Perform Gas Metal Arc Welding

Workbook (AUM8057A)
AUM8057A

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Workbook
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Contents

Introduction ......................................................................................................................... 1
Gas metal arc welding process (GMAW) ........................................................................ 2
Advantages of the GMAW process ............................................................................. 3
Limitations of the GMAW process ............................................................................. 3
Safety in gas metal arc welding .................................................................................. 3
  Darker welding filters ................................................................................................. 3
  Body protection ........................................................................................................ 4
  Ventilation ................................................................................................................ 5
  Protecting others ....................................................................................................... 6
Equipment .................................................................................................................... 6
  Power source .......................................................................................................... 7
  Wire feed unit .......................................................................................................... 7
  Gun cable assembly ............................................................................................... 8
  Gas supply system ................................................................................................. 8
  Interconnecting cables ........................................................................................... 9
  Wire feed systems .................................................................................................. 9
  Drive rollers ........................................................................................................... 10
  Wire conduit (liner) ............................................................................................... 11
  Contact tip ............................................................................................................. 12
Metal transfer models .................................................................................................. 12
  Dip transfer ........................................................................................................... 12
  The dip transfer cycle ............................................................................................ 13
  Spray transfer ........................................................................................................ 14
  Globular transfer ................................................................................................... 15
Comparison between GMAW and MMAW ............................................................... 19
Weld positions ............................................................................................................. 20
Weld symbols .............................................................................................................. 22
  Joint symbols ........................................................................................................ 23
  Length and pitch of fillet welds ............................................................................ 24
Classification of consumables .................................................................................... 30
  Solid wire electrodes ............................................................................................. 30
Shielding gases
................................................................................................................. 32
  Carbon dioxide .................................................................................................. 32
  Argon .................................................................................................................. 32
  Gas mixtures ...................................................................................................... 33
  Flow rates ........................................................................................................... 34

GMAW variables
........................................................................................................ 34
  Wire speed/amperage ........................................................................................ 34
  Arc voltage ......................................................................................................... 35
  Electrical stickout ................................................................................................. 36
  Travel speed ...................................................................................................... 38
  Torch angle ......................................................................................................... 38
  Angle of travel .................................................................................................... 39
  Gas flow rate ...................................................................................................... 40

Other machine controls ...................................................................................... 41
  Spot timer ........................................................................................................... 41
  Burnback control ................................................................................................ 41
  Gas purge switch ............................................................................................... 41
  Inch wire control ................................................................................................. 41
  Spool brake ........................................................................................................ 41

Fillet and butt weld structures ............................................................................. 43
  Joint design for GMAW ..................................................................................... 44

Control of distortion ............................................................................................. 48
  Before welding .................................................................................................. 49
  During welding ................................................................................................... 52
  After welding ...................................................................................................... 53

Where not to weld ................................................................................................. 54

Procedure sheets .................................................................................................. 58

GMAW defects ..................................................................................................... 59
  Porosity .............................................................................................................. 59
  Cold lap/lack of fusion ....................................................................................... 60
  Lack of root penetration .................................................................................... 61
  Excessive penetration ........................................................................................ 61
  Contour defects .................................................................................................. 62
  Undercut ............................................................................................................. 62
Weld cracking ................................................................. 63
Stray arcing ................................................................. 64
Excessive spatter .......................................................... 64
Trouble shooting/equipment malfunction ....................... 64
Tanks and containers .................................................... 68
Practical exercises .......................................................... 70
Introduction

Since its introduction in the 1940s, gas metal arc welding (GMAW) has become a very popular welding process for the vehicle body building industry, as it has several advantages over other welding systems. It is particularly suited to a wide range of light and heavy applications ranging from one-tonne tray bodies and tradesman vans to semi-tippers and road trains. The versatility, ease of operation and relative low distortion rate allow this process to be used on a wide range of materials.
Gas metal arc welding process (GMAW)

Gas metal arc welding (GMAW) is an arc welding process where the necessary heat for fusion is produced by an electric arc maintained between a continuously fed wire electrode and the part to be welded. The heated weld zone, the molten weld metal, and the consumable electrode are shielded from the atmosphere by a shroud of gas which is delivered through the welding torch to the weld pool.
Advantages of the GMAW process

The major advantage of the GMAW process is its high deposition rate compared with the Manual Metal Arc, and Gas Tungsten Arc welding processes. This is brought about by the high ratio of current to wire diameter, and the removal of the need to change electrodes, chip slag etc. These advantages are facilitated by the use of a continuously fed, gas-shielded electrode. The advantages of this process compared to manual metal arc welding (MMAW) are summarised below:

• high deposition rates when compared to manual metal arc welding
• no wastage from electrode stubs
• elimination of slag removal
• less operator skill required
• has a wide range of applications
• low hydrogen deposit
• reduced distortion on thin materials when compared to manual metal arc welding.

Limitations of the GMAW process

Although GMAW is a popular and versatile welding process offering the advantages listed above, it is also limited by the following:

• high initial equipment cost
• high maintenance requirements and low mechanical reliability of the welding equipment
• cannot be used in windy conditions (AS 1554-1 limits the use of gas-shielded processes where the wind velocity exceeds 10 km/hr). This makes the process generally unsuitable for work outside the factory
• lack of fusion defects can be a major problem under some circumstances
• a degree of expertise required for setting weld parameters
• requires a knowledge of equipment trouble shooting.

Safety in gas metal arc welding

Darker welding filters

The primary concern in this regard is arc intensity, which is much greater than that associated with MMAW electrodes. A darker welding filter will be required for the GMAW process when compared with MMAW. A filter one shade darker than that used for welding at the same amperage with the MMAW process will be required.

For example:

• up to 200 amps: a shade 11 is required
• 200–300 amps: a shade 12 is required.
Safety glasses worn at all times are essential, as the higher emission of ultraviolet (UV) radiation may result in increased and more severe arc flashes.

Body protection
This same arc intensity also requires operators to ensure their body is completely covered with protective clothing. Even extraneous light from the arc (UV radiation bouncing from a reflecting wall) can result in a rather uncomfortable ‘ray burn’.
You must wear safety boots, gloves, long sleeves, and a suitable face shield. For more intense work, wearing a leather apron and a cap are also necessary.

Experience has shown that cotton materials have less resistance to ultraviolet rays than woollen materials. Cotton, and particularly synthetics, will quickly break down and eventually disintegrate. It is therefore preferable to wear leather or woollen materials.

**Ventilation**

During arc welding a toxic gas called ozone (O₃) is given off from the arc, with higher current densities producing higher ozone levels. Although ozone is not dangerous under most conditions, it is advisable to use exhaust extraction when working in confined spaces where ventilation is restricted. Natural ventilation and exhaust fans can also be advantageous. Any ventilation system used must not interfere with the gas shielding of the weld zone.
Protecting others

To protect other workers, you must shield your working area with suitable screens to prevent stray arc rays escaping the work area as well as any sparks from welding or grinding.

Equipment

The major equipment items which make up a GMAW plant are:

- the power source
- the wire feeder
- the welding gun cable assembly
- the gas supply system
- the interconnecting cables.

GMAW equipment
Power source

A constant voltage (constant potential) power source is required for GMAW. This is commonly a transformer/rectifier or, increasingly, an inverter. The output requirement is for direct current. All solid wires for GMAW run on direct current electrode positive (DC+). The GMAW process is intolerant to variations in arc voltage, and the constant voltage output provided by the constant voltage (CV) power source ensures that the arc length is self-adjusting and remains constant despite uneven torch movement.

Wire feed unit

The primary function of the wire feed unit is to feed wire to the arc pool. This unit houses a reel of electrode wire and a DC motor to which feed rollers are attached. Feed rollers push the electrode wire to the arc pool. The speed of the drive motor is governed by a potentiometer (the wire feed control) and is influenced by variations in arc voltage. Increasing the wire speed also increases the amperage. Incorporated into the unit are the shielding gas connections, gas solenoid and, in the case of a water-cooled torch, water connections.
Gun cable assembly

- The gun cable assembly consists of a large outer cable which covers and protects several smaller conduits by which electrode wire, current and shielding gas are conveyed to the welding arc pool. It connects to the wire feeder and terminates at the ‘gun’ or ‘handpiece’.
- The electrode wire travels through the wire conduit or ‘liner’ which runs through the centre of the gun cable. The welding current is carried through the cable by a heavy copper lead within the cable.
- Shielding gas is also carried through the cable, and is distributed at the weld pool via the gas diffuser and gas nozzle.
- There are two trigger control wire cables, a positive and a negative, which send back a signal to the power unit when the torch trigger on the handpiece is depressed. This starts the whole welding operation.

Welding is started by depressing the torch trigger. This initiates three separate functions:

1. The welding current contactor solenoid is ‘pulled in’ (closed) and welding current becomes available. Welding current is transferred to the wire as it passes through the contact tip.
2. The gas solenoid valve opens and allows shielding gas to flow.
3. The wire feed motor starts up and feeds wire at the preset, constant speed through the wire conduit.

