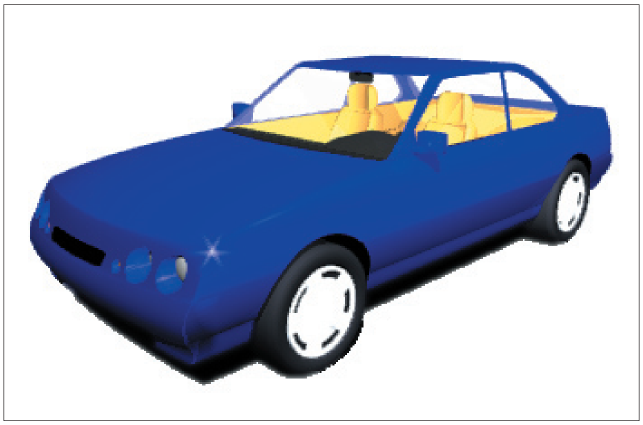
Introduction

I-CAR®

Topic A. Obligations To The Customer And Liability



The Collision Repair Industry has an obligation to correctly repair the customer's vehicle. Collision repairs must be performed using:

- recommended or tested procedures from vehicle makers, I-CAR, and other research and testing organizations.
- quality replacement parts and materials.
- repair processes and parts as written and agreed upon in the repair order.

If items on the repair agreement are not consistent with the repair order, it can be considered fraud.

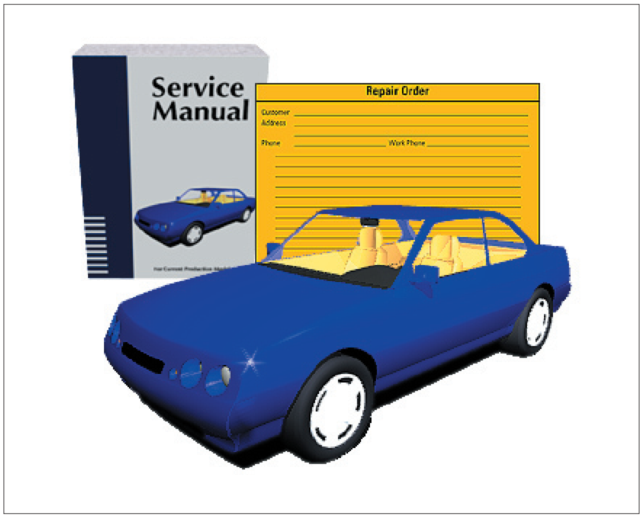
Performing proper collision repairs requires using parts and procedures that keep remaining warranties intact. Collision repairs must restore:

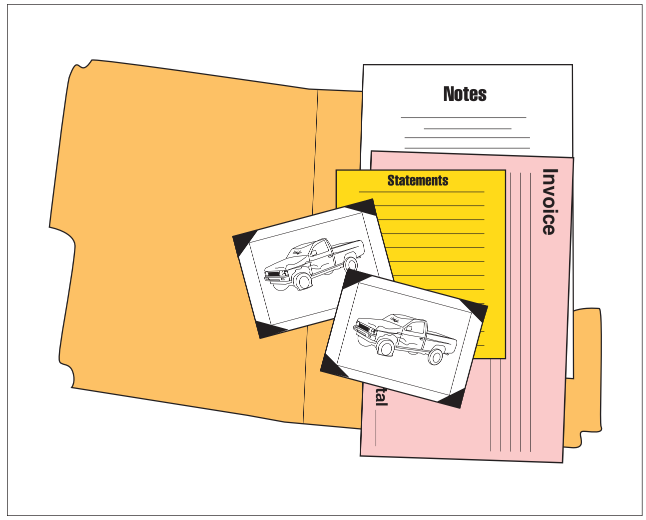
- safety.
- structural integrity.
- durability.
- performance.
- fit.
- finish.

Throughout the damage analysis and repair process, the repairer and insurer must communicate with each other and the customer. They must be in agreement with each other and the customer on how repairs will be performed. The customer must be informed of any changes in the repair plan from the original repair agreement and explain the changes and why they have to be made.

To reduce liability, make sure that all repairs are performed thoroughly and correctly. Perform the repairs as listed in the damage report and have documentation of required repairs available for customers. Be sure of the proper procedures. Technicians are considered the experts and are expected be knowledgeable on how to perform a quality repair.

Liability insurance that covers the repair facility may not always cover all damages. For example, the policy may not cover faulty repairs, leaving liability responsibility completely on the facility. A shop owner may find that repair facility liability coverage may not cover the full amount awarded in a lawsuit. The shop owner would have to pay the difference.





It is difficult to reduce the risk of liability exposure. The part that the repairer can control is the chance of being found at fault. Chances can be minimized by using recommended or tested procedures from the vehicle makers, I-CAR, or other research and testing organizations. It is also important to use quality replacement parts and materials that restore fit, finish, durability, and perform at least as well as the original. Lastly, keep thorough records that document the repair process.

Keeping thorough records includes more than recording the date, mileage, and pre-existing damage. Record keeping also includes:

- making sure all notes are legible.
- verifying the repairs that were made or not made.
- having the customer sign a waiver for repairs that they do not want performed. Repairers must determine their liability on not repairing safety systems such as restraint and anti-lock brake systems.
- keeping computer printouts or worksheets on file showing wheel alignment readings or vehicle dimensions before and after repairs.
- keeping scan tool printouts and records of computer codes for airbag, anti-lock brake, emission, and powertrain control module (PCM) systems.
- attaching the OEM procedure printout to the vehicle repair order.
- keeping receipts for all sublet work performed.

Steel GMA (MIG) Welding

Textbook

I-CAR®

IMPORTANT NOTICE

This material provides general directions for collision damage repair using tested, effective procedures. Following them will help assure the reliability of the repair.

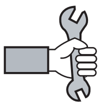
I-CAR cannot accept responsibility for any individual repair, nor can it warrant to the quality of such repair. Anyone who departs from the instructions in this program must first establish that neither personal safety nor the integrity of the repair of the vehicle is compromised by the choice of methods, tools, or supplies.

I-CAR does not endorse or recommend any brands or makes of vehicles, repair equipment and supplies or other products. The appearance of various makes and brand names in any I-CAR material is purely coincidental and is based on the availability of those products at the time of production.

All recommendations presented in this program are based upon research programs or upon tests conducted by laboratories, manufacturers, or selected collision repair facilities. If performed as outlined, these recommendations will provide the basis for a thorough, professional repair.

CONTENTS

Topic A. Introduction To Gas Metal Arc Welding (GMAW)

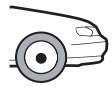


I-CAR RECOMMENDED TRAINING PATHS
Select the Demonstration icon found on screen A-1 of your CD-ROM for an example of the training paths.

A-2 A GMA (MIG) welder is being used to section a uniside on this vehicle.

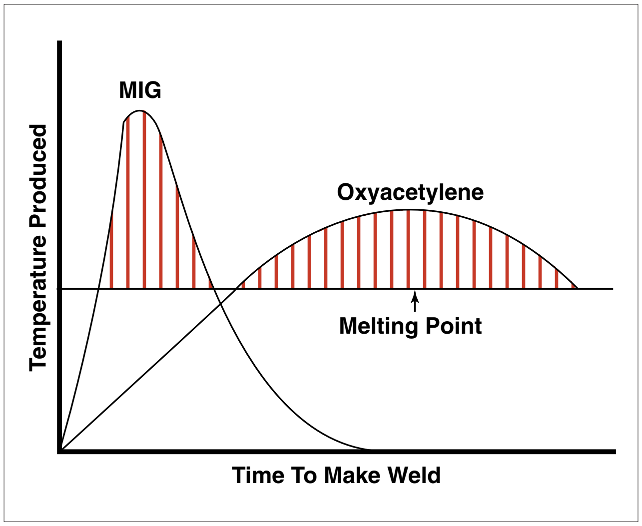
Gas Metal Arc (GMA) Welding:

- is commonly called Metal Inert Gas (MIG) Welding.
- is a consumable electrode, wire feed, fusion welding process. GMA welding uses a continuously fed spool of wire as the electrode. The electrode wire is deposited as a filler metal into the molten weld puddle, producing a raised weld bead.
- produces heat using a short electric arc between the base metal and a bare wire electrode. GMA (MIG) welding is a type of arc welding. Arc welding uses an electrical arc as the heat source.
- typically uses an externally supplied shielding gas to protect the molten weld pool from atmospheric contamination.



Induction of current or voltage spikes can destroy sensitive electronic parts. When welding, protect computers and other electronic parts by:

- keeping the current path short by placing the work clamp close to the weld site.
- disconnecting and isolating both battery cables. Remove the negative battery cable first.
- keeping the machine as far away from vehicle computers as possible.
- not allowing cables to pass near computers or sensors.
- removing computers or other sensitive electronic parts if welding closer than 300 mm (12").
- covering glass and other areas of the vehicle with a welding blanket.



A-3 This chart shows the difference in heat input into the metal between GMA (MIG) welding and oxyacetylene welding.

A-4 Because of its simplicity and controllability, it takes very little instruction to make quality welds with a GMA (MIG) welding machine.

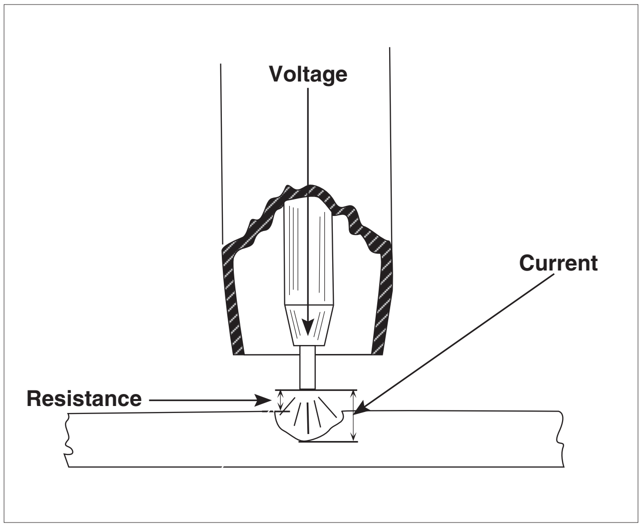
Advantages of GMA (MIG) welding include it:

- produces a small heat-affected zone. The heat-affected zone is much smaller when compared to oxyacetylene welding. Low current output can be used to weld thin metals, and the small area of metal being welded is heated for only a short period of time. This is a consideration when welding high-strength steel (HSS).
- can be used to weld all commercial metals and alloys. With the proper electrode wire and shielding gas, GMA (MIG) welding can typically weld any metal found on a vehicle.
- works well in all welding positions, including horizontal, vertical, and overhead.
- does not produce a heavy welding slag and requires minimal post-weld cleaning.

Additional advantages of GMA (MIG) welding include its:

- simplicity. GMA (MIG) welding is relatively easy to learn when compared to some of the other welding methods. A welder can generally make quality welds with only a few hours of instruction and practice.
- controllability. With enough practice, the arc can be made smoother and the weld puddle kept smaller so it is easily controlled.
- speed. GMA (MIG) welding is a faster process than many other types of welding.

Topic B. Electricity And Welding



B-1 To understand electricity and welding you must understand voltage, current, and resistance.

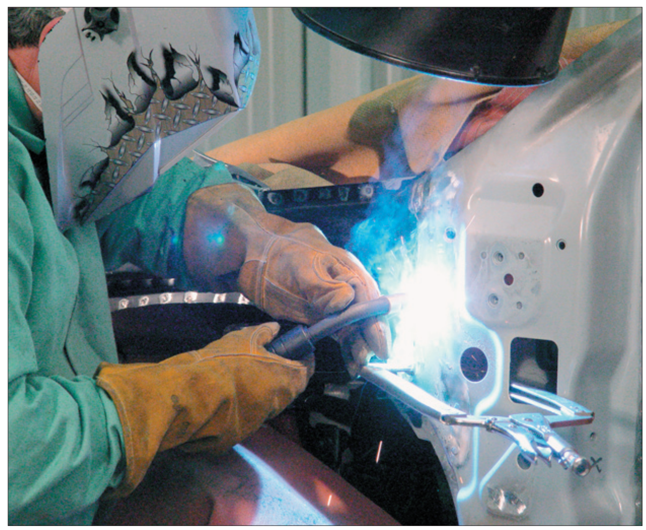
In order to understand welding, it is important to understand some basic electrical terms such as voltage, current, and resistance.

Voltage is the pressure applied to an electrical circuit that forces electrons to move through a conductor. The more voltage, the faster the electron flow. This can be visualized by thinking of water and a water tower, with the water representing the electrical energy or electrons in a circuit. Voltage can be visualized as the pressure put on the water by gravity from having it in a high tower. Voltage is also called the "potential difference" that's available in a circuit.

This is important because the welder must be capable of applying enough pressure, or voltage, to keep the current flowing.

Current is the volume of electrons, or how many electrons are moving past a point in a given period of time. This can be visualized by thinking of current as the amount of water that flows through a hose, per second of time, when the valve is opened. Current may also be called amperage. Current flows from negative to positive in an electrical circuit.

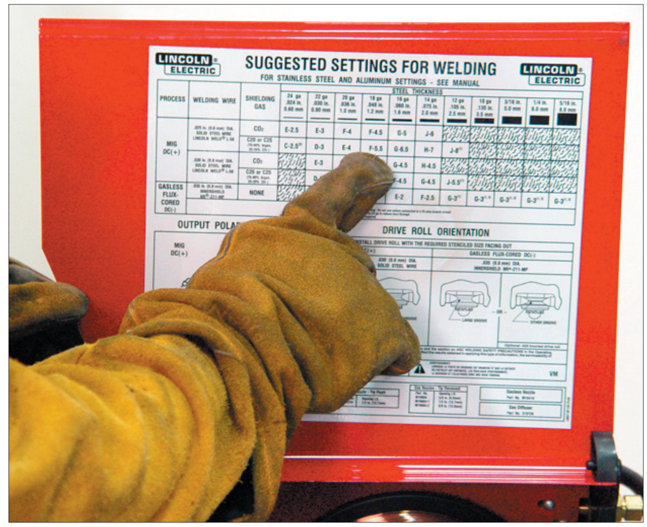
Resistance is the limit of the flow of electrons. The more resistance, the less the current is allowed to flow. This can be visualized by thinking about the valve used to turn a water hose on and off. The more the valve is opened, the lower the resistance and more water that is allowed to flow. With the valve completely closed there is an infinite amount of resistance and no flow takes place. Resistance is the restriction of the flow of electrons in a circuit. Resistance is overcome by voltage. If resistance is increased, and we want current flow to remain the same, higher voltage is required to force or push the electrons through the point of higher resistance.



B-2 The heat from the arc in GMA (MIG) welding produces a bright light.

Arc welding converts electrical energy to heat or thermal energy. This thermal energy is what melts the metal and allows it to fuse together. The heat of the arc melts both the base metal and the electrode. The electrical output of the welder through the filler wire is what produces this heat. The amount of heat put into the base metal is a function of the voltage and current outputs of the welder and the travel speed at which the welding gun is moving. During welding there is enough heat generated to bring metal to a molten state.

B-3 The amperage output of this welding machine is being changed by adjusting the wire speed.



B-4 Most welding machines have a chart with recommended amperage or wire speed and voltage settings for different types and thicknesses of metal.

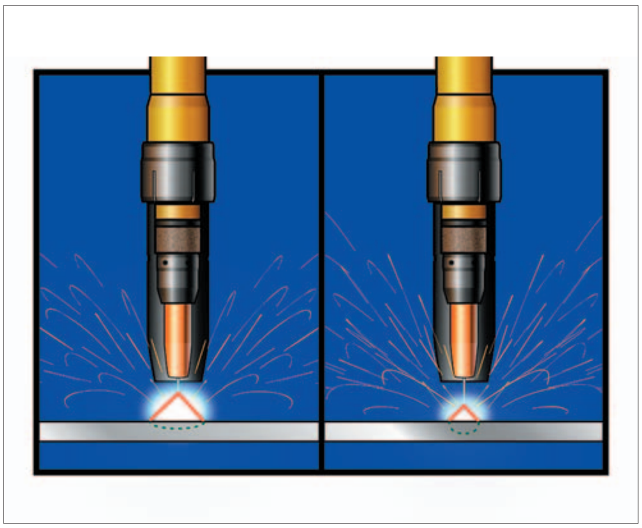
The current or amperage output of a GMA (MIG) welder is:

- adjusted by changing the wire speed setting of the machine. The number of electrons or amount of current that a wire can carry is dependent on the amount of voltage pushing the current, the diameter of the wire, and the resistance in the welding circuit. In order to put more current into the weld, the wire speed must be increased. Increasing the wire speed puts more wire and thus more electrons or current into the weld puddle for a given amount of time.
- affected by the welding technique. Amperage is a function of voltage and resistance, (amperage equals voltage divided by resistance). Anything that increases resistance will decrease amperage or current output. Decreases in resistance will increase current output. The main variable that can affect the resistance is electrode extension. Any increase in electrode extension will increase resistance and therefore decrease the amperage output.

The current, or amperage output of a GMA (MIG) welder:

- controls the heat generated by the arc between the electrode and base metal. The flow of current, across the gap between the electrode wire and the base metal is what produces the electric arc that generates the heat used for welding. The amount of amperage is directly proportional to the amount of heat put into the weld. Amperage settings are what primarily control the amount of heat produced during the welding process. The amperage output, or wire speed, is the first variable that should be set when adjusting a welder. Other parameters should then be set to create the desired weld bead with the amperage setting being used.
- must be matched to the thickness of the metal being welded. A general rule for a good starting setting is one amp per .025 mm (0.001") of metal thickness. Other variables such as the root gap between the pieces being welded, the position of the weld, and welding technique will also affect the final setting.
- controls both the depth and width of the weld penetration. More current will result in deeper and wider penetration of the weld bead.

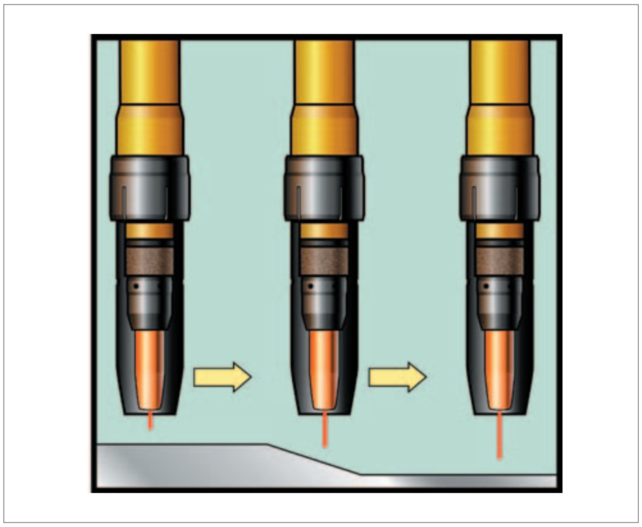
- determines the deposition rate of the filler material. Since the current is controlled by the amount of wire being fed into the weld, higher amperage settings will deposit more filler material than lower amperage settings. Amperage settings will have an effect on the weld bead size. Higher current will result in a larger weld bead size than lower currrent. This may not be readily visible since higher currents increase penetration and more of the weld bead may be penetrated into the base metal making the bead look smaller on the top.



B-5 This illustration shows the difference in arc length and width for higher (left) and lower (right) voltage settings.

The voltage output of a typical GMA (MIG) welder:

- remains constant once it is set. GMA (MIG) welders typically use constant voltage power sources. The exception to this is synergic welding machines. A synergic welding machine is computer controlled. These machines may be referred to as single knob machines. Typically only the wire speed or current is set by the technician. A micro-processsor controller inside the machine automatically adjusts other parameters, including voltage, to achieve a good quality weld. This adjustment is done on a continual basis as the weld is being made.
- controls the arc length. The voltage is what controls the rate at which the electrode wire melts, or how fast it burns. The faster the wire melts, the longer the arc between the electrode wire and the base metal. Since the arc is triangular in shape, more voltage or arc length, will also produce a wider arc at the base metal.
- controls both the height and width of the weld bead.
- must be matched to the amperage setting being used. Increasing the amperage, or wire speed, may require an increase in voltage to match the electrode melting rate to the electrode feed rate. Too much voltage for a given amperage may cause the electrode wire to melt back faster than it is being fed and fuse into the contact tip. Too little may cause stubbing of the wire into the weld puddle, as the wire is being fed faster than it can melt.
- is one of the main factors for determining heat input into the metal. Remember that the heat input into the base metal is a function of voltage and amperage. Since the amperage can only be increased so much for a given voltage setting without resulting in electrode stubbing, the voltage setting may sometimes be referred to as the setting that controls the heat of the weld.



B-6 As stick-out increases, resistance increases and the amperage output of the welding machine decreases.

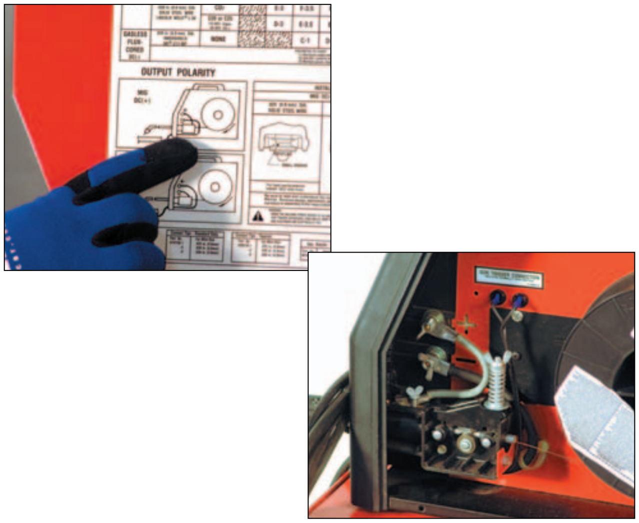
Resistance in the welding circuit is:

- important because any changes in resistance will result in a change in the amperage output of the welder.
- affected by the amount of electrode extension, which may be called stick out. Stick-out is the distance from the welding gun tip to the base metal, or how long the wire is from the contact tip to the base metal. Increasing stick-out increases the resistance in the circuit. Decreasing stick-out results in less resistance.

B-7 These are examples of 115 volt GMA (MIG) welding machines that are commonly used for collision repairs.

GMA (MIG) welders:

- are plugged into an AC power supply.
- convert AC to DC in the welding machine. The incoming or primary alternating current is converted into a direct current, secondary output that is used to make the weld.
- can be set to reverse or straight polarity.



