Introduction

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:

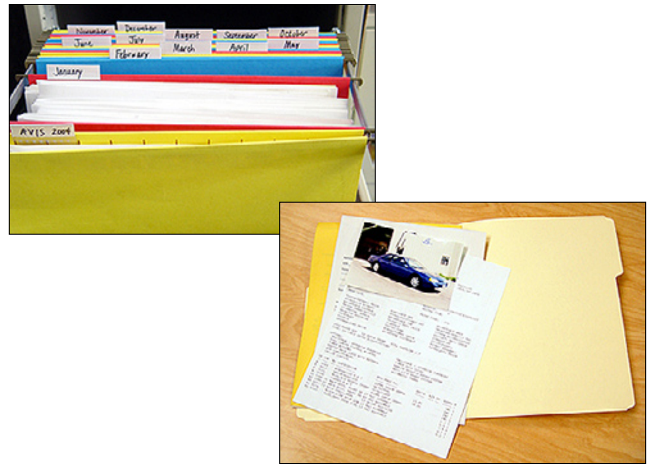
- safety.
- structural integrity.
- durability.
- performance.
- fit.
- finish.

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.

Aluminum GMA (MIG) Welding

Textbook

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.

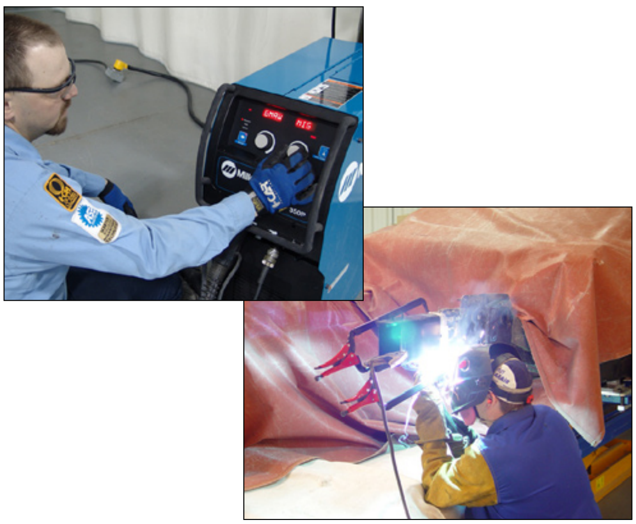
I-CAR does not endorse or recommend any brands or makes of vehicles, repair equipment and supplies or other products. The appearance of various makes and brand names in any I-CAR material is purely coincidental and is based on the availability of those products at the time of production.

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. Aluminum Vs. Steel

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.

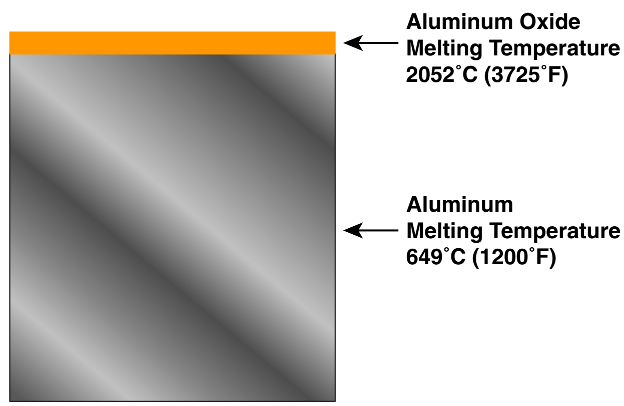

A-2 GMA (MIG) is a widely accepted and familiar welding process.

Aluminum can be welded using a variety of processes. There are several advantages of the Gas Metal Arc (GMA), or MIG, welding process for welding aluminum. These include:

- GMA (MIG) welding is widely accepted.
- most technicians are familiar with the GMA (MIG) welding process. GMA (MIG) welding equipment is commonly found in collision repair facilities.
- GMA (MIG) welding can be used on a wide variety of aluminum alloys and thicknesses.
- GMA (MIG) welding has a good production rate.
- there is no problem with a high-frequency arc, as with the GTA (TIG) welding process.

There are differences between GMA (MIG) welding aluminum when compared to steel. Aluminum has:

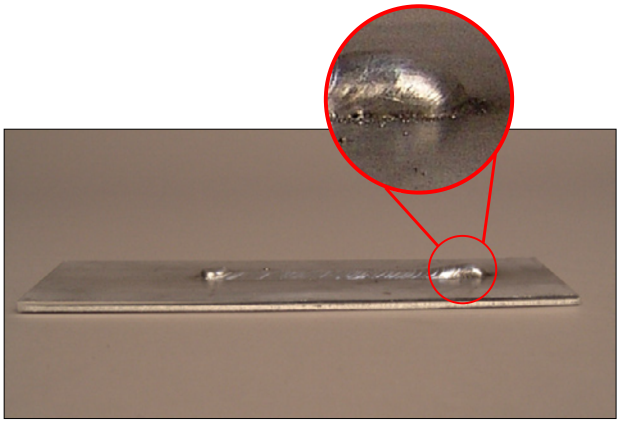
- a lower melting temperature. Aluminum melts at 649°C (1,200°F). Steel melts at 1480°C (2700°F).
- faster heat transfer. Heat travels very rapidly through aluminum. It will spread, rather than stay concentrated in a small area. Panel thickness also affects the heat transfer. A thick panel will have more heat transfer than a thin panel.
- a greater thermal expansion rate. When aluminum is heated, it typically expands twice as much as steel.
- no color change when heated. It will appear to change state just before it melts. There is no other indication that the surface temperature is rising.



A-4 Aluminum oxide protects the aluminum from corroding.

Aluminum forms a protective coating called aluminum oxide. This is what makes aluminum highly corrosion resistant. Aluminum oxide:

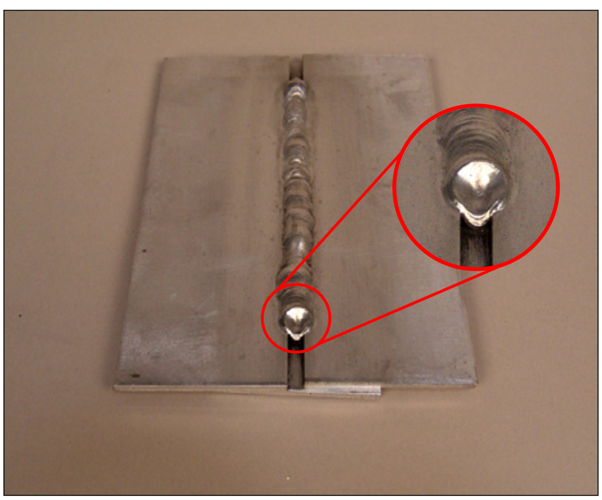
- is self healing and begins to re-form instantly if it is removed from the surface.
- has a melting temperature of 2050°C (3725°F).
- must be removed from the aluminum prior to being welded.
- can lead to contamination of the weld. This contamination is called porosity.



A-5 Cold start is very common with aluminum.

A common characteristic of aluminum GMA (MIG) welding is a cold start. Typically, a cold start:

- is at the beginning of the weld.
- is caused by the rapid heat transfer of aluminum.
- will cause a lack of penetration at the beginning of the weld.



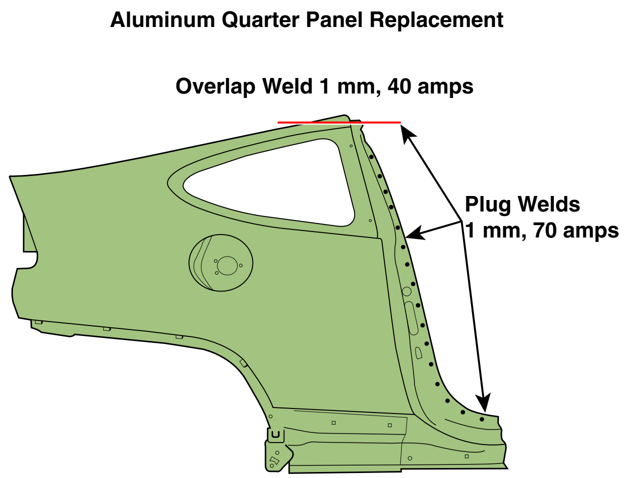
A-6 Craters will appear at the end of a weld.

Another common characteristic of aluminum GMA (MIG) welding is craters. Craters are typically:

- at the end of the weld.
- caused by the high amounts of heat that are generated by the time an aluminum weld is being completed.
- seen as a sunken or undercut area at the end of the weld. A crater will commonly be a weak spot in the weld bead.

Cracks may occur when welding aluminum. Typically, cracking occurs:

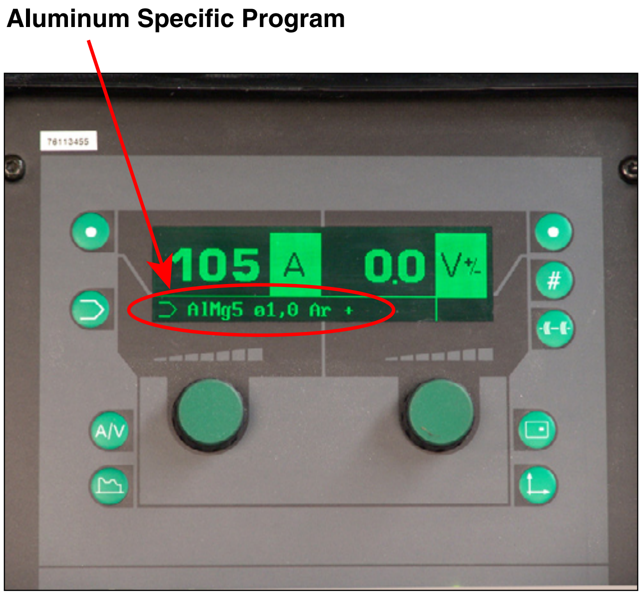
- from overheating the aluminum, and the increased expansion that overheating causes.
- more frequently on thicker aluminum.
- more frequently on aluminum castings. Aluminum castings are commonly designed with varying thicknesses and reinforcements throughout, which makes them very rigid.



A-8 Changes in joint type can affect welder settings, even on similar thicknesses of aluminum.

Aluminum has a greater sensitivity to welder settings when working with different alloys, material thicknesses, and joint types.

Changes in these factors will typically require adjustments to the welder settings. For example, a butt weld with backing joint on 1 mm aluminum would require a different amount of amperage than a plug weld on 1 mm aluminum.



A-9 There are differences in equipment for GMA (MIG) welding aluminum compared to welding steel.

Aluminum GMA (MIG) welding typically requires some different types of welding equipment. Typically, GMA (MIG) welders used for aluminum:

- generate more amperage. This is to compensate for the rapid heat transfer.
- may have specific settings for welding on aluminum.
- have a different electrode wire feed system, such as a spool gun.
- use a different shielding gas, usually 100% argon.
- have dedicated parts for aluminum electrode wire feeding. Dedicated parts may help reduce the possibility of cross contamination and galvanic corrosion.

A-10 Personal safety is first and foremost when GMA (MIG) welding aluminum.

Personal safety measures include using:

- a welding helmet. The proper lens shade should be used for the amperage being used.
- a welding jacket.
- welding gloves.
- a HEPA (P100) or N95 particulate respirator, or a filtered-air supplied welding helmet.
- ear plugs.
- safety glasses.

