Maintenance Welding of Aluminum

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Hardly any other metal gives as many difficulties as maintenance welding of Aluminum. Most welders avoid getting involved trying to repair or manufacture items made of aluminium because it simply requires a completely different welding / handling procedure compared to other more common metals like steel or stainless steel. This paper outlines information on the different alloys and realistic welding methods and procedures for performing maintenance welding onboard.

Introduction

Aluminum is the most widely used metal in engineering apart from iron. The reason why aluminium is widely used is because the combination of properties makes it one of the most versatile of engineering and construction materials. Aluminum is light in weight, yet some of its alloys have strengths greater than that of structural steel. It has good electrical and thermal conductivities and high reflectivity to both heat and light. It is highly corrosion resistant under a great many service conditions and is nontoxic. Aluminum can be cast, extruded, forged, drawn, hot rolled and cold rolled.

Aluminum and its alloys

Aluminum is available as **Wrought** (shaping processes: rolling, forging, extrusion, pressing, stamping) and **Cast** Aluminum alloys. Alloy systems are classified by a number system American National Standards Institute (ANSI) or by names indicating their main alloying constituents (DIN and ISO).

The main alloying elements are copper, zinc, magnesium, silicon, manganese and lithium. Small additions of chromium, titanium, zirconium, lead, bismuth and nickel are also made and iron is invariably present in small quantities. Wrought alloys are normally identified by a four-digit system (for example ANSI 1XXX) which identifies the alloying elements. The system which originated in the USA is now universally accepted. Cast alloys have similar designations and use a four to five-digit number with a decimal point (for example ANSI 4XXX0). The digit in the hundreds place indicates the alloying elements, while the digit after the decimal point indicates the form (cast shape or ingot).

Most aluminum alloys are weldable using Gas Welding/ Brazing, Electrode/Stick, TIG or MIG welding. However, some are not. Let us take a quick look at the common families of aluminum alloys, their weldability characteristics and what filler material to use:

1XXX alloys. Essentially pure aluminum (99 % pure) and used to carry electrical current or for corrosion resistance in specific environments, these alloys are all weldable. The most common filler metal is **1100**. AWS/SFA 5.10 ER1100. For example, Washington Alloy 1100 (commonly referred to as Al99.5) is a 99% aluminium filler metal that is available in spools or cut lengths for MIG or TIG welding processes.

3XXX alloys. Alloying element Manganese. Comes as wrought only. This family comprises medium-strength alloys that are very formable. They are often used for heat exchangers and air conditioners. All are weldable using either **4043** (ANSI/AWS A5.10 (ER & R), AMS 4190. EN ISO 18273 designation AlSi. Similar to AlSi5, BS N21) or **5356** (ANSI/AWS A5.10 (ER & R). EN ISO designation AlMg5Cr(A). Similar to AlMg5 (DIN)) filler metal.

4XXX alloys. Alloying element Silicon. These are used as welding or brazing filler alloys. However, they are sometimes used as base materials. If that is the case, they are readily welded with **4043** (ANSI/AWS A5.10 (ER & R), AMS 4190. EN ISO 18273 designation AlSi. Similar to AlSi5, BS N21) filler metal.

5XXX alloys. Alloying element Magnesium (seawater resistant aluminum). This is a family of high-strength sheet and plate alloys. All of them are welded using **5356** (ANSI/AWS A5.10 (ER & R). EN ISO designation AlMg5Cr(A). Similar to AlMg5 (DIN)) filler metal, although **5183** (ANSI/AWS A5.10(ER & R. EN ISO designation AlMg4.5Mn0.7(A) Similar to AlMg4.5M) or **5556** (ANSI/AWS A5.10 (ER & R). EN ISO designation AlMg5Cr(A). Similar to AlMg5 (DIN)) should be used for the stronger alloys, such as 5083.