B-8 This GMA (MIG) welding machine is set up for reverse polarity, which is most often used for collision repairs.

Reverse polarity (DC reverse) is:

- when the electrode is positive and the workpiece is negative. Current flows from the workpiece to the electrode.
- called direct current electrode positive (DCEP) by the AWS.

Reverse polarity with solid wire is used most often for collision repair, because it provides:

- the best fusion, leaving less weld on the surface to grind off.
- a more stable arc.

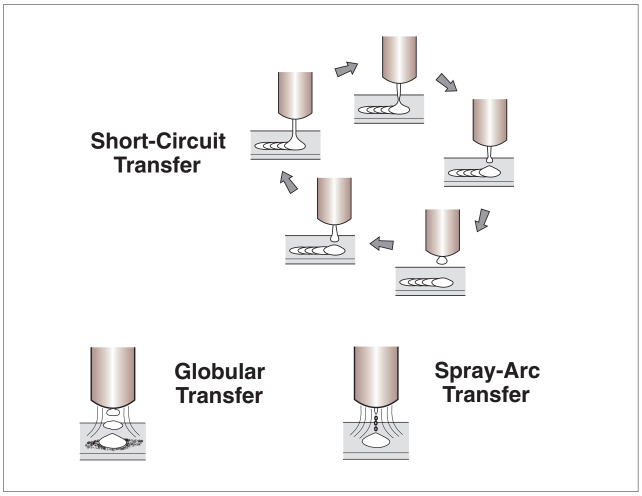
B-9 Straight polarity, or DC straight, is used when welding with flux-cored welding wire.

Straight polarity (DC straight):

- is when the electrode is negative.
- is when the workpiece (through the work clamp) is positive.
- is called direct current electrode negative (DCEN) by the AWS.
- applies most of the heat to the workpiece rather than to the electrode. This is because the current flows from the electrode to the workpiece.
- is recommended for all positions when welding with flux-cored wire.

Methods of changing the polarity of a welding machine include:

- using a toggle switch, if the machine is equipped.
- reversing the cable power supply hookups.



B-10 There are three main types of transfer used for GMA (MIG) welding steel.

When the electrode is fed through the welding gun and makes contact with the metal, the arc is struck. This arc creats heat that melts the electrode wire. The depositing of this molten filler wire into the weld puddle is called transfer. The electrode is transferred to the workpiece using any of three methods. The methods include:

- short-circuit transfer.
- globular transfer.
- spray-arc transfer.

GMA (MIG) WELDING TRANSFER METHODS

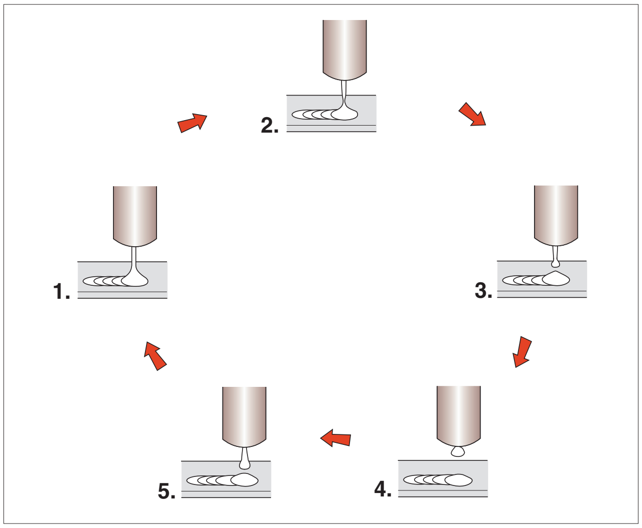
Refer to screen B-11v of your CD-ROM for a video on the different types of GMA (MIG) welding transfer methods.

B-12 Short-circuit transfer is the preferred method for welding on sheet metal.

Short-circuit transfer:

- is the preferred transfer method for welding on sheet metal.
- uses very thin welding wire.
- requires lower current when compared to globular and spray transfer.
- requires lower voltage when compared to globular and spray transfer.

All of these combined means that less heat is generated and the metal stays cooler with short-circuit transfer.



B-13 These illustrations show the short-circuit transfer sequence that can occur at a rate of up to 230 times per second during welding.

Just as the name implies, the electrode touches, or short circuits, the metal. There is a continuing sequence:

1. The wire touches or "short circuits" the base metal.
2. The wire begins to break off.
3. The wire separates, transferring metal to the weld puddle, and an arc is ignited between the end of the electrode wire and the base metal.
4. The heat of the arc heats and flattens the weld puddle and the end of the electrode wire.
5. The wire speed overcomes the heat of the arc and the wire contacts the base metal, short circuiting and turning off the arc, starting the process over.

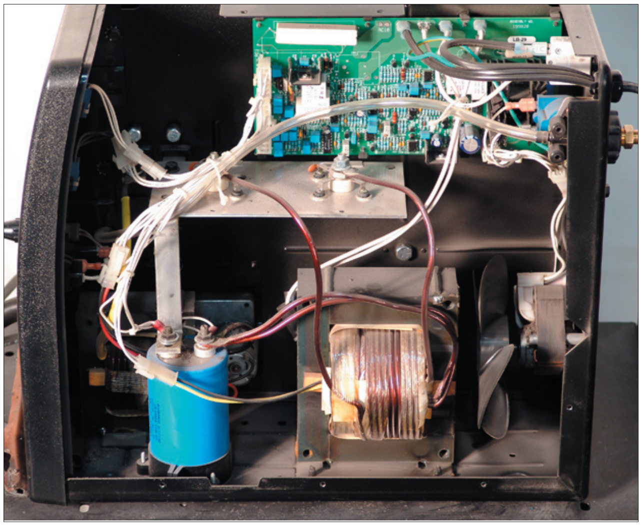
During welding, this short-circuit sequence occurs between 90–230 times per second using 0.6 mm (.023") wire.

Topic C. GMA (MIG) Welding Equipment

C-1 GMA (MIG) welders all have the same basic parts regardless of their type or size.

Regardless of the type of GMA (MIG) welder used, the basic parts are the same. Each type will have a:

- power source.
- spool of electrode wire.
- wire feeder.
- supply of shielding gas.
- regulator/flow meter.
- welding gun at the end of the cable.
- work clamp at the end of a cable.



C-2 The transformer and electronic parts that make up the welding machine power source can be seen when the cover is removed.

Gauge	Metal Thickness		Required Amps (1 Amp/.001 Thickness)
	mm	Inches	
8	4.2	.164	164
10	3.4	.135	135
12	2.7	.105	105
14	1.9	.075	75
16	1.5	.060	60
18	1.2	.048	48
20	0.9	.036	36
22	0.8	.030	30
24	0.6	.024	24

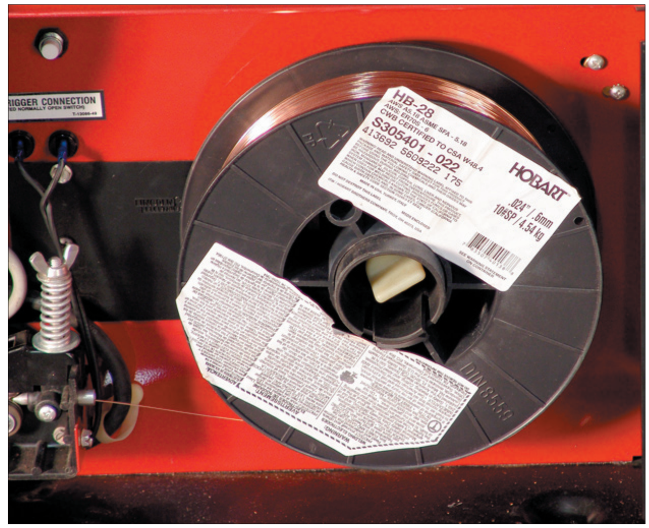
C-3 This chart can be used to determine the required amperage for welding different thicknesses of metal.

Collision repair GMA (MIG) welders typically operate on either 220 or 110 volts, AC. 220 and 110 are common terms used to describe the available voltage delivered from a power company. Actual voltages will be in a range from 220–240 and 110–120, depending on a number of variables. The power source is the electronics in the welding machine that convert the incoming AC power supply to the DC output that is used for welding. Every machine has a rated amperage and duty cycle. The thickness of the metal being welded determines how much amperage is required. Generally, one amp is required for every .025 mm (.001") of metal thickness. The power source used must be capable of producing the amperage needed for the material being welded. The power supply to the welder must also deliver sufficient current and voltage to the power source for the output voltage and amperage required. Inadequate wiring to electrical outlets can result in a voltage drop and insufficient current at the outlet. If the incoming power supply is insufficient for the weld being made, the output welding current and voltage will also be insufficient.

DETERMINING REQUIRED AMPERAGE

Select the Activity icon on screen C-3 of your CD-ROM for an interactive exercise on determining amperage requirements.

C-4 The duty cycle of the welding machine is typically listed on the front of the machine.



C-5 The label on this spool of electrode wire has a wealth of information, including the size of the wire and the AWS code for the wire type.

Duty cycle is:

- how many minutes out of ten a machine can safely operate continuously at a rated amperage.
- listed as a percentage.
- normally posted on the machine and in the instruction manual.
- different if the welding machine is being operated at a different amperage than the duty cycle is rated at. The duty cycle is lower if the machine is operated at higher levels than the rated amperage, and higher if the machine is operated at lower levels than the rated amperage that the duty cycle was calculated at.

For example, a 130-amp machine rated at 40% duty cycle at 90 amps, can operate:

- four out of ten minutes continuously at 90 amps.
- less than four out of ten minutes if operated at more than 90 amps.
- longer than four out of ten minutes if operated at less than 90 amps.

Rated amperage is not always the maximum output of the welding machine. Welding machines that are operated beyond their duty cycle will overheat and may produce poor quality welds.

The electrode is a bare metal wire, wound on a spool and fed through a contact tip at the end of the welding gun. The wire may be coated with copper to increase conductivity and provide corrosion protection. Electrode wire is identified by an American Welding Society (AWS) code. AWS ER70S 6 is recommended for most collision repair applications. Using "ER70S-6" as an example:

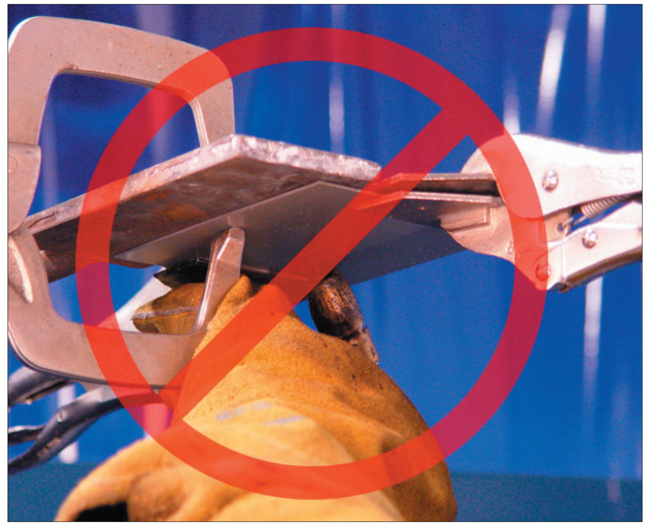
ER Electrode rod
70 Tensile strength of at least 70,000 psi
S Solid wire electrode
6 Chemical makeup of wire and ability to keep oxygen out of the weld (weld deoxidizers generally include manganese and silicon)

C-6 AWS ER70S-3 electrode wire is being used for this full frame sectioning procedure.

Electrode wires for steel vary with the amount of deoxidizers added. This is represented by the last digit.

AWS ER70S-3:

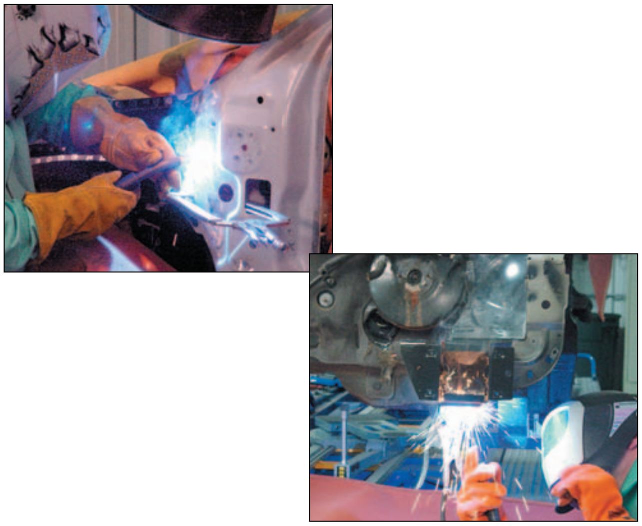
- contains a relatively low percentage of deoxidizers compared to other electrode wires.
- may produce welds of lower tensile and yield strengths under certain conditions.
  - straight CO_2
  - high welding currents
- is recommended by some vehicle makers for full frame sectioning procedures.



C-7 AWS ER70S-5 electrode wire should not be used to make overhead welds, and is not recommended for collision repairs.

AWS ER70S-5:

- contains aluminum, allowing higher heat settings (when using straight CO_2).
- is not good for overhead or vertical welds because the weld puddle stays fluid too long.
- is not recommended for collision repairs.



C-8 AWS ER70S-6 electrode wire works well in all welding positions and is the recommended wire for most collision repairs.

AWS ER70S-6:

- compared to other wires, has the highest amounts of silicon and manganese.
- produces smooth, well-shaped welds. The high silicon content increases the weld puddle fluidity and helps to "wet out" the weld.
- is good for overhead and vertical welds because the weld puddle turns solid quickly.
- is recommended for collision repairs. One of the reasons that ER70S-6 is the recommended wire for most collision repairs is that it has the best performance when welding over scale, rust, and other contaminants. It also has one of the highest weld bead strengths of all the carbon steel GMA (MIG) welding electrode wires.

C-9 AWS ER70S-7 electrode wire is also a recommended wire for collision repairs.

AWS ER70S-7:

- has high amounts of manganese which adds to the weld quality when used on coated steels.
- has the same strength as ER70S-6.
- recommended for collision repairs, but availability may be limited.

C-10 This is an example of a spool of flux-cored electrode wire that may be recommended for specific applications by some vehicle makers.

At least one vehicle maker recommends using flux-cored wire for specific applications. Flux-cored wire:

- has an inner core of flux material. Flux has a similar role to shielding gas. It is designed to protect the weld from contaminants.
- is only available in diameters of 0.8 mm (.030") or larger.
- works well on steels thicker than 20 gauge and is not recommended for steels thinner than 18 gauge.
- usually requires no shielding gas. Shielding gas may be helpful for out-of-position welding as it helps solidify the weld puddle quicker. If a shielding gas is to be used with flux-cored wire, consult the electrode manufacturer for the type of gas to use.
- forms a slag that must be removed after welding. Welds made with flux-cored wire have a slag, similar to an arc weld, that must be chipped or cleaned off after the weld has been made.
- produces more spatter than solid wire.

C-11 The AWS code for flux-cored wire is different from solid electrode wire.

The AWS code for flux-cored wire is different than solid electrode wire. Using AWS E70T-9 as an example:

E	Electrode
7	Tensile strength multiplied by ten-thousand (70,000 psi)
0	Can only be used in flat or horizontal position (1 means wire can be used in all positions)
T	Tubular wire
9	Use and performance of the electrode wire

The last digit can be any number between 1 and 11, or the letters “G” or “GS,” depending on recommended:

- shielding gas.
- polarity.
- number of passes for the finished weld.

C-12 MGA Research Corporation performed testing for I-CAR using flux-cored electrode wire.

C-13 This welding machine is having the polarity switched to weld with solid electrode wire.

MGA Research Corporation conducted research for I-CAR on flux-cored electrode. This research confirms that flux-cored electrode:

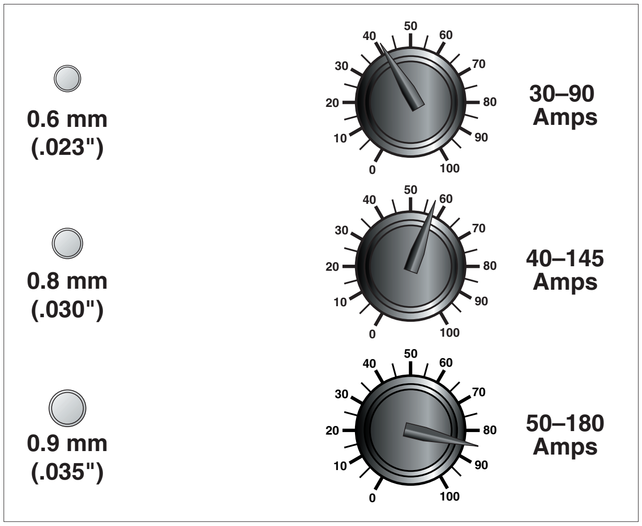
- burns too hot for galvanized metal thinner than 18 gauge.
- is especially suited to welding zinc-coated steel.
- may result in welds of less-than-ideal appearance.
- creates a smoke problem due to the burning flux, especially in the overhead position. Proper ventilation can control this. A welding respirator must be worn.

Based on the results of this study, it is recommended that flux-cored electrode be used only:

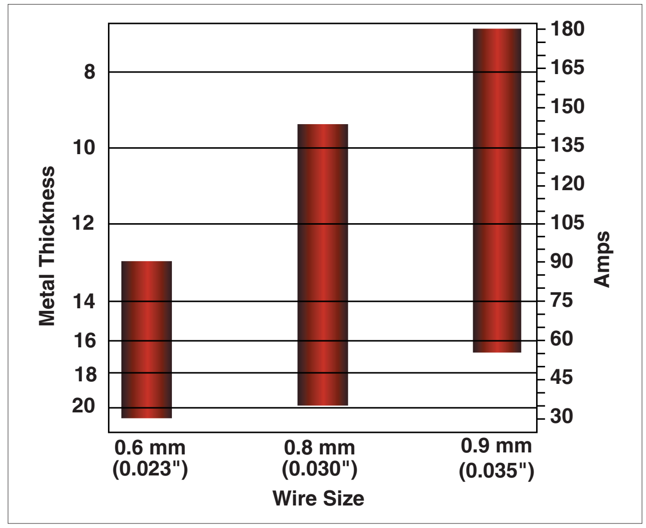
- on 18 gauge or thicker galvanized steel.
- where there is proper ventilation to draw away the excess smoke.
- where there is enough room to chip away the flux after welding.

GMA (MIG) welders that are designed to be plugged into a 110/120-volt power outlet are typically called 115-volt welding machines. 115-volt GMA (MIG) machines may:

- be originally set up for flux-cored electrodes.
- have knurled drive rolls. If converting a GMA (MIG) machine from flux-cored to solid electrode wire, it may be necessary to change the drive rolls.
- require switching the polarity of the machine to weld with solid electrode wires.
- require a conversion kit to weld with solid electrode wires.



C-14 Electrode wire diameter is selected based on the material thickness and amperage requirements.



C-15 This chart shows the amperage range capabilities of different electrode wire diameters.

Electrode wire diameters common for collision repair include:

- 0.6 mm (.023–.025").
- 0.8 mm (.030").
- 0.9 mm (.035").

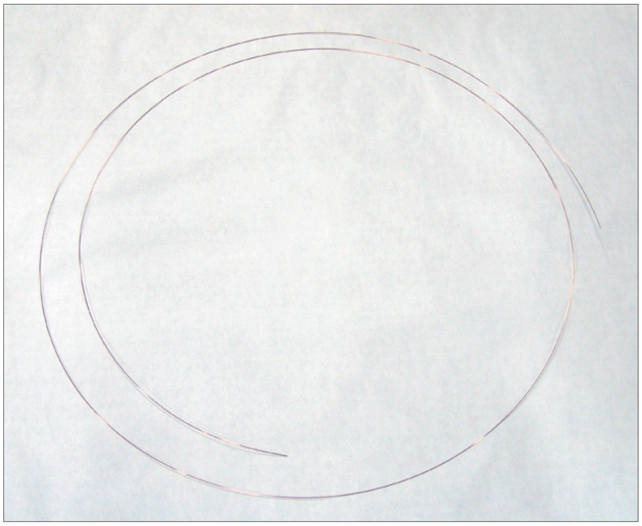
Electrode diameter is selected based on the material thickness and amperage requirements. For example:

- 0.6 mm (.023") wire is recommended when welding in the 30–90 amp range.
- 0.8 mm (.030") wire is recommended when welding in the 40–145 amp range.
- 0.9 mm (.035") wire is recommended when welding in the 75–250 amp range.

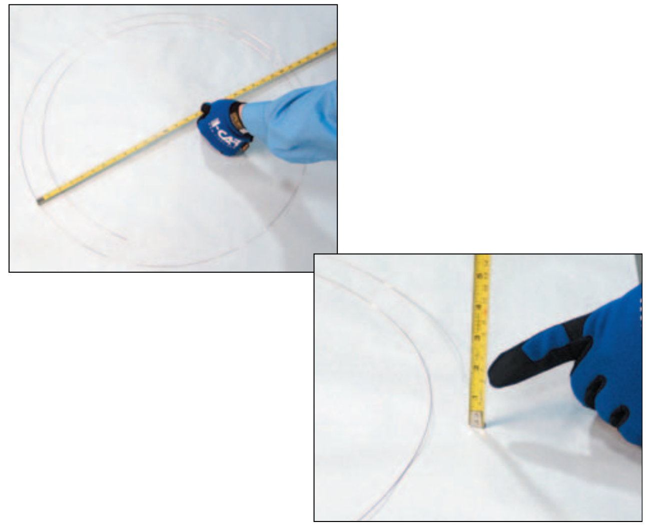
When the amperage range overlaps another diameter wire:

- either diameter can be used.
- select the wire diameter where the amperage to be used while welding is closest to the middle of the amperage range for the wire. This will prevent a change in the type of weld transfer.

Some vehicle makers may have specific recommendations for wire diameter.



C-16 This loop of electrode wire demonstrates the cast and helix of the spool of wire.



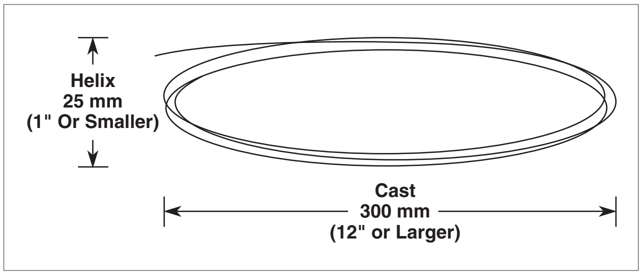
C-17 Both the cast and helix of the electrode wire can be measured with a tape measure.