Because of the heat generated in the weld pool and the heat generated through electrical resistance at the contact tip, torches have to be efficiently cooled. The majority of torches are air-cooled; however, water-cooled torches may be required when high amperages are used on a continuous basis.

Gas supply system

Shielding gases for gas metal arc welding (GMAW) are usually supplied from a single cylinder; however, large consumers may use manifolded systems. The components of the gas supply system are:

- a cylinder of gas containing either carbon dioxide (CO₂), argon (Ar) or an argon/CO₂ mixture which may include oxygen (O₂)
- a regulator to reduce cylinder pressure
• a flowmeter to control shielding gas flow rate
• a heater – when CO₂ is used as a shielding gas, a heater is fitted between the cylinder and the regulator to prevent freezing at the regulator.

Interconnecting cables
These consist of:
• the work return lead
• the electrode lead – from the power source to the gun cable adaptor of the wire feeder
• the control cable from the power source to the wire feeder.

Wire feed systems
There are three basic types of GMAW wire feeding systems, each requiring different torches.

1. The push system
The push system is by far the most popular wire feed system. The wire feed unit pushes the electrode wire along the wire conduit (liner), through the gun and contact tip and to the weld pool. Push systems are generally robust, lightweight and very functional, as well as being the least expensive of the three systems. The system works very well with hard wires such as steel and stainless steel up to 4.5 metres in length. Wire in spools of 15 kg or larger are usually used with this system. This keeps costs down and increases efficiency.

The major disadvantage of the push system is unreliability of wire feeding caused by friction in dirty liners or kinked gun cables. This is a particular problem when feeding soft wires such as aluminium.

2. The pull system
The pull system is ideally suited to feeding soft wires such as aluminium or where welding is to be carried out at a location remote from the power source. The drive motor and drive rollers are built into the handle of the welding torch. This offers a short, direct wire travel, with little friction through the conduit.

The drawbacks of this system are the high initial cost of equipment, the cost of consumable wire on small spools and the weight of wire carried on the gun. Although this system is mainly used for aluminium work, mild steel and stainless steel wires can also be used.
3. The push/pull system

As the name implies, both push and pull motors are employed. One motor is in the welding torch handle and pulls the wire through the torch. The other motor is in the wire feeder and pushes the wire through the wire conduit. The motors are synchronised to feed the wire at the same speed. This enables the feeding of both hard and soft wires up to 10 metres from the welding machine and still offers the economy of 15 kg (or larger) spools of wire. The push/pull system is a versatile system; it is particularly suited to aluminium, but may also be used for hard wires as well.

Drive rollers

Friction created by the pressure applied to the electrode wire as it passes through the rotating drive rollers enables the electrode to be pushed along the wire conduit. Resistance in the gun cable may cause the wire to slip as it passes through the drive rollers. Increasing the pressure of the top roller increases friction and prevents this slippage. However, excessive pressure can deform the wire, making it more difficult to feed.

Deformation caused by excessive roll pressure

Wire feeders use either a two or four roll drive system. Two roll systems are cheaper to buy and are best suited to feeding hard wires such as carbon steels and stainless steels through short gun cables.

Four roll feeders create greater friction between the rollers and the wire with less roller pressure, resulting in a smoother wire feed with less slippage and less distortion of the wire.
The four roll system offers advantages for:
- feeding soft wires such as aluminium
- feeding wires through long gun cables
- use with cored wires.

Cross-sectional shapes of the rollers vary according to the manufacturer and the type of wire being used.

Common configurations/sections of drive rolls and their uses:

<table>
<thead>
<tr>
<th>Diagram</th>
<th>Description</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Flat top roller with a 'V' bottom roller." /></td>
<td>Flat top roller with a ‘V’ bottom roller.</td>
<td>Used for general purpose feeding of hard wires such as steel and stainless steel</td>
</tr>
<tr>
<td><img src="image2" alt="Flat top roller with a ‘U’ bottom roller." /></td>
<td>Flat top roller with a ‘U’ bottom roller.</td>
<td>Used mainly for aluminium wires. The ‘U’ profile reduces deformation of the soft wire</td>
</tr>
<tr>
<td><img src="image3" alt="Serrated ‘V’ top roller with a serrated ‘V’ bottom roller." /></td>
<td>Serrated ‘V’ top roller with a serrated ‘V’ bottom roller.</td>
<td>Used for cored wires and large diameter solid wires</td>
</tr>
</tbody>
</table>

**Note:** This list is not exhaustive, but these are the most commonly used.

**Wire conduit (liner)**

The liner is used to guide the wire through the gun cable to the handpiece, and through to the contact tip. When welding with carbon and stainless steels the liner is made of spiral wound wire. Teflon® is used when feeding aluminium wire. To ensure reliable wire feeding, it is imperative that the liner is cut to the correct length and properly fitted in the gun cable. It is also important that the gun cable is kept as straight as possible when welding.
Contact tip

The contact tip serves two functions:

- to guide the wire to the arc
- to transfer welding current to the wire.

The contact tip is a most important component of the welding torch. It is here that the filler-wire is energised or 'picks-up' the welding current. It is usually made from copper and is directly attached to the power lead via the gas diffuser and torch body. Contact tips are matched to each wire size. It is important that the contact tip is maintained in a clean condition free from spatter on the end, and with a smooth internal bore. Worn contact tips reduce the efficiency with which the welding current is transferred to the electrode wire and contribute to uneven wire feeding. They should be replaced when worn.

Metal transfer modes

With most of the commonly used welding processes the operator has little control over the way metal is transferred across the arc. With GMAW the operator can select and control the type of metal transfer. This is done primarily by selection of arc voltage, although wire diameter and shielding gas also influence metal transfer.

The metal transfer mode determines the characteristics of the GMAW process. The operator must select the most appropriate mode of transfer and set the machine accordingly before starting the weld.

Apart from the pulsed transfer mode, which requires sophisticated power sources, the welding operator can select from three transfer modes:

- dip (or short arc) transfer
- globular transfer
- spray transfer.

Dip transfer

Dip transfer is also known as 'short arc' transfer (short for 'short circuiting arc'). In the dip transfer mode, low current and low voltage settings are used. The low voltage employed cannot maintain a continuous current flow across the gap between the electrode wire and the work piece. As the electrode nears the work piece the electrical resistance across the arc gap is overcome and an arc is established.

During welding, the tip of the electrode wire contacts the work piece and a short circuit occurs. This results in a rapid temperature rise in the wire (caused by the short circuit current flowing through to the work piece) and the end of the electrode wire is melted off. An arc is immediately formed between the tip of the wire and the weld pool. This arc maintains the electrical circuit for a short time until the electrical resistance across the increasing arc gap causes the arc to be extinguished.

The electrode wire continues to feed, and the tip once again dips into the pool and the cycle is repeated. This sequence of events is repeated at a frequency of up to 200 times per second, and produces sufficient heat for fusion and to keep the weld pool fluid.
This method of transfer is suitable for all positional welding due to rapid freezing of the weld pool, and has the advantage that the heat input to the work piece is kept to a minimum. This limits distortion and enables thin sheet material to be welded. However, on thicker material, the low heat input tends to give rise to lack of fusion defects if care is not taken with machine adjustment and welding technique.

**Typical weld conditions:**
- Volts: 13–23
- Amps: 60–200
- Stickout: 6 mm–15 mm

**The dip transfer cycle**
1. Trigger is depressed – wire starts to feed.
2. Wire contacts the work piece and heats up due to electrical resistance and begins to melt.
3. Wire melts off and an arc is established.
4. Arc length increases as the end of the wire melts slightly.
5. Arcing ceases due to the low arc voltage being unable to overcome the electrical resistance across the arc gap.
6. Wire is fed into the weld pool which has been created and the cycle begins again.

**Features of dip transfer:**
- low currents are used
- low heat input
- low penetration
- moderate spatter
- low deposition rate compared with other transfer modes
- relatively cold weld pool
- ideal for thin materials
- can be used for out-of-position welding such as vertical ups and overhead welds
- ‘lack of fusion’ faults are a problem, particularly when plate thickness exceeds 5 mm.
**Spray transfer**

Unlike dip transfer, spray transfer employs an arc which burns continuously. To achieve this, the arc voltage is relatively high and must be above approximately 23 volts when welding steel (depending on wire size and shielding gas composition).

Additionally, the amperage used must be above the ‘threshold current’. The threshold current is the current above which tiny droplets are pinched off and projected axially across the arc gap. Below the threshold current, droplet detachment is brought about by the molten droplet of wire growing in size, until it is heavy enough to be detached by gravitational forces.

**Typical weld conditions:**

Volts  24–40  
Amps  200–Upwards  
Stickout  15 mm–30 mm

**Spray transfer** offers greatly increased deposition rates compared with dip transfer, minimal spatter, and is not accompanied by the lack of fusion faults sometimes associated with dip transfer. Because of the hot, fluid weld pool associated with spray transfer, it is only suitable for use on plates above approximately 5 mm thick, and in the downhand (flat) position.

