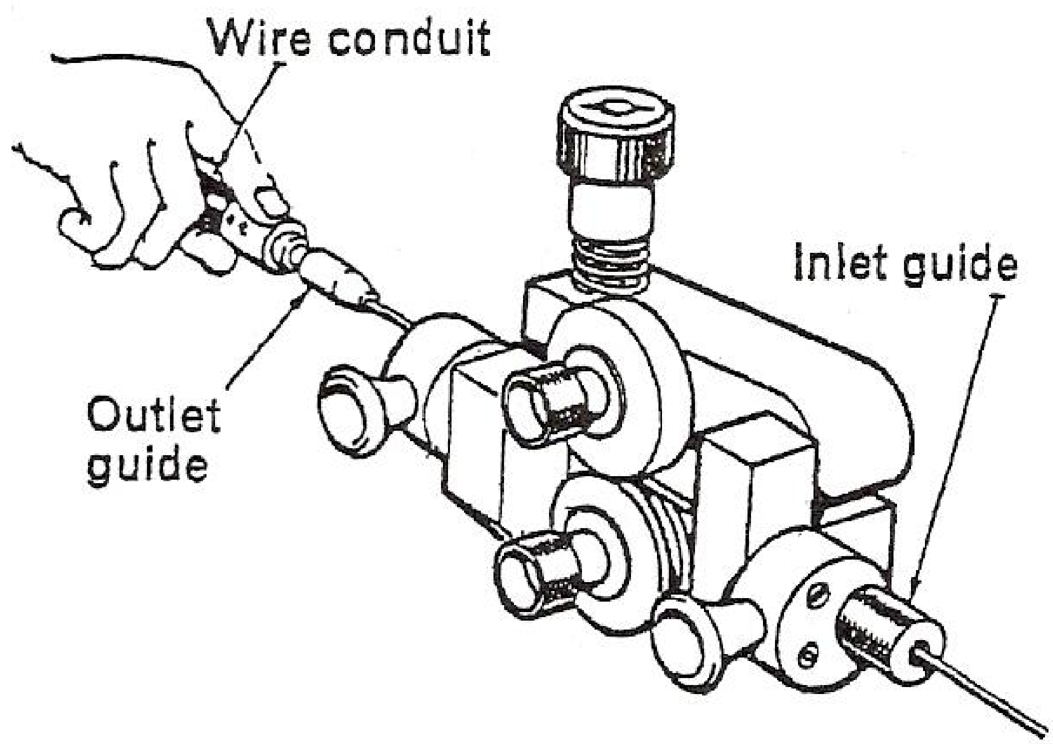


Figure 15 – Wire Feed Unit.

SAFETY!

Do not touch electrode wire when the current is switched on.

General Instructions

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 bench 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 the gas cylinder valve is open and when using carbon dioxide from syphon cylinder that the heater-vaporiser is switched on.
7. Check that the regulator pressure is set to 30 lb./in.^{2}.
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.

In addition to the general instructions given above others apply depending upon the type of equipment and the welding technique to be employed.

Spray Transfer

1. When fitted, the inductance control should be set at minimum.

2. Set open circuit voltage about 5 - 6 V above the recommended operating voltage.

3. Select the correct diameter and type of wire and set the wire feed speed control to the recommended value.

4. When welding commences adjust the wire feed speed control to give correct current, i.e. correct heat input.

5. Adjust voltage to correct value as indicated the correct weld profile:

   Narrow weld, high excess metal - raise voltage.
   Wide, flat weld - lower voltage.

   (Warning: on some power sources the current must be switched off before adjusting voltage).

Costs and Trends

As an industrial process, the cost of welding plays a crucial role in manufacturing decisions. Many different variables affect the total cost, including equipment cost, labour cost, material cost and energy cost. Depending on the process, equipment cost can vary from inexpensive for methods like shielded metal arc welding and oxyfuel welding, to extremely expensive for methods like laser beam welding and electron beam welding. Because of their high cost, they are only used in high production operations. Similarly, because automation and robots increase equipment costs they are only implemented when high production is necessary. Labour cost depends on the deposition rate (the rate of welding), the hourly wage and the total operation time, including both time welding and handling the part. The cost of materials includes the cost of the base and filler material and the cost of shielding gases. Finally, energy cost depends on arc time and welding power demand.