Checking electrode wire cast and helix is a trouble-shooting step, and does not need to be done whenever setting up a machine. Cast is the curvature of a length of welding wire caused by winding it on the spool. Helix is the pitch of a length of welding wire. A length of wire with no helix, laying on a flat surface, would contact the surface along its entire length. Cast and helix are important because:

- there must be some coil in the wire to allow the wire to touch the contact tip and transfer the current.
- the straighter the wire, the easier it will come off the spool. A larger cast generally means the wire will feed better.
- a larger cast reduces wear on the liner and welding gun assembly.
- a large helix will make the wire tend to wander as it leaves the contact tip. The helix should be small.

Cast and helix describe a length of spooled wire left to uncoil naturally. To check cast and helix:

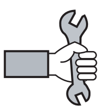
1. Cut off about 300 cm (10') of electrode wire from a spool.
2. Loop the wire by hand, and toss it on the floor.
3. Measure the cast of the wire. The cast is the diameter of the wire loop as it is laying loose on the floor.
4. Measure the helix of the wire. The helix is how high one end of the wire loop is above the floor.



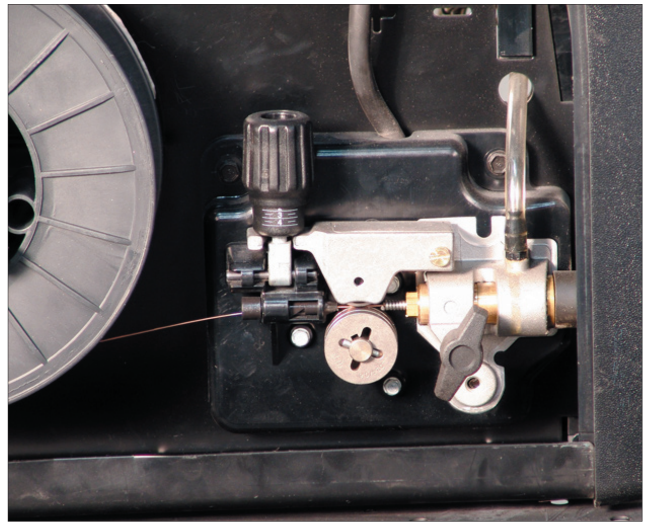
C-18 This illustration shows what cast and helix are, and the AWS recommendations for each on a spool of 0.8 mm (.030") or smaller diameter wire.

Regarding cast and helix for electrode wire:

- AWS requires a 100 mm (4") and larger diameter spool of 0.8 mm (.030") or smaller diameter wire to have a cast of at least 300 mm (12") and a helix of not more than 25 mm (1").
- electrode wire that has improper cast and helix should not be used. It should be returned to the supplier or discarded.



CAST AND HELIX
Select the Demonstration icon found on screen C-18 of your CD-ROM for examples of checking cast and helix.



C-19 This is a typical wire feeder for a GMA (MIG) welding machine.

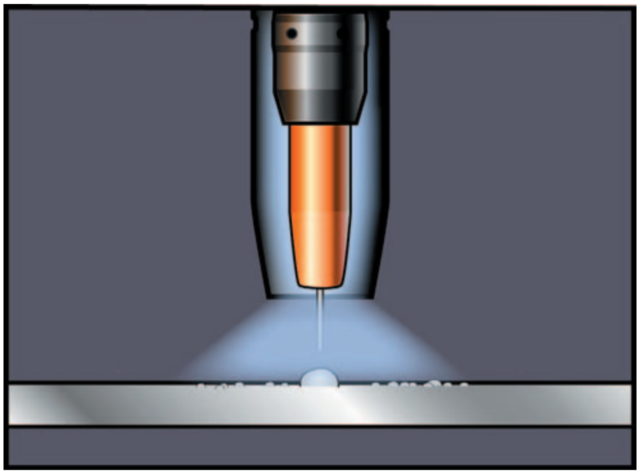
The wire feeder:

- delivers the electrode wire to the arc automatically at a constant speed.
- speed determines the current.
- may have an adjustable burnback control to allow the welding current to stay on for a short time after the feed has stopped, allowing the wire to burn back just enough to be ready for the next arc.

The wire is pulled off the spool by drive rolls that are powered by a drive motor and sent through the cable to the welding gun. The pressure of the drive rolls against the wire has to be correct because too:

- little pressure and the wire will not be pulled through.
- much pressure and the wire will deform and wind into a spiral which can bind as it goes through the contact tip.

The correct dirve roll pressure setting for each wire diameter should be provided with the welding machine.



C-20 This illustration shows how the shielding gas envelopes and protects the molten weld puddle.

Shielding gas:

- protects the weld site from oxygen, nitrogen, and hydrogen which cause holes, or porosity in the weld.
- is stored in a high-pressure cylinder. The cylinder must be fastened securely in an upright position.
- is a factor in managing weld-pool heat.

C-21 The shielding gas is stored separately from the welding machine in an external cylinder.

There are two types of shielding gas:

- active, which combines with the arc to contribute to the quality of the weld. Active shielding gases typically produce a hotter weld with more penetration than inert gases. However, they produce a harsher arc and create a less smooth weld with more spatter and sparks. This also may result in globular transfer, due to the higher voltage and amperage values, and make out-of-position welding difficult. CO_2, or carbon dioxide is a common example of an active shielding gas.
- inert, which protects, but does not combine with the arc. Argon and helium are common examples of inactive shielding gas.

Shielding gas can be pure or mixed in various combinations.

C-22 The type of shielding gas to use depends on the type of metal being welded.

C-23 75% argon/25% CO_2 shielding gas produces the best welds for collision repairs.

The type of shielding gas used depends on the metal being welded. For example:

- a mix of 75% argon/25% CO_2 is used for most collision repairs on mild and high-strength steels.
- pure argon is used when welding aluminum or when using silicon bronze wire. Silicon bronze wire is used for some exterior joints, such as sail panels.
- there are tri-mix shielding gases available that can be used when welding steel. A common tri-mix gas is 90% helium–7.5% argon–2.5% CO_2. This mix is typically used when welding stainless steel with the short circuit transfer process.

75% argon/25% CO_2:

- improves mechanical weld strength properties.
  - yield strength
  - tensile strength
- produces a smooth and stable arc with less spatter than pure CO_2.
- produces a small weld puddle that sets up quickly. This is an advantage when welding out of position.

C-24 Pure CO_2 shielding gas increases weld penetration and is not recommended for collision repairs.

Pure CO_2 reduces the amperage required and provides deep weld penetration. Disadvantages of pure CO_2 are that it:

- penetrates too deeply on thin-gauge metal.
- makes an unstable arc and increases spatter.

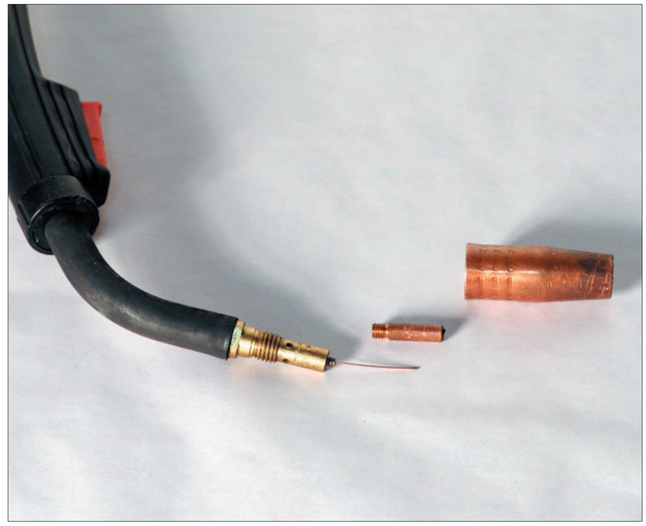
Because it produces a much hotter weld bead, and therefore a larger heat affected zone, pure CO_2 is not recommended for welding HSS.

C-25 This regulator is designed for use on a 75% argon/25% CO_2 shielding gas cylinder.

A regulator is attached to the gas cylinder. Regulators:

- reduce cylinder pressure to working pressure.
- must be matched to the type of shielding gas used.

C-26 *These are examples of different styles of flow meters for measuring the working pressure of the shielding gas.*



C-28 *The contact tip and gas nozzle are removed from this welding gun assembly.*

Flow meters:

- measure flow rate in cubic feet per hour (cfh).
- are generally adjusted to 25–30 cfh for collision repair welding. Shielding gas flow rates may need to be increased when there is a breeze present in the area where welding will be done. Welding stainless steel with tri-mix gas typically requires a higher gas flow rate of about 35 cfh. Many welding machines will have gas type and flow rate recommendations included in the set up chart under the lid.

Some welders may have a cylinder equipped with a non-adjustable orifice, rather than a regulator.

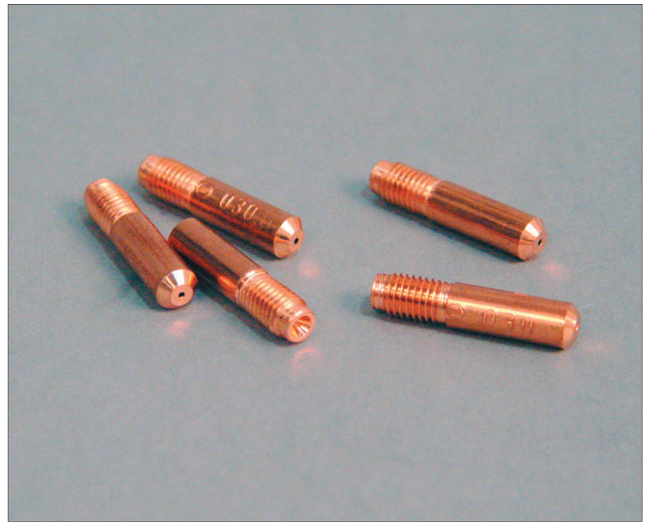
ATTACHING THE SHIELDING GAS CYLINDER
Refer to screen C-27v of your CD-ROM for a video on how to properly attach a shielding gas cylinder.

The gas cylinder cap should never be removed unless the cylinder is secured in an upright position. Gas cylinders can only be transported in an upright position with the cylinder cap on.

A welding gun consists of a:

- gun liner.
- handle.
- neck.
- nozzle.
- contact tip.
- trigger.

C-29 Welding gun cable liners come in a variety of sizes and should be matched to the diameter of the electrode wire being used.



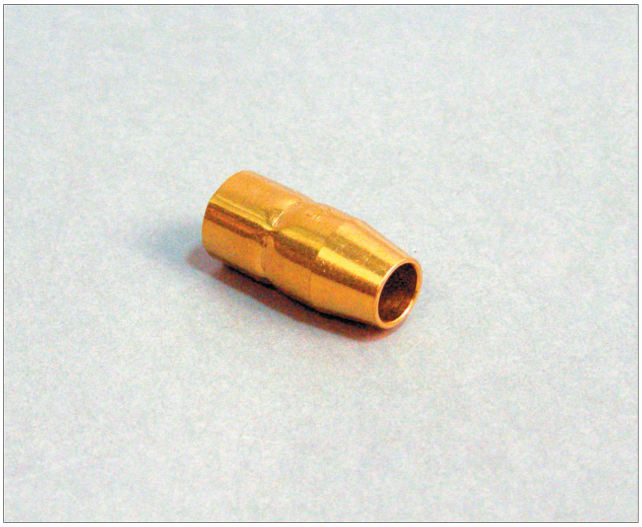
C-30 Contact tips must be matched to the diameter of the electrode wire being used.

The welding gun liner:

- guides the electrode wire from the drive rolls to the contact tip.
- inside diameter (I.D.) must be matched to the diameter of the electrode wire used.
- must be properly installed to provide proper feeding.
- should be cleaned to remove metal particles. Copper-coated wire tends to leave copper particles that can build up and affect wire feeding. Liners can be cleaned by blowing compressed air through them from both ends.

The contact tip or tube:

- transfers current to the electrode wire. The electrode wire does not carry any current until it goes through the contact tip or tube.
- is usually made of copper or copper alloy.
- inside diameter must match the diameter of the electrode wire used. This is usually stamped on the tip.
- must be changed when the hole diameter becomes enlarged with use. This reduces current transfer efficiency.



C-31 This is a typical shielding gas nozzle for a GMA (MIG) welder using the short circuit transfer method.

Shielding gas nozzles:

- protect the contact tip.
- direct the shielding gas to the weld area.
- must be kept clean. A dirty nozzle can cause an inadequate flow of shielding gas to the weld puddle and result in holes (porosity) in the weld.
- have an insulator, where they attach to the welding gun, to prevent short circuiting the machine to the workpiece.
- can have an anti-spatter compound applied to reduce spatter buildup between the nozzle and contact tip.
- may have to be larger diameter to weld at higher amperage settings.

C-32 Shielding gas nozzles are available in a variety of shapes and sizes.

Shielding gas nozzles can be:

- tapered. Tapered nozzles are typically used with short-circuit transfer.
- straight. Straight nozzles are typically used when a greater flow of shielding gas is required, such as when higher voltage and amperage settings are used for globular or spray transfer.
- slotted. These are generally used for maintaining a set distance from the workpiece or for GMA (MIG) spot welds.

The type and size of the nozzle should be appropriate for the type of welding application.

C-33 This work clamp completes the electrical circuit for the output of the welding machine, but is not the electrical ground for the input side.

The work clamp:

- completes the electrical circuit.
- must be tightly attached close to the weld site, directly to the workpiece if possible.
- must be large enough to carry the current load without overheating.
- is not the electrical ground for the welder. The ground connection is made in the third wire of the AC power cord and goes from the machine case to the building ground.

WELDING MACHINE MAINTENANCE
Refer to screen C-34v of your CD-ROM for a video on performing routine maintenance on a GMA (MIG) welding machine.

Topic D. Setting Up A GMA (MIG) Welder

D-1 The instructions from the equipment maker are your best source of information when setting up a welding machine.

When first using a GMA (MIG) welder:

- read the equipment maker's instructions for proper use.
- become familiar with the settings.
- learn how to connect the cables and load the wire spools.

D-2 Be sure you know how to adjust the machine settings and change parts that require maintenance before welding.

When first using a GMA (MIG) welder, learn how to:

- adjust the wire feeder and drive rolls for proper feeding of the electrode wire.
- change the contact tip, insulator, and liner.
- set the voltage and follow the equipment maker's recommendations for different types and thicknesses of metal.
- set the wire speed to achieve the correct output amperage for different types and thicknesses of metal.
- set the shielding gas flow rate.

SETTING UP A GMA (MIG) WELDER
Refer to screen D-3v of your CD-ROM for a video on setting up a GMA (MIG) welding machine.

Topic E. Surface Preparation

E-1 The immediate weld zone is being stripped of all paint and coatings before welding.

Surfaces to be welded must be clean. Cleaning the surface may include:

- cleaning with wax and grease remover. Wax and grease removers are flammable. DO NOT store wax and grease remover or cleaning cloths in the welding or repair area.
- removing the finish, undercoating, corrosion, dirt, oil, and grease. Do not remove galvanized coatings.
- using a plastic woven pad, sander, putty knife, media blaster, or wire brush. A wire brush should only be used on non-galvanized metal.
- using a grinder only when absolutely necessary. If a grinder is used, do not reduce the thickness of the metal.

PANEL PREPARATION TOOLS AND PROCEDURES
Select the Demonstration icon found on screen E-1 of your CD-ROM for examples of panel preparation tools.

E-2 There are many different types of weld-through primer available.

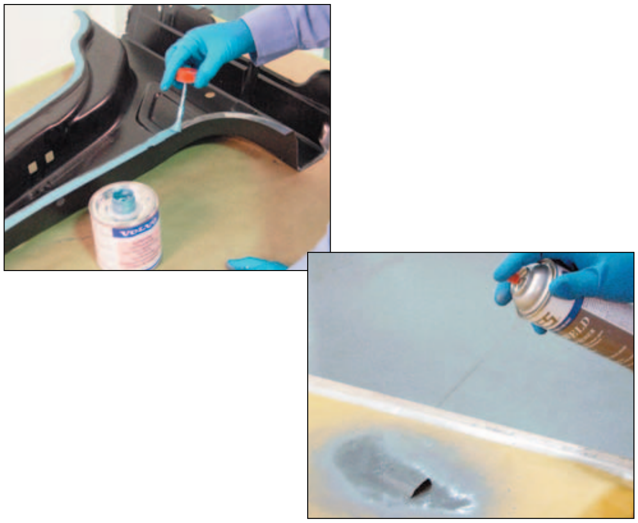
E-3 A spot blaster works good for removing the weld-through primer from the immediate weld zone of plug weld holes.

Apply weld-through primer to any bare-metal mating surfaces where the galvanized coating was removed or where there was no galvanized coating. Weld-through primer:

- is typically applied to the mating surfaces of overlapping weld joints where a galvanized coating is not present or has been removed. Weld-through primer does not have to be applied to galvanized metals where the galvanized coating intact. Galvanized coating thickness can be checked, or verified, with an electronic thickness gauge.
- is available as a spray and brush-on.
- is generally rich in zinc, which is more chemically active than steel. Corroding zinc forms zinc oxide which protects the steel. This is called sacrificial corrosion.

Weld-through primer:

- require removal from the weld zone before welding. Typically, it is recommended that the weld-through primer be removed from the direct weld zone before welding the joint. This is done to ensure that contaminants, that may cause porosity, are not introduced into the weld.
- must have any excess removed after welding to allow for the proper adhesion of other coatings. Mask to prevent overspray.
- may not be recommended by the vehicle maker.



E-4 Weld-through primers may be brush-on or aerosol.

I-CAR conducted a test of weld-through primers. The test concluded that weld-through primer is effective for controlling corrosion on mating surfaces that are not galvanized. I CAR recommends applying weld-through primer to mating surfaces where there is no zinc coating or where the zinc coating has been removed.

Weld-through primers:

- were either aerosol or brush-on products. There was no performance difference between the product types.
- protected against severe corrosion on ungalvanized mating surfaces, and tested well on most samples.
- allowed various amounts of corrosion on the mating surfaces around the separated GMA (MIG) plug welds. The amount of corrosion depended on the type of primer used on the rest of the sample.

While I-CAR and several vehicle makers recommend the use of weld-through coatings, the paint makers may not. Failure to follow the recommendations of the paint maker may void the paint maker's warranty.

WELD-THROUGH PRIMER SAMPLES
Select the Demonstration icon found on screen E-4 of your CD-ROM for examples of weld-through primer.

Topic F. Welding Technique

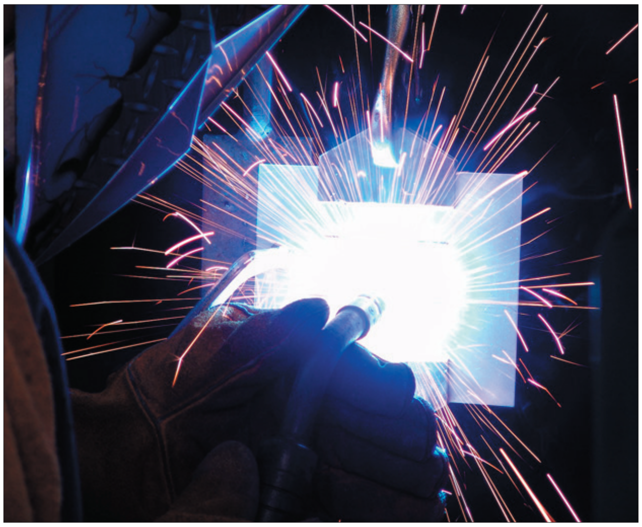
F-1 The proper balance between the voltage and amperage, or wire speed, settings is critical to making a quality weld.

GMA (MIG) welding depends on a number of operator variables, all of which must work together to make a good weld. These variables include:

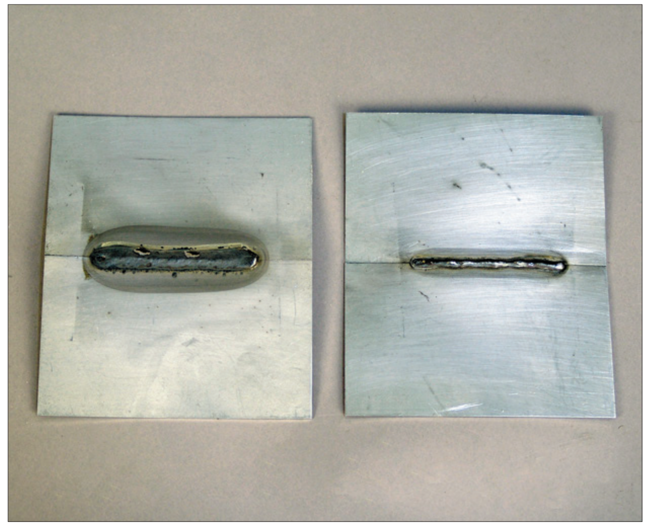
- travel speed.
- welding gun angle. This includes both the travel angle and work angle.
- welding gun direction, or whether the weld is being pushed or pulled.
- electrode stick-out.
- joint fit-up.
- amperage and voltage setting balance.

The following clothing, equipment, and practices are recommended to protect technicians when welding:

- NIOSH-approved welding respirator
- Welding helmet
- Safety glasses
- Protective clothing
- Leather gloves, sleeves, and apron
- Ear protection
- Leather boots
- Clothing and shoes free of flammables
- No matches or lighters in pockets
- Fire extinguisher nearby



F-2 The travel speed, or how fast the welding gun is moved along the joint, has an effect on the weld being made.



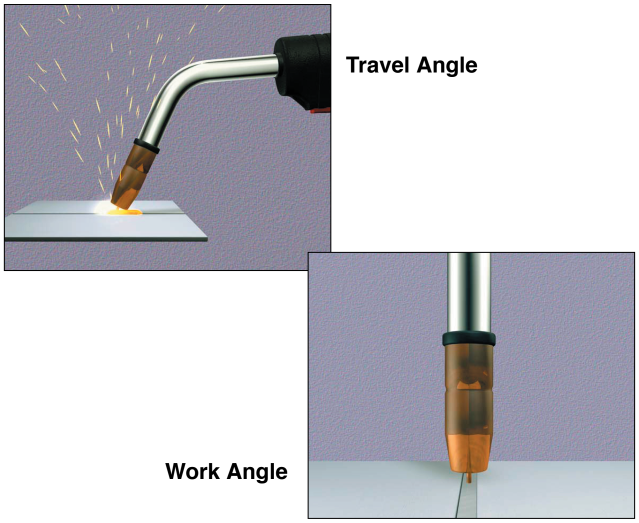
F-3 These welds show the difference in weld bead shape and heat input between a fast and slow travel speed, with all other parameters being the same.