**Features of spray transfer:**

- high currents are used  
- high heat input  
- moderate/deep penetration  
- high deposition rates  
- low spatter  
- good appearance  
- fluid weld pool  
- unsuitable for out-of-positional welding such as overhead welding  
- requires a shielding gas with high argon content.
Globular transfer

Globular transfer occurs at current levels between those used for dip and spray transfer. Voltages are high enough to ensure a constant arc, but amperage is set below the threshold current that produces spray transfer. The result is that the wire melts in the arc, and a molten globule forms on the end of the wire. As melting continues, the size of the globule grows until its own weight causes detachment of the droplet due to gravitational forces. This droplet detachment is erratic because of the influence of arc forces repelling the droplet away from the wire; high spatter levels result. Droplet size is considerably larger than the wire diameter.

Typical weld conditions:
Volts  20–26
Amps   200–280
Stickout  12 mm–22 mm

Features of globular transfer:
• moderate amperages are used
• low to moderate penetration
• moderate to high spatter levels
• coarse appearance
• metal droplets are detached by gravitational forces
• largely unsuitable for out-of-position welding
• occurs even at high amperages when the shielding gas contains in excess of approximately 23% CO₂.

The tables on the next page show the amperage and voltage ranges for the transfer modes described above.
Volt and current ranges for transfer modes

Working range for the different types of transfer modes.

By carefully selecting the amperage (wire speed) and the voltage, it is possible to set the parameters to weld effectively in the three modes of transfer shown above. However, if the welding parameters are set outside the three circles, your welding conditions will become erratic and uncontrollable.

The GMAW transfer modes

<table>
<thead>
<tr>
<th>Transfer mode</th>
<th>Welding positions</th>
<th>Volts</th>
<th>Amps</th>
<th>Wire diameter</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short arc (dip)</td>
<td>All</td>
<td>13 to 23</td>
<td>60 to 200</td>
<td>0.6 mm to 1.2 mm</td>
<td>Light material. Out-of-position welding</td>
</tr>
<tr>
<td>Globular</td>
<td>Flat or horizontal fillets</td>
<td>20 to 26</td>
<td>200 to 280</td>
<td>0.6 mm to 1.6 mm</td>
<td>Between dip and spray</td>
</tr>
<tr>
<td>Spray</td>
<td>Flat or horizontal fillets</td>
<td>24 to 40</td>
<td>210 to 410</td>
<td>0.8 mm to 1.6 mm</td>
<td>Material over 5 mm thick</td>
</tr>
</tbody>
</table>
Questions
1. What is the primary function of a shielding gas used in the GMAW process?

2. List four advantages offered by the GMAW process over MMAW.

3. State the shade of lens which would be required when welding with a setting of 190 amps.

4. In what type of situation would ozone gas present a problem?

5. List the five major equipment items which make up a GMAW plant.

6. In a GMAW plant, what type of current is used for welding with solid wire?

7. When the torch trigger is depressed, what three separate functions occur?

8. State the difference between the wire electrode push system and the pull system.

9. Where would a four roller system be used in preference to a two roller system?
10. State the two major functions of a contact tip.

_________________________________________________________________
_________________________________________________________________

11. Of the three modes of metal transfer, which has the highest deposition rate?

_________________________________________________________________

12. In what weld positions can short arc (dip) welding be used?

_________________________________________________________________

13. How many amps are required before spray welding can begin?

_________________________________________________________________
## Comparison between GMAW and MMAW

The following table shows a comparison of gas metal arc welding (solid wire) with manual metal arc welding.

<table>
<thead>
<tr>
<th>Item</th>
<th>Gas metal arc welding</th>
<th>Manual metal arc welding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital cost</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td></td>
<td>More complicated plant</td>
<td>Relatively simple plant</td>
</tr>
<tr>
<td>Deposition rates</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td></td>
<td>Higher current densities result in higher deposition rates</td>
<td>Length of run that can be deposited is dependent on the electrode length</td>
</tr>
<tr>
<td></td>
<td>Increased arcing times (longer weld lengths)</td>
<td></td>
</tr>
<tr>
<td>Consumable costs</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td></td>
<td>Electrodes by weight are classed as similar but additional costs of gases must be considered</td>
<td>Lower, although there is a high wastage of consumables as electrode ends are not used</td>
</tr>
<tr>
<td>Operator appeal</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Less cleaning</td>
<td>More portable</td>
</tr>
<tr>
<td></td>
<td>Control of variables</td>
<td>Less maintenance</td>
</tr>
<tr>
<td></td>
<td>Less stopping</td>
<td>Ease of machine control</td>
</tr>
<tr>
<td></td>
<td>Thin material can be welded</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Greater control</td>
<td></td>
</tr>
<tr>
<td>Deposited metal</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>Standard wires considered to be hydrogen-controlled, resulting in higher mechanical properties</td>
<td>Greater selection of electrodes available</td>
</tr>
</tbody>
</table>
Weld positions

Vehicle body builders are required to weld in many different positions. The common weld positions are:

- flat
- vertical
- horizontal
- overhead.

When deciding which mode to set the welding machine, the position of the weld must be considered. In positions between flat and horizontal vertical, all modes can be employed. Below horizontal vertical, spray and globular modes are not recommended.
For the following weld positions the ISO (International Organization for Standardization) have codes rather than the entire word. The codes for these positions run from ‘A’ to ‘G’.

‘P’ stands for position and a letter indicates the area it is situated in.

PF stands for Vertical Up.
PG stands for Vertical Down.

On plate the welds would look like this:

<table>
<thead>
<tr>
<th>Weld</th>
<th>Flat</th>
<th>Horizontal</th>
<th>Vertical</th>
<th>Overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Butt</td>
<td><img src="image1.png" alt="image" /></td>
<td><img src="image2.png" alt="image" /></td>
<td><img src="image3.png" alt="image" /></td>
<td><img src="image4.png" alt="image" /></td>
</tr>
<tr>
<td>1G/PA</td>
<td>2G/PC</td>
<td>3G/PF</td>
<td>4G/PE</td>
<td></td>
</tr>
<tr>
<td>Fillet</td>
<td><img src="image5.png" alt="image" /></td>
<td><img src="image6.png" alt="image" /></td>
<td><img src="image7.png" alt="image" /></td>
<td><img src="image8.png" alt="image" /></td>
</tr>
<tr>
<td>1F/PA</td>
<td>2F/PB</td>
<td>3F/PF</td>
<td>4F/PE</td>
<td></td>
</tr>
</tbody>
</table>
Weld symbols

Welding symbols are found on drawings to inform the vehicle body builder what the designer requires in regard to the following:

- what type of weld is required
- how the parent material must be prepared
- which side of the joint to weld
- how high the weld must be
- how long the weld must be
- how large the spacing in between the welds
- whether the weld is to be done in the factory or out on site.

This information would take too much time to write out and take up too much space on a drawing so ISO symbols are used. The welds themselves are not actually drawn on the drawing; only the symbols are used.

The two most common types of weld used in the vehicle body building industry are the butt weld and the fillet weld.

So that the weld symbols can convey as much information as possible, several elements are included.

Welding symbol elements

These are the welding symbol elements that would be typically shown on a drawing within the vehicle body building industry.
T Other information can be added here. If there is none the tail will be left off.
S Size of the weld: throat thickness in mm.
L Length of the weld: end to end in mm.
P Pitch: distance between welds measured from centre to centre.
O Weld all around: fully weld total joint.
> Tail: Omitted when reference information is not used.
___ Reference line: basis of the symbol.
  Arrow: This indicates where the weld will be and which side of the joint will be welded.

Joint symbols

This is how the weld symbols would be shown on a drawing. Note: if the joint symbol is on the top of the reference line, the weld will be on the opposite side to the arrow. If the joint symbol is on the bottom of the reference line, the weld will be on the same side as the arrow.

**Square butt**

- Weld on arrow side
- Weld on other side
- Weld on both sides

**Square butt symbols**

**V butt**

- Weld on arrow side
- Weld on other side
- Weld on both sides

**V butt**

**Fillet**

- Weld on arrow side
- Weld on other side
- Weld on both sides

**Fillet symbols**
Length and pitch of fillet welds

In addition to the symbols the size, length and spacing may be included. These will appear as symbols on a drawing but the weld joint will look like the interpretation.

