

# MIG Welding

## Introduction

### Gas Metal Arc Welding (GMAW)

GMA – commonly referred to as Metal Inert Gas (MIG) – welding embraces a group of arc welding processes in which a continuous electrode (the wire) is fed by powered feed rolls (wire feeder) into the weld pool. An electric arc is created between the tip of the wire and the weld pool. The wire is progressively melted at the same speed at which it is being fed and forms part of the weld pool. Both the arc and the weld pool are protected from atmospheric contamination by a shield of inert (non-reactive) gas, which is delivered through a nozzle that is concentric with the welding wire guide tube.

### Operation

MIG welding is usually carried out with a handheld gun as a semiautomatic process. The MIG process can be suited to a variety of job requirements by choosing the correct shielding gas, electrode (wire) size and welding parameters. Welding parameters include the voltage, travel speed, arc (stick-out) length and wire feed rate. The arc voltage and wire feed rate will determine the filler metal transfer method.

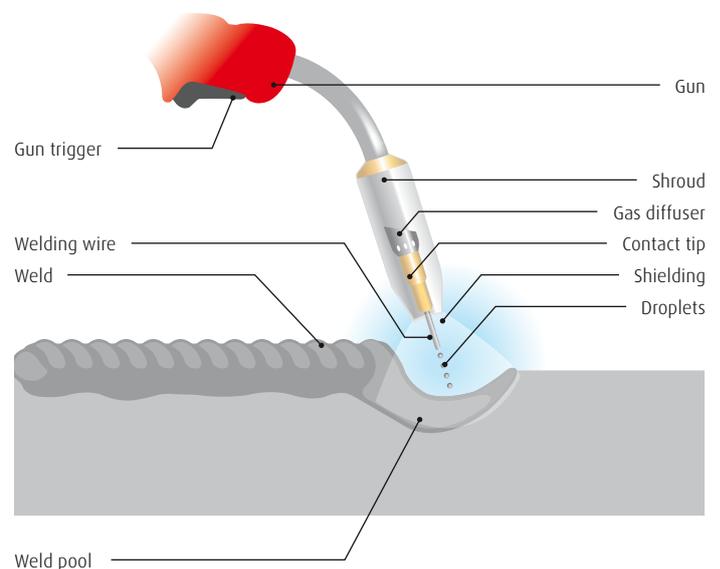
This application combines the advantages of continuity, speed, comparative freedom from distortion and the reliability of automatic welding with the versatility and control of manual welding. The process is also suitable for mechanised set-ups, and its use in this respect is increasing.

MIG welding can be carried out using solid wire or flux cored wire.

- Argon
- Carbon dioxide
- Argon and carbon dioxide mixtures
- Argon mixtures with oxygen or helium mixtures

BOC recommends BOC shielding gas mixtures (see page 29).

Each gas or gas mixture has specific advantages and limitations. Other forms of MIG welding include using a flux cored continuous wire and carbon dioxide shielding gas, or using self-shielding flux cored wire, requiring no shielding.



### Flux Cored Arc Welding (FCAW)

#### How it Works

Flux Cored Arc Welding (FCAW) uses the heat generated by a DC electric arc to fuse the metal in the joint area, the arc being struck between a continuously fed consumable filler wire and the workpiece, melting both the filler wire and the workpiece in the immediate vicinity. The entire arc area is covered by a shielding gas that protects the molten weld pool from the atmosphere.

FCAW is a variant of the MIG process and, while there are many common features between the two processes, there are also several fundamental differences.

As with MIG, direct current power sources with constant voltage output characteristics are normally employed to supply the welding current. With flux cored wires, the terminal that the filler wire is connected to depends on the specific product being used (some wires run electrode positive and others run electrode negative). The work return is then connected to the opposite terminal. It has also been found that the output characteristics of the power source can have an effect on the quality of the welds produced.

The wire feed unit takes the filler wire from a spool, and feeds it through the welding gun, to the arc at a predetermined and accurately controlled speed. Normally, special knurled feed rolls are used with flux cored wires to assist feeding and to prevent crushing the consumable.

Unlike MIG, which uses a solid consumable filler wire, the consumable used in FCAW is of tubular construction, an outer metal sheath being filled with fluxing agents plus metal powder.

The flux fill is also used to provide alloying, arc stability, slag cover, de-oxidation and, with some wires, gas shielding.