Travel speed:

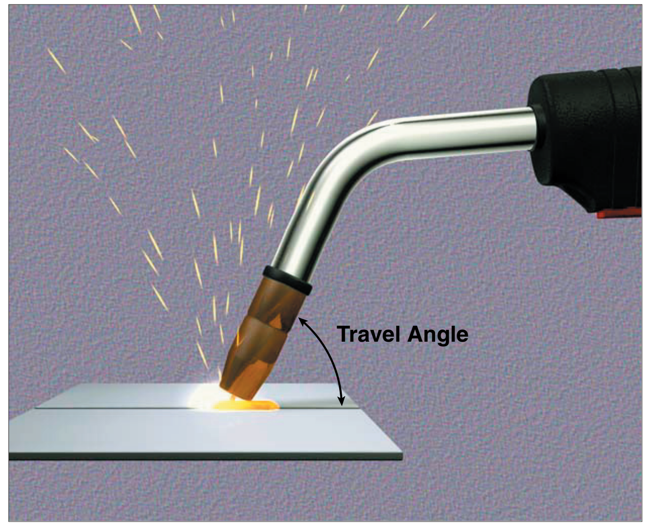
- is how fast the technician moves the welding gun along the weld joint. Travel speed is a welding variable that is controlled by the technician.
- will depend on the thickness of the material being welded, the type of joint, and the position the weld is being made in. The correct travel speed to use will be dependent on a number of factors that are not controlled by the technician.
- affects the weld bead penetration, size, and shape.

A travel speed that is too:

- slow, with all other parameters being correct, can cause either poor weld bead penetration or burnthrough. Whether or not bead penetration is poor or excessive and results in burnthrough depends on a number of variables. These include the degree of the travel speed problem and thickness of material being welded. Too slow a travel speed can result in poor penetration because the arc becomes concentrated on top of the weld puddle instead of on the base metal ahead of the puddle. The weld bead will have more deposited weld metal but very limited fusion and penetration. This is more likely when welding on thicker gauge metal, such as a full frame. Thinner gauge sheet metal is more susceptible to burnthrough with travel speeds that are too slow. Excesssively slow travel speeds can result in burnthrough even on thicker gauge metal. Too slow of a travel speed will also result in a large, flat, and wide weld bead.
- fast, with all other parameters being correct, will result in poor weld bead penetration and fusion. This is because of a reduction in heat input due to the arc not staying in one place long enough to create complete melting of the base metal. The metal only melts near the surface so the bead cannot penetrate the base metal. This also results in a taller narrower bead, due to a lack of wetting out of the weld puddle, and a reduction in the amount of weld metal deposited.



F-4 Welding gun angle is viewed from two different planes, including the travel angle and the work angle.



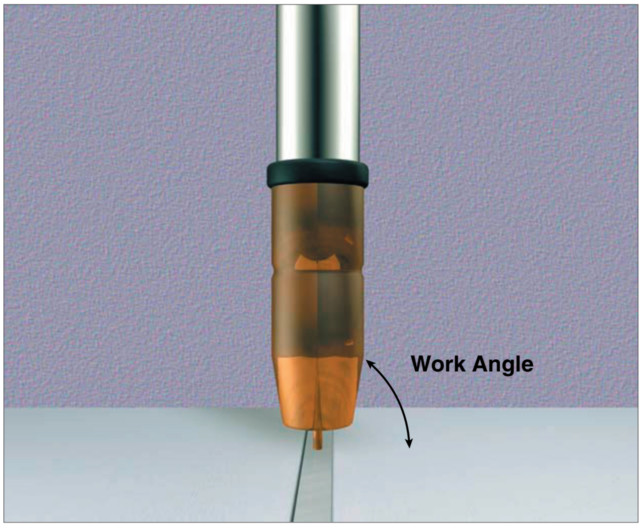
F-5 Travel angle is the angle between the gas nozzle and the workpiece in relation to the direction of gun travel.

Welding gun angle:

- affects where the heat is directed to the joint.
- includes the travel angle, which is the angle the welding gun travels along a joint.
- includes the work angle, which is the angle the welding gun is directed towards the joint.
- varies depending on the type of joint being welded.

Welding gun travel angle:

- is the angle that the welding gun is pointed either towards or away from the direction of gun travel. The gun is pointed towards the direction of travel for the push technique, and away for the pull technique.
- affects weld bead penetration, spatter, shielding gas coverage, and arc stability. Travel angles that are too high, typically over 30° from perpendicular, may cause poor penetration, excessive spatter, poor shielding gas coverage, and general arc instability. Too much angle on the welding gun directs the heat and shielding gas away from the weld puddle which can cause a lack of penetration and spatter. It also effectively increases the stick-out length which if too severe can cause the arc to wander and become unstable.



F-6 Work angle affects where the electrode wire is aimed at the joint.

F-7 The pull technique aims the electrode wire back towards the weld puddle as the gun is dragged away from it.

Work angle:

- can be described as the angle that the plane of the welding gun has in relation to the joint being welded. It affects where the electrode wire is aimed at the joint.
- affects weld bead penetration and shape, shielding gas coverage, and weld undercut. Incorrect work angles may lead to poor penetration, undercut, poor shielding gas coverage, and a poorly shaped weld bead.

The work angle must be correct for the joint being welded. The electrode wire must be pointed where the weld bead is to be placed.

Welding gun direction refers to either the:

- pull technique.
- push technique.

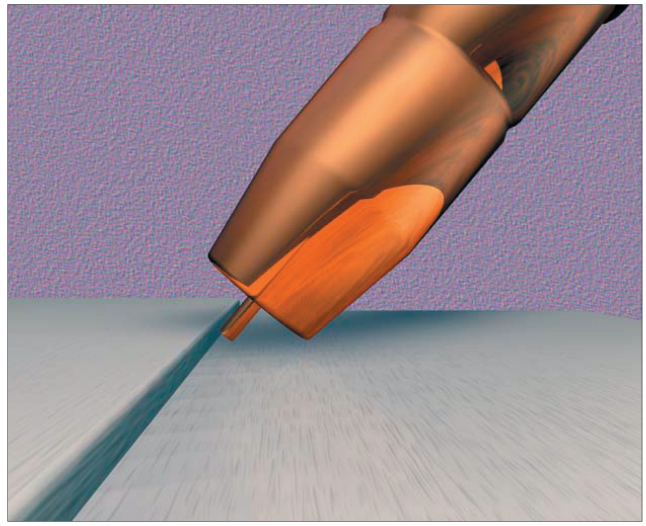
The pull technique:

- is when the welding gun is pointed at and dragged away from the weld.
- may be called drag or backhand with a drag in AWS manuals.
- produces a higher, narrower bead.
- increases penetration. This is because the pull technique directs the arc at the preheated base metal.
- positions the welding gun at a 70° travel angle to the workpiece.

F-8 The push technique aims the electrode wire away from the weld puddle as the gun is pushed away from it.

The push technique:

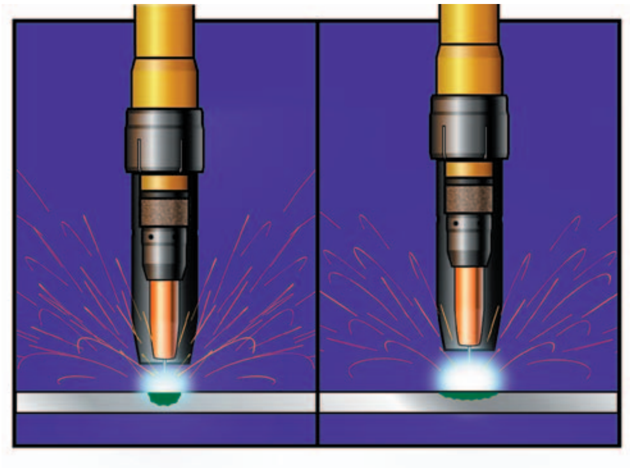
- is when the welding gun is pointed and pushed away from the weld.
- may be called forehand or lead angle in AWS manuals.
- produces a flatter, wider bead.
- decreases penetration when all other parameters are kept the same. This is because the arc and heat are directed away from the weld puddle and the preheated base metal.
- positions the welding gun at a 70° travel angle to the workpiece.



F-9 Stick-out is a variable that can be controlled by the technician.

Stick-out:

- is the distance from the end of the contact tip to the end of the electrode wire.
- may also be called contact tip height.
- should remain constant along the weld pass.
- for 0.6 mm (.023") wire should be 6–13 mm (¼–½").
- for larger diameter wire, such as 0.9 mm (.035"), should be 13–25 mm (½–1").

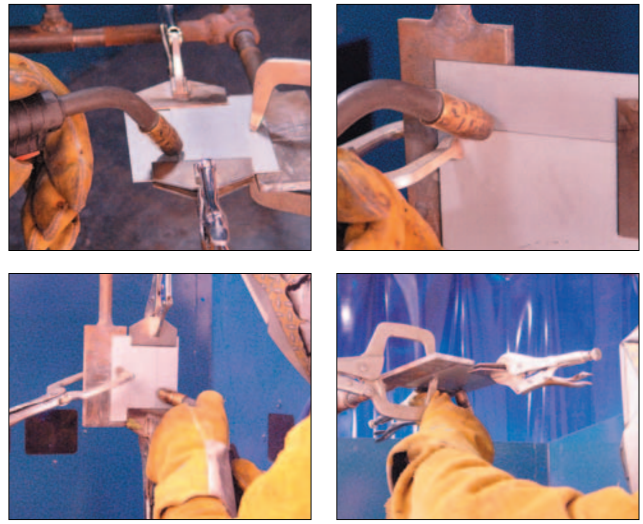


F-10 Proper stick-out is important because it affects weld bead penetration.

Stick-out affects:

- the amperage output of the welder. Changes in stick-out result in changes in resistance, which causes the amperage output to change. Shorter stick-out will have less resistance and therefore more amperage, when compared to longer stickout.
- weld penetration. Because changing stick-out changes amperage output, shortening stickout will increase penetration. Lengthing stickout will decrease penetration.

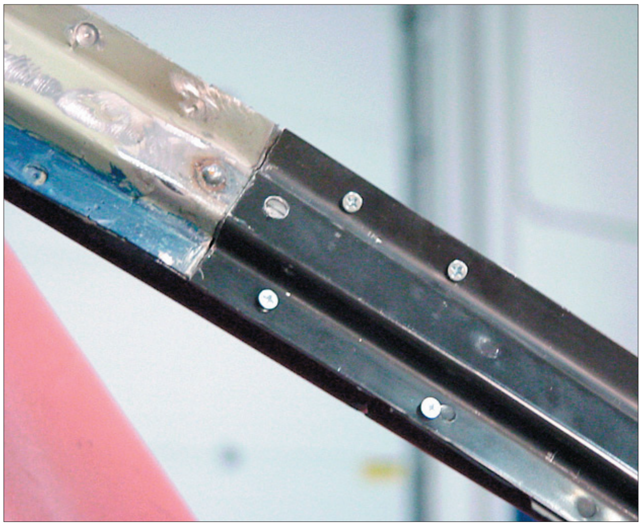
Because changing stickout changes amperage, and weld penetration, it should be kept consistent for the entire length of a weld.



F-11 Welding may be required in any one of four positions when doing collision repairs.

GMA (MIG) welds can be performed in any position. The position depends on the location of the repair. Welding in the:

- flat position is usually easiest. Try to position the weld flat as often as possible.
- horizontal position is usually easiest if the welding gun is angled upward.
- vertical position is usually easiest if the welding gun is angled upward and pulled down on thin-gauge metal. This helps prevent too much penetration and helps manage the weld puddle.
- overhead position requires lower heat settings than other positions. Correct machine settings and stick-out can reduce spatter falling into the shielding gas nozzle or on the operator.

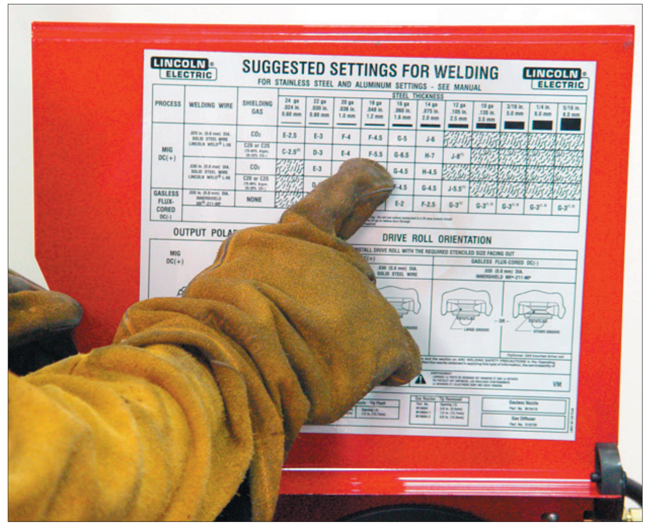


F-12 This joint is using both screws and tack welds to hold the parts in position.

Proper joint fit-up requires:

- the parts to fit tightly together.
- proper root gap on some joints.
- using clamps, screws, or tack welds to hold parts in position. If screws are used, they must be removed and holes filled after welding.

Topic G. Tuning A GMA (MIG) Welding Machine



G-1 The chart inside the welding machine lid can be used to set the voltage and wire speed before making test welds.

Amperage and wire feed speed are the same setting on most GMA (MIG) welding machines. The wire feed speed must be balanced with the voltage for the proper "heat" setting. To tune the machine:

1. Set the machine to the recommended voltage setting.
2. Set the wire speed at the mid-range position.
3. Make a practice weld and listen for a steady crackling sound or look for a steady arc.

Many welding machines will have a chart included that gives recommended voltage and amperage settings for the type and thickness of metal being welded and the size of wire being used.

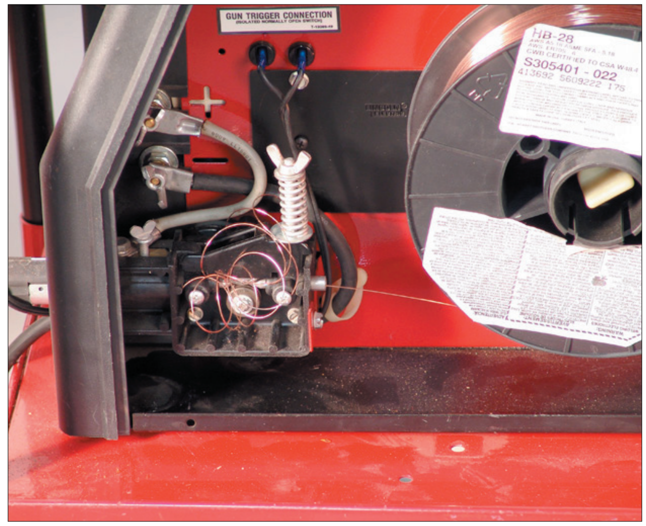
G-2 Test welds should be made on the same type and thickness of metal that will be welded, and in the same position that will be welded on the vehicle.

While tuning the machine, be sure to:

- use practice metal the same thickness as the metal to be welded.
- keep the proper stick-out for the wire diameter being used.
- move the welding gun across the metal. Do not keep it in one spot.
- test the strength of the sample weld.

TUNING A GMA (MIG) WELDING MACHINE

Refer to screen G-3v of your CD-ROM for a video on what to look and for when tuning a GMA (MIG) welding machine.

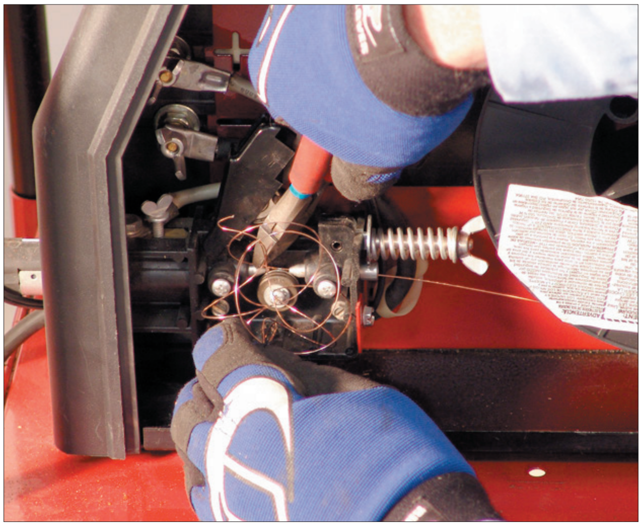


G-4 This bird nest was a combined result of a plugged contact tip and excessive drive roll tension.

Bird nesting is one problem that can occur if the welder is not set up properly. If no wire comes out of the contact tip when the trigger is pulled and the wire feed keeps on rolling wire, a tangled mess at the wire feeder can occur.

Bird nesting can be caused by:

- too much tension on the drive rolls or wire spool. If the tension on the wire spool is excessive it will require excessive tension on the drive rolls to feed the wire off of the spool. During welding situations may arise where the wire is temporarily stopped from coming out of the contact tip. Excessive pressure on the drive rolls can cause the wire to bird nest in these instances.
- tangled wire.
- a clogged gun liner, or a contact tip that is too small for the wire size.



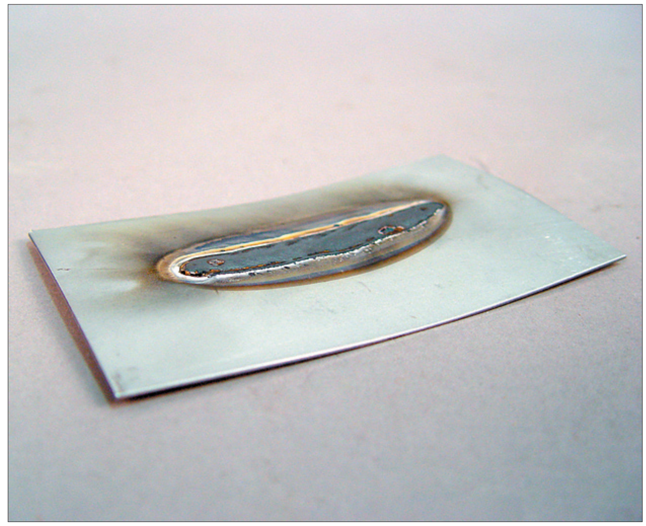
G-5 Turn off and unplug the welding machine before attempting to fix a bird nest.

To fix this problem:

- turn off the welder.
- remove and discard any wire between the contact tip down to the drive rolls.
- re-load the wire into the welding gun liner.

BIRD NESTING
Refer to screen G-6v of your CD-ROM for a video on what a bird nest is and how to fix one.

Topic H. Heat Management



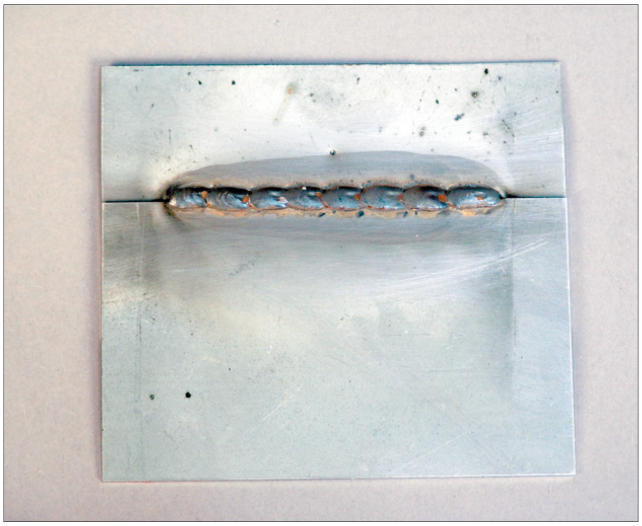
H-1 This coupon is severely distorted from excessive heat input during welding.

Heat management is a combination of the:

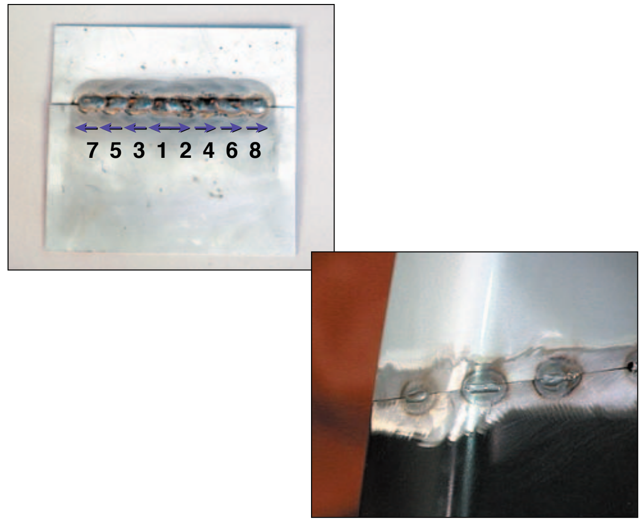
- voltage and amperage, or heat settings that the weld is made at. These settings control the amount of heat put into the base metal.
- total time that a weld is continuously made, and the time allowed between welds that are made close to each other.
- weld location. Alternating weld locations, so that concurrent welds are not made directly next to each other, will help manage the build up of heat in an area.

Too much heat when making one continuous weld bead distorts and weakens the workpiece. Welding techniques used to manage heat buildup include:

- stitch welds.
- skip welds.
- alternating plug welds.



H-2 This stitch weld was made to reduce distortion of the metal while welding.



H-3 A skip weld can be made in more than one way, either starting in the center of the panel and working out alternately in opposite directions, or randomly and then filling in the spaces.

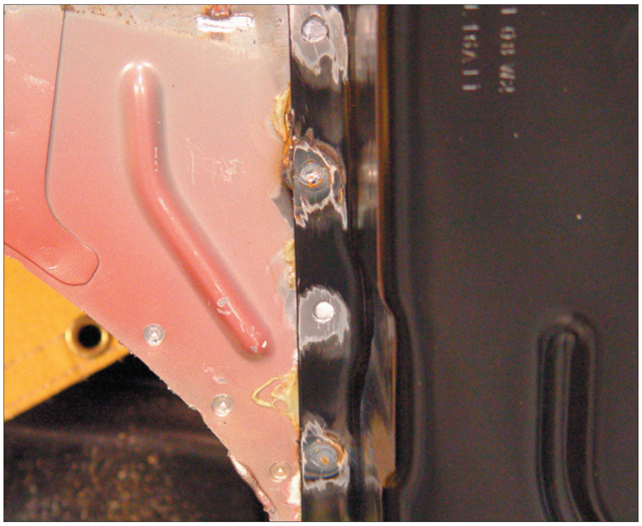
A stitch weld is one technique used to control heating of the base metal. A stitch weld:

- is made by starting and stopping briefly between welds to allow some cooling.
- may be made automatically by some welding machines. Some machines have a stitch weld setting that automatically pulses the arc, and leaves the shielding gas on between pulses.