For manual welding methods, labour costs generally make up the vast majority of the total cost. As a result, many cost-saving measures are focused on minimising the operation time. To do this welding procedures with high deposition rates can be selected, and weld parameters can be fine-tuned to increase welding speed. Mechanisation and automatisation are often implemented to reduce labour costs, but this frequently increases the cost of equipment and creates additional setup time. Material costs tend to increase when special properties are necessary and energy costs normally do not amount to more than several percent of the total welding cost.

In recent years, in order to minimise labour costs in high production manufacturing industrial welding has become increasingly more automated, most notably with the use of robots in resistance spot welding (especially in the automotive industry) and in arc welding. In robot welding, mechanised devices both hold the material and perform the weld, and at first, spot welding was its most common application. But robotic arc welding has been increasing in popularity as technology has advanced. Other key areas of research and development include the welding of dissimilar materials (such as steel and aluminium, for example) and new welding processes, such as friction stir, magnetic pulse, conductive heat seam and laser-hybrid welding. Furthermore, progress is desired in making more specialised methods like laser beam welding practical for more applications, such as in the aerospace and automotive industries. Researchers also hope to better understand the often unpredictable properties of welds, especially microstructure, residual stresses and a weld’s tendency to crack or deform.

Quality

Most often, the major metric used for judging the quality of a weld is its strength and the strength of the material around it. Many distinct factors influence this, including the welding method, the amount and concentration of heat input, the base material, the filler material, the flux material, the design of the joint and the interactions between all these factors. To test the quality of a weld, either destructive or non-destructive testing methods are commonly used to verify that welds are defect-free, have acceptable levels of residual stresses and distortion and have acceptable heat-affected zone (HAZ) properties. Welding codes and specifications exist to guide welders in proper welding technique and in how to judge the quality of welds.

Adaptable Addition for MIG Welding

Self-Shielded Flux Cored Wire

Self-shielded flux cored wires are used without an additional gas shield and can be usefully employed in outdoor or other on site draughty situations where a cylinder-supplied gas shield would be difficult to establish.

The core of these wires contains powdered metal together with gas-forming compounds and deoxidisers and cleaners. The gas shield formed protects the molten metal through the arc and slag-forming compounds form a slag over the metal during cooling, protecting it during solidification. To help prevent absorption of nitrogen from the atmosphere by the weld pool, additions of elements are made to the flux and electrode wire to effectively reduce the soluble nitrogen.

This process can be used semi- or fully automatically and is particularly useful for on-site work.

Synergetic Welding

Sets are now also available with programmable power sources. Using known quantities such as amperes, seconds, metres per minute feed, the welding program is divided into a chosen number of sections and the welding parameters as indicated previously are used to program the computer which controls the welding source. The program can be stored in the computer memory of up to say 50 numbered welding programs or it can be stored on a separate magnetic data card for external storage or use on another unit. By pressing the correct numbers on the keyboard of the unit any programs can be selected and the chosen program begins, controlling welding current, shielding and backing gas, gas pre-flow, wire feed speed, arc length, pulsed welding current and slope control, etc. All safety controls are fitted and changes in the welding program can be made without affecting other data.

MIG Welding of Aluminium

While most welding equipment is supplied primarily for the welding of ferrous metals, some can also be used for the welding of aluminium. Equipment with low amperages is really not suitable, although it can be used for short periods of welding. The larger-amperage machines (180 A and over) are better equipped to handle aluminium. The wire sizes used are 1.0 mm and 1.2 mm for the larger machines for welding thicker aluminium. The torch contact tip must be of the correct size for the wire to be used. When welding with aluminium wire a Teflon liner must be used in order to prevent the aluminium from sticking and damage occurring to the wire itself. Also, pure argon must be used as the shielding gas owing to its total inert characteristics, and not argon mixes or carbon dioxide.

Gases for MIG/MAG Welding

Carbon, carbon-manganese and high strength low alloy steels

CO_2 is used to weld these steels. The choice depends on the composition of the steel and the operating requirements.

General guidelines:

- Penetration increases with the addition of helium. Penetration also increases with higher carbon dioxide contents.
- Carbon dioxide can be useful for fillet welds in thickplate.
- Spatter increases with increase in carbon dioxide content.
- Steel which contains chromium needs special consideration.
  There is a danger that carbon dioxide in the gas will react with the chromium to form a carbide.
  This renders the chromium in the steel less effective.
  The amount of carbon dioxide which can be tolerated depends on the chromium content.