**Interpretation**

Length and pitch of increments of intermittent welds

![Interpretation Diagram](image)

**Length and pitch of increments of chain intermittent welding**

![Chain Intermittent Diagram](image)

**Length and pitch of increments of staggered intermittent welding**

![Staggered Intermittent Diagram](image)

**Note:** In the last drawing the fillet symbol is slightly offset to indicate that the top and bottom fillet welds are staggered.
## Basic symbols for welding

<table>
<thead>
<tr>
<th>Type of weld</th>
<th>Sketch of weld</th>
<th>Symbol</th>
<th>Indication of drawing</th>
</tr>
</thead>
<tbody>
<tr>
<td>General butt</td>
<td>Full penetration butt weld by a welding procedure to be agreed.</td>
<td>![Symbol for General Butt Weld]</td>
<td>![Indication of Drawing]</td>
</tr>
<tr>
<td>Square butt</td>
<td>![Sketch for Square Butt Weld]</td>
<td>![Symbol for Square Butt Weld]</td>
<td>![Indication of Drawing]</td>
</tr>
<tr>
<td>Fillet</td>
<td>![Sketch for Fillet Weld]</td>
<td>![Symbol for Fillet Weld]</td>
<td>![Indication of Drawing]</td>
</tr>
<tr>
<td>Bead</td>
<td>![Sketch for Bead Weld]</td>
<td>![Symbol for Bead Weld]</td>
<td>![Indication of Drawing]</td>
</tr>
<tr>
<td>Surfacing</td>
<td>![Sketch for Surfacing Weld]</td>
<td>![Symbol for Surfacing Weld]</td>
<td>![Indication of Drawing]</td>
</tr>
<tr>
<td>Plug or Slot</td>
<td>![Sketch for Plug or Slot Weld]</td>
<td>![Symbol for Plug or Slot Weld]</td>
<td>![Indication of Drawing]</td>
</tr>
</tbody>
</table>
## Supplementary symbols

<table>
<thead>
<tr>
<th>Description</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backing strip or bar</td>
<td>![Image]</td>
</tr>
<tr>
<td>Weld all round</td>
<td>![Image]</td>
</tr>
<tr>
<td>Field or site weld</td>
<td>![Image]</td>
</tr>
<tr>
<td>Flush contour</td>
<td>![Image]</td>
</tr>
<tr>
<td>Convex contour</td>
<td>![Image]</td>
</tr>
</tbody>
</table>
Fill in the missing sections of this exercise

<table>
<thead>
<tr>
<th>Type of weld</th>
<th>Sketch of weld</th>
<th>Indication of drawing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fillet</td>
<td>![Fillet Sketch]</td>
<td>![Fillet Indication]</td>
</tr>
<tr>
<td>Single V butt</td>
<td>![Single V butt Sketch]</td>
<td>![Single V butt Indication]</td>
</tr>
</tbody>
</table>
Questions
1. On the chart below indicate which is higher or lower when comparing GMAW with MMAW.

<table>
<thead>
<tr>
<th>Item</th>
<th>Gas metal arc welding</th>
<th>Manual metal arc welding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumable costs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deposition rates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capital cost</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Correctly label the weld positions in the diagram below.

a) ____________

b) ____________

c) ____________

d) ____________
3. On the diagram below indicate the weld positions between flat and horizontal vertical.

4. Using the ISO codes for weld positions, what do the following letters indicate?

PE ___________ PA ___________ PC ___________ PF ___________
Classification of consumables

There are many different types of solid and flux-cored electrode wires commercially available. They are classified to a particular standard, which makes it possible to identify and select the most suitable type of wire for a job. It is important to understand classification systems and the information they represent.

Solid wire electrodes are always connected to the positive (+) terminal. They contain a number of de-oxidising agents to promote a cleaning or scavenging action in the weld pool. The wires are also copper-coated for two main reasons: to prevent them from rusting and to allow good electrical conductivity when the wire is passed through the contact tip. The wire is wound onto a spool or coil; this ensures the wire is passed through the feed rolls and flexible conduits as continuously as possible.

Classification systems list a number of essential features about the wire; for example, its chemical composition, gas shielding requirements, mechanical strength of the weld deposit and whether it is hydrogen controlled or not.

Solid wire electrodes

Australian Standards AS2717 Part 1 classifies solid wire electrodes under three groups of elements separated by hyphens. Each group consists of a number of letters or letters and numerals.

For example, the classification ES2-GM-W503H on a reel of wire can be broken down to decipher the chemical composition of the wire and its strength.

Group 1

ES2, the first group of digits, indicates that it is an electrode, solid (ES) with the numeral 2, which denotes the chemical composition of the wire by putting it in the chemical classification 2.

From the chart below you can see that a wire ES2 contains 0.07% carbon, 0.9% to 1.4% manganese and 0.4% to 0.7% silicon.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Carbon %</th>
<th>Manganese %</th>
<th>Silicon %</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES2</td>
<td>0.07</td>
<td>0.9 to 1.4</td>
<td>0.4 to 0.7</td>
</tr>
<tr>
<td>ES3</td>
<td>0.06 to 0.15</td>
<td>0.9 to 1.4</td>
<td>0.45 to 0.7</td>
</tr>
<tr>
<td>ES4</td>
<td>0.07 to 0.15</td>
<td>1.0 to 1.5</td>
<td>0.6 to 0.85</td>
</tr>
<tr>
<td>ES5</td>
<td>0.07 to 0.15</td>
<td>0.9 to 1.4</td>
<td>0.3 to 0.6</td>
</tr>
<tr>
<td>ES6</td>
<td>0.07 to 0.15</td>
<td>1.4 to 1.85</td>
<td>0.8 to 1.15</td>
</tr>
<tr>
<td>ES7</td>
<td>0.07 to 0.15</td>
<td>1.5 to 2.0</td>
<td>0.5 to 0.8</td>
</tr>
</tbody>
</table>

Note: Electrodes may also contain very small additions of copper, titanium, zirconium and aluminium.
Group 2
The second group consists of two letters that indicate the type of shielding gas used during qualification tests. In our example ES2-GM-W503H, the digits GM stands for Gas which is a Mixture.

Gas chart

<table>
<thead>
<tr>
<th>Classification</th>
<th>Type of gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>G</td>
<td>Gas shielding which is followed by the type</td>
</tr>
<tr>
<td>C</td>
<td>Carbon dioxide (CO₂)</td>
</tr>
<tr>
<td>M</td>
<td>Mixture of gases</td>
</tr>
<tr>
<td>I</td>
<td>Inert gas</td>
</tr>
</tbody>
</table>

The classification ES2-GM-W503H indicates that the wire is to be shielded by use of a mixture of gases.

Group 3
In our example of ES2-GM-W503H the third group of digits involves a letter W followed by a three-digit number. W stands for weld metal. The first two digits refer to the minimum strength of the deposited weld, which is measured in Mega Pascals (500 MPa), and presented as 10% of that value, in this case 50 MPa. The third digit 3 refers to the minimum impact value set at different temperatures. The letter H completes the classification which indicates that the process is hydrogen-controlled.

<table>
<thead>
<tr>
<th>Classification</th>
<th>Weld metal</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>The tensile strength of the weld metal expressed as 10% of the total MPa, ie 50 = 500 MPa</td>
</tr>
<tr>
<td>3</td>
<td>Impact strength (J value) at a particular temperature. 3 equals a J value of 47 at –30° C as specified in AS 2717</td>
</tr>
<tr>
<td>H</td>
<td>Hydrogen-controlled</td>
</tr>
</tbody>
</table>

Here is an example of a plain carbon steel wire electrode, ES4-GC-W503H.
The chemical composition will be 0.07% to 0.15% carbon, 1.00% to 1.50% manganese, and 0.60% to 0.85% of silicon.

When deposited with CO₂ shielding gas, the weld metal will have a minimum tensile strength of 500 MPa and an impact value of 47 J at –30 °C. The weld is hydrogen-controlled.

Filler wires for welding of steels are de-oxidised with manganese and silicon, and are generally copper-coated (nickel is sometimes used). The copper coating of the wire serves three purposes:

- prevents corrosion of the wire
- improves current pick-up
- improves feeding characteristics.
Common wire sizes for GMAW of steels:

<table>
<thead>
<tr>
<th>Wire Size</th>
<th>Usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6 mm</td>
<td>Generally used for sheet metal and other light applications</td>
</tr>
<tr>
<td>0.8 mm</td>
<td></td>
</tr>
<tr>
<td>0.9 mm</td>
<td>General purpose GMAW</td>
</tr>
<tr>
<td>1.0 mm</td>
<td></td>
</tr>
<tr>
<td>1.2 mm</td>
<td></td>
</tr>
<tr>
<td>1.6 mm</td>
<td>Welding of heavy plates</td>
</tr>
</tbody>
</table>

**Shielding gases**

In Australia GMAW is also commonly known as 'MIG Welding' (Metal Inert Gas). This is misleading, as it suggests that all shielding gases are inert. All GMAW of carbon and low-alloy steels employs the use of an active shielding gas. This means there is a reaction between the shielding gas and the metal droplets as they travel across the arc. Inert shielding gasses are used for welding stainless steels and non-ferrous metals. To achieve the desired arc stability when welding carbon and low-alloy steels, some oxidising action is required in the arc. This can be achieved in one of two ways:

- using carbon dioxide ($CO_2$) as a shielding gas
- using argon (Ar) as the base with the addition of $CO_2$ and/or $O_2$ (oxygen).

**Carbon dioxide**

Carbon dioxide, when used as a shielding gas, produces a highly reactive arc. $CO_2$ promotes the following characteristics to the welding arc:

- deep penetration
- high spatter levels
- high deposition rates
- high heat input
- true spray transfer cannot be achieved when using $CO_2$ as a shielding gas.