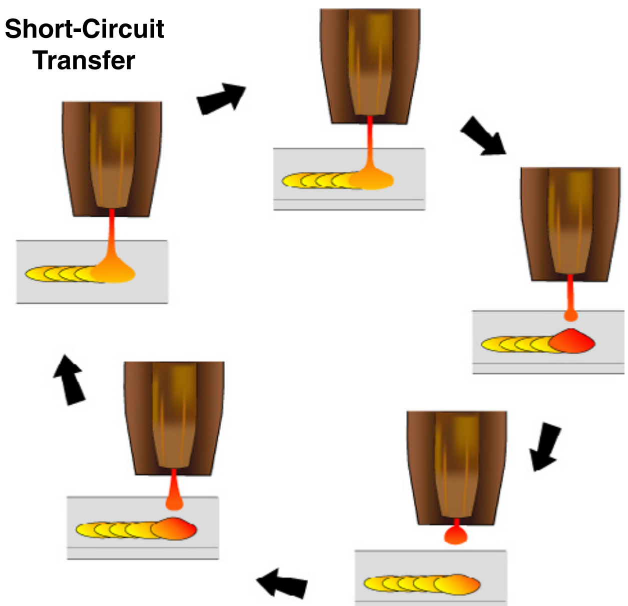
The American Welding Society (AWS) recommends the following helmet shades for welding aluminum:

- Under 60 amps, 7–9 shade number range
- 60–160 amps, 10–11 shade number range
- 160–250 amps, 10–12 shade number range

Topic B. Transfer Methods

Three electrode transfer methods most often recommended for aluminum include short-circuit, spray-arc, and pulsed spray-arc.

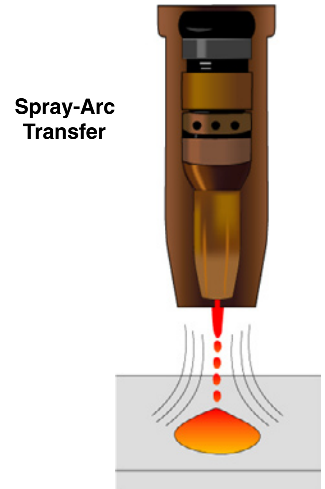
Globular transfer is usually not recommended for aluminum welding since it produces more spatter than short-circuit transfer, is more likely to produce weld defects in aluminum, and does not promote good penetration.



B-2 Short-circuit transfer uses lower amperage than other transfer methods.

Short-circuit transfer:

- deposits aluminum as the electrode wire touches and short circuits against the base metal many times per second.
- uses lower amperage and voltage than other transfer methods.
- produces less penetration and smaller weld puddles than other transfer methods.
- makes a steady crackling sound when correctly adjusted.



B-3 Spray-arc transfer uses higher amperage than short-circuit transfer.

Spray-arc transfer:

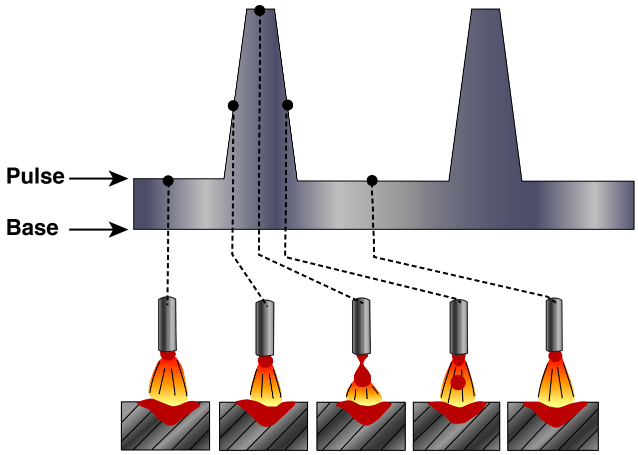
- uses higher voltage, amperage, and wire speed than short-circuit transfer.
- sprays a tiny stream of molten drops across the arc, from the electrode wire to the base metal. The molten drops are much smaller than the diameter of the electrode wire.
- makes a steady humming sound when correctly adjusted.

Spray-arc transfer:

- produces a large, more fluid weld puddle due to the higher heat for the same electrode size.
- produces little or no spatter.
- typically requires gun travel speed to be increased after starting the weld. This is due to the higher heat generated using spray-arc transfer compared to other transfer methods.
- requires increased operator skill to weld thin aluminum.

Spray-arc transfer can be used in all positions, with the proper size electrode wire, when welding aluminum.

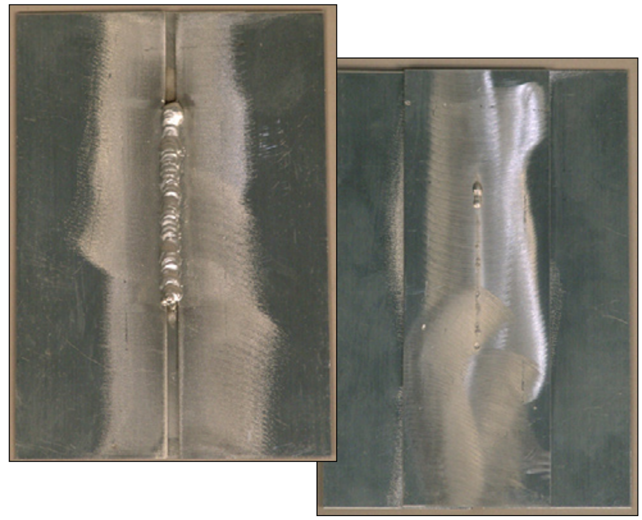
THE SOUND OF SPRAY ARC
Refer to screen B-5v of your CD-ROM for a video comparing the sound of spray-arc to short-circuit transfer.



B-6 Pulsed spray-arc transfer uses two types of welding current.

Pulsed spray-arc transfer uses a base current and pulsed current. During pulsed spray-arc transfer:

- the base current maintains the arc.
- the pulse current "peaks" at higher amperages. This "peak" detaches a droplet from the electrode wire.
- the high current pulses rapidly. High current pulses occur between 60–200 times per second.
- electrode wire transfers only during the high current pulses.



B-7 Pulsed spray-arc transfer allows for cooler welding with good penetration.

Pulsed spray-arc transfer:

- allows for cooler welding. This is due to the time between low current and high current pulses where the electrode wire does not transfer. This allows cooling while still maintaining the arc.
- may offer less chance of burnthrough on thin aluminum, while still giving good penetration on thicker aluminum.
- produces little or no spatter.
- may allow a larger electrode wire to be used.
- can be used in all positions.
- usually requires an inverter power source that will pulse the current.

The Aluminum Association recommends the spray-arc, or pulsed spray-arc transfer methods when welding aluminum.

PULSED SPRAY-ARC TRANSFER
Refer to screen B-8v of your CD-ROM for a video showing pulsed spray-arc transfer in slow motion.

Topic C. Electrode Wire

Electrode wires are alloys, which means they are aluminum mixed with other elements. Electrode wire is classified in one of four different series, either 1000, 2000, 4000, or 5000, with each number identifying a specific type of filler alloy. Electrode wire commonly used for collision repair includes alloys in the 4000 series, usually 4043, and the 5000 series, usually 5356.

Different alloys give the electrode wire different qualities, for example:

- 4043 is softer than 5356 electrode wire.
- 4043 makes a more fluid weld puddle than 5356 electrode wire.
- 4043 has a lower tensile strength than 5356 electrode wire.

Closely matching the electrode wire alloy to the base metal alloy helps ensure good weld quality. 5356 alloy electrode wire is close to a general, all-purpose electrode that will work with most series of alloy based metal. 4043 alloy electrode wire is not compatible with some series alloys used on vehicles. Some vehicle makers may have specific recommendations for electrode wire alloy.

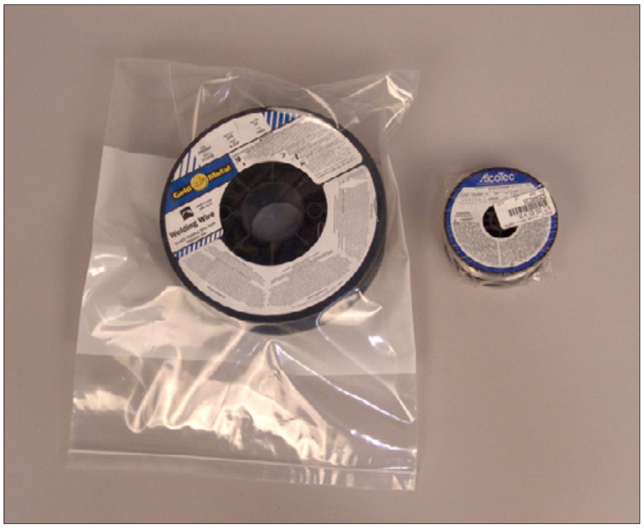
C-2 Electrode wire is available in different diameters.

Recommended electrode wire diameters are dependent upon the metal thickness, the amount of welding current, and the transfer method. Pulsed spray-arc transfer can allow thin aluminum to be welded with thicker electrode wire. Using a small diameter electrode wire may lead to problems with some wire feed systems.

Electrode wire diameters common for collision repair include:

- 0.8 mm (.030").
- 0.9 mm (.035").
- 1.0 mm (.040").
- 1.2 mm (.047").

Some vehicle makers may have specific recommendations for electrode wire diameter.



C-3 Electrode wire should be stored properly when not in use.

The best welding results are obtained by using clean electrode wire. When not in use, electrode wire should be stored:

- in a warm, dry area. Condensation may form on cold wire when it meets warmer air.
- in a sealed plastic bag.
- to slow oxidation.

Like all aluminum, avoid contaminating the electrode wire. Using clean electrode wire will help reduce weld porosity.

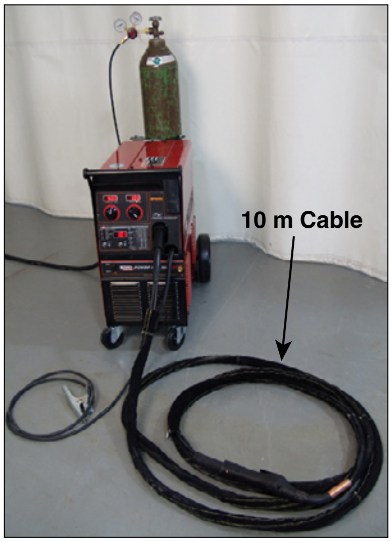
Aluminum electrode wire has no specifications for the amount of cast and helix.

Topic D. Electrode Wire Feed Systems

D-1 Spool guns may have flexible ends to increase accessibility.

A spool gun:

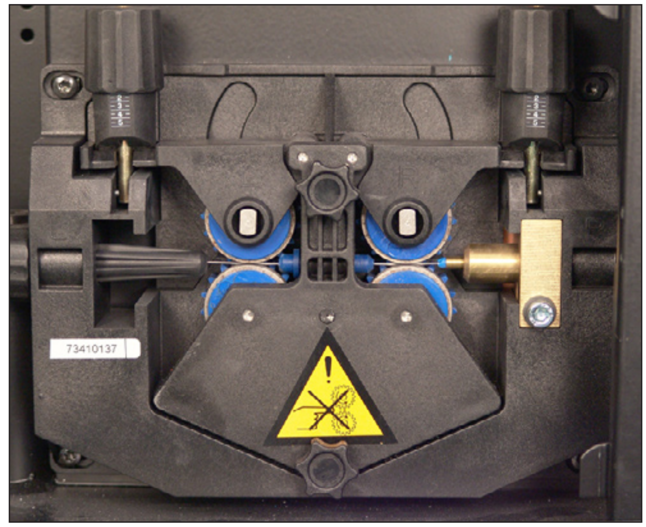
- has a spool of wire attached directly to the welding gun.
- uses one motor and drive roll set attached directly to the gun body.
- has a short liner, contained inside the gun.
- may have limited access to welding areas due to its size.
- may have a flexible end to help increase accessibility.