Manually starting and stopping the machine stops and starts the shielding gas flow which may cause pinholes in the weld.

A skip weld is another heat management technique. A skip weld:

- is made by making 13–19 mm ($\frac{1}{2}$–$\frac{3}{4}$") long welds in one direction at random locations along the joint. The spaces are then filled in, making a continuous weld.
- is made by starting from the middle and making short welds to the outside in both directions.
- can create problems with cold starts at the start and stop points. Practice on scrap metal to tune the machine for the hottest start possible.

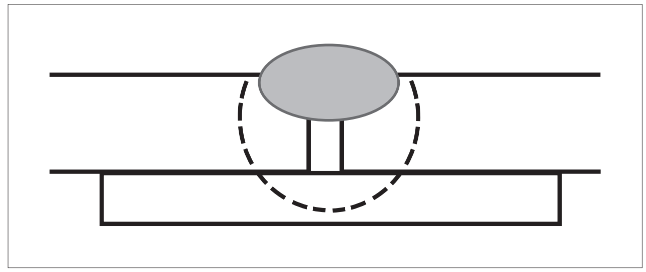


H-4 These plug welds were made at alternating locations to control the amount of heat put into one area.

Another method used to limit heat input and distortion of the metal being welded is the alternating plug weld technique. To alternate plug welds:

- avoid making two or more welds next to each other concurently. This allows the area to cool before the next weld is made and limits the buildup of heat.
- are made by randomly alternating the locations of plug welds.

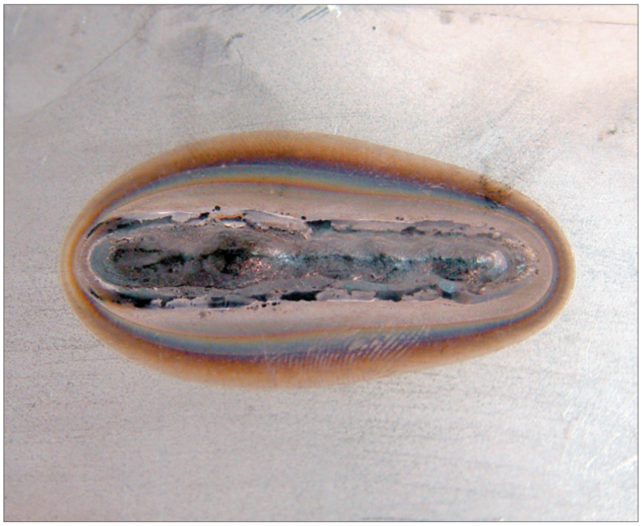
Topic I. Weld Penetration



I-1 The root gap on this joint was too small to allow adequate penetration for the thickness of metal being welded.

The ability to recognize causes of weld defects is an important skill to develop. Proper weld penetration is critical to the soundness of a weld. Poor penetration may result in incomplete fusion and lead to failure of the weld. Causes of penetration problems vary with the type of weld. Poor penetration may be caused by:

- heat settings that are too low.
- travel speed that is too fast. On thicker metal, a travel speed that is slightly slower than ideal can also cause poor weld penetration. This is because the arc and heat become concentrated on top of the weld puddle instead of on the base metal.
- stick-out that is too long.
- using the wrong welding gun angle.
- not leaving the proper root gap, when required.



I-2 The ripple on the backside of this weld is an indication of good weld penetration.

Signs of good weld penetration on the backside are:

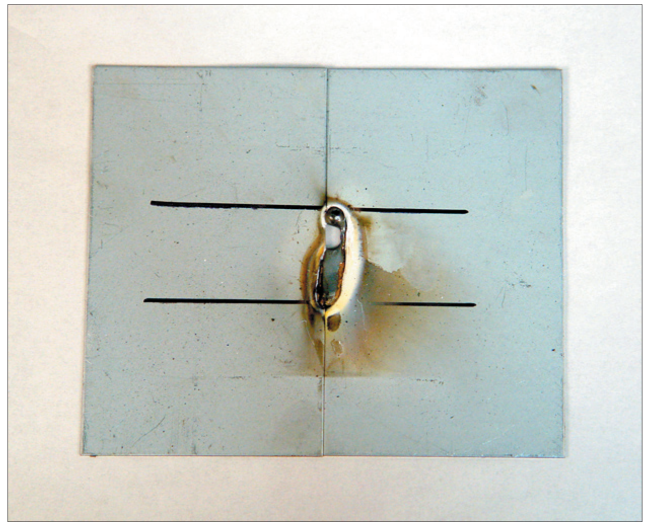
- more than just a heat mark.
- a small ripple that can be felt, which is called melt-through.

	Welding Parameter			
Variable To Adjust	Increase Penetration	Decrease Penetration	Less Bead Height	More Bead Height
Amperage	1↑	1↓	4↑	4↓
Voltage	3↑	3↓	1↑	1↓
Travel Speed	4↓	4↑	2↑	2↓
Stick-Out	2↓	2↑	3↓	3↑

Numbers indicate the order in which the variables should be adjusted.

I-3 This chart can be used as a quick-guide to help adjust a welding machine for a specific criteria.

On this chart, numbers indicate the order in which the variables should be adjusted.



I-4 This example of burnthrough was caused by heat settings that were too high.

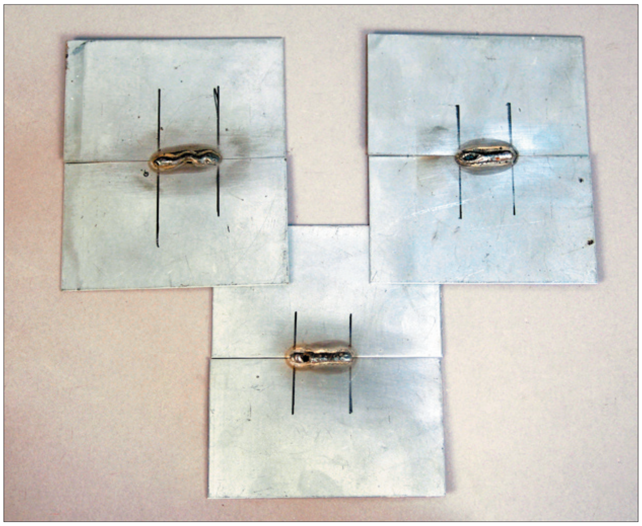
If there is so much penetration that there is a large bead or ripple on the backside, or a hole through the metal, it is called burnthrough. Causes of burn through include:

- heat settings that are too high.
- too slow of a travel speed. Burnthrough in plug welds may be caused by not keeping the welding gun moving in a circle around the base of the hole.
- stick-out that is too short.
- an incorrect welding gun angle. This is especially true in fillet welds. If the work angle directs the electrode at only the bottom piece, there may be too much heat input for a single thickness.
- a root gap that is too wide. This applies to butt joint welds, both open and with a backing.

PROPER AND IMPROPER WELD PENETRATION

Select the Demonstration icon found on screen I-4 of your CD-ROM for examples of welds that have proper and improper penetration.

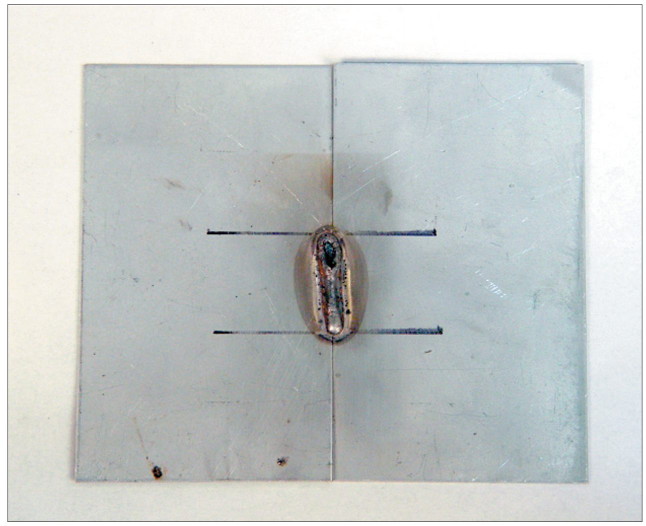
Topic J. Weld Defects



J-1 These welds have a variety of defects that are visible.

Incorrect welding machine settings or improper welding technique can result in poor weld penetration as well as other types of weld defects. Types of weld defects include:

- porosity.
- cracks.
- distortion.
- spatter.
- undercut.
- overlap.

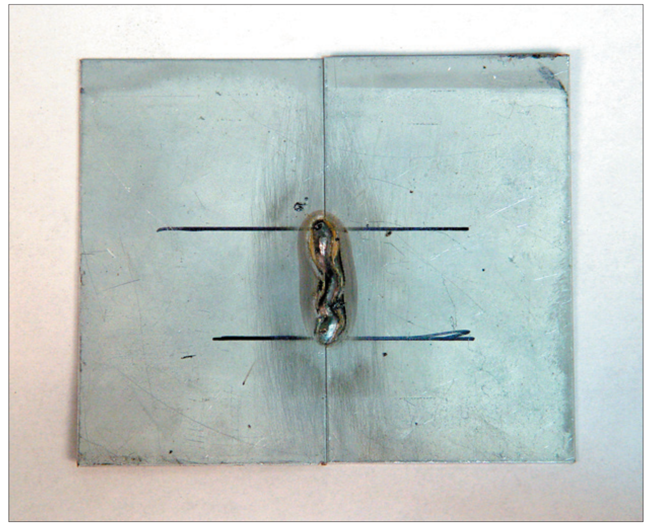


J-2 The porosity holes in one end of this weld were the result of a blocked shielding gas nozzle.

Porosity is holes in the weld that are generally caused by a lack of shielding gas. To prevent this, make sure that the:

- shielding gas is on and that the proper shielding gas is being used.
- shielding gas hose is not pinched or leaking, the hose is sealed correctly, and the shielding gas flow rate is correct. Too low a flow rate will not put enough shielding gas around the weld to protect it, while too high a flow rate will draw air and moisture into the weld with the shielding gas.
- electrode wire, shielding gas nozzle, or base metal is not dirty. Contaminants on the electrode wire or shielding gas nozzle may burn off and introduce contaminants into the weld puddle. Contaminants on the base metal may burn off during welding causing porosity.
- stick-out is not too long. If the stick-out is too long, there may be too much distance from the shielding gas nozzle to the weld puddle, and the shielding gas may disperse too much to properly protect the weld puddle from the atmosphere.

J-3 Welding with the voltage and wire speed set too high can cause weld metal cracking on heavy gauge material.



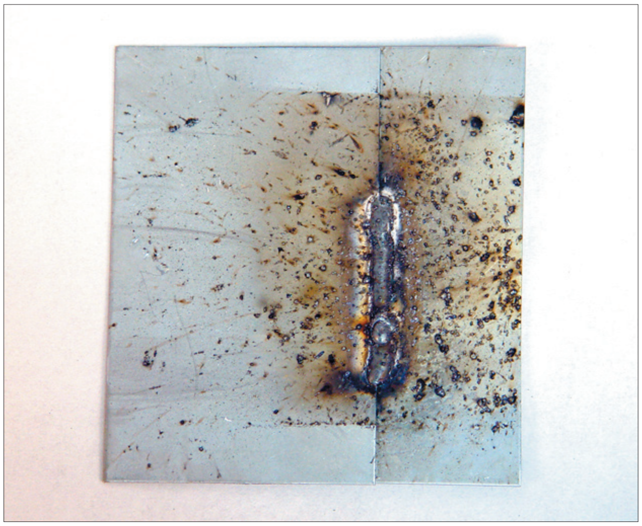
J-4 This distorted bead was caused by a technician's unsteady hand when welding.

Cracks on the top or inside of the weld bead are usually the result of:

- strains on the base metal. This is why heat management and the control of distortion are important factors.
- too much heat input into the metal. This is typically a result of the voltage and wire speed (current) setting being too high for the material thickness being welded.
- unbalanced voltage and amperage settings. If the ratio of the weld bead depth-to-width is too high, cracking may occur.
- improper welding technique or settings when welding on heavy gauge material. Collision repair welding is typically not done on material thick enough for weld cracking to be an issue.

Causes of distorted, or uneven beads include:

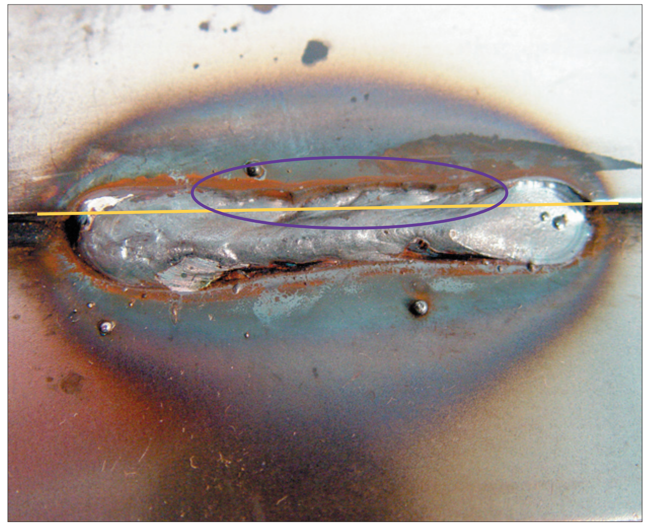
- a technician with an unsteady hand.
- a worn or recessed contact tip, or too much stick-out, causing the electrode to wander as it comes out.
- voltage that is set too high, causing the electrode to melt off in large drops with narrow areas of bead width in between.
- uneven travel speeds.



J-5 Excessive spatter may be caused by welding on dirty or contaminated metal.

Spatter is defined as metal particles that are blown away from the welding arc and adhere or fuseto the base metal, but do not become part of the finished weld. Excessive spatter is a concern because the things that cause spatter can also cause other weld defects. Common causes of excessive spatter around the weld bead include:

- improper or unbalanced voltage and current settings. Spatter can be caused by voltage settings that are too high, resulting in an excessive arc length. It can also be the result of excessive amperage settings, or a misbalance of the voltage and amperage settings. Restrictions to the smooth feeding of the electrode wire, such as too much tension on the wire spool, or drive rolls that are worn or an incorrect size may also change the wire feed speed and amperage output enough to create an imbalance and produce excessive spatter.
- a worn or excessively recessed contact tip. This causes the arc to be unstable and wander, which may result in excessive spatter.
- improper shielding gas flow rate. Both too little and too much shielding gas flow can cause excessive amounts of spatter. This is because both of these lead to inadequate shielding of the weld puddle from atmospheric contamination.
- the welding gun being angled up or down too much. Too much travel angle will result in inadequate shielding gas concentrations over the weld puddle. This is because the gas nozzle is pointed too much ahead of or behind the weld puddle, and is not directing the gas flow at the puddle.
- contamination or corrosion on the base metal.



J-6 Unbalanced wire speed and voltage settings can lead to undercut of the weld bead.

Undercut:

- is a groove cut into the base metal on one or both sides of the weld.
- may be caused by an unbalanced setting of the wire speed and voltage, an incorrect welding gun angle, or too fast of a travel speed.

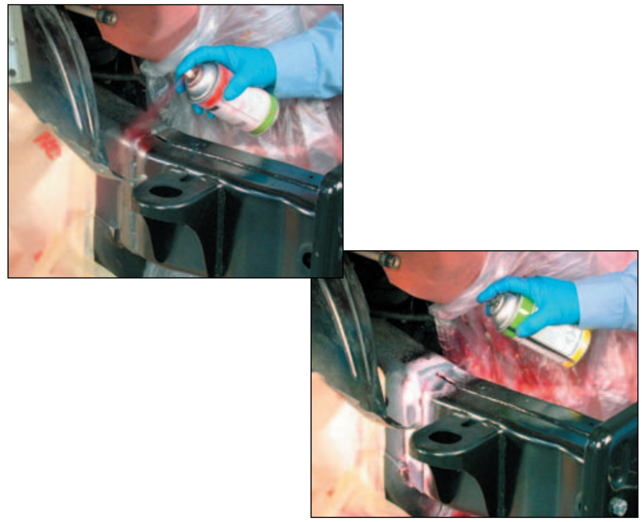
To help eliminate undercut, ensure that the proper settings are used for the material being welded. Undercut may be caused by both excessively high amperage and voltage settings for the thickness of material being welded. Correct gun angles will allow the arc to aid in the proper placement of the weld metal being deposited, and reduce the chance of undercutting. With all other parameters being correct, the proper travel speed must be used to avoid undercut. A travel speed that is too fast will not allow enough weld metal to be deposited to fill the joint to the proper level.

J-7 Too high a wire speed with too slow a travel speed may cause an excessive amount of weld metal to be deposited on the weld bead.

Overlap is:

- an excess amount of weld metal deposited on the top and either side of the weld bead.
- caused by too high a wire speed, too low of a voltage setting, or a travel speed that is too slow.

As with most weld defects, ensuring that the voltage and amperage settings are correct for the metal thickness being welded, and properly balanced to each other, will help reduce the chance of overlap.



J-8 This dye penetrant kit can be used to inspect finished welds for cracks and other flaws.

A dye penetrant may be used to check for weld cracks and other flaws. The penetrant:

- is applied after the welding process is completed.
- highlights cracks, skips, or porosity so they can be easily found.

DYE PENETRANT

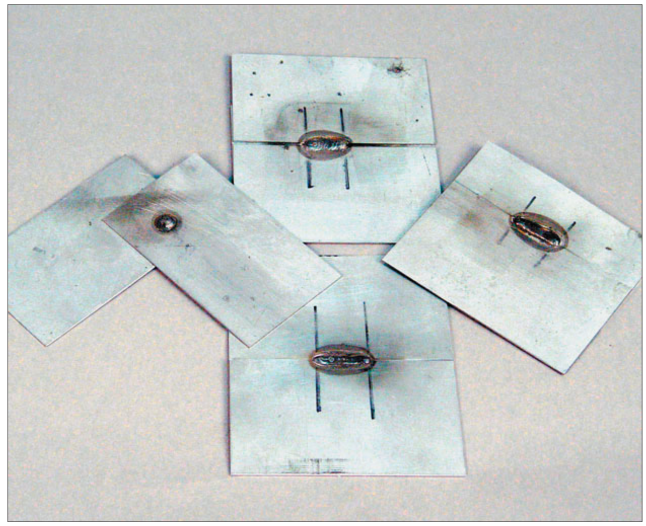
Select the Demonstration icon found on screen J-8 of your CD-ROM for an example of dye penetrant.

Topic K. I-CAR Automotive Steel GMA (MIG) Welding Qualification Test (SWQT)

K-1 Passing the I-CAR Automotive Steel GMA (MIG) Welding Qualification Test (SWQT) demonstrates welding skill.

The I-CAR Automotive Steel GMA (MIG) Welding Qualification Test (SWQT):

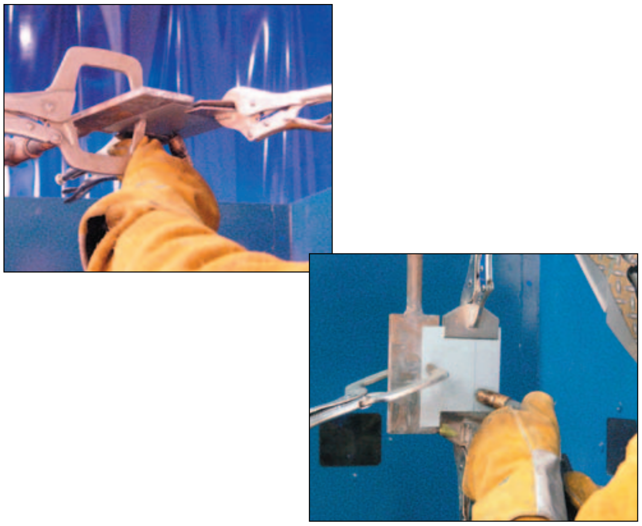
- was developed in response to a demand in the collision repair industry.
- is a method to qualify collision repair technicians who are welding on a daily basis.
- was developed following AWS guidelines as closely as possible.
- is not a course, but rather a test of skill.



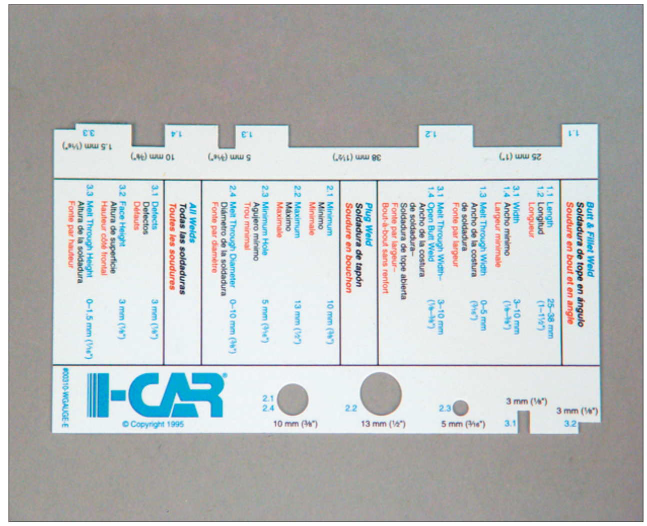
K-2 The SWQT includes these four welds (clockwise from the bottom): open butt joint weld, plug weld on lap joint, butt joint with backing weld, and fillet weld on lap joint.

The I-CAR Automotive Steel GMA (MIG) Welding Qualification Test (SWQT):

- is performed on 75 x 125 mm (3 x 5") zinc coated 18-gauge automotive-grade steel coupons.
- consists of four different welds.
  - plug weld on lap joint
  - fillet weld on lap joint
  - butt joint with backing weld
  - open butt joint weld



K-3 *Each of the four SWQT welds is made in both the vertical and overhead positions, for a total of eight welds.*



K-4 *This I-CAR Steel GMA (MIG) Welding Gauge can be used to measure all of the parameters for the SWQT.*

The SWQT:

- consists of two different positions.
  - vertical
  - overhead
- provides each participant with two sets of coupons for each weld for a total of eight welds.
- includes visual inspection.
- includes destructive testing.