In terms of gas shielding, there are two different ways in which this may be achieved with the FCAW process:

- Additional gas-shielding supplied from an external source, such as a gas cylinder
- Production of a shielding gas by decomposition of fluxing agents within the wire (self-shielding)

Gas shielded wires are available with either a basic or rutile flux fill, while self-shielded wires have a broadly basic-type flux fill. The flux fill dictates the way the wire performs, the properties obtainable, and suitable applications.

#### Gas-Shielded Operation

Many cored wire consumables require an auxiliary gas shield in the same way that solid wire MIG consumables do. These types of wire are generally referred to as 'gas-shielded'.

Using an auxiliary gas shield enables the wire designer to concentrate on the performance characteristics, process tolerance, positional capabilities and mechanical properties of the products.

In a flux cored wire, the metal sheath is generally thinner than that of a self-shielded wire. The area of this metal sheath surrounding the flux cored wire is much smaller than that of a solid MIG wire. This means that the electrical resistance within the flux cored wire is higher than with solid MIG wires and it is this higher electrical resistance that gives this type of wire some of its novel operating properties.

One often quoted property of fluxed cored wires are their higher deposition rates than solid MIG wires. What is often not explained is how they deliver these higher values and whether these can be utilised. For example, if a solid MIG wire is used at 250 amps, then exchanged for a flux cored wire of the same diameter, and welding power source controls are left unchanged, then the current reading would be much less than 250 amps, and perhaps as low as 220 amps. This is because of Ohms Law, which states that as the electrical resistance increases (and if the voltage remains stable) then the current must fall.

To bring the welding current back to 250 amps, it is necessary to increase the wire feed speed, effectively increasing the amount of wire being pushed into the weld pool to make the weld. It is this effect that produces the 'higher deposition rates' that the flux cored wire manufacturers claim for this type of product. Unfortunately, in many instances, the welder has difficulty in utilising this higher wire feed speed and must either increase the welding speed or increase the size of the weld. Often in manual applications, neither of these changes can be implemented and the welder simply reduces the wire feed speed back to where it was and the advantages are lost. However, if the process is automated in some way, then the process can show improvements in productivity.

It is also common to use longer contact tip to workplace distances with flux cored arc welding than with solid wire MIG welding, which has the effect of increasing the resistive heating on the wire further accentuating the drop in welding current. Research has also shown that increasing this distance can lead to an increase in the ingress of nitrogen and hydrogen into the weld pool, which can affect the quality of the weld.

Flux cored arc welding has a lower efficiency than solid wire MIG welding, because part of the wire fill contains slag forming agents. Although the efficiency varies by wire type and manufacturer, it is typically between 75 and 85%.

Flux cored arc welding does, however, have the same drawback as solid wire MIG in terms of gas disruption by wind, and screening is always necessary for site work. It also incurs the extra cost of shielding gas, but this is often outweighed by gains in productivity.

#### Self-Shielded Operation

There are also self-shielded consumables designed to operate without an additional gas shield. In this type of product, arc shielding is provided by gases generated by decomposition of some constituents within the flux fill. These types of wire are referred to as 'self-shielded'.

If no external gas shield is required, then the flux fill must provide sufficient gas to protect the molten pool and to provide de-oxidisers and nitride formers to cope with atmospheric contamination. This leaves less scope to address performance, arc stabilisation and process tolerance, so these tend to suffer when compared with gas shielded types.

Wire efficiencies are also lower, at about 65%, in this mode of operation than with gas-shielded wires. However, the wires do have a distinct advantage when it comes to site work in terms of wind tolerance, as there is no external gas shield to be disrupted.

When using self-shielded wires, external gas supply is not required and, therefore, the gas shroud is not necessary. However, an extension nozzle is often used to support and direct the long electrode extensions that are needed to obtain high deposition rates.

## Metal Cored Arc Welding (MCAW)

### How it Works

Metal Cored Arc Welding (MCAW) uses the heat generated by a DC electric arc to fuse metal in the joint area, the arc being struck between a continuously fed consumable filler wire and the workpiece, melting both the filler wire and the workpiece in the immediate vicinity. The entire arc area is covered by a shielding gas, which protects the molten weld pool from the atmosphere.

As MCAW is a variant of the MIG welding process, there are many common features between the two processes, but there are also several fundamental differences.

As with MIG, direct current power sources with constant voltage output characteristics are normally employed to supply the welding current. With metal cored wires, the terminal that the filler wire is connected to depends on the specific product being used. (Some wires are designed to run on electrode positive, while others run on electrode negative, and some run on either.) The work return lead is then connected to the opposite terminal. Electrode negative operation will usually give better positional welding characteristics.