D-2 Push-pull feeders can use long liners.

A push-pull feeder:

- has two motors and two sets of drive rolls. One set of each is in the power source cabinet and in the welding gun.
- can have a liner over 9 m (30') in length.
- works well with soft electrode wire. A push-pull feeder also provides uniform feeding for small diameter electrode wire.

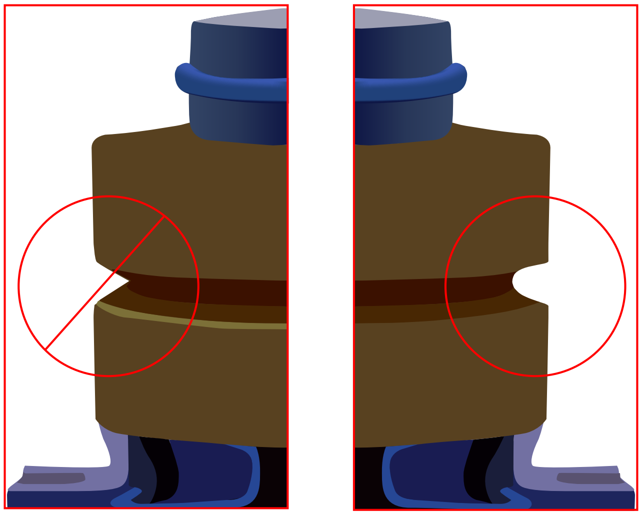


D-3 Push feeders may use two sets of drive rolls.

A push feeder, similar to what is used for most steel GMA (MIG) welding applications:

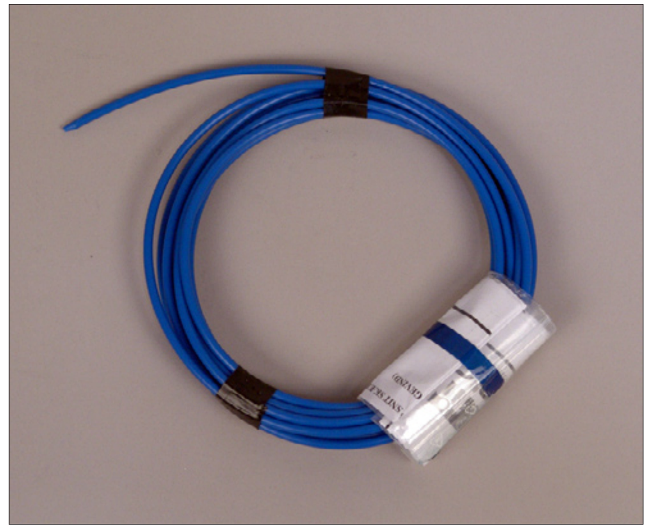
- has the feed motor and drive rolls located in, or on the power source cabinet.
- pushes the electrode wire through a flexible gun liner and into the welding gun.
- uses a liner that is usually limited to about 3 m (10'). Aluminum wire tends to buckle and bind at the drive rolls when using long liners. This can cause birdnesting.

Some welding machines use two sets of drive rolls inside the power source cabinet to help cut down on birdnesting.



D-4 Wire feed drive rolls should not be V-shaped.

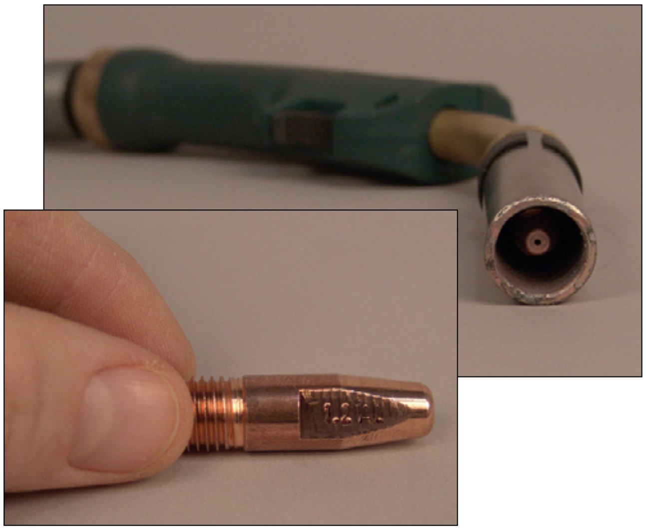
Wire feed drive roll designs vary with the type of wire feed system being used. Knurled drive rolls are typically used in spool guns and pull feeders. Knurled drive rolls are not recommended for push feeders. The knurling may cause aluminum to flake off the wire, causing resistance in a long liner. U-shaped drive rolls are typically used in push feeders. V-shaped drive rolls are not recommended for push feeders. V-shaped drive rolls typically compress aluminum electrode wire. Compressing the electrode wire will cause birdnesting.



D-5 Gun liners must be dedicated for aluminum.

The welding gun liner for aluminum electrode wire:

- may be nylon or Teflon®, which helps the wire slide with less resistance.
- must be dedicated for aluminum.
- should be blown out with clean, dry compressed air to remove aluminum particles. Electrode wire tends to leave small particles that can build up and affect electrode wire feed and possibly weld quality.



D-6 Contact tips should be recessed from the shielding gas nozzle.

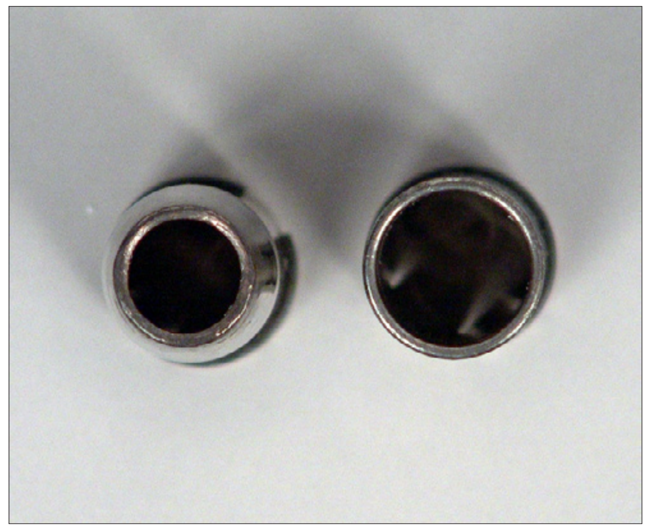
The contact tip:

- is usually made of copper or copper alloy.
- should be recessed about 3–5 mm ($\frac{1}{8}$–$\frac{3}{16}$") from the nozzle outlet. Some welding guns may be recessed more than that.
- may become worn, reducing current transfer efficiency and causing the electrode wire to wander. Change the contact tip when the hole diameter becomes enlarged with use.
- may be oversized. Oversizing is done to prevent resistance from wire that may be expanding from heat during the welding process.
- may be labeled with an “A” or “AL” to indicate that it is a contact tip specific for aluminum GMA (MIG) welding.

Topic E. Shielding Gas

100% argon is used for aluminum GMA (MIG) welding. A mixture of argon and helium should not be used because it typically welds hotter. This makes penetration harder to control on thin aluminum. Pure argon provides:

- good cleaning action.
- stable arc.
- better control of penetration on thinner aluminum.



E-2 Shielding gas nozzles are typically not tapered for welding aluminum.

Straight shielding gas nozzles are generally used for welding aluminum. Straight nozzles are used to envelop larger bead and joint areas, and deliver more gas flow.

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

Flow meters are generally set to 25–50 cfh for aluminum collision repair welding. This compares to 25–30 cfh for steel. This range depends on the type of transfer method, thickness of the aluminum, and nozzle size used.

Before attaching the regulator, open the cylinder valve for a second or two to blow out any dirt or contaminants that may be near the valve opening.

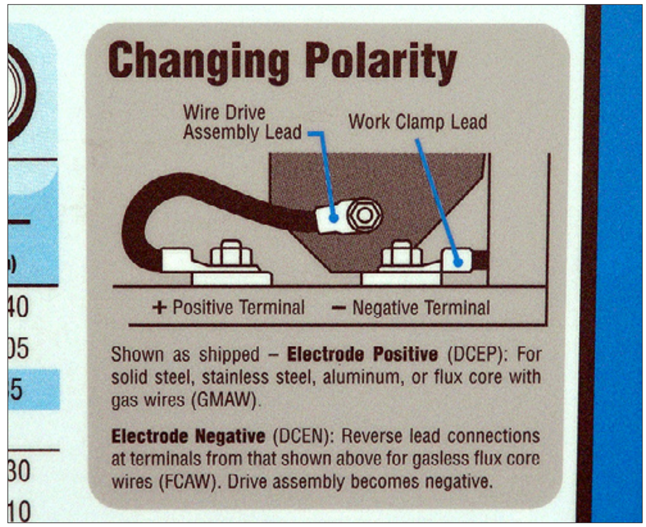
Always direct the gas cylinder valve away from yourself and others in the work area.

Never use oil on any regulator or gauge. This may cause an explosion or fire.

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.

Topic F. Aluminum Welding Machines



F-1 Reverse polarity is also referred to as DCEP.

Reverse DC polarity, when the electrode is positive and the workpiece is negative (DCEP), is used almost exclusively for aluminum GMA (MIG) welding. With reverse polarity, 80% of the arc heat is at the electrode.

Reverse polarity is used for aluminum welding because it provides the highest concentration of heat and a narrow heat focus zone, which is needed for aluminum.

Collision repair facilities often convert an existing GMA (MIG) welding machine to weld aluminum. These welders typically have:

- drive rolls changed from “V” to “U” shaped.
- a liner made from nylon or Teflon® installed.
- the contact tip changed.
- a larger diameter, straight shielding gas nozzle installed. The shielding gas diffuser should also be changed.
- the shielding gas changed to 100% argon.
- settings for relatively low amperage and voltage. This may only allow for short-circuit transfer, and limited choice of electrode wire diameter.

F-3 Aluminum-specific machines may have pre-programmed aluminum settings.

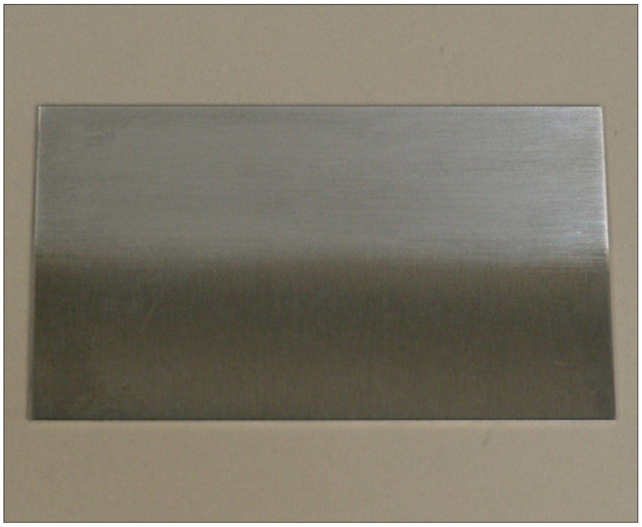
For improved weld quality and ease of use when welding aluminum, some equipment makers have GMA (MIG) welding machines that are specifically for aluminum welding. Aluminum-specific welding machines:

- have higher amperage capabilities to allow spray transfer. An output of 200 amps at 30% duty cycle is recommended.
- typically come equipped with a spool gun, a push-pull feeder, or a dual drive roll electrode wire feed system. This allows use of a wider variety of electrode wire diameters and alloys.
- may have pre-programmed settings for welding aluminum. Settings for different alloys and diameters of electrode wire may be available. Some machines may have settings for different thicknesses of aluminum and joint configurations. Features to reduce cold start and crater defects are also programmed in some welding machines.
- typically use pulsed spray-arc transfer.