The I-CAR Steel GMA (MIG) Welding Gauge is used to visually inspect welds. The gauge measures minimum and maximum:

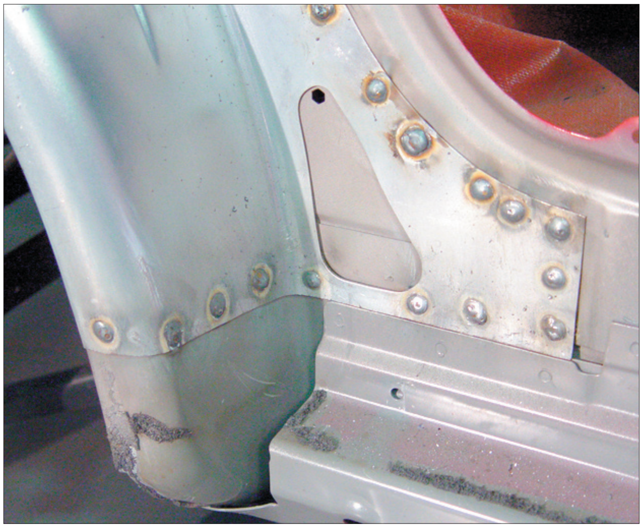
- height.
- width. There are two melt-through width measurements listed on the gauge for butt joints and fillet welds. The first measurement 0–5 mm (0–3⁄16") is the melt-through width for the fillet and butt joint with backing welds, and the second 3–10 mm (1⁄8–3⁄8") is for the open butt joint weld.
- diameter.
- length.

Topic L. Review

REVIEW

Refer to screens L-1 through L-3 of your CD-ROM for review questions on GMA (MIG) welding.

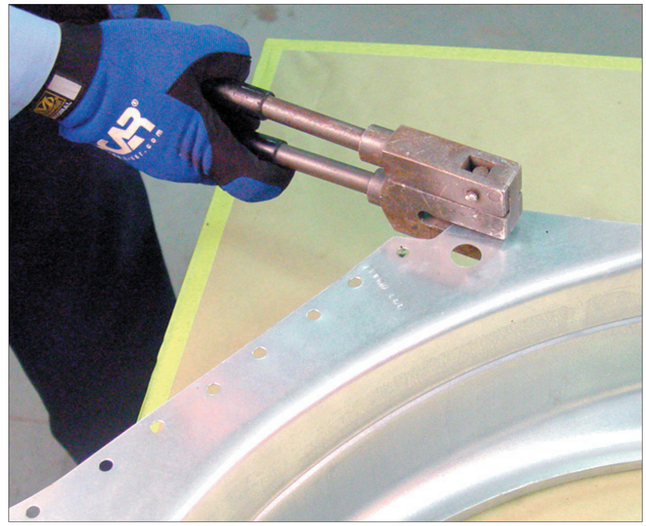
Topic A. Plug Weld Description



A-2 The plug weld on lap joint is used to replace factory spot welds.

The plug weld:

- joint joins two or more lapped pieces together. The top piece has punched or drilled holes.
- when welding three pieces of metal, requires holes in the two top pieces. Make the hole in the top piece slightly larger than the hole in the middle piece.
- is used to replace factory spot welds.

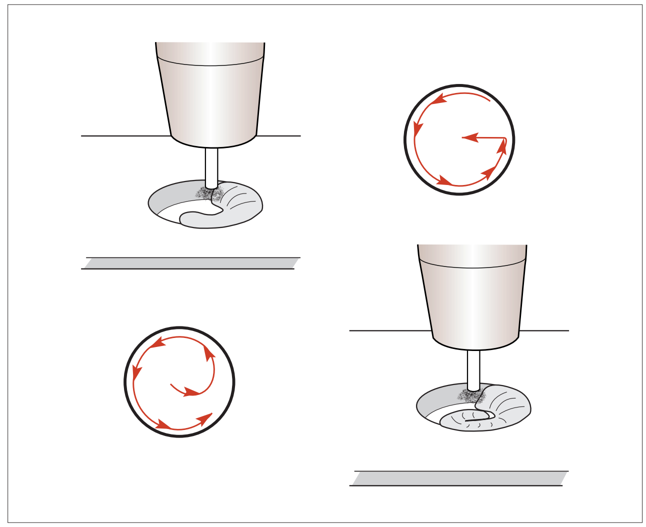


A-3 A hand punch is a good method of making plug weld holes in parts.

Plug weld holes should be:

- the size recommended by the vehicle maker.
- 8 mm (5⁄16") if no vehicle maker recommendations exist. This is a general recommendation for metal thicknesses typically used on vehicles. Thicker material may require a larger hole for adequate penetration into the lower piece.
- punched or drilled at the same locations used by the vehicle maker for the spot welds they are replacing.
- larger than factory spot welds.
- larger on the top piece when overlapping more than two panels.

A-4 To make a plug weld, the electrode wire is aimed at the bottom piece through the hole in the top piece.



A-5 The method used to make a plug weld is a matter of personal preference.

The plug weld:

- is made by aiming the electrode, through the hole in the top piece, at the base metal and circling around the hole to fuse the edges. All edges of the plug weld hole must be fused to the base metal.
- electrode wire should be at a 90° angle to the base metal.
- requires the correct technique to avoid trapping a gas pocket in the weld.
- may be easier to make by turning up the heat settings slightly and using a faster travel speed.

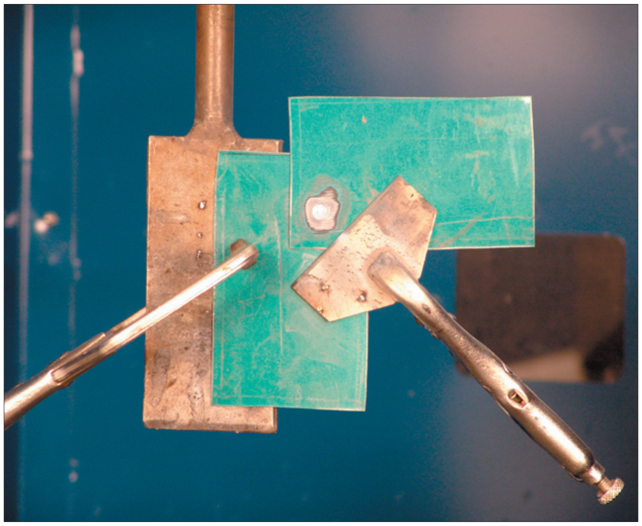
There are two different ways to make plug welds:

- start at the edge of the joint and move around the piece either clockwise or counterclockwise.
- start in the center of the bottom coupon and move out towards the edges.

The method to use is simply a matter of personal preference. Both techniques should be practiced and technicians should choose which technique they are more comfortable with.

PLUG WELD TECHNIQUE
Refer to screen A-6v of your CD-ROM for a video animation on how to make a plug weld.

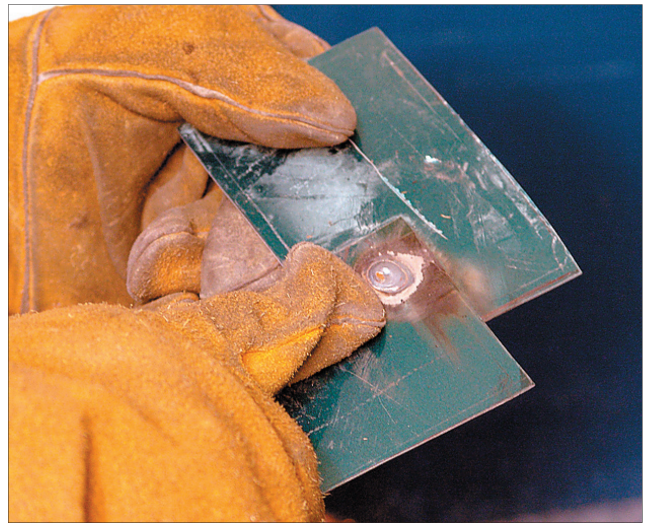
Topic B. On-Vehicle Plug Welding Procedure



B-1 Test welds can be made on pieces of scrap metal from the vehicle.

Before welding on a vehicle, test welds should be made, visually inpsected, and destructively tested to ensure that the proper welder setup and welding technique is being used. When making sample test plug welds:

- use the same thickness and type metal that will be welded on the vehicle. Damaged parts that are to be replaced may provide scrap pieces.
- perform the test welds in the same position as the welds on the vehicle.
- visually inspect and destructively test the sample welds before welding on the vehicle.
- use small pieces of flat scrap steel, trimmed to about 75 x 125 mm (3 x 5").
- use weld-through primer if applicable.
- weld two pieces together at right angles, using a single plug weld for each sample. This is done to make it easier to destructively test the welds.

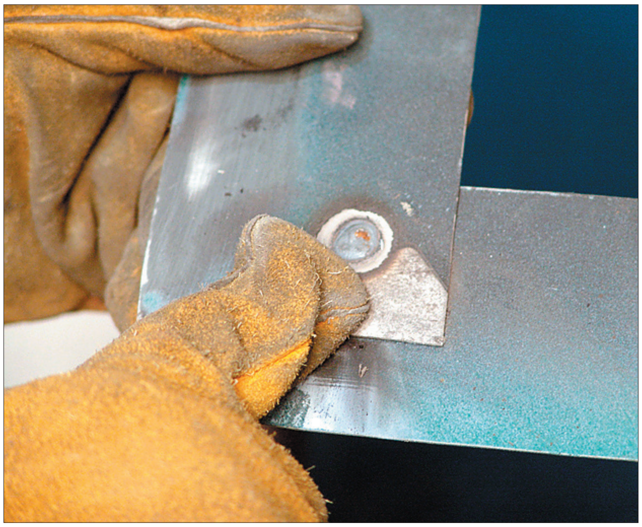


B-2 This practice, or test plug weld is being visually inspected on the front side for flaws.

Visually inspect the test welds. Visual inspection criteria on the front side include:

- a nugget height no greater than 3 mm (1⁄8").
- no cracks, porosity, skips, voids, or undercut.
- the hole is completely filled.

The plug weld is a visual failure if any of these criteria are not met. If the test plug weld fails the visual inspection, the welding machine or welding technique must be adjusted accordingly.



B-3 The backside of this plug weld is being inspected for evidence of penetration.

B-4 This test plug weld has passed the visual inspection and is being destructively tested with a twist test.

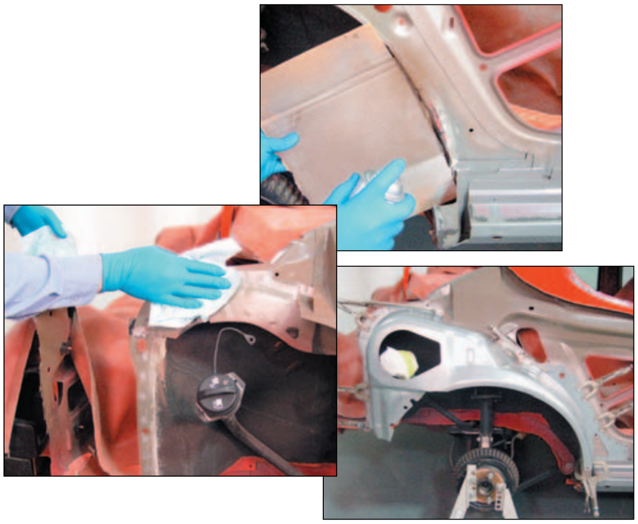
The backside of the plug weld must also be inspected. Visual inspection criteria on the backside include:

- no burnthrough.
- evidence of penetration, such as a ripple or melt-through.
- a melt-through height of no more than 1.5 mm (1⁄16") from the bottom.

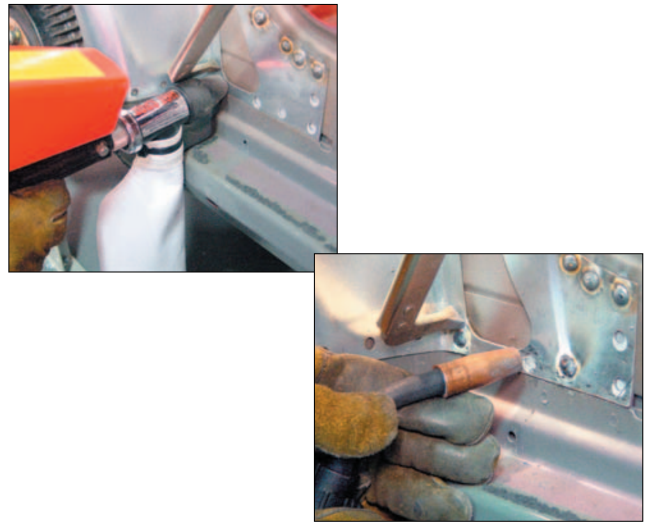
The plug weld is a visual failure if any of these requirements are not met. If the test plug weld fails the visual inspection, the welding machine or welding technique must be adjusted accordingly.

If the test welds pass the visual inspection they should be destructively tested to ensure they have adequate strength. Ways of destructively testing plug welds include a:

- twist test. To perform a twist test, both pieces of the test sample are bent to form a 90º "L" shape. This is done to strengthen the pieces, and is especially helpful when testing sample plug welds made on thin gauge metal. Next, the bottom piece of the sample is placed in a vise, and the top piece is twisted off. Keep the faces of the pieces parallel. A good weld will pull a nugget out of the bottom piece of metal, leaving a nugget hole. The minimum diameter of the hole left should be approximately 5⁄8 of the diameter of the hole used for the plug weld. For welds made through an 8 mm (5⁄16") hole, the size of the nugget hole should be at least 5 mm (3⁄16").
- tensile shear test. If tensile testing equipment is available, it can be used to measure the strength of the weld. Tensile testing pulls the two pieces apart, at 180º to each other, and measures the force necessary to separate them.



B-5 Before making plug welds the mating surfaces must be cleaned, bare metal primed with a weld-through primer, and the joint tightly clamped together.



B-6 A spot blaster is an excellent way to remove weld-through primer from the weld zone before making a plug weld.

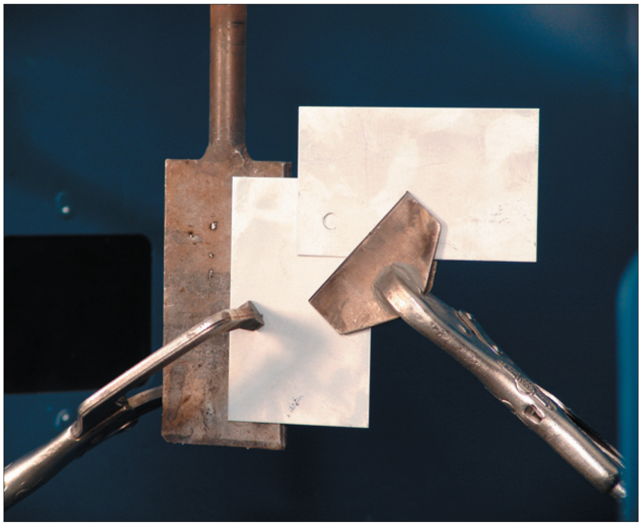
To make a plug weld on a vehicle:

1. Clean the mating surfaces. Avoid removing any zinc coating.
2. Refer to the vehicle maker's recommendation for the location, number, and size of plug weld holes. If no recommendations are available, punch or drill 8 mm ($\frac{5}{16}$") holes in the outer panel at the same locations used originally by the vehicle maker. When plug welds are used to join three or more panels, punch or drill holes in every piece except the base piece. Make the holes progressively smaller from the outer to the base piece.
3. Apply weld-through primer to all mating surfaces that do not have zinc coating or where the zinc coating was removed. Follow the vehicle maker's recommendations on the use of weld-through primer. Due to the poor adhesion quality of some weld-through primers, it may have to be removed from all exposed surfaces after welding and before applying other coatings.
4. Clamp the mating surfaces tightly together.

To make a plug weld on a vehicle:

5. Remove the weld-through primer from the immediate weld zone. Using a spot-blaster or wire brush, remove the weld-through primer from the base piece through the hole in the top piece.
6. Locate the work clamp as close to the welding site as possible.
7. Make the welds. Use the welder settings that were decided upon from the test welds. Before making the welds, it may be recommended to remove any weld-through primers from the immediate weld zone.
8. Dress the welds, if necessary. Do not reduce the thickness of the surrounding sheet metal or remove the zinc coating.

Topic C. Welding Qualification Test (SWQT) Plug Welds



C-1 An SWQT plug weld is made by lapping two coupons at one corner, with an 8 mm (5/16") hole in the top coupon.

When making plug welds for the Steel Welding Qualification Test (SWQT):

- two coupons are lapped at one corner.
- the coupon with the pre-drilled 8 mm (5/16") hole is on top.
- tack welds are not allowed for fit-up. This is to allow the coupons to be separated during the destructive test.

SWQT participants are required to make plug welds in the vertical and overhead position. Each participant is given two coupons for each position. After performing the welds, the participant chooses one weld from each position to turn in.

C-2 The diameter of the front side of an SWQT plug weld must be within a certain range to pass the visual inspection.

The front side of the plug weld must meet certain requirements. These requirements include:

- a nugget height of no greater than 3 mm (1/8").
- a nugget diameter between 10–13 mm (3/8–1/2").
- having no cracks, porosity, skips, voids, or undercut.
- the hole being completely filled.

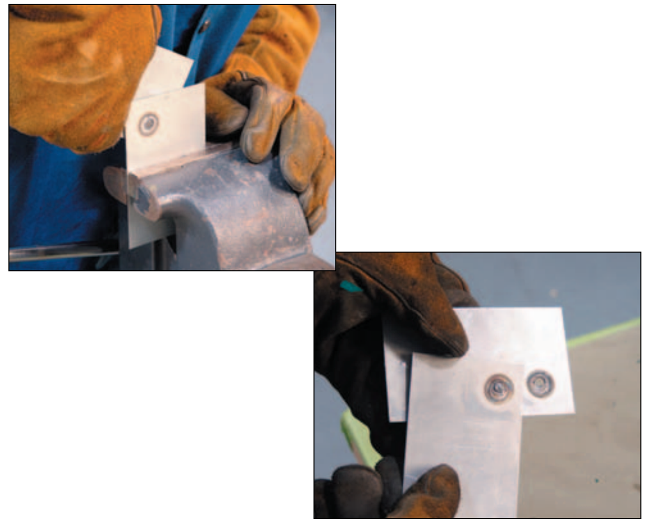
C-3 The backside melt-through height on an SWQT plug weld is checked with the I-CAR Steel GMA (MIG) Welding Gauge.

The back side of the plug weld must also meet requirements. These include:

- no burnthrough.
- an evidence of penetration.
- a penetration diameter no greater than 5 mm (3/16").
- a melt-through height no more than 1.5 mm (1/16") from the bottom.

The plug weld is a visual failure if any of these requirements are not met.

PLUG WELD ON LAP JOINT
Select the Demonstration icon found on screen C-3 of your CD-ROM for examples of plug welds that pass the visual inspection and plug welds that fail the visual inspection.



C-4 The destructive test for an SWQT plug weld involves twisting the top coupon off of the bottom coupon and measuring the size of the remaining nugget hole.

Test the plug welds using this procedure:

1. Secure the bottom piece in a vise.
2. Use both hands or a locking pliers to twist the top piece off the bottom piece. Keep the faces parallel.
3. Measure the diameter of the nugget hole left in the bottom piece. The plug weld passes if the nugget hole is at least 5 mm (3/16").

SAMPLES OF DESTRUCTIVELY TESTED WELDS
Select the Demonstration icon found on screen C-4 of your CD-ROM for examples of destructively tested plug welds.

DESTRUCTIVE TESTING FOR THE SWQT
Refer to screen C-5v of your CD-ROM for a video on how to destructively test an SWQT plug weld.

Topic D. Review

REVIEW
Refer to screens D-1 and D-2 of your CD-ROM for review questions on making plug welds.

Topic A. Fillet Weld Description

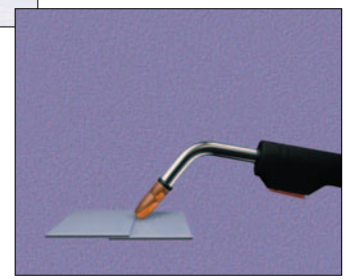
A-2 This fillet weld on lap joint and fillet weld on corner joint are examples of fillet welds that may be found on vehicles.

The fillet weld:

- is a roughly triangular bead deposited in a corner formed by the fit-up of two pieces. A fillet weld may be made to a lap, corner, or T-joint. Examples of corner and T-joints on vehicles include cross-members and brackets joined to the side rails of full frames.
- may be called a lap weld. A fillet weld on lap joint joins two lapped pieces together, and is the most common fillet weld used for collision repairs.

Travel Angle

Work Angle



A-3 A fillet weld on lap joint is typically made using a 70° travel angle and a 45° work angle.

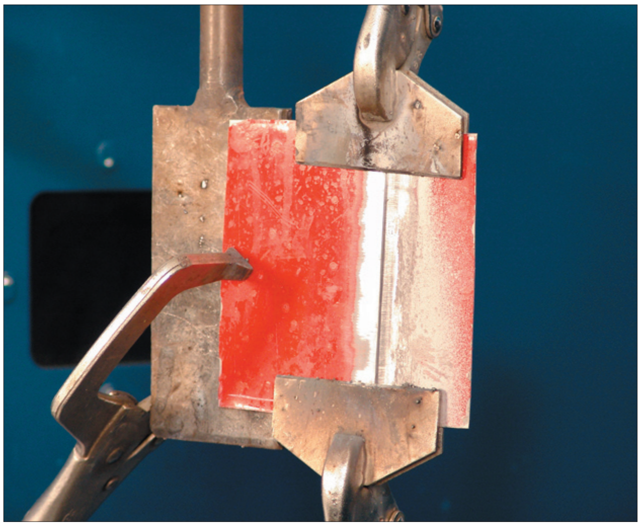
When making a fillet weld:

- the welding gun should be held at a 70° travel angle and a 45° work angle. The gun angle should allow for equal penetration into both the upper and lower pieces.
- the electrode wire should be aimed at the joint but slightly off center towards the lower piece when compared to the centerline of the joint. The electrode wire should be at a 45° angle to the joint, and aimed so that it contacts the lower coupon.
- either the push or pull technique may be used. Vertical fillet welds on thin gauge material are typically easiest using the pull technique and moving from top to bottom.