Sheet thickness mm	swg	in	Joint gap mm	Electrode dia mm	Current A	Voltage V	Gas [1]
Carbon steel							
0.9	20	1/32	0.8	0.8	55 - 65	16 - 17	Ferromaxx™ Plus
1.2	18	3/64	0.8	0.8	80 - 100	17 - 19	Ferromaxx™ Plus
1.6	16	1/16	0.8	0.8	90 - 110	17 - 19	Ferromaxx™ Plus
2.0	14	5/64	0.8	0.8	110 - 130	18 - 20	Ferromaxx™ Plus
3.2	10	1/8	0.8	1.0	180 - 200	20 - 23	Ferromaxx™ Plus
4.0	8	5/32	1.2	1.0	180 - 200	20 - 23	Ferromaxx™ Plus
6.0[2]	4	1/4	1.6	1.0	180 - 200	20 - 23	Ferromaxx™ Plus
Stainless steel							
1.6	16	1/16	1.0	0.8	70 - 90	19 - 20	Inomaxx™ Plus
2.0	14	5/64	1.0	1.0	75 - 95	19 - 20	Inomaxx™ Plus
3.2	10	1/8	1.0	1.0	90 - 130	18 - 21	Inomaxx™ Plus
6.0[2]	4	1/4	1.6	1.2	180 - 240	22 - 26	Inomaxx™ Plus
Aluminium and alloys							
1.6[3]	16	1/18	1.0	1.0	70 - 100	17 - 18	Alumaxx™ Plus
2.0[3]	14	5/64	1.0	1.0	70 - 100	17 - 18	Alumaxx™ Plus
3.2	10	1/8	1.0	1.2	100 - 130	19 - 20	Alumaxx™ Plus
6.0[2]	4	1/4	1.6	1.2	150 - 200	26 - 29	Alumaxx™ Plus

Table 5 - Typical Conditions for MIG/MAG Welding Sheet

Stainless steel	
Inomaxx™ Plus	Recommended for all material thickness on dip, spray and pulse transfer. Stable arc conditions offer all-positional capability. Solid and metal cored wires. Excellent weld bead profiles and appearance with very little oxidation. Suitable for manual automated and robotic welding.
Inomaxx™ 2	Recomended for materials up to 10mm thick on dip, spray and pulse transfer. Offers all-positional capability with solid wires.
argon + 1% to 3% oxygen	Suitable only for spray transfer.
Aluminium and alloys	
Alumaxx™ Plus	Recommended for all material thickness on spray and pulse transfer. Higher arc temperatures promotes better penetration and increased welding speeds. Produces less porosity Suitable for manual, automated and robotic welding.
argon + 75% helium	Suitable for very thick sections.
argon	Stable and controllable arc. Suitable for pure alluminium and all alloys

Table 6 - Gases for MIG/MAG Welding

Gas Shielded Metal Arc Welding

Metal Inert Gas (MIG), Metal Active Gas (MAG) including CO_2 and Mixed Gas Processes

The MIG semi-automatic and automatic processes are increasing in use and are displacing some of the more traditional oxy-acetylene and MMA uses.

For repair work on thin sheet as in the motor trade, semi-automatic MIG using argon-$C0_2$ mixtures has displaced the traditional oxy-acetylene methods because of the reduced heat input and narrower HAZ, thus reducing distortion. For larger fabrication work, mechanical handling equipment with automatic MIG welding leads has revolutionised the fabrication industry, while the advent or robots, which are program controlled and use a fully automated MIG welding head with self-contained wire feed, make less demands on the skilled welder.

Argon could not be used alone as a shielding gas for mild, low-alloy and stainless steel because of arc instability but now sophisticated gas mixtures of argon, helium, CO_2 and oxygen have greatly increased the use of the process.

The process has very many applications and should be studied by the student as one of the major processes of the future.

It is convenient to consider, under this heading, those applications which involve shielding the arc with argon, helium and carbon dioxide ($C0_2$) and mixtures of argon with oxygen and/or CO_2 and helium, since the power source and equipment are essentially similar except for the gas supply. These processes fall within the heading MIG/MAG.

The process is suitable for welding aluminium, magnesium alloys, plain and low-alloy steels, stainless and heat-resistant steels, copper and bronze, the variation being filler wire and type of gas shielding the arc.