Topic G. Review

REVIEW
Refer to screens G-1 and G-2 of your CD-ROM for review questions on aluminum welding equipment.

Topic A. Surface Preparation



A-2 Aluminum oxide protects aluminum from corroding.

Aluminum oxide:

- forms on the surface of bare aluminum, protecting the aluminum from further corrosion. Oxide can be compared to the zinc coating on steel, in that the oxide protects the aluminum from deterioration.
- will begin to re-form immediately on the surface.
- can trap moisture and dirt. A thick layer of oxide tends to hold more dirt and moisture than a thin layer.
- can cause porosity in an aluminum weld bead.

A-3 Every area of the weld joint must have coatings and oxide removed.

Poor welds occur from aluminum surfaces that are covered with coatings and oxidation. Coatings and oxidation must be removed 30–40 mm from the weld joint. Every area of the weld joint should be cleaned, including the backside and the edges.

Leaving coatings and oxidation too close to the adjacent weld zone may cause contaminants to be drawn in to the weld bead from heat transferring through the aluminum.

The coatings and oxidation can be removed using a:

- wax and grease remover before oxide removal to remove residue. Sanding before using wax and grease remover smears the contaminants into the surface of the aluminum.
- plastic woven pad. These are available either as individual pads or pads that attach to small grinder pads.
- disc sander with 80–120 grit sandpaper. Sandpaper can be also be used by hand to access small hard-to-reach areas.
- stainless steel wire brush.

Use tools and abrasives dedicated for use on aluminum. Tools and abrasives used for steel may contaminate an aluminum surface.

When working with solvents, personal protection includes:

- chemical-resistant gloves.
- eye protection.
- vapor respirator.

Because of the low density of aluminum, repair facilities should use an enclosed motor dust extraction unit to remove aluminum dust created during coating and oxide removal.

If a disc sander is used, do not press too hard. Excessive sanding pressure may:

- remove too much aluminum, thinning the metal. Thinning the metal may also lead to warping from overheating.
- clog the disc. Using a clogged disc on aluminum may scratch or gouge the surface.
- imbed impurities into the surface.

Do not use mild steel brushes for oxide removal. Mild steel brush particles may flake off, contaminating the aluminum. Weld-through primers are not necessary and should not be used on aluminum.

After cleaning, avoid handling the surfaces to be joined with bare hands. This may contaminate the clean surface and adversely affect weld quality.

A-6 Weld as soon as possible following cleaning and part fit-up.

After cleaning to bare aluminum, a slight amount of aluminum oxide quickly forms on the surface. This is the self-healing feature of aluminum alloys. Welding should be done as soon as possible following cleaning and part fit-up. The weld joint should be cleaned again with a small stainless steel brush immediately before welding. The amount of time that can pass before complete re-cleaning is required will vary with temperature and humidity levels.

PANEL PREPARATION
Select the Demonstration icon found on screen A-6 of your CD-ROM for an example of aluminum panel preparation.

Topic B. Technique Variables

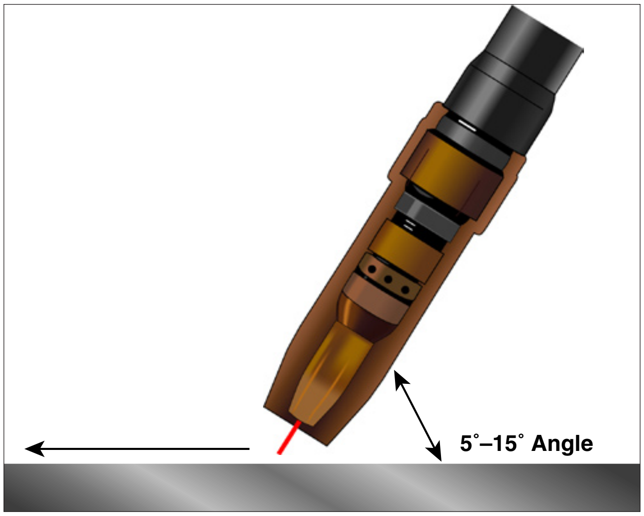
B-1 The welding gun is pointed and pushed away from the weld puddle.

Welding aluminum requires the push technique. The push technique:

- is when the welding gun is pointed and pushed away from the weld puddle. The push technique is also called forehand or lead angle by the American Welding Society (AWS).
- helps direct the shielding gas to the front of the weld puddle.
- provides an arc cleaning action to remove aluminum oxide from the surface.
- is done straight. The welding gun is not weaved back and forth on the joint. Weaving will change where the arc is being focused.

The pull technique, also called the drag or backhand with drag, is when the welding gun is pointed at and dragged away from the weld puddle. This type of technique is not used for aluminum because it:

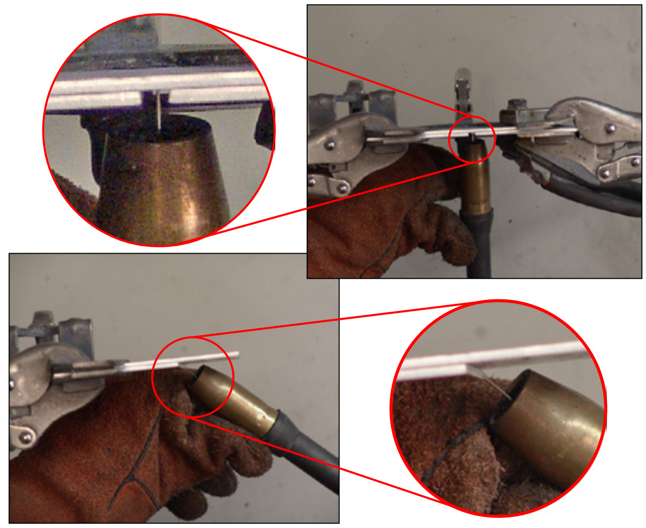
- increases the chance of porosity and a poor weld by not providing enough shielding gas and cleaning action.
- may cause the joint to be rough, or have large amounts of black soot on the weld bead.
- may overheat the weld area, causing excessive penetration.



B-2 The gun angle for pushing does not need to be excessive.

Welding gun angle for the push technique should be about 5–15° from vertical.

The angle does not need to be excessive, such as 45° from vertical. Angling the welding gun too far back may cause a loss of shielding gas effect at the front of the weld. Too much gun angle may also draw contaminants in from the backside of the welding gun, due too a vacuum effect.



B-3 Work angle affects where heat is directed.

The work angle:

- affects where the heat is directed to the joint.
- varies by different welding joint designs.
- for butt joints or butt joints with backing is 90°, directed at the center of the root.
- for lap joints using the same thickness of aluminum is 45°, directly at the root. When a lap joint has two different thicknesses of aluminum, the work angle should be directing more heat on the thicker aluminum. This may help reduce burning away of the thinner aluminum.

B-4 Nozzle-to-workpiece distance should be about 10–16 mm ($\frac{3}{8}$–$\frac{5}{8}$").

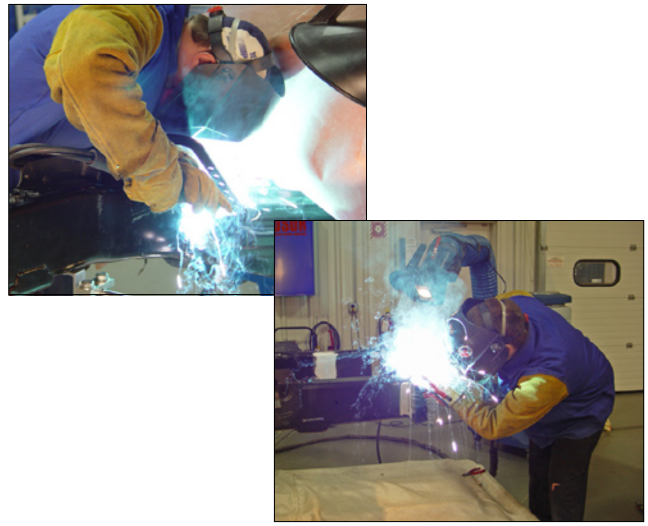
The nozzle-to-workpiece distance:

- should be about 10–16 mm ($\frac{3}{8}$–$\frac{5}{8}$").
- may help control bead height. Varying the nozzle-to-workpiece distance may also affect penetration along a continuous weld.
- is an important factor for pulsed spray-arc welding, as this affects the arc length.

Travel speed:

- affects penetration and overall bead dimensions.
- varies by the transfer method being used. The travel speed typically needs to be increased as the weld progresses when using the spray-arc transfer method. This is from the constant high amperage being used. For pulsed spray-arc, the travel speed can remain more constant. This is from the cooler welding action of the pulsed current.

Travel speed may need to be increased no matter which transfer method is used when working on thinner aluminum.

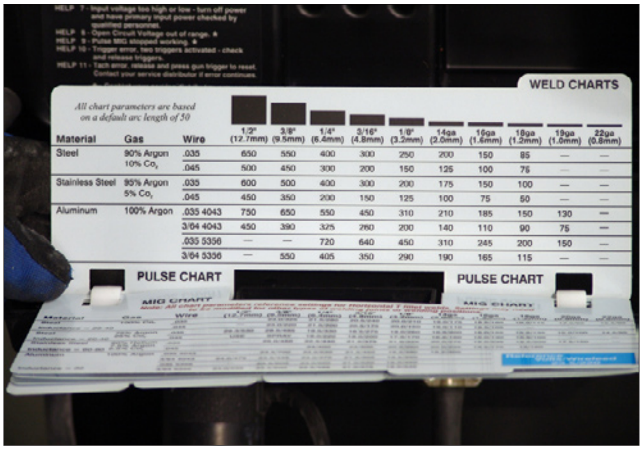


B-6 Body positioning can affect how well you see the weld.

Body positioning is one of the most overlooked factors with all types of welding. When aluminum GMA (MIG) welding, it is very important that a technician can fully see the area to be welded. Reading glasses or magnifying lenses for the welding helmet may improve a technician's ability to see the joint while welding.

Being able to see may help with gun control and arc direction to focus the heat where it is wanted.

Topic C. Tuning The Welder



C-1 Amperage and voltage settings vary greatly.

Amperage and voltage settings used for GMA (MIG) welding aluminum vary depending on:

- electrode wire diameter and alloy. Larger diameters and higher alloy series will typically require higher amounts of amperage and voltage.
- material thickness. The thicker the aluminum is, the higher the amperage required.
- joint type. Different joint types typically require different amounts of amperage and voltage.