The exact welding gun angle and welding technique used may vary with the type of joint and thickness of the pieces being welded. When welding two different thicknesses of metal together, the work angle should be adjusted so that the wire is angled more towards the thicker piece.

FILLET WELD TECHNIQUE
Refer to screen A-4v of your CD-ROM for a video animation on how to make a fillet weld.

Topic B. On-Vehicle Fillet Welding Procedure



B-1 This practice fillet weld is being made in the same position as the weld will be made on the vehicle.

Before welding on a vehicle test welds should be made, visually inspected, and destructively tested, to ensure the proper welder setup and welding technique is being used. When making sample test welds:

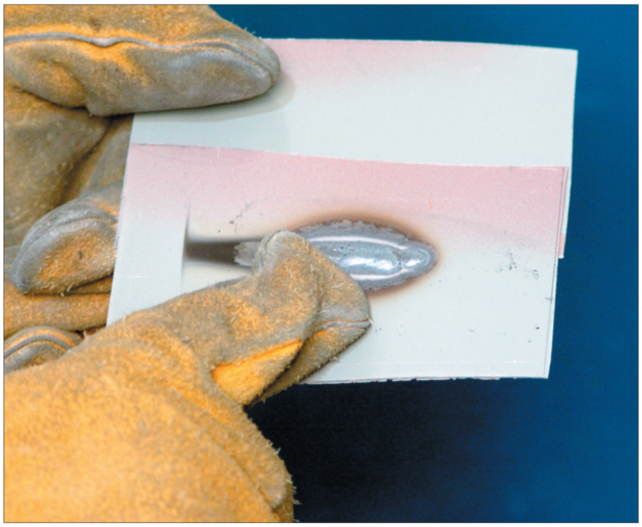
- use the same thickness and type metal that will be welded on the vehicle. Damaged parts that are to be replaced may provide scrap pieces.
- perform the test welds in the same position as the welds on the vehicle.
- visually inspect and destructively test the sample welds before welding on the vehicle.
- use small pieces of flat scrap steel, trimmed to about 75 x 125 mm (3 x 5").
- use weld-through primer if applicable.
- use the same joint type that will be used on the vehicle. For a fillet weld on lap joint, weld two pieces together by overlapping them lengthwise and making a 25–38 mm (1–1½") long weld, centered on the overlap joint.

B-2 The front side of the practice weld is being visually inspected for flaws.

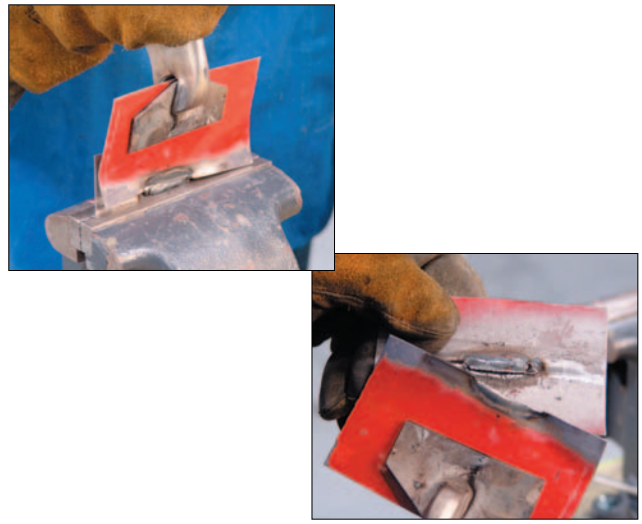
Visual inspection criteria on the front side include:

- a bead height of 0–3 mm (0–⅛") above top coupon.
- no porosity, skips, or voids greater than 3 mm (⅛") and the total of all not to exceed 6 mm (¼").
- no cracks.
- no undercut.
- the joint is completely filled.

The fillet weld is a visual failure if any of these criteria are not met.



B-3 The backside of the practice weld must be inspected for evidence of penetration.



B-4 Destructively testing practice welds will help ensure that welds of adequate strength are being made.

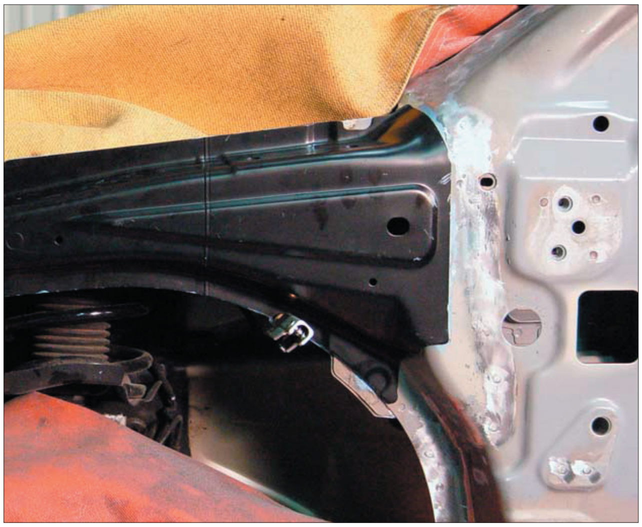
Visual inspection criteria for the backside of the fillet weld include:

- no burnthrough.
- a melt-through width of 0–5 mm (0–3⁄16").
- a melt-through height that cannot exceed 1.5 mm (0–1⁄16"). There must be a ripple on the backside as evidence of penetration.

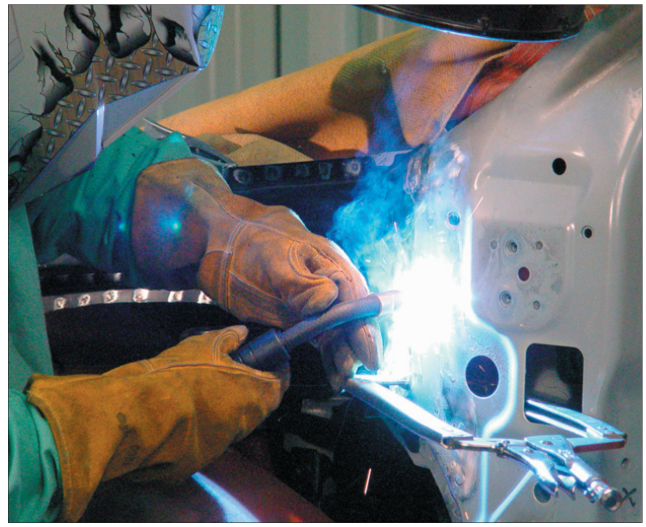
The fillet weld is a visual failure if any of these criteria are not met.

If the test welds pass the visual inspection, they should be destructively tested to ensure they have adequate strength. To destructively test a fillet weld:

1. Secure the bottom piece in a vise with the fillet weld facing the front.
2. Use both hands to rock the top piece back and forth until it breaks free from the bottom piece.
3. The weld is good only if there is continuous fusion between the pieces along the full length of the weld. Evidence of fusion is metal pulling out of the top piece and the weld still holding firm. A very small void, due to a cold start, is permissible at the beginning of the weld.



B-5 A fillet weld on lap joint is used where this upper frame rail attaches to the A pillar.



B-6 This fillet weld on lap joint is being made in an area where it will not require dressing.

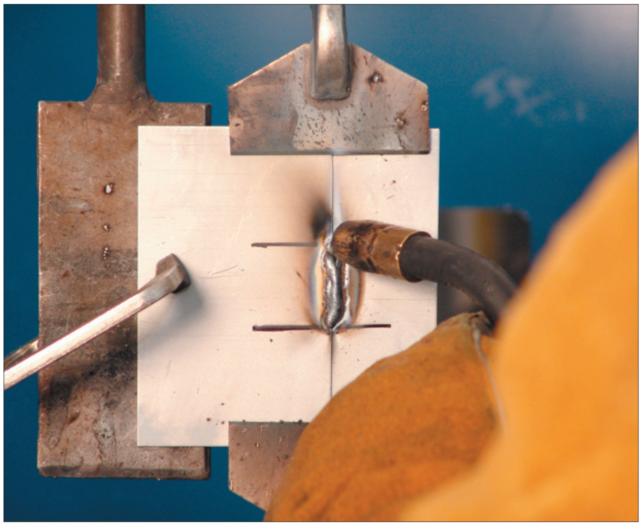
To make a fillet weld on a vehicle:

1. Clean the mating surfaces. Avoid removing any zinc coating.
2. Apply weld-through primer to all mating surfaces that do not have zinc coating or where the zinc coating was removed. Follow the vehicle maker's recommendations for the application of weld-through primer. Due to the poor adhesion property of some weld-through primers, it may have to be removed from all exposed surfaces after welding, before applying other coatings.
3. Clamp the mating surfaces tightly together.
4. Remove the weld-through primer from the immediate weld zone.

To make a fillet weld on a vehicle:

5. Locate the work clamp as close to the welding site as possible.
6. Make the welds on the vehicle. Use the welding machine settings that were successfully used for the test welds. Before making the welds, it may be recommended to remove any weld-through primers from the immediate weld zone.
7. Dress the welds, if necessary. Do not reduce the thickness of the surrounding sheet metal or remove any zinc coating.

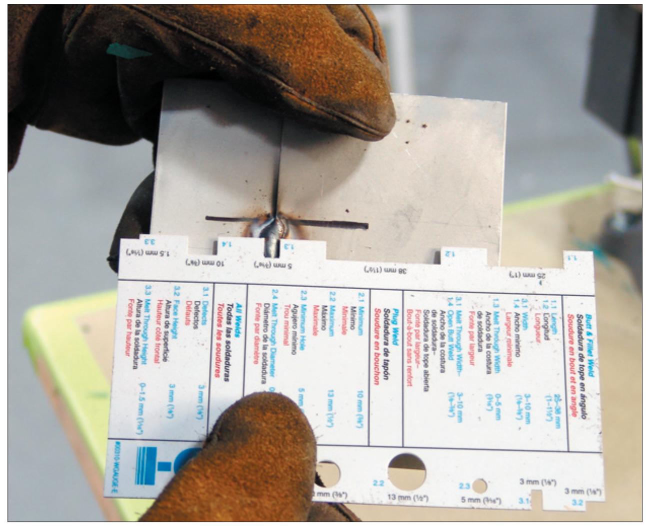
Topic C. Welding Qualification Test (SWQT) Fillet Welds



C-1 SWQT fillet welds must be 25–38 mm (1–1½") long to pass the test.

When making fillet welds for the Steel Welding Qualification Test (SWQT):

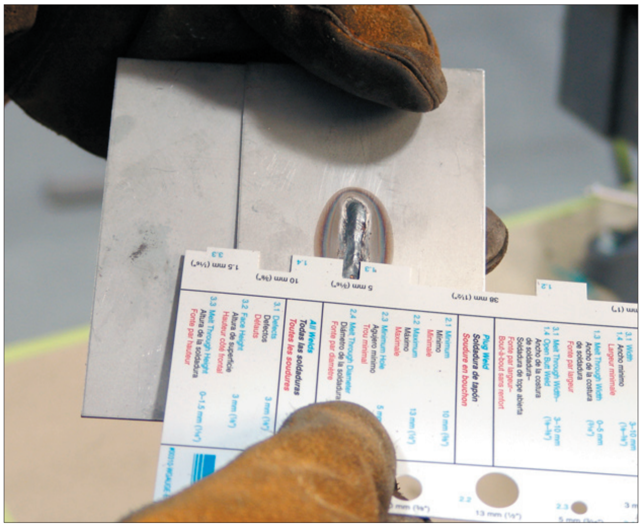
- two coupons are lapped about halfway. The test weld is a fillet weld on lap joint.
- the weld should be 25–38 mm (1–1½") long, centered on the overlap joint. This is to make it easier to take apart during the destructive testing.
- tack welds, outside of the test weld bead, are not allowed for fit-up.
- participants are required to make fillet welds in both the vertical and overhead positions. Each participant is given two coupons for each position. After making the welds, the participant chooses one weld from each position to turn in.



C-2 The I-CAR Steel GMA (MIG) Welding Gauge can be used to measure the width of the fillet weld bead.

The front side visual inspection parameters for the I-CAR SWQT fillet weld include:

- a bead length of 25–38 mm (1"–1½").
- a bead width of 5–10 mm (3/16"–3/8").
- a bead height of 0–3 mm (0–1/8") above top coupon.
- no porosity, skips, or voids greater than 3 mm (1/8") and the total of all not to exceed 6 mm (1/4").
- the joint is completely filled.
- no cracks.
- no undercut.



C-3 The melt-through on the backside is also measured with the I-CAR Steel GMA (MIG) Welding Gauge.

C-4 When destructively testing a fillet weld, a pair of duck bill locking pliers can be used to rock the top coupon off the bottom.

Visual inspection parameters for the backside of the fillet weld include:

- no burnthrough.
- a melt-through width of 0–5 mm (0–3/16").
- a melt-through height that cannot exceed 1.5 mm (0–1/16"). There must be a ripple on the backside as evidence of penetration.

The fillet weld is a visual failure if any of these requirements are not met.

FILLET WELD ON LAP JOINT
Select the Demonstration icon found on screen C-3 of your CD-ROM for examples of fillet welds that pass the visual inspection and fillet welds that fail the visual inspection.

1. Secure the bottom coupon in a vise with the fillet weld facing the front.
2. Use both hands to rock the top piece back and forth until it breaks free from the bottom piece.
3. The weld is good only if there is continuous fusion between the pieces along the full length of the weld. Evidence of fusion is metal pulling out of the top piece and the weld still holding firm. A very small void, due to a cold start, is permissible at the beginning of the weld.

SAMPLES OF DESTRUCTIVELY TESTED WELDS
Select the Demonstration icon found on screen C-4 of your CD-ROM for examples of destructively tested fillet welds.

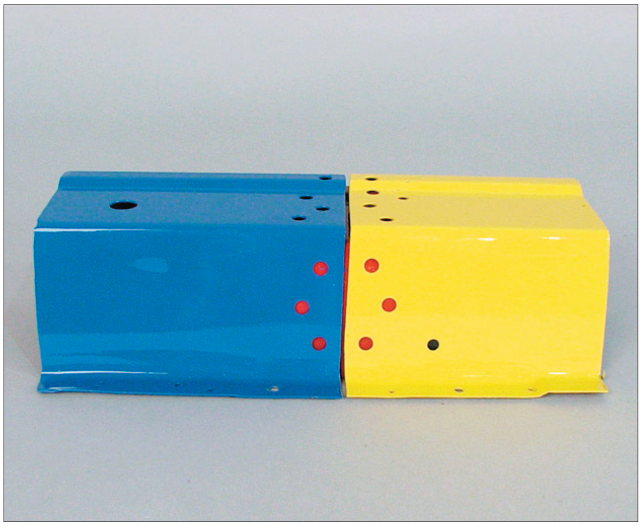
DESTRUCTIVE TESTING FOR THE SWQT
Refer to screen C-5v of your CD-ROM for a video on how to destructively test an SWQT fillet weld.

Topic D. Review

REVIEW
Refer to screens D-1 and D-2 of your CD-ROM for review questions on making fillet welds.

MODULE 4–GMA (MIG) BUTT JOINT WITH BACKING WELD

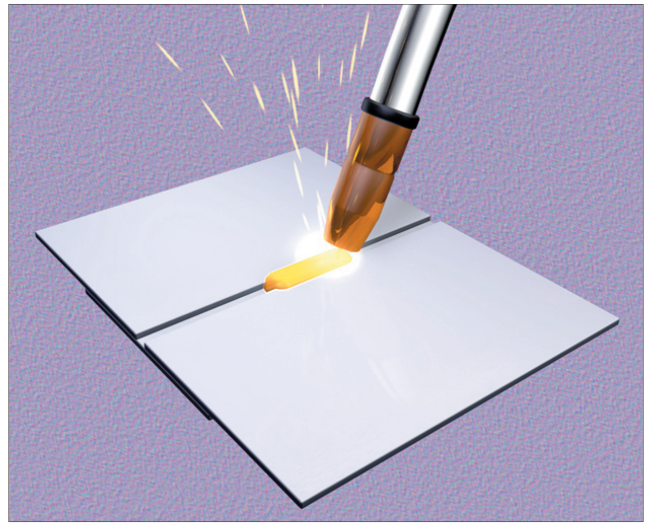
Topic A. Butt Joint With Backing Description



A-2 This color-coded simulator illustrates the three pieces required to make a butt joint with backing weld.

The butt joint with backing:

- joins two pieces nearly butted against each other with a backing piece usually the same thickness as the other two pieces.
- requires a gap between the two butted pieces of about two to three metal thicknesses. This allows penetration into the backing. Close-fitting gaps require more heat to penetrate into the backing.



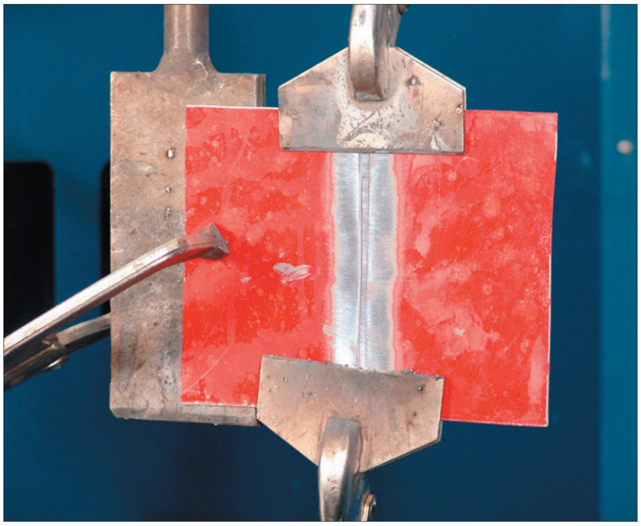
A-3 A butt joint with backing weld is being made by pulling the weld at a 70º travel angle.

The butt joint with backing weld is made by aiming the electrode wire at the backing piece and pulling or pushing the welding gun at a 70° travel angle while keeping the welding gun at a 90º work angle. A 90º work angle has the welding gun plane at a right angle to the base metal. The electrode wire is aimed straight into the joint.

BUTT JOINT WITH BACKING WELD TECHNIQUE

Refer to screen A-4v of your CD-ROM for a video animation on how to make a butt joint with backing weld.

Topic B. On-Vehicle Butt Joint With Backing Weld Procedure



B-1 Test welds should be made on the same type and thickness of metal that will be welded on the vehicle.

Before welding on a vehicle, test welds should be made, visually inspected, and destructively tested to ensure the proper welder setup and welding technique is being used. When making sample test butt joint with backing welds:

- use the same thickness and type metal that will be welded on the vehicle. Damaged parts that are to be replaced may provide scrap pieces.
- make the test welds in the same position as the welds on the vehicle.
- visually inspect and destructively test the sample welds before welding on the vehicle.
- use small pieces of flat scrap steel, trimmed to about 75 x 125 mm (3 x 5").
- butt two pieces together, leaving a gap of 2–3 metal thicknesses and clamp a third piece behind the joint as a backing.
- use weld-through primer if applicable.

B-2 The front side of the practice weld is being visually inspected for flaws.

After making test welds they should be visually inspected. Signs of a good butt joint with backing weld on the front side include:

- a joint that is completely filled.
- a bead height of 0–3 mm (0–1⁄8") above top coupons.
- no porosity, skips, or voids greater than 3 mm (1⁄8") and the total of all not to exceed 6 mm (1⁄4").
- no cracks.
- no undercut.

The butt joint with backing weld is a visual failure if any of these requirements are not met.

B-3 Checking the backside of test welds helps ensure that the heat settings on the welding machine are correct for the metal being welded.

B-4 A destructive test is the best way to ensure that test welds have proper penetration and strength.

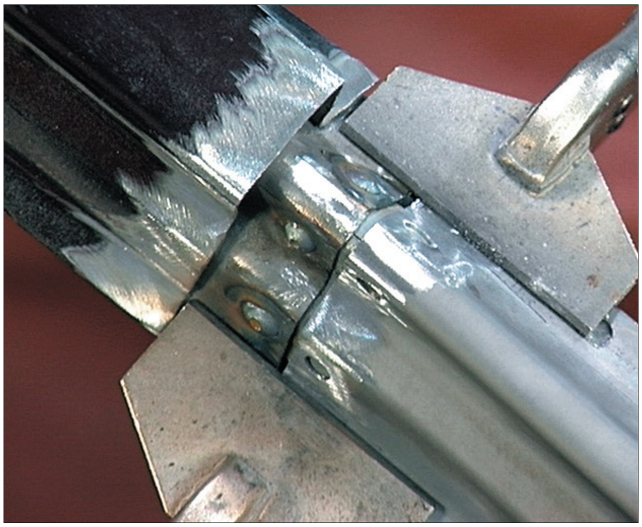
The backside of the butt joint with backing weld must also be inspected. Signs of a good weld on the backside include:

- no burnthrough that creates a hole.
- evidence of penetration into the backing. There must be a ripple on the backside of the backing piece as evidence of good weld penetration. This ripple is called melt-through.
- a melt-through height and width that are not excessive. Excessive melt-through is an indication of too much penetration. Melt through height should be no more than 1.5 mm (0–1⁄16"). The maximum width should be close to the width of the root gap between the top pieces of the sample.

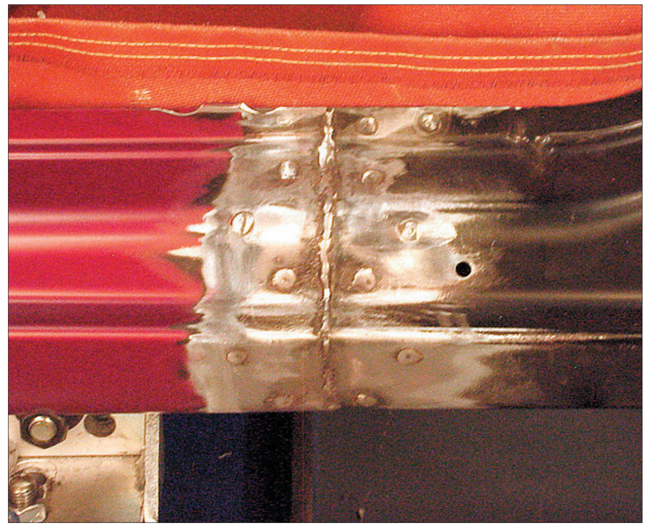
The butt joint with backing weld is a visual failure if any of these requirements are not met.