Carbon dioxide is best suited to dip transfer. The additional heat of $CO_2$ helps to overcome the problem of 'lack of fusion' and increases deposition rates. Carbon dioxide tends to produce convex bead shapes and high spatter levels.

**Argon**

Argon is a true inert gas, which by itself cannot be used to weld carbon and low-alloy steels. When used by itself to weld non-ferrous metals, it produces an arc which, when compared with $CO_2$, has the following characteristics:

- smooth arc
- lower penetration
- lower heat input
- lower spatter
• improved bead shape
• promotes spray transfer.

**Gas mixtures**

Gas mixtures for welding steel use argon as a base, with the addition of differing levels of CO₂ and/or O₂ to achieve desirable arc characteristics.

The greater the O₂ and CO₂ levels, the more the arc characteristics align to the characteristics of CO₂. The reverse is true: the lower the addition of CO₂ and O₂, the more the arc aligns toward characteristics produced by argon shielding gas.

<table>
<thead>
<tr>
<th>Shielding gas</th>
<th>Chemical behaviour</th>
<th>Effect/Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon</td>
<td>Inert</td>
<td>For welding all metals except carbon and low-alloy steels</td>
</tr>
<tr>
<td>CO₂</td>
<td>Active</td>
<td>Produces high spatter and deep penetration. Used with de-oxidised wire on carbon steels</td>
</tr>
<tr>
<td>Argon/CO₂</td>
<td>Active</td>
<td>For welding carbon and low-alloy steels. Produces low spatter and moderate penetration</td>
</tr>
<tr>
<td>Argon/CO₂/O₂</td>
<td>Active</td>
<td>Additional oxygen increases penetration. Used with de-oxidised wire to weld carbon and low-alloy steels</td>
</tr>
</tbody>
</table>

Each gas company will supply mixtures of their own formulation. However, as a rough guide for welding carbon and low-alloy steels, uses for mixtures approximating the following compositions are as follows:

<table>
<thead>
<tr>
<th>Gas</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>Dip transfer, particularly on thicker plates</td>
</tr>
<tr>
<td>Ar + 25% CO₂</td>
<td>General use in dip transfer</td>
</tr>
<tr>
<td>Ar + 15% CO₂</td>
<td>Multi-purpose for dip and spray transfer</td>
</tr>
<tr>
<td>Ar + 5% CO₂</td>
<td>For spray transfer</td>
</tr>
</tbody>
</table>
The ionising effect of the shielding gas influences bead shape as well as the amount of penetration obtained. The effect of shielding gas upon bead shape can be seen below.

Flow rates
Flow rates for CO₂ should be set at 16–18 litres per minute (L/min). Flow rates for Ar/CO₂ mixtures should be set at 14 L/min.

GMAW variables
The variables affecting the GMAW process are:

- wire speed/amperage
- arc voltage
- electrode stickout
- travel speed
- torch angle
- shielding gas flow rate.

Wire speed/amperage
Wire speed and amperage are controlled by the same potentiometer on a GMAW plant. Consequently these variables cannot be adjusted independently of each other.

As amperage is increased, the current density in the wire increases, and the melt-off rate of the wire increases. Amperage is the most important factor when determining heat input into the metal being welded. Turning up the wire speed/amperage control will:

- increase the wire feed speed
- increase amperage
- increase deposition rate
- increase penetration
- increase heat input
- for a given travel speed, increase the size of the weld bead.
Decreasing wire speed will have the opposite effect.

Arc voltage

Arc voltage determines the mode of metal transfer during GMAW welding. At low arc voltages, resistance across the arc causes extinguishment of the arc, which results in dip transfer. Higher arc voltages are enough to maintain the arc by overcoming the electrical resistance. As the arc voltage is increased, arc length is increased. This enables more wire to be melted off without ‘stubbing’, as sometimes occurs when high wire feed speeds and low arc voltages are used. Increased arc length also increases the width of the weld bead. To fully understand why, it is necessary to consider shielding gas for a moment.

The ionising potential of the shielding gas determines the width of the arc column.

Argon promotes a narrow arc column with deep and narrow penetration.

Helium promotes a wider arc column with increased side wall fusion, and shallower penetration.

Bead shape due to shielding gas composition
If the arc column is lengthened, but the angle the arc column burns at does not change, the weld bead is widened.

It can be seen therefore that, if arc voltage is increased without changing the wire speed or travel speed, a wider, flatter bead will result.

**Electrical stickout**

When discussing GMAW, two types of ‘stickout’ are referred to:

1. **Visible stickout** – the distance that the electrode protrudes beyond the gas nozzle.
2. **Electrical stickout** – the distance that the electrode protrudes from the contact tip.
Visible stickout has little effect upon welding conditions except that, if excessive, gas shielding efficiency will be reduced. However, electrical stickout is an important consideration. Welding current is transferred to the wire via the contact tip. The wire between the end of the contact tip and the arc offers electrical resistance. If the electrical stickout is halved, so is the electrical resistance.

![Diagram showing stickout distance and electrical resistance with and without stickout halved.]

**Reduced resistance due to reduced electrical stickout**

The effect of this increased resistance is:
- reduced amperage
- reduced penetration
- reduced heat input
- higher deposition rate.

The increased deposition rate is brought about by:
- preheating of the wire
- the wire feed motor.

There is an increase in electrical resistance due to the increase in electrical stickout; this in turn preheats the wire, which tends to melt off sooner. This has the effect of increasing the arc length, which in turn tends to increase arc voltage. The drive motor senses the increase in arc voltage and speeds up as a means of reducing the arc voltage to the preset level. The drive motor will speed up to compensate for increased arc voltage and slow down when the arc voltage is reduced. Increased deposition rates are obtained with a longer electrical stickout because the arc voltage is self-adjusting.
Travel speed
As travel speed is reduced, the weld bead becomes more convex due to greater deposition of filler wire. Heat input is increased due to the fact that the arc remains above any particular point for a greater period of time.

The opposite is achieved when travel speed is increased.

Torch angle
As with any welding process, the angle of approach must be adjusted to distribute the weld metal evenly in the joint.
Angle of travel

The angle of the gun is maintained such that it is 'pushed' in the direction of travel.

The exception to this is when making heavy welds in spray transfer where the gun is 'dragged'. This is done to direct shielding gas over the solidifying and cooling weld metal, which will remain hot for an extended period of time.

The operator determines the actual angle of travel used, by seeking the best compromise between good visibility and efficient shielding.

As the torch angle is lowered, shielding efficiency is reduced due to the Venturi effect, which draws air into the gas shield.
Gas flow rate

Gas flow rates should be set so as to provide adequate shielding.

Recommended rate of flow for argon mixtures = 14 L/min.
Recommended rate of flow for CO₂ = 16–18 L/min.

It should be kept in mind that excessively high flow rates cause turbulence and increase the Venturi effect when torch angles are too low.
Other machine controls

Spot timer
The spot timer allows the weld time to be preset as a means of making consistent weld sizes for spot welding. The timer is activated when the gun trigger is depressed.

Burnback control
This control enables wire to feed for a small amount of time after current flow is terminated when the torch trigger is released. This can be adjusted to prevent the wire fusing to the contact tip, or stop it sticking to the weld pool when welding is terminated.

Gas purge switch
The gas purge switch enables shielding gas to flow without feeding wire. It is used to set gas flow rates or to purge lines of contaminated gas before starting welding.

Inch wire control
This enables wire to be fed without gas or current flow.

Spool brake
The wire spool carrier employs a braking device to prevent overrun of the wire due to the inertia of the spool of wire. It should be adjusted to provide enough braking to prevent overrun, but with no unnecessary drag that would cause slippage of the wire at the drive rollers.
Questions

1. The Australian Standards classifies solid wire electrodes under three groups of elements. Name the three elements.
   a) ____________________ b) ___________________ c) ___________________

2. Name the three gases commonly used in a tri gas mix.
   a) ____________________ b) ___________________ c) ___________________

3. Which gas produces the deepest penetration?
   ________________________________________________________________

4. The flow rate for an Ar/CO₂/O₂ gas mixture should be set at __________ litres per minute.

5. List five controllable GMAW variables which affect the outcome of a weld.
   a) _______________________________________________________________
   b) _______________________________________________________________
   c) _______________________________________________________________
   d) _______________________________________________________________
   e) _______________________________________________________________

6. Will moving the electrode from a short arc length to a long arc length increase or decrease the weld bead width?
   ________________________________________________________________

7. Give a definition of an electrical stickout.
   ________________________________________________________________

8. What may occur when the nozzle angle used for welding is too low?
   ________________________________________________________________

9. What does a wire inch control do?
   ________________________________________________________________

10. State the purpose of a gas purge switch.
   ________________________________________________________________
Fillet and butt weld structures

Fillet weld

1. Parent metal
2. Reinforcement
3. Fusion zone
4. Weld face
5. Weld metal
6. Toe
7. Heat-affected zone
8. Root fusion

Butt weld

1. Parent metal
2. Reinforcement
3. Fusion zone
4. Weld face
5. Weld metal
6. Toe
7. Heat-affected zone
8. Root fusion
9. Penetration

Fillet weld measurements

1. Reinforcement
2. Leg length
3. Nominal throat thickness
4. Actual throat thickness
Joint design for GMAW

Pre-qualified joint preparation for GMAW of steel structures can be found in AS 1554.1. It can be seen that joint design is similar to that used for MMAW butt welds in steels but with the following variations:

- Included angles of butt welds are reduced by 10 degrees. This is because the thinner electrode and lack of flux provides easier access to the root of the joint.