Some welding machines have charts for the technicians to find a starting point that can be used for making practice welds. Determining the required amperage is important to determine if the welding machine being used is capable of supplying the necessary amperage for a given thickness of metal. For thinner metal, it will help to know that maximum amperage is not required to produce a quality weld.

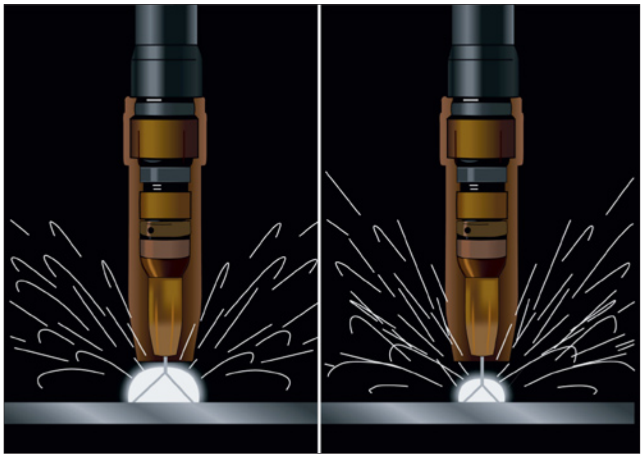
C-2 Increasing or decreasing amperage affects the heat of the weld.

Adjusting the amperage, or current, is the same as increasing or decreasing the wire speed. An increase in amperage will make the weld hotter. This will increase penetration and make a larger weld bead.

Decreasing the amperage will make the weld cooler. This will decrease penetration and make a smaller weld bead.

Adjusting the amperage to the material is typically the first step in tuning the welding machine.

Some welding machines adjust voltage automatically when the amperage is changed. Changes made to the voltage when aluminum GMA (MIG) welding typically affects the arc length. The arc length is the distance that the electrode wire is burning from the surface of the workpiece.

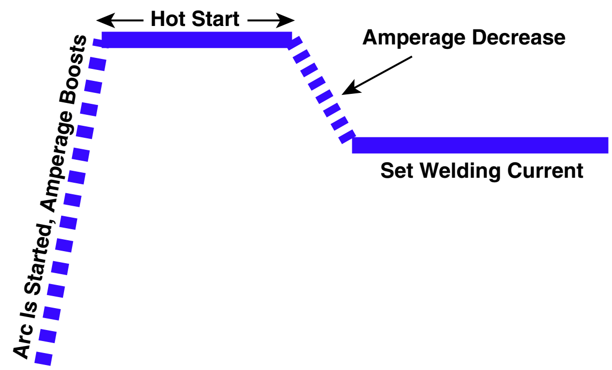


C-4 Arc length affects the distance the electrode wire is burning from the workpiece.

Arc length adjustment:

- is typically an independent adjustment on pulsed spray-arc welding machines.
- is typically more of a fine-tuning adjustment.
- affects weld penetration and bead dimensions.
- negatively, makes the electrode wire burn closer to the surface of the workpiece. A decrease in arc length will result in increased penetration, but make the weld bead narrower.
- positively, makes the electrode wire burn farther away from the surface of the workpiece. Increased arc length decreases penetration, but makes the weld bead wider.

Topic D. Welding Technique

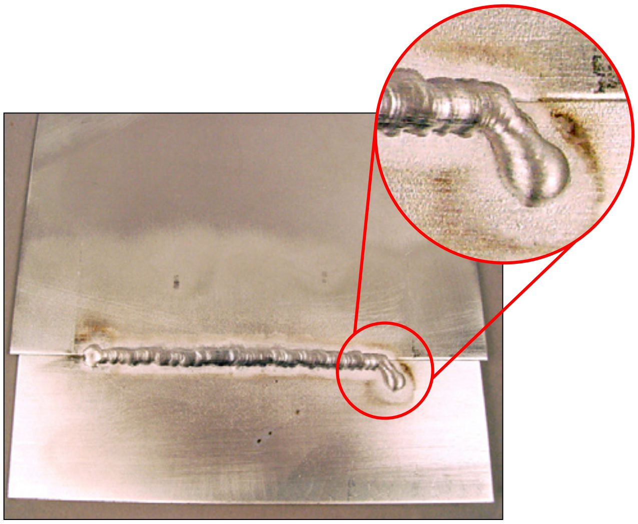


D-1 Cold start appears as a buildup of weld bead sitting on the surface.

A major concern when welding aluminum is poor penetration at the beginning of the weld. This is called a cold start. Cold start is caused by the rapid heat transfer characteristic of aluminum.

If the welder has a hot-start function, this can be avoided. A hot-start function will boost the amperage at the beginning of the weld to heat the aluminum quicker. Some welders that have a hot-start function use a time setting for how long the hot start stays on.

With most welders, it is necessary to compensate for the cold start.

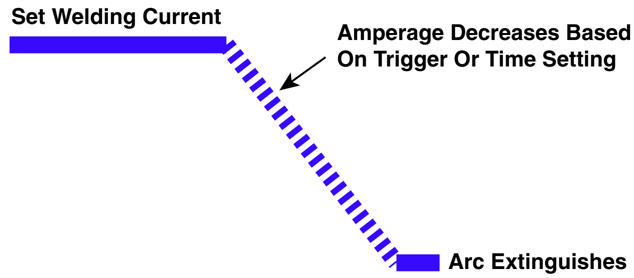


D-2 "Tailing in" can be used for any type of weld.

One method to compensate for a cold start is to start the weld off the joint and move into the joint after the arc is established, sometimes called "tailing in." This can be used for any weld.

Good weld bead consistency is key for making strong aluminum GMA (MIG) welds. Key items for achieving good weld bead consistency include:

- keeping the same work angle on the joint throughout the weld.
- keeping the same gun distance from the joint throughout the weld.
- travel speed. Spray-arc transfer typically requires an increased travel speed while making the weld. A more even travel speed can be used when while making the weld using pulsed spray-arc transfer.



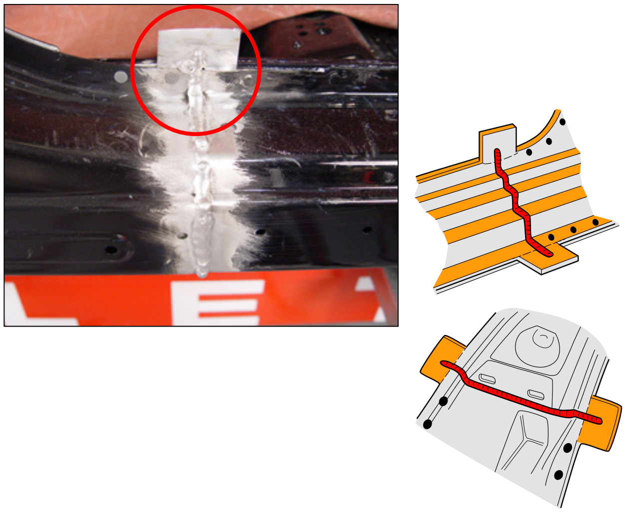
D-4 Craters should not be left at the ends of aluminum welds.

There are techniques to fill craters, which are common at the end of an aluminum weld. Techniques for avoiding craters include

- speeding up slightly when approaching the end of the weld, and then backtracking onto the weld bead.
- stopping the weld, and pausing to let the weld bead cool. If the welder allows, half-trigger the gun to keep the shielding gas flowing. Then re-strike the arc and fill the crater.

Some welding machines have settings for a crater fill. Crater fill settings allow the welder to drop the amperage down gradually when approaching the end of the weld bead. Some welders that have a crater fill function use a time setting for how long the crater fill stays on.

FILLING CRATERS
Refer to screen D-5v of your CD-ROM for a video on two methods that can be used to fill craters at the end of an aluminum weld bead.



D-6 Run-on and run-off tabs can be used for start and stop areas.

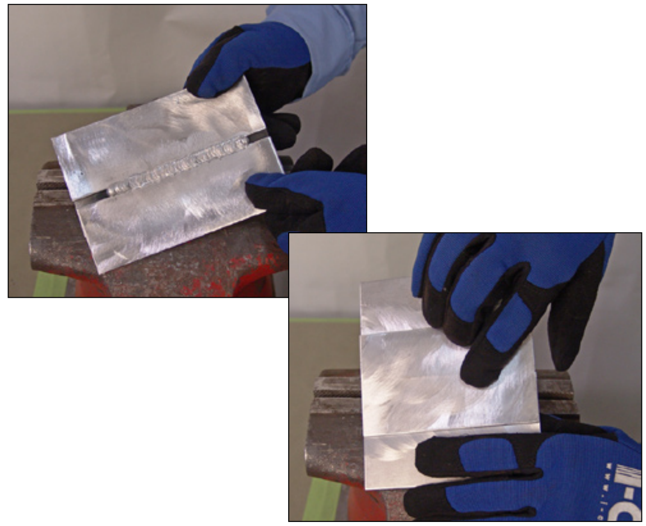
Besides helping to align a joint and provide strength, a backing strip may be used on an aluminum butt joint to provide “run-on” and “run-off” tabs.

Run-on and run-off tabs:

- may be an extension of the backing.
- may be separate tabs welded on at the ends of the joint.
- are used as areas for the weld to be started and stopped.
- keep the cold start area of the weld from being made on the panel.
- prevent making a crater at the end of the weld pass.
- are removed after welding.

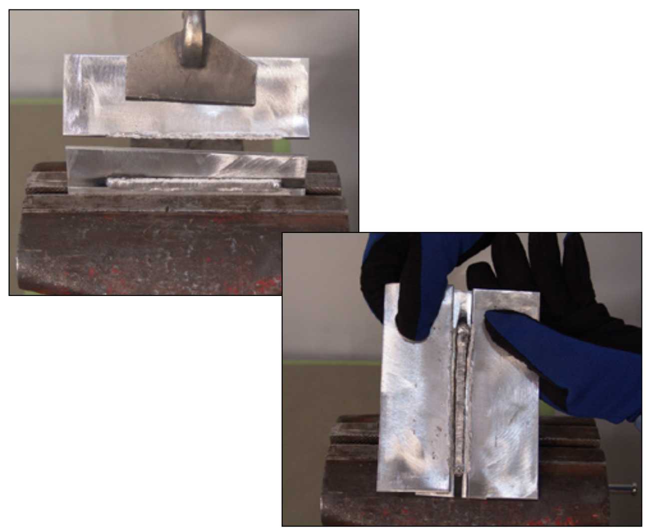
Initial visual inspection after making an aluminum GMA (MIG) weld include looking to see whether:

- the joint is completely filled.
- craters are filled at the end of the weld.
- the weld bead has good width and height dimensions.
- penetration is evident, but not excessive on the backside.



D-8 Weld appearances can be deceiving.