The output characteristics of the power source can have an effect on the quality of the welds produced.

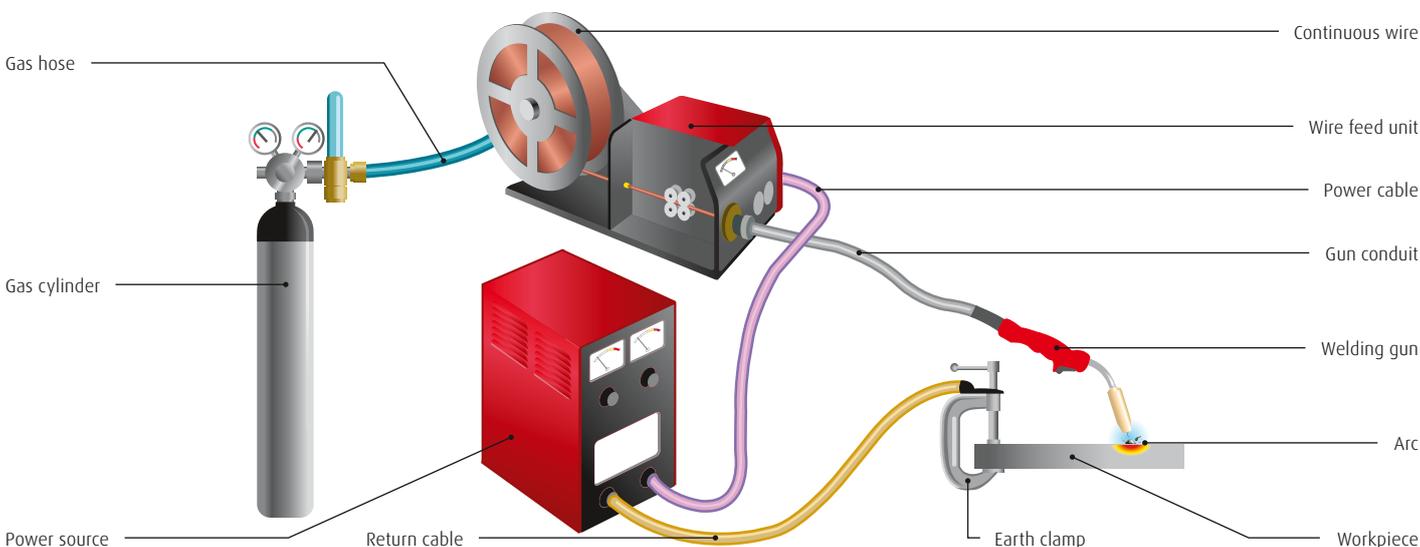
The wire feed unit takes the filler wire from a spool or bulk pack, and feeds it through the welding gun to the arc at a predetermined and accurately controlled speed. Normally, special knurled feed rolls are used with metal cored wires to assist feeding and to prevent crushing the consumable.

Unlike MIG, which uses a solid consumable filler wire, the consumable used in MCAW is of tubular construction, an outer metal sheath being filled entirely with metal powder, except for a small amount of non-metallic compounds. These are added to provide some arc stability and de-oxidation.

MCAW consumables always require an auxiliary gas shield in the same way that solid MIG wires do. Wires are normally designed to operate in argon-carbon dioxide or argon-carbon dioxide-oxygen mixtures or carbon dioxide. Argon-rich mixtures tend to produce lower fume levels than carbon dioxide.

As with MIG, the consumable filler wire and the shielding gas are directed into the arc area by the welding gun. In the head of the gun, the welding current is transferred to the wire by means of a copper alloy contact tip, and a gas diffuser distributes the shielding gas evenly around a shroud which then allows the gas to flow over the weld area. The position of the contact tip relative to the gas shroud may be adjusted to limit the minimum electrode extension.

Modes of metal transfer with MCAW are very similar to those obtained in MIG welding, the process being operable in both 'dip transfer' and 'spray transfer' modes. Metal cored wires may also be used in pulse transfer mode at low mean currents, but this has not been widely exploited.



Circuit diagram of MIG process

## Modes of Metal Transfer

The mode or type of metal transfer in MIG welding depends upon the current, arc voltage, electrode diameter and type of shielding gas used. In general, there are four modes of metal transfer.