To destructively test butt joint with backing welds:

1. Bend the top pieces up toward each other.
2. Bend the edges of the backing piece down toward each other.
3. Lightly hammer the test sample flat so it will fit in a vise.
4. Tighten the top pieces of the test sample in a vise, just below the joint. If the jaw depth on the vise is too shallow for the sample, the test sample may be cut to fit.
5. Rock the backing piece back and forth until it breaks free. A pair of duck bill locking pliers works good for this.
6. The weld is good only if there is continuous fusion between the pieces along the full length of the weld. Evidence of fusion is tearout of metal from the piece that the weld separates from. If the weld bead stays on the backing piece there must be tearout, from both top pieces, along the entire length of the weld. If the weld bead stays on the top pieces there must be tearout, from the backing piece, along the entire length of the weld. There should be no evidence of separation of the weld bead from the piece that it remains on.



B-5 Butt joints with a backing must be clean and tightly clamped together before being welded.



B-6 This rocker panel was sectioned using a butt joint with backing weld.

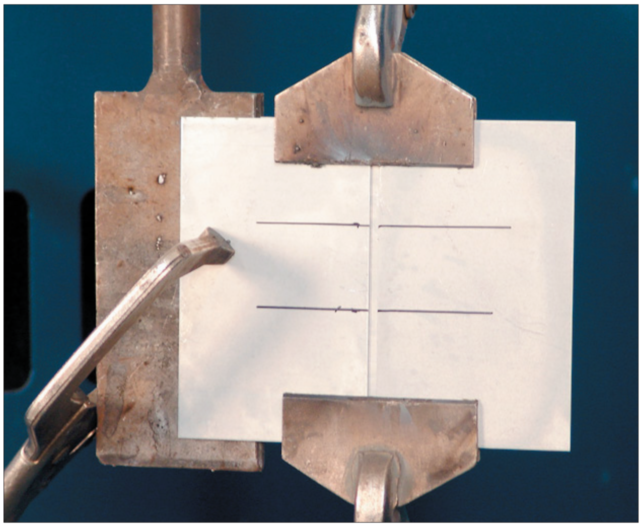
To make a GMA (MIG) butt joint with backing weld on a vehicle:

1. Clean the mating surfaces thoroughly. Avoid removing any zinc coating.
2. Apply weld-through primer to all mating surfaces that do not have a zinc coating or where the zinc coating was removed. Follow the vehicle maker's recommendations. Due to the poor adhesion property of some weld-through primers, it may have to be removed from all exposed surfaces after welding, before applying other coatings.
3. Clamp the mating surfaces tightly together. Some procedures may call for the backing piece to be plug welded to one or both of the top pieces.
4. Remove the weld-through primer from the immediate weld zone.

To make a GMA (MIG) butt joint with backing weld on a vehicle:

5. Attach the work clamp as close to the welding site as possible.
6. Make the welds on the vehicle. Use the welder settings that were decided upon from the test welds. Before making the welds, it may be recommended to remove any weld-through primers from the immediate weld zone.
7. Dress the welds, if necessary. Do not reduce the thickness of the surrounding sheet metal or remove any zinc coating.

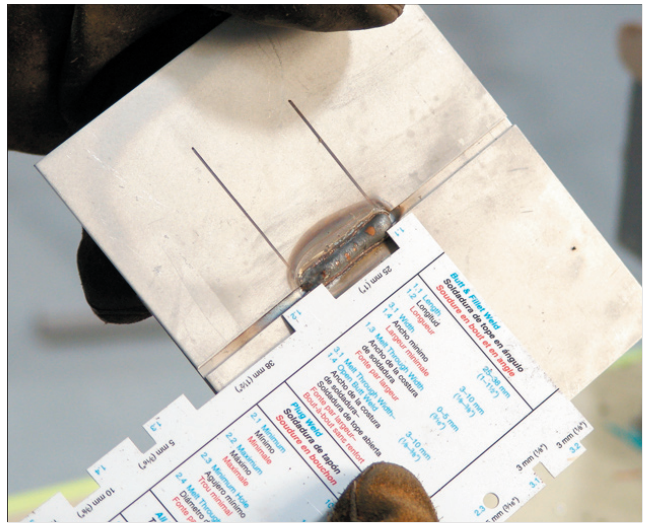
Topic C. Welding Qualification Test (SWQT) Butt Joint With Backing Welds



C-1 The joint must be off of the positioner so that it does not act as a heat sink.

When making butt joint with backing welds for the Steel Welding Qualification Test (SWQT):

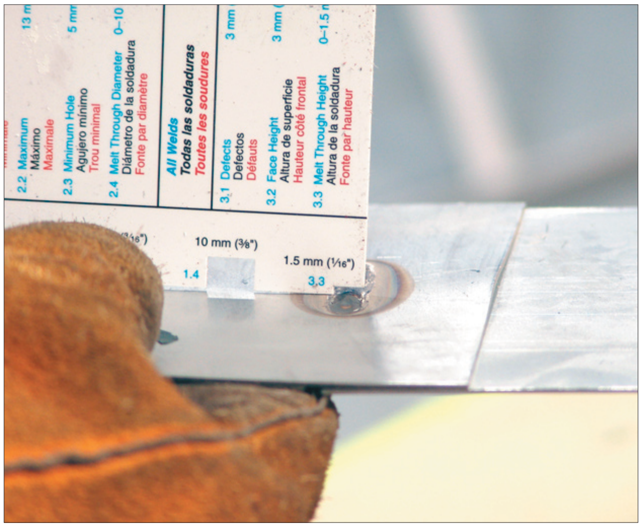
- butt two coupons together leaving a gap of 2–4 coupon thicknesses. This is about 3–4 mm (1⁄8–3⁄16").
- center a third coupon behind the joint.
- clamp the coupons together, and to the positioner. Tack welds are not allowed for fit-up.
- make a 25–38 mm (1–1½") weld in the center of the coupons.
- participants are required to make butt joint with backing welds in both the vertical and overhead positions. Each participant is given two coupons plus a backing coupon for each position. After performing the welds, the participant chooses one weld from each position to turn in.



C-2 Use the I-CAR Steel GMA (MIG) Welding Gauge to measure the length and width of the weld bead.

The front side visual inspection parameters for the I-CAR SWQT butt joint with backing weld include:

- a bead length of 25–38 mm (1–1½").
- a bead width of 5–10 mm (3⁄16–3⁄8").
- a bead height of 0–3 mm (0–1⁄8") above the top coupon.
- no porosity, skips, or voids greater than 3 mm (1⁄8") and the total of all not to exceed 6 mm (1⁄4").
- a joint that is completely filled.
- no cracks.
- no undercut.



C-3 The melt-through height on the backside of this butt joint with backing weld is being measured with the I-CAR steel GMA (MIG) welding gauge.

Visual inspection parameters for the backside of the butt joint with backing weld include:

- no burnthrough.
- a melt-through width of 0–5 mm (0–3/16").
- a melt-through height that cannot exceed 1.5 mm (0–1/16"). There must be a ripple on the backside as evidence of penetration.

The butt joint with backing weld is a visual failure if any of these requirements are not met.

BUTT JOINT WITH BACKING WELDS
Select the Demonstration icon found on screen C-3 of your CD-ROM for examples of butt joint with backing welds that pass the visual inspection and butt joint with backing welds that fail the visual inspection.

C-4 After separating the backing coupon from the top coupons, the coupons are checked for at least 25 mm (1") of metal tearout.

To test butt joint with backing welds:

1. Bend the top pieces up toward each other.
2. Bend the edges of the backing piece down toward each other.
3. Lightly hammer the test sample flat so it will fit in a vise.
4. Tighten the top pieces of the test sample in a vise, just below the joint. If the jaw depth on the vise is too shallow for the sample, the test sample may be cut to fit. Do not remove more than 25 mm (1").
5. Using a pair of duck bill locking pliers, rock the backing back and forth until it breaks free from the top coupons.
6. The weld is good only if there is continuous fusion between the pieces along the entire length of the weld. Evidence of fusion is tearout of metal from the coupons that the weld separates from. If the weld bead stays on the backing, there must be tearout, from both top coupons, along the entire length of the weld. If the weld bead stays on the top coupons there must be tearout from the backing along the entire length of the weld. There should be no evidence of separation of the weld bead from the coupon that it remains on.

SAMPLES OF DESTRUCTIVELY TESTED WELDS

Select the Demonstration icon found on screen C-4 of your CD-ROM for examples of destructively tested butt joint with backing welds.

DESTRUCTIVE TESTING FOR THE SWQT

Refer to screen C-5v of your CD-ROM for a video on how to destructively test an SWQT butt joint with backing weld.

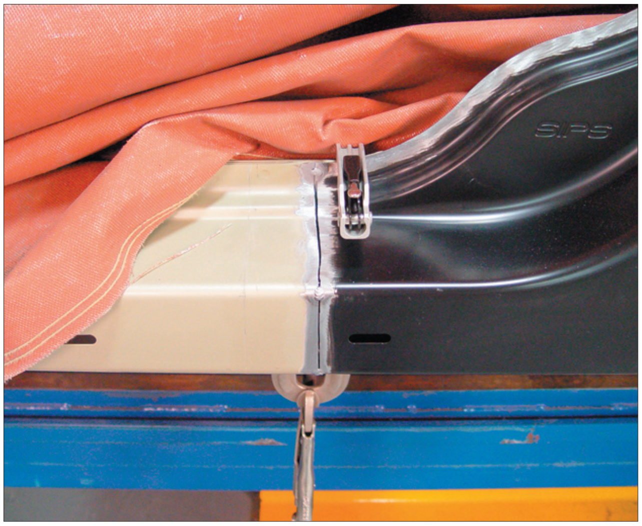
Topic D. Review

REVIEW

Refer to screens D-1 and D-2 of your CD-ROM for review questions on making butt joint with backing welds.

MODULE 5–GMA (MIG) OPEN BUTT JOINT WELD

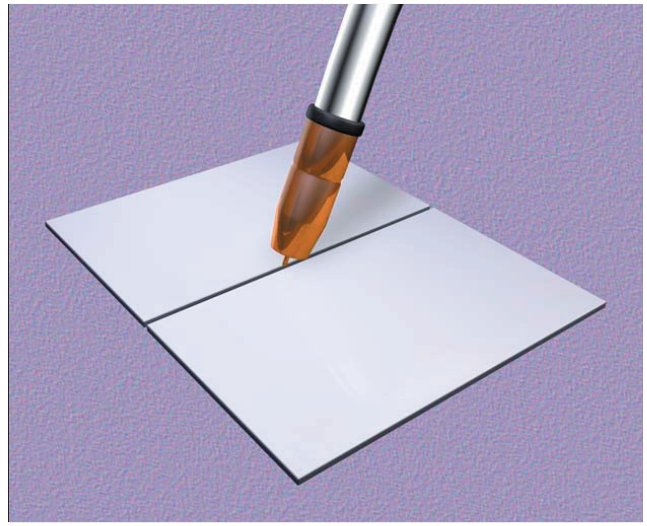
Topic A. Open Butt Joint Description



A-2 Because it is easier to apply corrosion protection on the backside, the open butt joint is a common sectioning joint on many vehicles.

The open butt joint:

- joins two pieces that are in the same plane and butted against each other.
- may have a root gap of 0–1 metal thicknesses between the two pieces. A root gap is not required for this joint, but having a small gap will help minimize distortion of the pieces being welded. Too large a root gap will make welding the joint without burnthrough difficult.

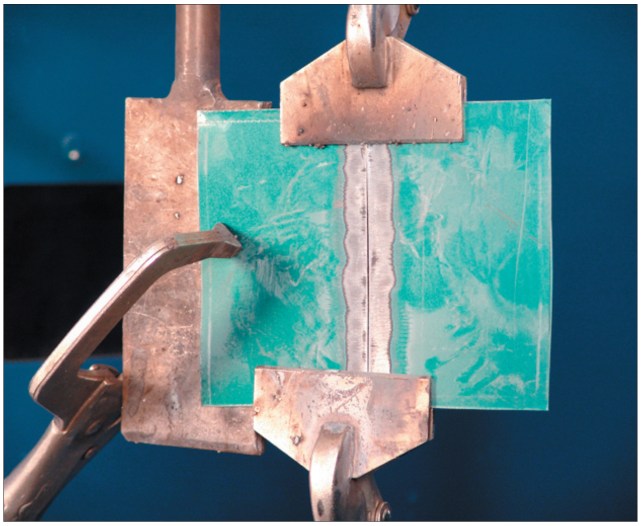


A-3 An open butt joint weld is made using a 90º work angle, aiming the electrode wire at the center of the joint.

The open butt joint weld is made by aiming the electrode wire at the center of the joint and pulling or pushing the welding gun at a 70° travel angle while keeping the welding gun at a 90º work angle. A 90º work angle means that the welding gun plane is at a right angle to the base metal. The electrode wire is aimed straight into the joint.

OPEN BUTT JOINT WELD TECHNIQUE
Refer to screen A-4v of your CD-ROM for a video animation on how to make an open butt joint weld.

Topic B. On-Vehicle Open Butt Joint Welding Procedure



B-1 Scrap pieces from the vehicle being repaired can be used to make test welds.

Before welding on a vehicle, test welds should be made, visually inspected, and destructively tested to ensure that the proper welder setup and welding technique is being used. When making practice open butt joint welds:

- use the same thickness and type metal that will be welded on the vehicle. Damaged parts that are to be replaced may provide scrap pieces.
- make the test welds in the same position as the welds on the vehicle.
- visually inspect and destructively test the sample welds before welding on the vehicle.
- use small pieces of flat scrap steel, trimmed to about 75 x 125 mm (3 x 5").
- butt two pieces together, leaving a gap of 0–1 metal thicknesses.

B-2 Just like the other joint types, test open butt joint welds should be visually inspected.

After making test welds they should be visually inspected. Signs of a good open butt joint weld on the frontside include:

- a joint that is completely filled.
- no porosity, skips, or voids greater than 3 mm (1⁄8") and the total of all not to exceed 6 mm (1⁄4").
- no cracks.
- no undercut.

The open butt joint weld is a visual failure if any of these requirements are not met.

B-3 If penetration is adequate, the line formed by the joint will not be visible on the backside of the test weld.

The backside of the open butt joint weld must also be inspected. Signs of a good weld on the backside include:

- no burnthrough that creates a hole.
- evidence of complete penetration for the length of the entire weld. There must be melt through on the backside of the joint as evidence of good weld penetration. The line left by the joint should not be visible anywhere along the length of the weld.
- a melt-through height that cannot exceed 1.5 mm (0–1⁄16").

The open butt joint weld is a visual failure if any of these requirements are not met.

B-4 A good open butt joint weld will not separate when folded over and hammered flat.

To destructively test open butt joint welds:

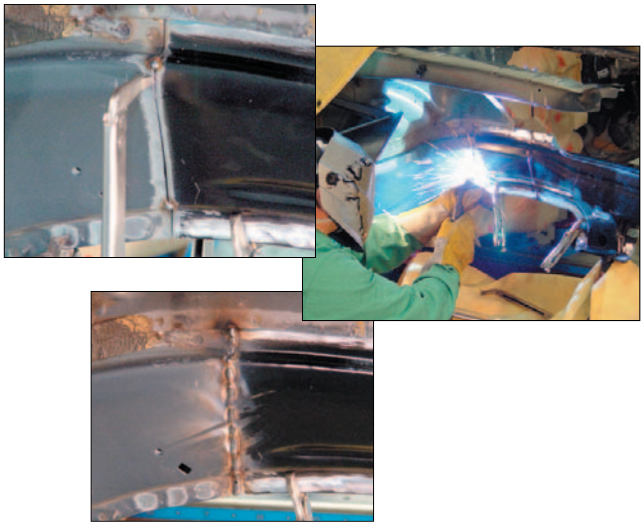
1. Bend the pieces up toward each other. Make the bend on the axis of the weld, with the root of the weld on the face of the bend.
2. Lightly hammer the test sample flat.
3. Inspect the weld for weld metal cracks.

The open butt joint weld passes the destructive test if:

- no cracks are visually detected.
- weld metal cracks are detected but the fractured face shows no visually detectable flaws such as slag or porosity, and the weld size is equal or greater than the metal thickness.
- cracks are limited to the base metal. Due to the severity of the test, base metal cracks are to be ignored as long as the pieces do not completely separate.

The open butt joint weld fails the destructive test if:

- the weld bead fractures completely apart.
- cracks in the weld metal show visually detectable flaws such as slag or porosity.

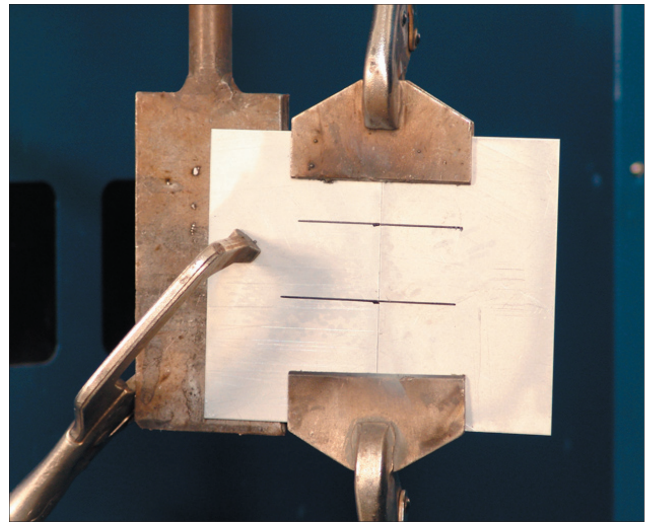


B-5 After careful cleaning and fit-up, this open butt joint weld was made using a stitch weld technique to avoid excessive heat buildup.

To make a GMA (MIG) open butt joint weld on a vehicle:

1. Clean the mating surfaces thoroughly. Avoid removing any zinc coating.
2. Clamp the pieces tightly together.
3. Locate the work clamp as close to the welding site as possible.
4. Make the welds on the vehicle. The open butt joint weld can be made using a continuous weld or a series of short stitch welds. Use the welder settings that were decided upon from the test welds. Use a welding technique that limits the heat input and controls metal distortion.
5. Dress the welds, if necessary. Do not reduce the thickness of the surrounding sheet metal or remove any zinc coating.

Topic C. Welding Qualification Test (SWQT) Open Butt Joint Welds

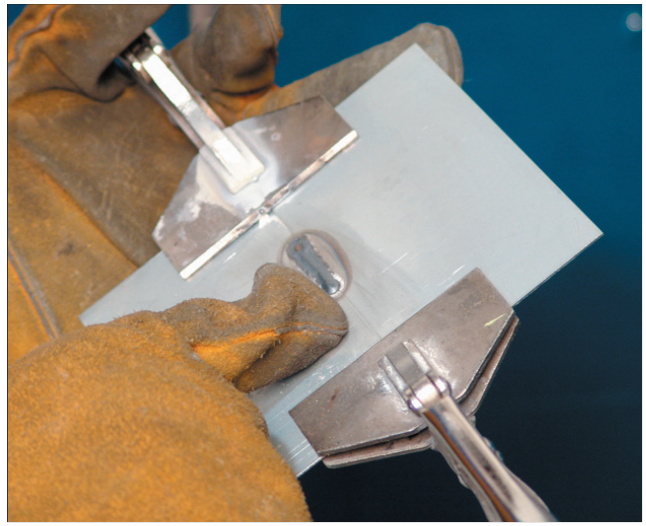


C-1 Like the other required welds, SWQT open butt joint welds are made in both the overhead and vertical positions.

When making open butt joint welds for the Steel Welding Qualification Test (SWQT):

- butt two coupons together leaving a gap of 0–1 coupon thicknesses. This is about 0–1 mm (0–$\frac{1}{16}$").
- clamp the coupons together, and to the positioner. Tack welds outside of the weld bead are not allowed.
- make a 25–38 mm (1–1$\frac{1}{2}$") weld in the center of the coupons.
- participants are required to make open butt joint welds in the vertical and overhead positions. Each participant is given two coupons for each position. After performing the welds, the participant chooses one weld from each position to turn in.

C-2 The minimum bead width for the SWQT open butt joint weld is narrower than for the fillet and butt joint with backing welds.



C-3 With good penetration the backside of an open butt joint weld looks very similar to the front side.

The front side visual inspection parameters for the I-CAR SWQT open butt joint weld include:

- a bead length of 25–38 mm (1–1½").
- a bead height of 0–3 mm (0–⅛") above the top coupon.
- a bead width of 3–10 mm (⅛–⅜").
- no porosity, skips, or voids greater than 3 mm (⅛") and the total of all not to exceed 6 mm (¼").
- no cracks.
- no undercut.
- the joint is completely filled.

Visual inspection parameters for the backside of the open butt weld include:

- no burnthrough.
- a melt-through width of 3–10 mm (⅛–⅜").
- a melt-through height that cannot exceed 1.5 mm (1/16"). There must be a melt-through on the backside as evidence of penetration. The line left by the joint must not be visible along the entire length of the weld.

The open butt joint weld is a visual failure if any of these requirements are not met.

OPEN BUTT JOINT WELDS
Select the Demonstration icon found on screen C-3 of your CD-ROM for examples of open butt joint welds that pass the visual inspection and open butt joint welds that fail the visual inspection.

C-4 An SWQT open butt joint weld is destructively tested by bending at the joint and hammering the weld flat.

To destructively test open butt joint welds use the following procedure:

1. Bend the coupons together along the axis of the weld, with the root of the weld on the face of the bend.
2. Lightly hammer the test piece flat to make a 180° bend.
3. Inspect the weld for weld metal cracks.

The open butt joint weld passes the destructive test if:

- no cracks are visually detected.
- weld metal cracks are detected but the fractured face shows no visually detectable flaws such as slag or porosity, and the weld size is equal or greater than the coupon thickness.
- cracks are limited to the base metal. Due to the severity of the test, base metal cracks are to be ignored as long as the pieces do not completely separate.

The open butt joint weld fails the destructive test if the:

- weld bead fractures completely apart.
- cracks in the weld metal show visually detectable flaws such as slag or porosity.

SAMPLES OF DESTRUCTIVELY TESTED WELDS
Select the Demonstration icon found on screen C-4 of your CD-ROM for examples of destructively tested open butt joint welds.

DESTRUCTIVE TESTING FOR THE SWQT
Refer to screen C-5v of your CD-ROM for a video on how to destructively test an SWQT open butt joint weld.

Topic D. Review

REVIEW
Refer to screens D-1 and D-2 of your CD-ROM for review questions on making open butt joint welds.