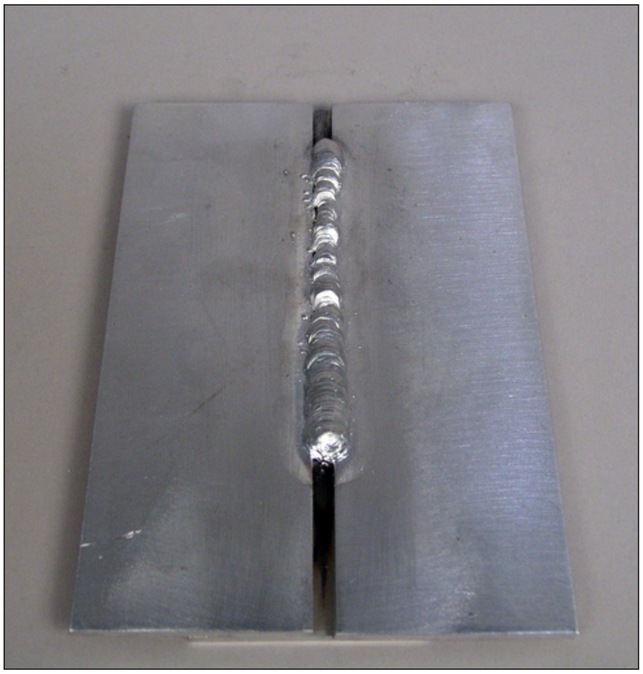
This butt joint with backing appears to be a good weld. There is a flat and consistent bead on the face and evidence of penetration on the backside along the full length of the joint. This does not ensure that the weld will pass destructive testing.



D-9 Destructive testing of welds is necessary.

Destructive testing shows that this weld is no good. There is no fusion to the top plates. This weld was done in a single pass. The root gap was too wide for a single pass.

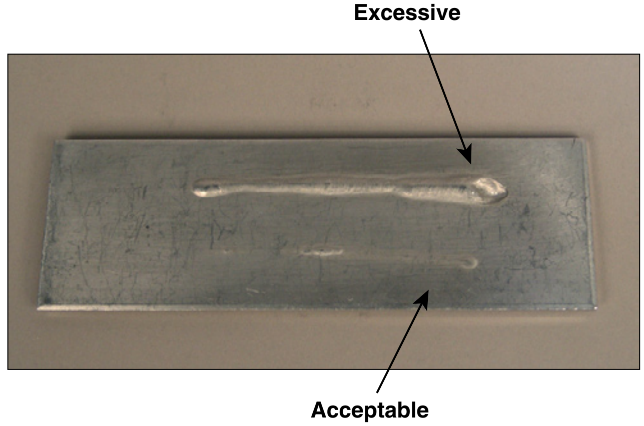
Topic E. Welding Defects



E-1 Cold welds may appear to be "sitting" on the surface.

A cold weld:

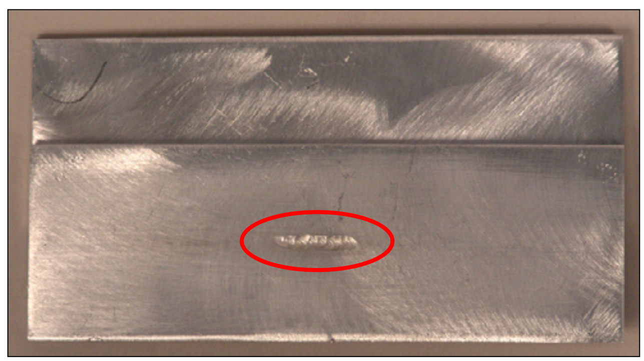
- appears as too much weld metal build on the surface.
- has little or no evidence of penetration.
- has little or no fusion to the workpiece.
- is usually caused by the amperage set too low.
- can occur from using too fast of a travel speed.



E-2 Too much heat can weaken the surrounding aluminum.

Too much heat can:

- cause excessive penetration.
- cause burnthrough on the workpiece.
- weaken material by permanently softening the surrounding area.
- be caused by an amperage setting that is too high.
- be caused by a travel speed that is too slow.



E-3 Suck-back looks like a crater on the backside.

Suck-back is when the weld bead shrinks back during cooling to form a crater on the backside of the weld. Suck-back is usually found on overhead welds and can result in weakening the weld bead or base metal.

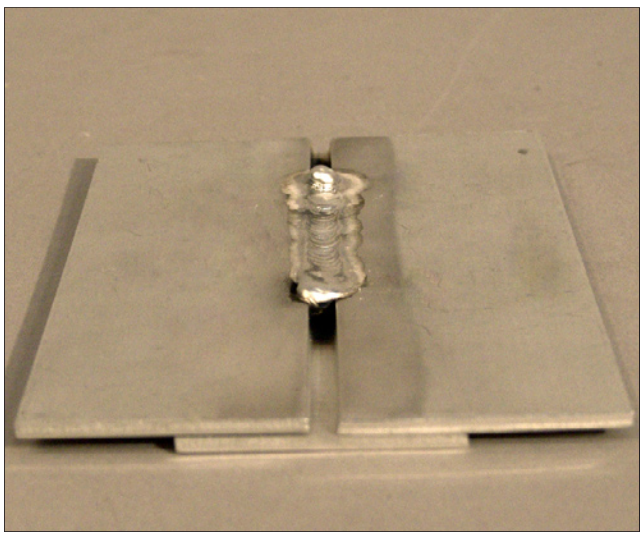
Some techniques to prevent suck-back include:

- reducing the voltage and amperage settings on the welding machine.
- increasing travel speed.
- on butt joints, reducing the root gap during fit-up.

Cracks or fracturing of an aluminum weld can occur if there is:

- too much amperage, or heat used.
- the wrong alloy electrode wire.
- rapid cooling practice used.
- improper joint fit-up, causing internal stress.
- inadequate penetration, causing weld failure from fatigue.

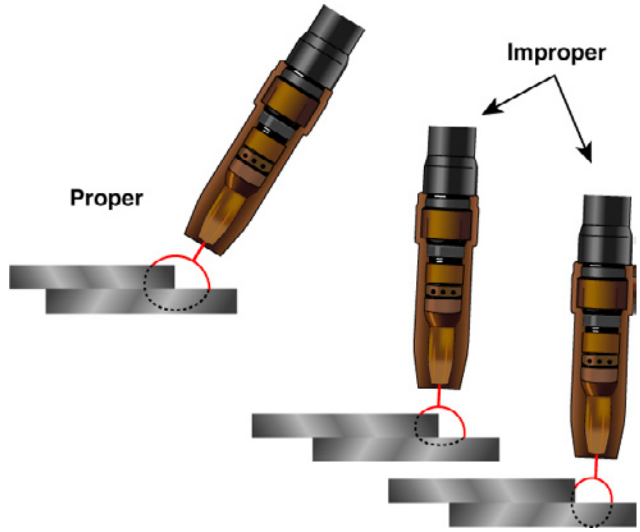
USING DYE PENETRANT
Refer to screen E-5v of your CD-ROM for a video on how dye penetrant may be used to check for weld cracks and other flaws.



E-6 Undercut welds look lower than the top plates.

An undercut weld:

- will look as if the weld bead is lower than the edge or edges of the top workpiece.
- typically has lack of fusion to the top workpieces.
- is commonly caused by a travel speed that is too fast.
- on a butt joint with backing weld can be caused by a root gap that is too wide.



E-7 Improper work angle affects heat focus.

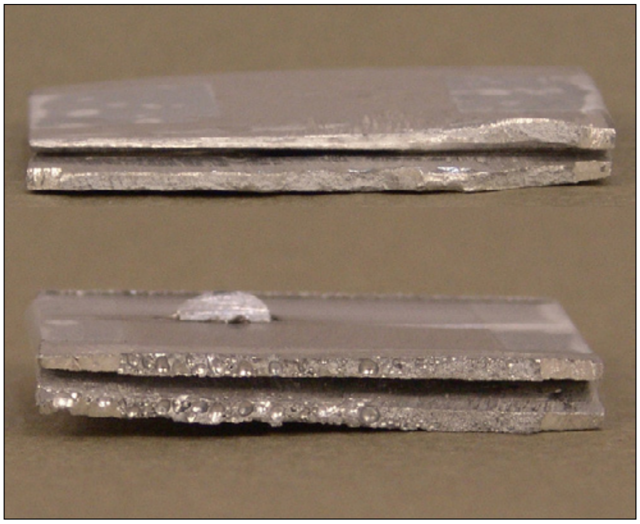
Using an improper work angle:

- will direct the arc incorrectly.
- will not focus the heat where it is wanted.
- may cause a lack of fusion between the workpieces. For example, a lap weld where the work angle is focused on the top piece will give the weld bead a very tall appearance and little or no penetration into the bottom piece.
- may cause excessive penetration and suck-back. For example, a lap weld where the work angle is focused on the bottom piece will give the weld bead a very shallow, almost undercut appearance and have excessive penetration into the bottom piece.

A weld bead that is inconsistent in size may be caused by inconsistent:

- travel speed. Speeding up and slowing down will change the width of the weld bead.
- gun distance. Moving the gun in and out will change the height of the weld bead.

Weld beads that wander off the joint are commonly caused by poor body positioning. A technician must be in position to see the area that will be welded.



E-9 Porosity will appear as internal holes from gassing.

An aluminum weld that has porosity will appear to have excessive soot on the exterior of the weld bead.

The interior of a porous weld:

- will appear to have several holes or pores, caused by internal gassing.
- may appear to have less filler material than required, if the pores are large.
- will be weak.

Porosity can be caused by:

- the workpiece not being cleaned enough to remove coatings and oxidation.
- a low shielding gas flow rate.
- not pushing the gun.
- using contaminated welding wire.

Topic F. Practical Application

Good practices should always be followed when aluminum GMA (MIG) welding is done in a collision repair facility.

F-2 Vehicles should be protected while welding.

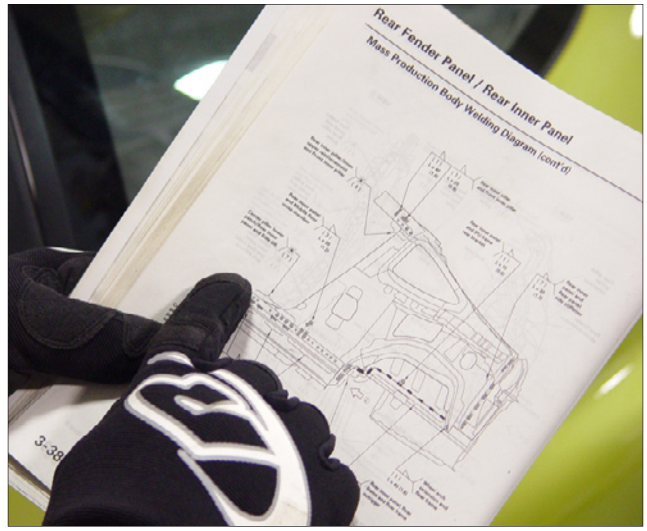
To avoid damaging the vehicle from welding sparks:

- cover the vehicle with welding blankets or spark paper.
- adjacent parts may be removed.

F-3 Keep the ground clamp close to the weld zone.

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

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



F-4 Vehicle repair information may be available for some aluminum vehicles.

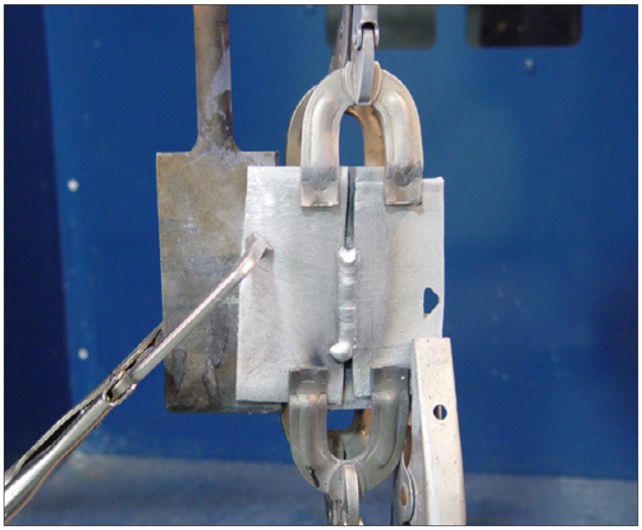
Vehicle makers may have repair information that will recommend:

- a specific electrode wire alloy and diameter that should be used for vehicle repairs.
- the type of transfer method preferred.
- weld locations, both where originally located and where to make replacement welds.
- the type of weld joints to use for repairs.
- the size the replacement weld should be and how far apart replacement welds should be spaced.