The root face for butt welds is decreased when dip transfer is used because penetration is limited, and increased when spray transfer is used as a means of preventing burn-through.

Weld sizes

Fillet and butt welded joints are designed to carry certain loads. These loads are calculated from tests carried out on similar joints. An allowance is made for safety.

The welding operator must deposit welds to the dimensions specified by the designer. The designer knows how the welds will behave in service and asks for weld deposits of a particular size to meet the conditions. If the welder then deposits an undersized weld, the weld may fail in service. If the weld is over-reinforced, the joint will be less flexible and the vehicle body may fail. The rigidity of an oversized weld can cause excessive stress loading on other sections of the weld.

Example: For a 6 mm fillet weld there should be a 6 mm leg length and a 4.2 mm throat thickness.

For a butt weld there should be an even curved reinforcement slightly above the alignment of the parent metals.

Where the size of the weld is not specified, the deposit should be in proportion to the plate thickness; for example, on a 10 mm plate there should be a 10 mm fillet weld.

Butt welds should be built up so that the weld section is at least equal to the thickness of the parent metal.
Fillet weld dimensions
The size of a fillet weld is determined by the following dimensions: leg length and throat thickness. These may be checked with a weld gauge.

Leg length
There is a vast difference between throat thickness and effective throat thickness, as the following figures indicate.

The strength of a weld is determined by the effective throat thickness, which for a mitre weld should be 70% of the leg length.
The assembly of parts for a fillet weld also influences the weld size. The parts should be close-fitting so that there is fusion over the entire area of the joint surfaces. In the diagram below there is a gap between the parts. The weld size is correct but the effective throat thickness is reduced.
Questions
1. Using weld definitions, identify the features of the fillet weld in the diagram below.

![Diagram of a fillet weld with labeled features]

2. In butt weld preparation the included angles vary between GMAW and MMAW. What is the difference?

_________________________________________________________________

3. As a 'rule of thumb', what should be the size of a fillet weld when joining 12 mm plate?

_________________________________________________________________

4. On the diagrams below, indicate where the effective throat thickness would be measured.

![Diagram 1]  ![Diagram 2]
Control of distortion

When metal is heated it expands and on cooling it contracts. Laying down a bead of expanded metal (the weld bead) onto a comparatively unheated and unexpanded piece of metal (the parent metal) results in the weld bead contracting or shrinking to a far greater degree compared with the parent metal. It is this uneven expansion and contraction between the two metals that causes distortion when welding.

The effects of distortion cannot be totally eliminated but they can be controlled. There are three general types of distortion:

• longitudinal shrinkage
• transverse shrinkage
• angular shrinkage.

Longitudinal shrinkage

As the weld contracts in the direction of its length (longitudinal shrinkage) it will pull the fabrication into a distorted shape. The weld is in a state of high tension in its long direction.

Transverse shrinkage

If a butt weld is made between two plates which are free to move, the plates will be drawn toward the weld. In extreme cases they may overlap.
Angular distortion
This is the result of rotation of the welded parts around the axis of the weld due to transverse contraction.

Angular distortion

The control of distortion can be broken into three areas:

• before welding
• during welding
• after welding.

Before welding
The control of distortion before welding can be facilitated by:

• good design
• tack welding
• jigs, clamps and fixtures
• uniform preheating
• presetting.

Good design
Well-designed joints use a minimum weld length and an appropriate joint preparation to prevent over-welding, which results in minimal distortion.

Good design would include:

• reducing the size of the welds to the minimum allowed
• reducing the number of runs to achieve the weld size
• reducing gaps to a minimum.
Double ‘V’ welds can help control distortion

Double ‘V’ preparation preferred as it can be welded from both sides

30°

Reduced bevel angles with larger root gap

**Tack welding**

Tack welds are small additional welds that act like clamps.

The number and size of tack welds needed depends on the type and thickness of the material. For example, stainless steel requires more tack welds than mild steel and thicker material requires fewer tacks than thinner material.

**Jigs, clamps and fixtures**

Jigs, clamps and fixtures are used to hold the parts being welded in place during the welding process.
Uniform preheating
Suitable preheating of parts to be welded can help reduce distortion. Preheating can be carried out using oxyacetylene equipment. If the part to be welded can be preheated and evenly expanded, welded and then evenly cooled, the effects of distortion will be minimised. This technique is often employed when welding king pins onto semitrailers, as it also minimises the stresses applied to the surrounding material.

Presetting
This technique consists of predicting how much distortion can be expected and misaligning the material by that amount before welding, so that on completion of the weld the distortion is minimal.
During welding

The control of distortion during welding can be facilitated by:

- backstep welding
- intermediate chain welding
- intermediate staggered welding
- balanced sequence welding.
After welding

Correction of distortion after welding is often difficult and sometimes impossible. For this reason it is best to control distortion before and during welding. Correction of distortion after welding can be done by:

- hammering or peening the weld
- pressing
- heating.

Hammering or peening the weld

Peening is used to stretch the weld and nearby parent metal by hitting the hot metal with hammer blows.

A sledgehammer applied to the correct area can be used to straighten out lighter materials such as square tubing on the side rails of a bus.

Pressing

This is a more subtle form of straightening distorted material. Pressing can be a more controlled process but often takes time to set up. Pressing can be performed by machines such as a ‘hydrabends’, ‘H’ frame press, ‘porta powers’ or hydraulic bottle jacks or other forms of rams.

Heating

The contraction of the weld bends the material towards the weld. By heating the opposite side of the material from the weld and then cooling it, the material will shorten slightly and will tend to straighten.
Where not to weld

A vehicle body is not a static item; it moves and flexes in service. The body must be able to twist and flex in relation to uneven road surfaces. A torsionally flexible body has the advantage of decreasing suspension loading when the vehicle is on uneven surfaces as all wheels can make contact with the road surface, thus sharing the payload over all the wheels. With this in mind, vehicle body builders must weld the vehicle body in a way that allows the vehicle to remain flexible but at the same time have the strength to remain in service without failing.

There are several general rules to apply to achieve a flexible but strong body. These rules may not always be possible to apply, but where practicable they should always be followed.

Always weld longitudinally along the body, not across the body. For example, weld in the direction of a main runner, not across it.

Do not weld across the main runner

Weld underneath the cross bearer in the same direction as the main runners

Cross bearer

Weld here in the direction of the main runner

Main runner

Section on centre line

This is extremely important where stresses are concentrated, such as in a gooseneck or where a drawbar meets the front of the body.
Do not fully weld gussets if there is to be a lot of flexing. Some manufacturers prefer not to weld to the extreme ends of gussets.

Weld at the extreme outer edges and the inner section. Depending on the size of the gusset, intermediate welds may be necessary.

It is not generally recommended to weld on a chassis frame except when joining after a wheelbase alteration. If it is necessary to weld on a chassis, check with the manufacturer and your workshop policy before beginning the work. Generally, it is not accepted to weld on the flange or in an area within 40 mm from the top and bottom edge of the web.
Where cross bearers pass through the main runners on a semitrailer body, only weld on the web of the cross bearers. This allows for maximum flexibility of the body.

- To weld spring retainers to the axle, do not weld across the axle – weld longitudinally along the axle.
- Never attach a work lead to components such as axles, springs, engines or drive lines. Arcing on these components may cause serious damage to bearings and springs. Parabolic leaf springs are particularly sensitive to surface damage.
- Pipes and conduits made of synthetic material such as those used for brakes and electrical systems must be protected from weld spatter and temperatures exceeding 80°C.
- Fuel tanks and fuel pipes in the vicinity of welding should be removed.
- Disconnect the battery to protect electronic components such as ABS, onboard computers and alternators.
- Unplug all onboard computers.
- Protect airbag suspensions and parabolic leaf springs which may fracture by even momentary exposure to weld spatter.
Questions

1. There are three general types of distortion, name them.
   a) ____________________ b) ____________________ c) ____________________

2. The control of distortion can be broken into three areas; give three methods which can be employed in each area to reduce distortion.
   a) Before welding
      1. __________________
      2. __________________
      3. __________________
   b) During welding
      1. __________________
      2. __________________
      3. __________________
   c) After welding
      1. __________________
      2. __________________
      3. __________________

3. What is the advantage of having a torsionally flexible body when travelling over uneven road surfaces?
   ________________________________________________________________

4. It is not recommended to weld across a drawbar. Why?
   ________________________________________________________________

5. List four places or items where the work lead (earth) should not be attached on a truck.
   a) ________________________________
   b) ________________________________
   c) ________________________________
   d) ________________________________
Procedure sheets

Procedure sheets vary from firm to firm and are used as a means of keeping track of how a weld was done and the type of material used. It is also useful to record who did the welding. These sheets are not used for all welds but often for selected welds such as king pin attachment.