Modes of metal transfer with FCAW are similar to those obtained in MIG welding, but here the mode of transfer is heavily dependent on the composition of the flux fill, as well as on current and voltage.

The most common modes of transfer in FCAW are:

- Dip transfer
- Globular transfer
- Spray transfer
- Pulsed arc transfer operation has been applied to flux cored wires but, as yet, is not widely used because the other transfer modes are giving users what they require in most cases.

Gas shielded wires are available with either a basic or rutile flux fill, while self-shielded wires have a broadly basic-type flux fill. The flux fill dictates the way the wire performs, the properties obtainable, and suitable applications.

### Dip Transfer

Also known as short-circuiting arc or short-arc, this is an allpositional process, using low heat input. The use of relatively low current and arc voltage settings cause the electrode to intermittently short-circuit with the weld pool at a controlled frequency. Metal is transferred by the wire tip actually dipping into the weld pool and the short-circuit current is sufficient to allow the arc to be re-established. This short-circuiting mode of metal transfer effectively extends the range of MIG welding to lower currents so thin sheet material can readily be welded. The low heat input makes this technique well-suited to the positional welding of root runs on thick plate, butt welds for bridging over large gaps and for certain difficult materials where heat input is critical. Each short-circuit causes the current to rise and the metal fuses off the end of the electrode. A high short-circuiting frequency gives low heat input. Dip transfer occurs between  $\pm 70$ –220A, 14–23 arc volts. It is achieved using shielding gases based on carbon dioxide and argon.

Metal cored wires transfer metal in dip mode at low currents, just like solid MIG wires. This transfer mode is used for all positional work with these types of wire.

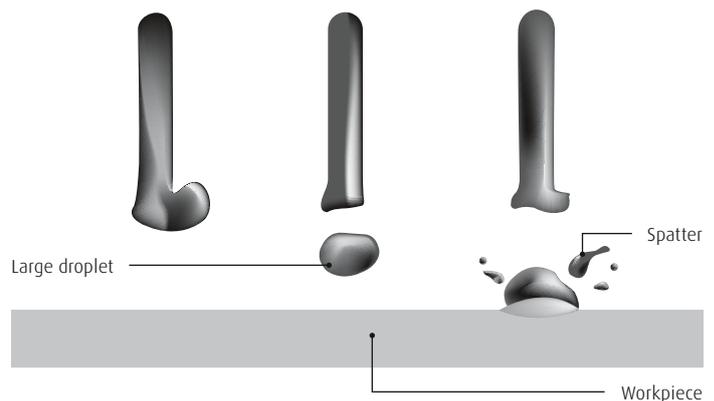
### Globular Transfer

Metal transfer is controlled by slow ejection, resulting in large, irregularly-shaped 'globs' falling into the weld pool under the action of gravity. Carbon dioxide gas drops are dispersed haphazardly. With argon-based gases, the drops are not as large and are transferred in a more axial direction. There is a lot of spatter, especially in carbon dioxide, resulting in greater wire consumption, poor penetration and poor appearance. Globular transfer occurs between the dip and spray ranges. This mode of transfer is not recommended for normal

welding applications and may be corrected when encountered by either decreasing the arc voltage or increasing the amperage. Globular transfer can take place with any electrode diameter.

Basic flux cored wires tend to operate in a globular mode or in a globular-spray transfer mode, where larger than normal spray droplets are propelled across the arc, but they never achieve a true spray transfer mode. This transfer mode is sometimes referred to as non-axial globular transfer.

Self-shielded flux cored wires operate in a predominantly globular transfer mode, although at high currents the wire often 'explodes' across the arc.



Schematic of Globular Transfer

### Spray Transfer

In spray transfer, metal is projected by an electromagnetic force from the wire tip in the form of a continuous stream of discrete droplets approximately the same size as the wire diameter. High deposition rates are possible and weld appearance and reliability are good. Most metals can be welded, but the technique is limited generally to plate thicknesses greater than 6mm. Spray transfer, due to the tendency of the large weld pool to spill over, cannot normally be used for positional welding. The main exception is aluminium and its alloys where, primarily because of its low density and high thermal conductivity, spray transfer in position can be carried out.