VEHICLE MAKER REPAIR INFORMATION
Select the Demonstration icon found on screen F-4 of your CD-ROM for examples of vehicle maker repair information on aluminum welding.

GMA (MIG) aluminum weld joints most commonly used for vehicle repairs include:

- fillet welds.
- butt joints with or without a backing.
- plug welds.
- slot fillet welds.



F-6 Practice welds should be done before welding on a vehicle.

Practice welding is a very important step in the repair process. Practice welding must be:

- done before welding on a vehicle.
- done using the same thickness and alloy of aluminum that is used on the vehicle. Similar joint styles should be constructed and practiced in the same position as will be done on the vehicle.
- destructively tested after passing visual inspection.

F-7 Record welder settings in a welding log book for future reference.

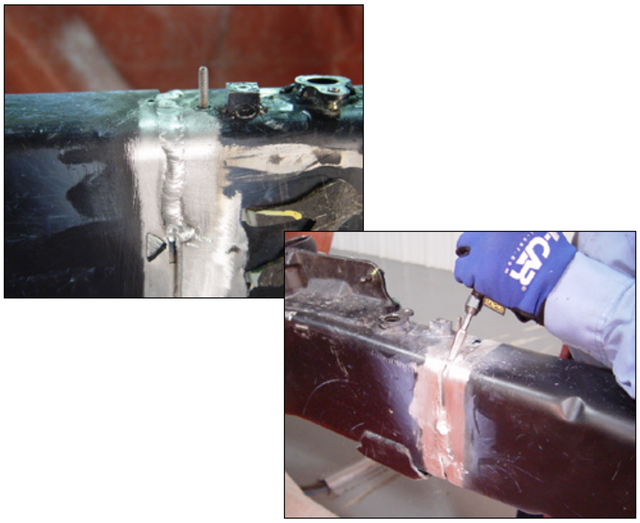
Aluminum welding may not be done every day in a collision repair facility. A welding log book is one way to keep track of welder settings that were successful for a particular application. A welding log book may help find a starting point for similar repairs that need to be done in the future.

WELDING LOG BOOK
Select the Activity icon found on screen F-7 of your CD-ROM for an activity on filling out a welding log book.

Aluminum welding may not be done every day in a collision repair facility. The student handout Aluminum GMA (MIG) Welding Log Book may be copied and used to start a welding log book that can be used to record welder settings that were previously used. This may help find a starting point for similar repairs that need to be done in the future.

When preparing to weld on the vehicle:

- make sure the parts have been cleaned thoroughly to remove all coatings and oxide from the immediate weld zone.
- do not apply weld-through primer to the weld zone.
- ensure that the parts fit flush. There should not be any gaps between panels.
- be positioned so the welding gun is at the proper angle. The technician should also be able to see the entire area to be welded.



F-9 Stitch welding aluminum requires grinding the start and stop points before finishing the weld.

While vehicle parts are being welded onto the vehicle:

- weld around corners if possible. Corners are typically a stronger area of a part, by design. Starting and stopping when aluminum GMA (MIG) welding can cause cold starts and craters, which are typically weak areas of the weld bead. Welding around corners will eliminate having cold start and craters on the corners.
- grind out where a stitch weld starts and stops. Grinding helps clean out cold start and craters.
- start and finish new welds on top of the existing weld bead. Starting and stopping on the existing weld bead typically helps eliminate cold start and craters from the weld joint completely, providing better fusion in the entire joint.

ALUMINUM BUTT JOINT WITH BACKING
Select the Demonstration icon found on screen F-9 of your CD-ROM for an example of a stitch welded aluminum butt joint with backing.

Defects in aluminum GMA (MIG) welds can be repaired. Repairing a crack or void in a weld is done by:

- grinding out the area twice the size of the defect.
- re-welding the area.

Repairs to an area of burnthrough should be allowed to cool before re-welding. The area should be cleaned with a stainless steel brush to remove any soot before welding. Amperage settings may need to be reduced. If the welding machine being used has a hot-start function, hot start should be turned off to avoid overheating the area too quickly while welding the burnthrough area shut.

Excessive burnthrough situations may require part replacement.

F-11 Grind welds where they will interfere with adjacent panel fit-up.

Grinding aluminum welds may be done using:

- 50 grit sanding discs.
- aluminum-specific grinding discs.
- light pressure. Light pressure helps prevent clogging of the discs and smearing the aluminum from overheating.

Check vehicle maker recommendations for weld grinding.

F-12 Epoxy primer is commonly used to coat bare aluminum.

Finishing aluminum welds typically requires:

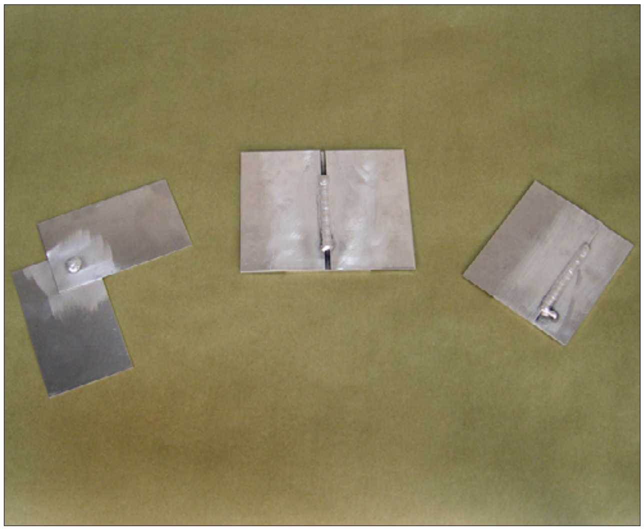
- using caution to not thin the surrounding weld area, as this may lead to cracking.
- using a fine tooth body file or P80 grit sanding disc to remove any coarse scratches left by grinding.
- coating the bare aluminum with either a primer or cosmetic filler. Vehicle makers typically recommend specific products for coating bare aluminum.

Topic G. Review

REVIEW
Refer to screens G-1 through G-3 of your CD-ROM for review questions on welding preparation and variables.

MODULE 3–I-CAR AUTOMOTIVE ALUMINUM GMA (MIG) WELDING QUALIFICATION TEST

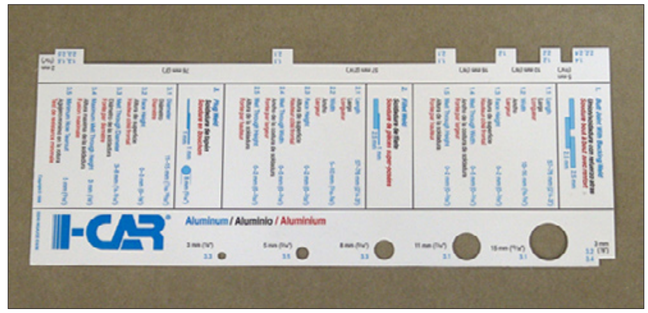
Topic A. Test Parameters



A-2 The I-CAR Automotive Aluminum GMA (MIG) Welding Qualification Test (AWQT) requires a total of six welds be completed.

The I-CAR Automotive Aluminum GMA (MIG) Welding Qualification Test (AWQT):

- is a method to verify skills of collision repair technicians who are welding aluminum on a daily basis.
- is performed on 5000 and 6000 series alloy aluminum coupons in two thicknesses. All coupons are 60 x 114 mm (2½ x 4½").
- requires three different welds in both the vertical and overhead positions. The welds are butt joint with backing, fillet, and plug welds.

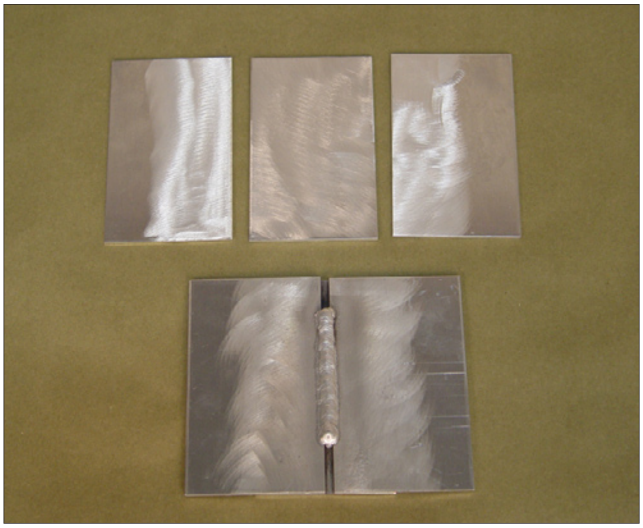


A-3 This is the I-CAR Aluminum GMA (MIG) Welding Gauge.

The I-CAR Aluminum GMA (MIG) Welding Gauge is used to visually inspect all of your test welds. The gauge measures minimum and maximum:

- face and melt-through height.
- bead width.
- nugget diameter.
- bead length.

Topic B. AWQT Butt Joint With Backing Weld



B-1 The AWQT butt joint with backing weld is done using three 2.5 mm coupons.

The butt joint with backing weld for the AWQT is made on three 2.5 mm, 5052-H32 alloy coupons. One coupon serves as the backing. Two of the coupons are positioned together along their length, leaving a gap of 2–3 coupon thicknesses. Root gap will depend on if the weld is being done in one or two passes.

AWQT participants are required to make a continuous weld, centered on the joint, in the vertical and overhead positions. Tack welds are not allowed. Each participant is given two coupons plus a backing coupon for each position. After making the welds, the participant chooses one weld from each position to turn in.

Visual requirements for the face of the butt joint with backing weld include:

- no cracks.
- no porosity, skips, or voids.
- the joint completely filled.
- no undercut.
- the crater completely filled.
- a bead length of 57–76 mm (2¼–3"). Use notch 1.1 on the aluminum welding gauge.
- a bead width of 10–16 mm (⅜–⅝"). Use notch 1.2 on the aluminum welding gauge.
- a bead height no greater than 2 mm (3⁄32"). Use notch 1.3 on the aluminum welding gauge

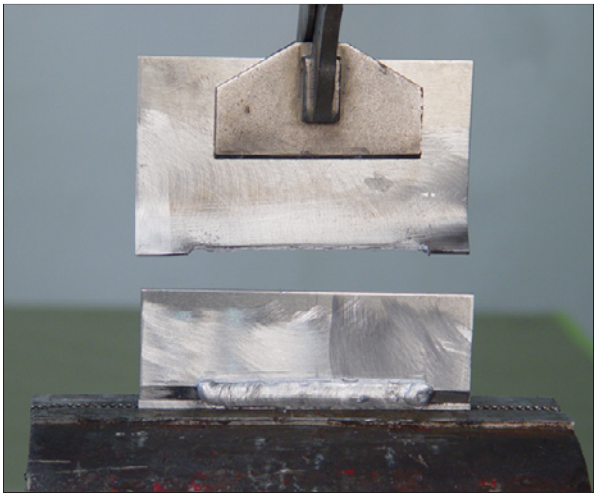
Visual requirements for the backside of the butt joint with backing weld include:

- no cracks.
- no suck-back, except at the stop point.
- a melt-through width no greater than 5 mm (3⁄16"). Use notch 1.4 on the aluminum welding gauge.
- melt-through extending no more than 2 mm (3⁄32") from the bottom. Use notch 1.5 on the aluminum welding gauge.