<table>
<thead>
<tr>
<th>PROCEDURE SHEET</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAME</td>
</tr>
<tr>
<td>Type of welding machine</td>
</tr>
</tbody>
</table>

**Control data**

<table>
<thead>
<tr>
<th>Run</th>
<th>Wire speed setting</th>
<th>Amperage reading</th>
<th>Voltage control setting</th>
<th>Transfer mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
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<td></td>
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<td>3</td>
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</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Electrode wire**

<table>
<thead>
<tr>
<th>Size Ø mm</th>
<th>Type</th>
</tr>
</thead>
</table>

**Material data**

<table>
<thead>
<tr>
<th>Type</th>
<th>Thickness</th>
</tr>
</thead>
</table>

**Shielding gas**

<table>
<thead>
<tr>
<th>Type</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Flow rate litres/min</th>
<th>Signature</th>
</tr>
</thead>
</table>
GMAW defects

Apart from slag inclusions, all the common weld defects that occur with other processes may occur with GMAW. Defects such as porosity and lack of fusion can be a particular problem with GMAW.

The defects commonly encountered in GMAW are:

- porosity
- cold lap/lack of fusion
- lack of root penetration
- excessive penetration
- contour defects
- undercut
- weld cracking
- stray arcing
- excessive spatter.

Porosity

**Definition:** a pore or group of gas pores in the weld metal. Porosity may be conveniently differentiated according to size and distribution. A number of different terms are used related to size. These are:

- Gas pore – a cavity (usually spherical) formed by entrapped gas during the solidification of molten metal.
- Wormhole – an elongated or tubular cavity in the weld metal caused by entrapped gas being forced away from the solidifying weld metal.
- Cluster – a group of pores in close proximity to each other.

As is the case with other welding processes, porosity may be caused by moisture, or surface contaminants on the plate.
With GMAW, by far the greatest cause of porosity is due to inadequate gas shielding. This may be due to:

- flow rate set too low
- flow rate set too high
- no gas flow at all
- excessive wind or air movement at the gun
- contaminated shielding gas
- stickout length too long
- gun angle too low.

Cold lap/lack of fusion

**Definition:** portions of the weld run that do not fuse to the surface of the metal or edge of the joint. With GMAW lack of fusion is commonly referred to as 'cold lapping' as it usually takes the form of lack of sidewall fusion over an extensive part of the joint.

Cold lapping is common when welding in the dip transfer mode, particularly when the plate thickness exceeds 5 mm. Welding downhand, or with high wire speed and low arc voltage settings, further increases the risk of this occurrence. Plates that are dirty or heavily scaled further exacerbate the problem.

Cold lapping does not generally occur when welding in the spray transfer mode. Therefore to minimise the likelihood of cold lapping, one or more of the following should be employed:

- Weld in the spray transfer mode.
- Clean plates.
- If in doubt, set the arc voltage slightly high.
- Set enough amperage to ensure sufficient heat for fusion.
- Keep the electrical stickout short.
- Use CO₂ shielding gas or a mixed gas high in CO₂.
Lack of root penetration

Definition: the failure of the weld metal to completely fill the root of the joint.

Root runs in butt welds are normally made in the dip transfer mode except for those in heavy plate, in which case spray transfer would be used. The dip transfer mode is inherently ‘cold’, employing low amperages and voltages. This means that root penetration is limited in this mode.

The solution to overcoming lack of root fusion is to use thinner root faces on butt welds than would be the case with other processes, ie typically in the range of ½ mm to 1 mm.

In fillet welds, the solution is to use comparatively high amperage settings when in the dip transfer mode. Additionally, CO₂ or a gas mixture high in CO₂ will help.

Excessive penetration

Definition: excess weld metal protruding through the root of a butt weld. This defect normally only occurs on thin (sheet) materials or when the spray mode of transfer is used. Adjustment of wire speed and arc voltage will usually overcome this problem with relative ease.

Another form of this defect is electrode wire protruding through the root of the butt in the form of ‘spikes’ or ‘icicles’. This is caused when arcing to the root face of the butt weld momentarily ceases, a small amount of wire penetrates the butt, and the arc is re-established when the wire contacts the parent metal.

The solution to this problem is to limit the width of the root gap and/or to increase the arc voltage, which results in a wider spread of the arc so that arcing to one or both sides of the weld is always present.
Contour defects
Contour defects may be in the form of overroll or overlap, excessive convexity or excessive concavity of the bead, or simply rough, uneven appearance.

Travel speed and torch angle adjustments may fix many of these problems, but the GMAW operator has an advantage in that he/she can control weld profile by adjusting the arc voltage.

Excessive convexity may be remedied by increasing arc voltage, and beads which are too wide or too concave may be remedied by decreasing arc voltage.

Undercut

Definition: a groove or channel in the parent metal occurring continuously or intermittently along the toes or edge of a weld.

Undercut is not a common problem in GMAW. However, it is likely to be encountered in two situations:

1. When fillet welding in spray transfer: This is normally caused by setting the arc voltage too high, causing a long arc length which results in undercutting of the toe of the weld of the vertical plate. The solution is quite simple and good practice for all welds in spray transfer. To facilitate this, set a smooth spray transfer mode using the lowest arc voltage.

2. Vertical up welds: Solid wires are largely unsuitable for making stringer beads in the vertical-up position. Convex beads with some undercut generally result. When a weave technique is used, a bead that is convex in the middle, with undercut toes, may result. The solutions are:
   • reduce the arc voltage, or
   • reduce the overall heat of the welding, or
   • pause longer at the toes.
Weld cracking

Definition: discontinuities produced either by tearing of the metal in the plastic condition (hot cracks) or by fracturing when cold (cold cracks). Hot cracks are common in materials with high coefficients of expansion and/or which suffer from hot shortness. Hot cracking occurs at elevated temperatures soon after solidification. This mode of cracking is common in aluminium and stainless steel. Cold cracking is most common in hardenable materials, particularly when cooling rates are rapid. Cracking is considered to be a serious defect and rarely tolerated.

Cracks may also be described depending on how, when and where they occur, e.g., longitudinal, transverse, crater, centre line, hot, cold, toe and underbead. Cracks may occur in either the parent metal, usually as fusion or heat-affected zone cracks or in the weld metal.

Hot cracking – Usually occurs in metals that are hot short and/or have high rates of thermal expansion. Hot cracking most commonly occurs in the weld metal with longitudinal cracks and crater cracks being the most common examples.

Cold cracking – Most commonly occurs in the base metal adjacent to the fusion zone. The most common example of this is underbead cracking in hardened steels.

Crater cracks – These come from hot shrinkage. The crater solidifies from all sides toward the centre, leading to a high concentration of stress at the centre of the crater. If the metal lacks ductility, or the hollow crater cannot accommodate the shrinkage, cracking may result. Crater cracks may, under stress, propagate from the crater and lead to failure of the weld.

Cracking in GMAW welds is not generally a major problem due to the following factors:

- GMAW is a ‘low-hydrogen’ process.
- Hollow craters are not usually a characteristic of GMAW welds.
- The inherent low heat input is ideal for stainless steels and other metals which are prone to hot cracking.
Stray arcing

**Definition:** damage on the parent metal resulting from the accidental striking of an arc away from the weld. Stray arcing is not a major problem associated with GMAW as the electrode is usually only live when the gun trigger is depressed. Care should be taken that the gun is not put down with the weight resting on the trigger, and also that arcing does not occur between the job and the work return lead connection.

Excessive spatter

**Definition:** the metal particles expelled onto the surface of the parent metal or weld, during welding, and not forming part of the weld.

This usually occurs due to one of the following factors:

- shielding gas or plate contaminated with moisture
- high levels of CO\textsubscript{2} or O\textsubscript{2} in the shielding gas
- excessive arc voltage in the dip transfer mode
- welding in the globular transfer mode.

**Note:** Spatter is not usually present in the spray transfer mode.

Trouble shooting/equipment malfunction

Compared with the manual welding processes, GMAW requires higher levels of care and maintenance. Major sources of frustration are the problems associated with feeding of the electrode wire. This is a particular problem when welding with aluminium wire, feeding wire through long gun cables, or when using a gun cable that has been poorly maintained.

Equipment malfunctions with GMAW fall into two main categories:

1. electrical
2. mechanical.