The consumable electrode of bare wire is carried on a spool and is fed to a manually operated or fully automatic gun through an outer flexible cable by motor-driven rollers of an adjustable speed, and rate of burn-off of the electrode wire must be balanced by the rate of wire feed. Wire feed rate determines the current used.

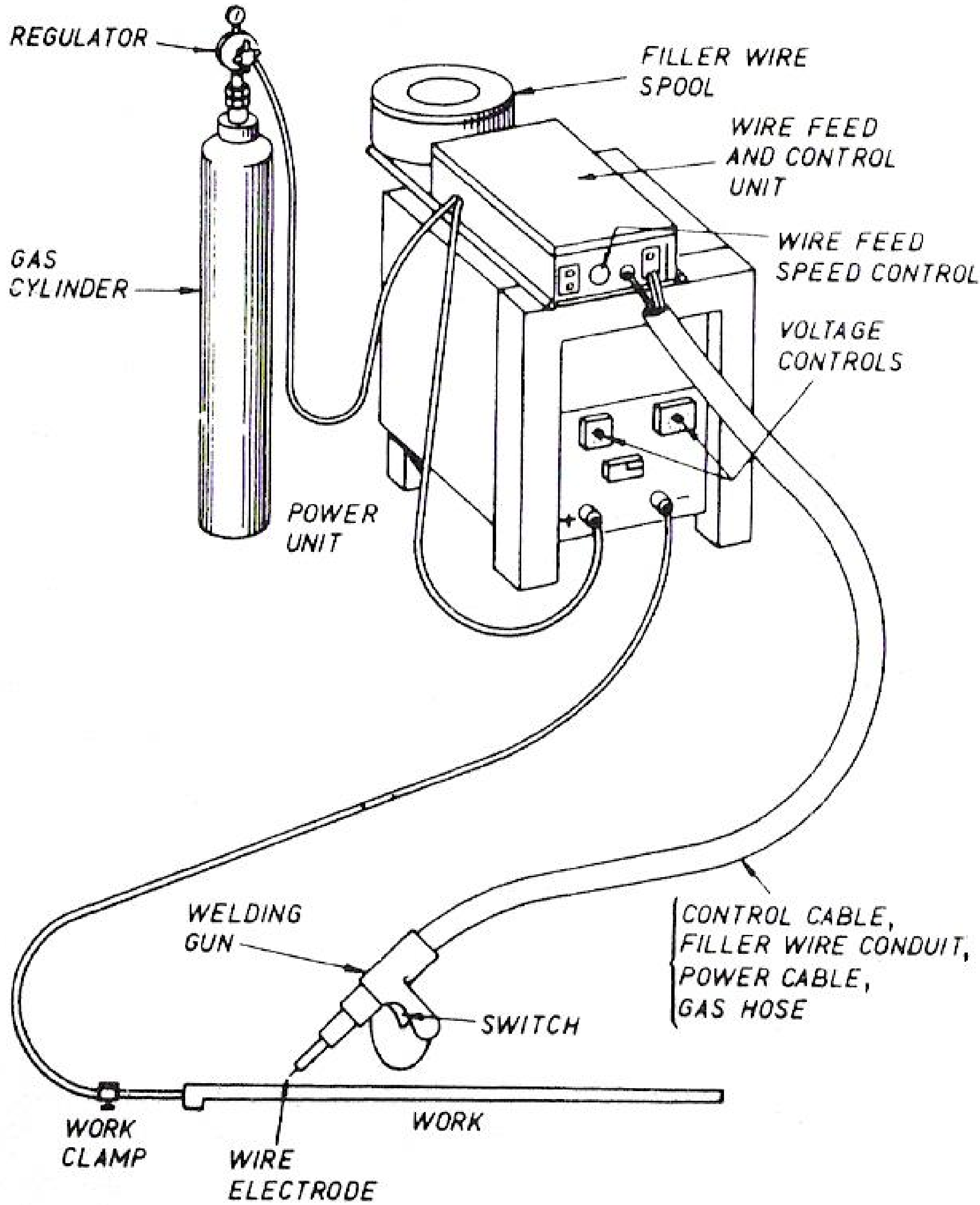


Figure 16 - Components of Gas Shielded Metal Arc Welding Process

MIG/MAG Welding

Control of the angle between the gun and the surface of the sheet is critical in MIG/MAG welding.