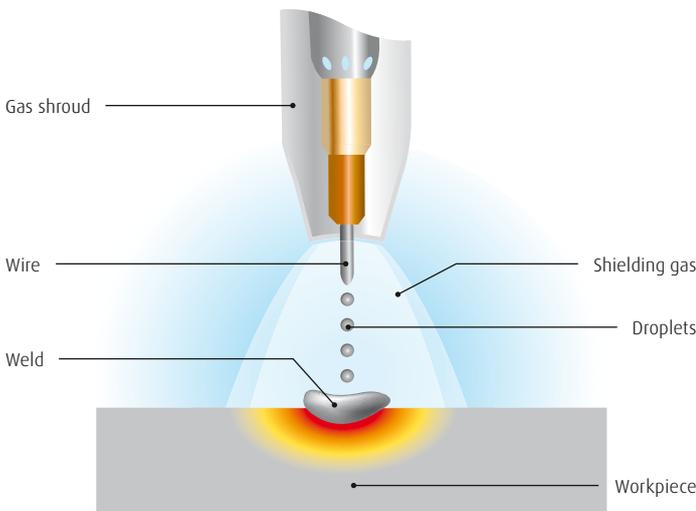
The current flows continuously because the high voltage maintains a long arc and short-circuiting cannot take place. It occurs best with argon-based gases.

In solid wire MIG, as the current is increased, dip transfer passes into spray transfer via a transitional globular transfer mode. With metal cored wires there is virtually a direct transition from dip transfer to spray transfer as the current is increased.

For metal cored wire, spray transfer occurs as the current density increases and an arc is formed at the end of the filler wire, producing a stream of small metal droplets. Often the outside sheath of the wire will melt first and the powder in the centre flows as a stream of smaller droplets into the weld pool. This effect seems to give much better transfer of alloying elements into the weld.

In spray transfer, as the current density increases, an arc is formed at the end of the filler wire, producing a stream of small metal droplets. In solid wire MIG, this transfer mode occurs at higher currents. Flux cored wires do not achieve a completely true spray transfer mode, but a transfer mode that is almost true spray may occur at higher currents and can occur at relatively low currents depending on the composition of the flux.

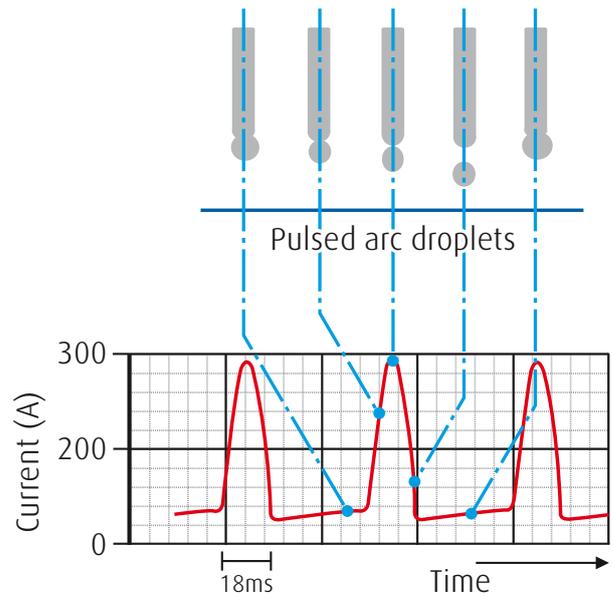
Rutile flux cored wires will operate in this almost-spray transfer mode at all practicable current levels. They are also able to operate in this mode for positional welding. Basic flux cored and selfshielded flux cored wires do not operate in anything approaching true spray transfer mode.



Schematic of Spray Transfer

**Pulsed Transfer**

Pulsed arc welding is a controlled method of spray transfer, using currents lower than those possible with the spray transfer technique, thereby extending the applications of MIG welding into the range of material thickness where dip transfer is not entirely suitable. The pulsed arc equipment effectively combines two power sources into one integrated unit. One side of the power source supplies a background current which keeps the tip of the wire molten. The other side produces pulses of a higher current that detach and accelerate the droplets of metal into the weld pool. The transfer frequency of these droplets is regulated primarily by the relationship between the two currents. Pulsed arc welding occurs between ±50–220A, 23–35 arc volts, and only with argon and argonbased gases. It enables welding to be carried out in all positions.



Schematic for Pulse Transfer

Process	Dip Transfer	Globular Transfer	Spray Transfer	Pulsed Transfer
Metal Inert Gas (MIG)	•		•	•
Flux Cored (Gas Shielded)	•	•	Not True Spray	
Flux Cored (Self Shielded)	•	•		
Metal Cored	•		•	•