The main problems with regard to **electrical** malfunctions and their likely causes are:

<table>
<thead>
<tr>
<th>Problem</th>
<th>Likely cause</th>
<th>Rectification</th>
</tr>
</thead>
<tbody>
<tr>
<td>No power at machine</td>
<td>Mains switch off</td>
<td>Check switches and fuses – If intact call electricians</td>
</tr>
<tr>
<td></td>
<td>Machine switched off</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Blown fuse</td>
<td></td>
</tr>
<tr>
<td>Mains power on but no welding power</td>
<td>Trigger switch not working</td>
<td>Check – If trigger is working wire feeder will operate, wire will feed</td>
</tr>
<tr>
<td></td>
<td>Wire feeder not connected</td>
<td></td>
</tr>
<tr>
<td>Wire feeds, but no arc</td>
<td>Work return not connected</td>
<td>Check work return</td>
</tr>
<tr>
<td></td>
<td>Blown fuse</td>
<td>Check fuses</td>
</tr>
</tbody>
</table>
**Mechanical** problems manifest themselves in the form of wire feeding problems. Common wire feeding problems and their likely causes are:

<table>
<thead>
<tr>
<th>Problem</th>
<th>Likely cause</th>
<th>Rectification</th>
</tr>
</thead>
<tbody>
<tr>
<td>No wire feed at all</td>
<td>Spool brake excessively tight</td>
<td>Check tension on spool brake</td>
</tr>
<tr>
<td></td>
<td>No friction at drive rolls</td>
<td>Check drive rolls and adjust as necessary</td>
</tr>
<tr>
<td></td>
<td>Wire jammed at drive rolls or in gun cable</td>
<td>Check guide tubes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Check wire conduit</td>
</tr>
<tr>
<td>Uneven wire feed</td>
<td>Dirty or damaged liner</td>
<td>Clean or replace</td>
</tr>
<tr>
<td></td>
<td>Slippage at drive rolls</td>
<td>Increase pressure</td>
</tr>
<tr>
<td></td>
<td>Liner cut too short</td>
<td>Replace</td>
</tr>
<tr>
<td></td>
<td>Kinks in gun cable</td>
<td>Keep as straight as possible</td>
</tr>
<tr>
<td></td>
<td>Insufficient roll pressure</td>
<td>Tighten drive rolls</td>
</tr>
<tr>
<td></td>
<td>Wire distorted due to excessive roll pressure</td>
<td>Reduce roll pressure</td>
</tr>
<tr>
<td></td>
<td>Wire is kinked or twisted</td>
<td>Look for misalignment of drive rolls or damaged liner</td>
</tr>
<tr>
<td></td>
<td>Contact tip worn or dirty</td>
<td>Inspect and replace</td>
</tr>
<tr>
<td></td>
<td>Spool brake excessively tight</td>
<td>Check tension on spool brake</td>
</tr>
<tr>
<td>Spool overrun</td>
<td>Spool brake too loose</td>
<td>Tighten</td>
</tr>
<tr>
<td>Wire fused to contact tip</td>
<td>Excessive arc voltage</td>
<td>Reduce arc voltage</td>
</tr>
<tr>
<td></td>
<td>Excessive burnback time</td>
<td>Reduce burnback time</td>
</tr>
<tr>
<td></td>
<td>Intermittent wire feed</td>
<td>See above</td>
</tr>
</tbody>
</table>

GMAW equipment requires a regular inspection and maintenance schedule:

- contact tips should be inspected at least daily
- liners, drive rolls and spool brake should be inspected weekly
- gas and electrical connections should be inspected monthly.

Feeding aluminium wire presents additional problems. It is essential that all sources of friction upon the wire be minimised. Recommendations are as follows:

- reduce spool braking
- use a Teflon® liner
- ensure the correct liner is used
- keep the gun cable as straight as possible
- avoid small diameter wire if possible
- fit a straighter gooseneck to the gun
• pay particular attention to drive roll pressure
• use good quality wire
• additionally, a welding machine with the following features is highly recommended:
  ◦ a push/pull gun
  ◦ a four roll wire feeder
  ◦ a soft-start feature.
Questions

1. List three types of useful information which can be taken off a procedure sheet.
   a) ____________________________________________
   b) ____________________________________________
   c) ____________________________________________

2. On the diagram below, label the defects on a butt weld that the arrows are pointing to.

   [Diagram showing defects labeled with blank spaces]

3. List three ways in which cold lapping could be minimised.
   a) ____________________________________________
   b) ____________________________________________
   c) ____________________________________________

4. Undercut in GMAW is more likely to be encountered in two situations. What are they?
   a) ____________________________________________
   b) ____________________________________________

5. Give three likely causes of wire being fused to the contact tip.
   a) ____________________________________________
   b) ____________________________________________
   c) ____________________________________________

6. What type of liner is recommended for use with aluminium welding?
Tanks and containers

Whenever possible always avoid welding tanks or containers which have held volatile substances. If there is another way around the problem, such as replacement of the tank, then make welding the very last resort.

Water-soluble substances

Tanks and containers that have held substances which dissolve in water (water-soluble) may be welded or cut with relative safety, provided a few simple precautions are taken. It is very important to be certain about the water solubility of the contents. Before welding do the following:

- Rinse the container with water several times.
- Fill the container with as much water as possible.
- Be sure there is a vent hole to let out the fumes created during the welding or cutting operation before starting to weld or cut.

**Important:** Never weld or cut containers until you know what has been stored in them.

Non-water-soluble substances

Welding and/or cutting tanks and containers that have held flammable or combustible substances present dangers if cleaning, purging and other procedures are not carried out carefully.
Important: Never trust your eye or sense of smell to determine if it is safe to weld or cut the container. Even a small amount of flammable substance is extremely dangerous and will cause an explosion.

Cleansing procedures are outlined below:

- Thoroughly wash out the container with a hot caustic soda solution, steam or some other cleansing agent. Do not use carbon tetrachloride because of its toxic fumes.
- Fill the container with an inert gas such as nitrogen, carbon dioxide, argon or helium to cleanse the remaining fumes.
- Fill the container with as much water as possible.
- Vent the container before starting welding or cutting, to let out the fumes during the welding or cutting operation.

Important:

- When using steam or caustic soda solution, wear safety glasses and clothing which gives your body full protection.
- While cleansing and washing the tanks/containers, make sure they are well aired (ventilated), as some cleansing agents give off toxic fumes.
## Practical exercises

<table>
<thead>
<tr>
<th>Type of weld</th>
<th>10 mm plate</th>
<th>Sign off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pad weld</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single run fillet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three run fillet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single vee butt weld</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat position</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of weld</th>
<th>1.6 mm plate</th>
<th>Sign off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single run fillet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed butt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single run fillet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical down position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Closed butt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vertical down position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of weld</td>
<td>3 mm plate</td>
<td>Sign off</td>
</tr>
<tr>
<td>---------------------------</td>
<td>------------</td>
<td>----------</td>
</tr>
<tr>
<td>Single run flat position</td>
<td><img src="image1.png" alt="Diagram" /></td>
<td><img src="image2.png" alt="Diagram" /></td>
</tr>
<tr>
<td>Open butt Flat position</td>
<td><img src="image3.png" alt="Diagram" /></td>
<td></td>
</tr>
<tr>
<td>Single run fillet Vertical down position</td>
<td><img src="image4.png" alt="Diagram" /></td>
<td></td>
</tr>
<tr>
<td>Open butt Vertical down position</td>
<td><img src="image5.png" alt="Diagram" /></td>
<td></td>
</tr>
</tbody>
</table>
### Type of weld | 10 mm plate | Sign off
--- | --- | ---
Pad weld | ![Pad weld](pad_weld.png) | Horizontal position
Out side corner | ![Out side corner](outside_corner.png) | Horizontal position
Single V butt | ![Single V butt](single_v_butt.png) | Horizontal position
Multi-run fillet | ![Multi-run fillet](multi-run_fillet.png) | Vertical up
Multi-run fillet | ![Multi-run fillet](multi-run_fillet_overhead.png) | Overhead position

### Type of weld | 3 mm plate | Sign off
--- | --- | ---
Open butt weld | ![Open butt weld](open_butt_weld.png) | Horizontal position
<table>
<thead>
<tr>
<th>Type of weld</th>
<th>1.6 mm plate</th>
<th>Sign off</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open butt weld</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Horizontal position</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


Perform Gas Metal Arc Welding
Workbook (AUM8057A)

DESCRIPTION
This workbook and guide is intended as an introduction to GMAW for trades which fabricate metals such as vehicle body building.

It contains the basic operation of a GMAW machine, modes of metal transfer, codes and symbols on through to practical exercises.

Incorporated into the workbook is a section of how to approach the welding of a dynamic unit such as a vehicle body.

EDITION
First edition

CATEGORY
Automotive Manufacture

COURSES AND QUALIFICATIONS
• Certificate III Automotive Manufacture (Bus, truck and trailer)

RELATED PRODUCTS
AUT031  Fabricate Parts for Sub-Assemblies Workbook
AUT033  Prepare and Operate Equipment, Tools and Machinery
- Hand Tools Workbook
AUT034  Prepare and Operate Equipment, Tools and Machinery
- Power Tools Workbook
AUT035  Modify or Repair Chassis/Frame and Associated Components Workbook

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