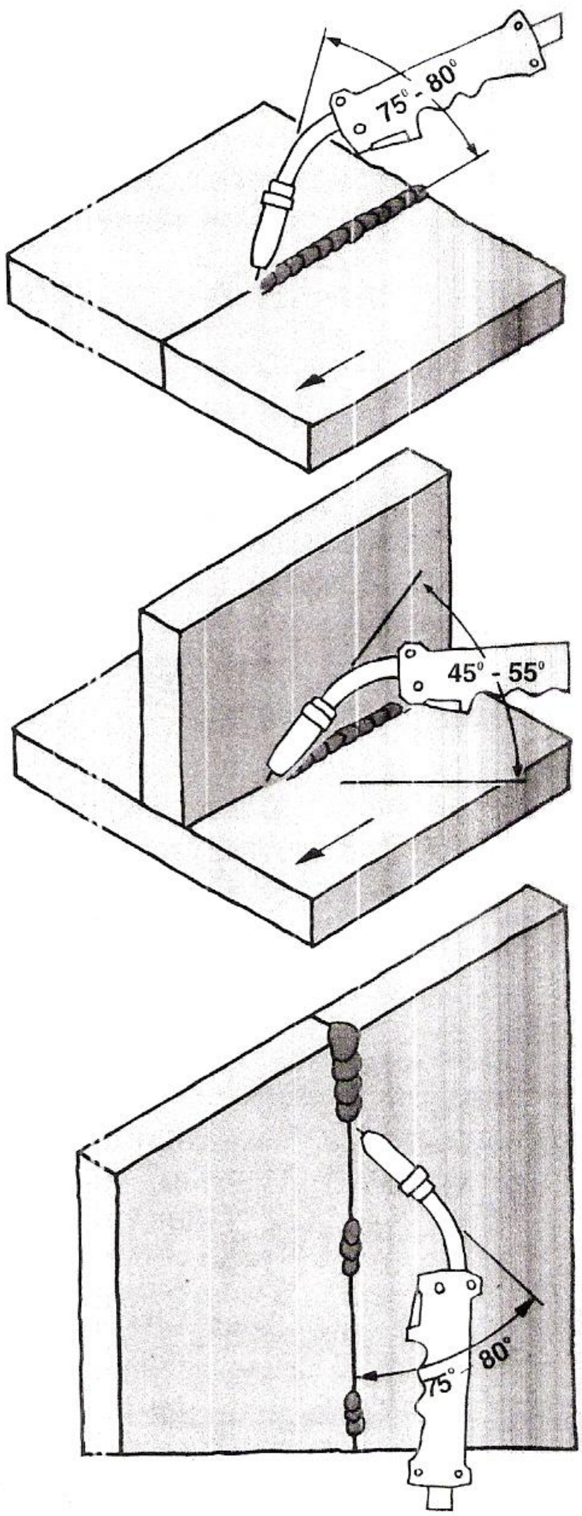


Figure 17 - MIG/MAG Welding

Pipe and Tube Joints

There are three main types of welded joint used in pipework.

- butt
- branch
- flange

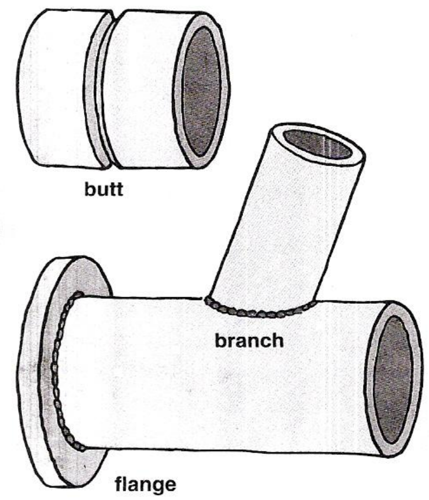
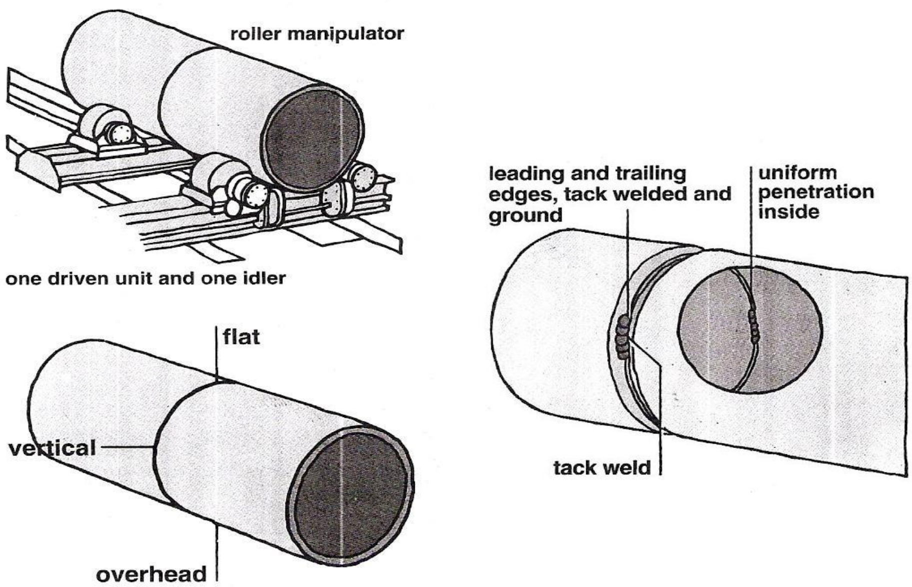