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

Welds that pass visual inspection must be destructively tested.

BUTT JOINT VISUAL INSPECTION
Select the Activity icon on screen B-3 of your CD-ROM for an example of doing a butt joint visual inspection and have your instructor lead you through the Butt Joint Visual Inspection activity.



B-4 Destructively test the butt joint with backing weld after it passes visual inspection.

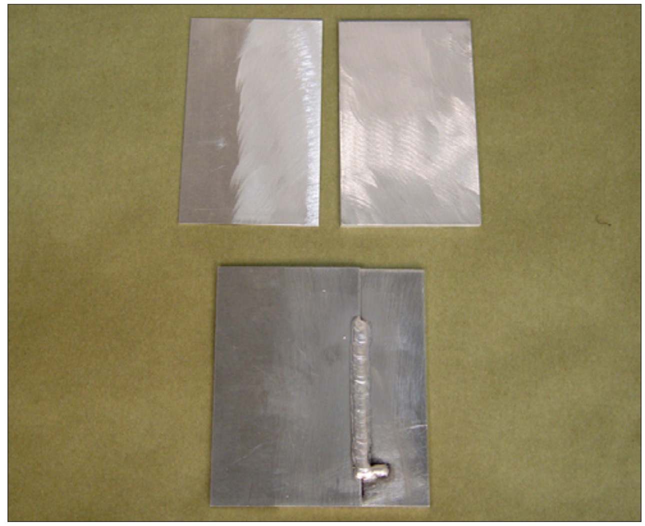
The following is an example of how to destructively test the butt joint with backing weld.

1. Clamp the weld sample in a vise so one of the top coupons faces the front of the vise, and is slightly above and parallel to the vise jaw.
2. Use a wide, flat-jawed locking pliers to bend the upper coupon back-and-forth until it breaks free from the backing.
3. Reverse the weld sample in the vise and, similarly, break the remaining coupon from the backing.
4. Inspect each face coupon for metal tearout. Also inspect the weld bead. The weld is good if there is metal tearout on each of the face coupons for at least the 57 mm (2¼") minimum length and the weld holds firm on the backing piece. The coupons, and not the weld, should break to pass the butt joint with backing weld.

DESTRUCTIVELY TESTED BUTT JOINTS
Select the Demonstration icon found on screen B-4 of your CD-ROM for an example of destructively tested butt joints.

THE BUTT JOINT WITH BACKING WELD
Refer to screen B-5v of your CD-ROM for a video on recommendations for making the AWQT butt joint with backing weld, visual inspection process, and destructive testing.

Topic C. AWQT Fillet Weld



C-1 The AWQT fillet weld uses two coupons that are different thicknesses.

The fillet weld for the AWQT is made on two thicknesses of coupons, a 1 mm, 6061 T6 alloy coupon and a 2.5 mm, 5052 H32 alloy coupon. The 1 mm coupon is lapped about halfway over the 2.5 mm coupon's length.

AWQT participants are required to make fillet welds, centered on the lap joint, in the vertical and overhead positions. Tack welds are not allowed. Each participant is given two coupons for each position. After making the welds, the participant chooses one weld from each position to turn in.

Visual requirements for the face of the fillet weld include:

- no cracks.
- no porosity, skips, or voids.
- no undercut.
- the joint and crater completely filled.
- a bead length of 57–76 mm (2¼–3"). Use notch 2.1 on the aluminum welding gauge.
- a bead width of 5–10 mm ($\frac{3}{16}$"–⅜"). Use notch 2.2 on the aluminum welding gauge.
- a bead height no greater than 2 mm ($\frac{3}{32}$"). Use notch 2.3 on the aluminum welding gauge.

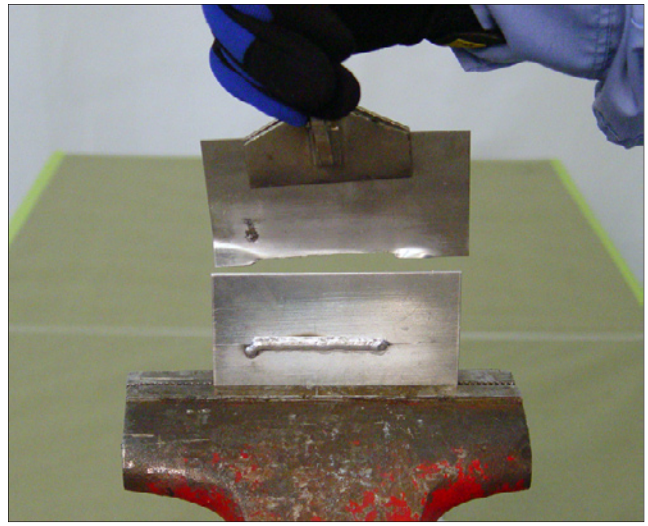
Visual requirements for the backside of the fillet weld include:

- no cracks.
- no suck-back, except at the stop point.
- a melt-through width no greater than 5 mm (3/16"). Use notch 2.4 on the aluminum welding gauge.
- melt-through extending no more than 2 mm (3/32") from the bottom. Use notch 2.5 on the aluminum welding gauge.

If the weld area does not meet the visual criteria, it does not have to be destructively tested. The fillet weld is a visual failure if any of these requirements are not met.

Welds that pass visual inspection must be destructively tested.

FILLET WELD VISUAL INSPECTION
Select the Activity icon on screen C-3 of your CD-ROM for an example of doing a fillet weld visual inspection and have your instructor lead you through the Fillet Weld Visual Inspection activity.



C-4 Destructively test the fillet weld after it passes visual inspection.

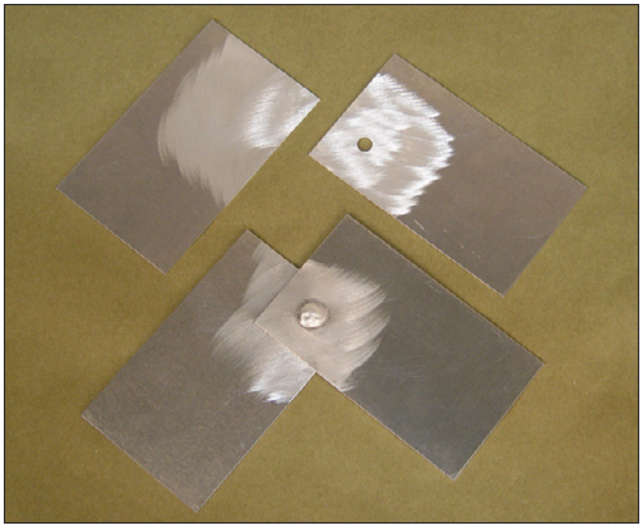
The following is an example of how to destructively test the fillet weld.

1. Clamp the bottom, 2.5 mm coupon in a vise so that the top, 1 mm coupon is above and parallel to the vise jaws.
2. Bend the 1 mm coupon until it breaks off from the 2.5 mm coupon.
3. To pass inspection, there must be metal tearout from the 1 mm coupon for at least the 57 mm (2¼") minimum length. The coupon, and not the weld, should break to pass the fillet weld on lap joint test.
4. Also inspect the weld bead on the bottom, 2.5 mm coupon. The weld should hold firm for at least the minimum 57 mm (2¼") length.

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

THE FILLET WELD
Refer to screen C-5v of your CD-ROM for a video on recommendations for making the fillet weld, visual inspection process, and destructive testing.

Topic D. AWQT Plug Weld



D-1 The AWQT plug weld uses two 1 mm coupons.

The plug weld for the AWQT is made on two 1 mm 6061-T6 alloy coupons. One of the coupons has an 8 mm (5⁄16") pre-drilled hole in one corner. This coupon is lapped onto the corner of the other coupon, at 90° to each other.

AWQT participants are required to make an 8 mm (5⁄16") plug weld in the vertical and overhead positions. Tack welds are not allowed. Each participant is given two coupons for each position. After making the welds, the participant chooses one weld from each position to turn in.

Visual requirements for the face of the plug weld include:

- no cracks.
- the crater completely filled.
- no porosity, skips, or voids.
- no undercut.
- the hole completely filled.
- a nugget height no greater than 3 mm (1⁄8"). Use notch 3.2 on the aluminum welding gauge.
- a nugget diameter of 11–15 mm (7⁄16–19⁄32"). Use the 3.1 hole on the aluminum welding gauge.

Visual requirements for the backside of the plug weld include:

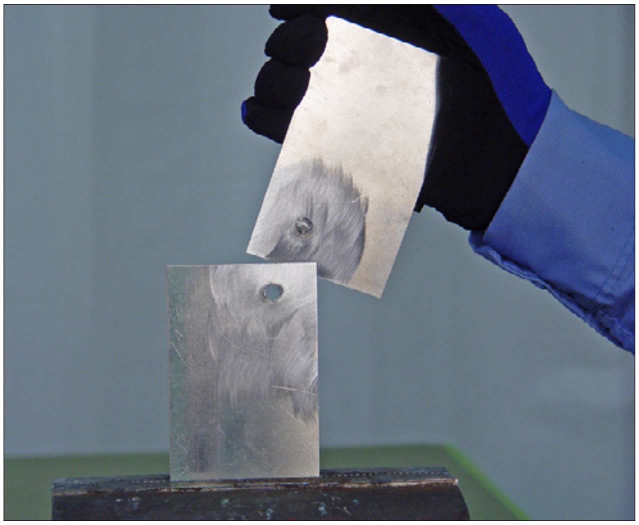
- no cracks or suck back.
- a melt-through nugget at least 3 mm (1⁄8") in diameter. Use the 3.3 hole on the aluminum welding gauge. The nugget diameter must be no larger than 8 mm (5⁄16"). Use the 3.5 hole on the aluminum welding gauge.
- a melt-through nugget at least level (no suck-back) with the bottom, but no higher than 3 mm (0–1⁄8"). Use notch 3.4 on the aluminum welding gauge.

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

Welds that pass visual inspection must be destructively tested.

PLUG WELD VISUAL INSPECTION

Select the Activity icon on screen D-3 of your CD-ROM for an example of doing a plug weld visual inspection and have your instructor lead you through the Plug Weld Visual Inspection activity.



D-4 Destructively test the fillet weld after it passes visual inspection.

The following is an example of how to destructively test the fillet weld.

1. Clamp the bottom coupon in the vise so the face of the weld faces the front of the vise.
2. Keeping the two coupons parallel to each other, twist off the top coupon until it breaks free from the bottom coupon.
3. There must be a tearout hole in the bottom coupon at least 5 mm ($\frac{3}{16}$") in diameter. Use hole 3.5 on the aluminum welding gauge.

DESTRUCTIVELY TESTED PLUG WELDS
Select the Demonstration icon found on screen D-4 of your CD-ROM for an example of destructively tested plug welds.

MAKING AND TESTING THE ALUMINUM PLUG WELD
Refer to screen D-5v of your CD-ROM for a video on recommendations for making the aluminum plug weld, visual inspection process, and destructive testing.