Figure 18 - Pipe and Tube Joints

If possible, during welding the pipe should be rotated so that the weld is made in the horizontal position - use spray, dip or pulse transfer for MIG/ MAG. If the weld must be made in a fixed position and changes from flat to vertical to overhead as the weld progresses round the joint - use dip or pulse transfer for MIG/MAG.



Before welding, the pipes can be clamped or tack welded to maintain alignment.

Spot Welding

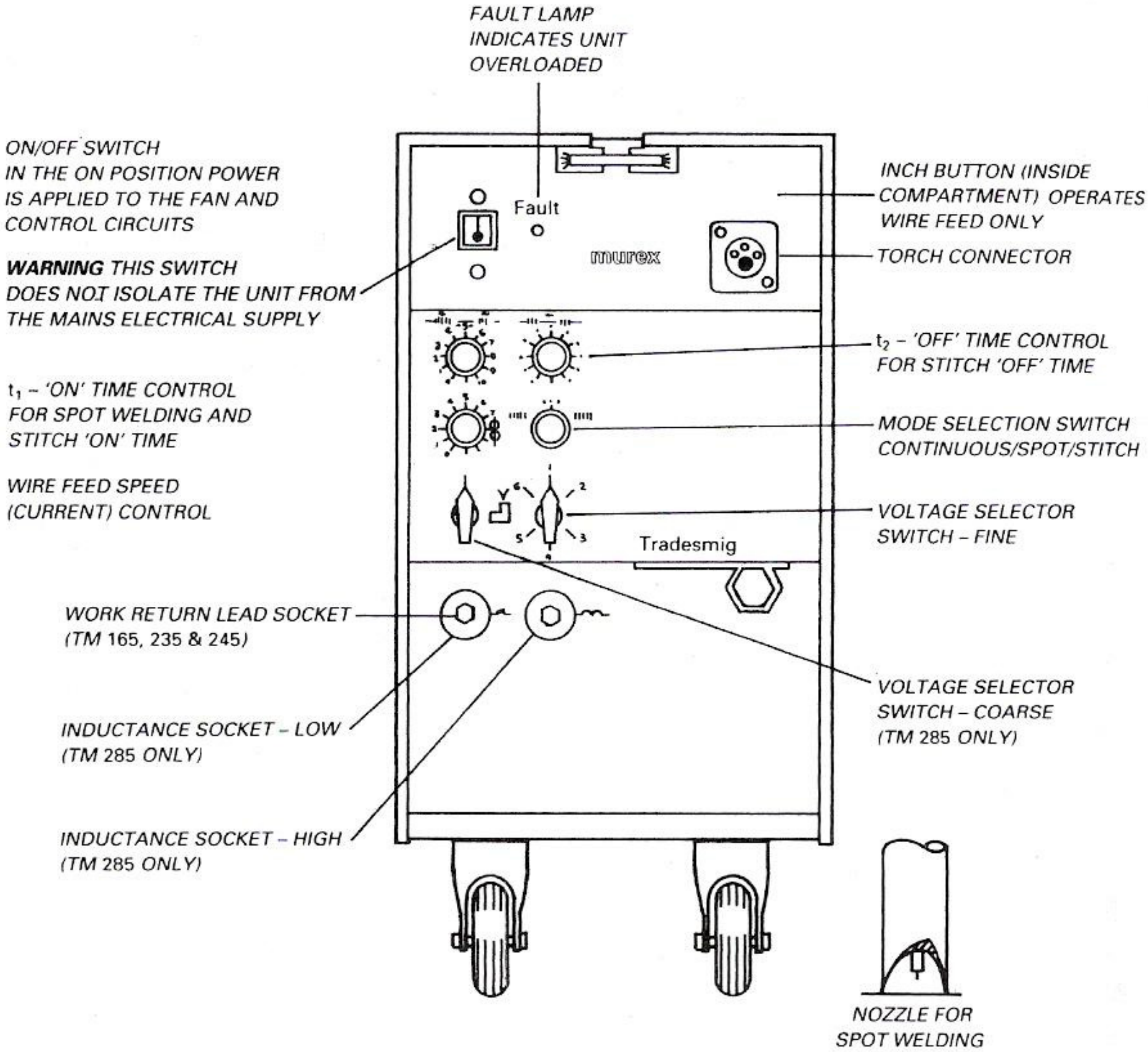


Figure 19 - Spot Welding

For spot welding the nozzle is changed for one that has a cut-away end, so that the contact tip is distanced from the work. Upon pressing the torch switch the wire moves down to the work to make the spot weld. The size of spot weld depends upon the thickness of plate being spot welded and is determined by the time setting on switch 1.

Self Assessment

Questions on Background Notes – Module 2.Unit 10

1. What does the abbreviation MIG / MAG Welding stand for?

2. Briefly explain Pulse and Dip Transfer in relation to MIG / MAG Welding.

3. Name two Gases suitable for MIG Welding.

4. List three Safety Precautions when MIG Welding.

5. In a couple of lines briefly explain the MIG Welding of Aluminium.

Answers to Questions 1-5. Module 2.Unit 10

1.

MIG / MAG Welding:

1. Metal Inert Gas Shielded Welding.
2. Metal Arc Gas Shield Welding.

2.

Pulse Transfer:

Direct the electrode wire at the gap between the sheets to form a pear-shaped melted area (keyhole).

Adjust the rate of upward travel so as to maintain the ‘keyhole’ ahead of the weld pool with a weld run built up above the sheet surface behind the weld pool.

Dip Transfer:
Establish the arc at the top end of the joint.

The electrode wire should be pointed upwards at an angle of 65° - 75°.

Direct the electrode wire at the gap between the sheets and adjust the rate of downwards travel to ensure even deposition and control of penetration.

3.

Suitable Gases for MIG Welding:	
Inert Gas:	Argon of welding grade purity is used as the shielding gas when welding non-ferrous metals.
Argon-Oxygen Mixtures:	The addition of small quantities of Oxygen to Argon make it more suitable for use when welding steels.
Argon-Carbon Dioxide Mixtures:	Dip and spray transfer welding techniques are possible with a mixed shielding gas of 80% argon and 20% carbon dioxide. The spray transfer can be further improved by the inclusion of up to 2% of oxygen.
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.
Carbon Dioxide:	Carbon dioxide is used as a shielding gas for mild steel welding, and is cheaper than argon-rich gases. It is more suitable for dip transfer at low currents but can be used at high currents for a form of 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 siphon-type which only allows liquid carbon dioxide.

4.

Safety Precautions:

- Use effective protective equipment and necessary protective clothing.
- Have full control of the torch/gun and hold it steady. Concentrate on the welding operation.
- Support the flexible hose assembly so that drag on the torch/gun is reduced.
- Hold the torch/gun with sufficient grip at the point of balance to give control, otherwise it will cause muscle fatigue.
- Warn any bystanders when about to strike the arc.
- Ensure that any portable screens required are in position.
- Keep the welding screen in front of the eyes until the arc is broken.
- Follow closing down procedure at the end of the work period or when there is a long interruption.

5.

MIG Welding of Aluminium:

While most welding equipment is supplied primarily for welding of ferrous metals, some can also be used for the welding of aluminium. Equipment with low amperages is not really suitable , although it can be used for short periods of welding. The larger amperage machines (180 A and over) are better equipped to handle aluminium. The wire sizes used are 1.0mm and 1.2mm for the larger machines for welding thicker aluminium. The torch contact tip must be of the correct size for the wire to be used. When welding with aluminium wire a Teflon liner must be used in order to prevent the aluminium sticking and damage occurring to the wire itself. Also, pure argon must be used as the shielding gas owing to its total inert characteristics, and not argon mixes or carbon dioxide.

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