6XXX alloys. Alloying elements Magnesium and Silicon. These are primarily the extrusion alloys, although they are available in sheet and plate as well. They are prone to be crack-sensitive. However, with the proper techniques, they can all be welded using **4043** (ANSI/AWS A5.10 (ER & R), AMS 4190. EN ISO 18273 designation AlSi. Similar to AlSi5, BS N21) or **5356** ((ANSI/AWS A5.10 (ER & R). EN ISO designation AlMg5Cr(A). Similar to AlMg5 (DIN)) filler metal.

So, what about the 2XXX and 7XXX alloys?

2XXX alloys. Alloying element Copper. These are high-strength aerospace alloys in sheet or plate form. Their chemistry makes most of them un-weldable using TIG or MIG because of hot cracking. The exceptions are 2219 and 2519, which are both welded using **2319** (ANSI/AWS A5.10(ER & R), AMS 4191) or **4043** (ANSI/AWS A5.10 (ER & R), AMS 4190. EN ISO 18273 designation AlSi. Similar to AlSi5, BS N21) filler metal. In any case, you should never weld 2024. It is very common and very high in strength, but it is extremely crack-sensitive.

7XXX alloys. Alloying element Zinc. This too is a family of high-strength aerospace alloys. Like the 2XXX alloys, most of them are un-weldable using TIG or MIG because of hot-cracking and stress-corrosion concerns. The exceptions are 7003 and 7005 extrusion alloys and 7039 plate alloys. All three of are readily weldable using **5356** (ANSI/AWS A5.10 (ER & R). EN ISO designation AlMg5Cr(A). Similar to AlMg5 (DIN)) fillers. Never weld 7075.

Alloys of 1xxx, 3xxx, 4xxx and 5xxx series are non-heat-treatable. The initial strength of these alloys is achieved due to the hardening effect of the alloying elements: manganese (Mn), silicon (Si), magnesium (Mg).

Heat-treatable alloys can be strengthened by heat treatment. Alloys of 2xxx, 6xxx and 7xxx series are heat-treatable. The initial strength of these alloys is achieved due to the hardening effect of the alloying elements: copper (Cu), silicon (Si), magnesium (Mg) and zinc (Zn).

NB. Welding heat-treatable alloys can to a higher or lesser degree influence on the item’s mechanical properties.

Two fillers stand out. When should I use 4043 or 5356 as filler?

As a basic description we can say that 4043 is an aluminum filler alloy with 5% silicon added and that 5356 is an aluminum filler alloy with 5% magnesium added.

When should we choose one of these filler alloys over the other?

When the filler alloy selection allows the use of either 4043 or 5356 as filler for a specific base alloy, as a guide, we may wish to consider the following facts about each of these filler alloys.

4043 should not be used if you are considering the best color match after post weld anodizing, as this filler alloy will typically turn dark gray in color after the anodizing process. 5356 will provide a much closer color match after anodizing.

4043 is suitable for service temperatures above 65^{O}C (150^{O}F), however, 5356, because of its 5% magnesium content is not suitable for these elevated temperature applications.

4043 has lower ductility than that of 5356. This may be of some consideration if forming, after welding is to be carried out.

4043 has lower shear strength than that of 5356. This may be of consideration when calculating the size of fillet welds.

4043 is a softer alloy in the form of spooled wire, when compared to 5356. Typically, when MIG Welding (GMAW), feed ability will become a less critical issue when feeding the more rigid 5356 alloys.

4043 will typically provide a higher rating for weldability and provide slightly lower crack sensitivity. 4043 will generally tend to produce welds with improved cosmetic appearance, smoother surfaces, less spatter and less smut. For this reason, it is sometimes more appealing to the welder.

Anodized aluminum

Anodized aluminum is simply standard aluminum that has been treated to produce a thick layer of oxides on its surface. The process of anodizing uses an electrolytic chemical application, usually with sulfuric acid, to create a layer of oxides several times thicker than would naturally form — 0,0051mm (0.0002 inch) to 0,0254mm (0.001 inch) thick.

The aluminum base is a very soft material and melts at approximately 660 ^{O}C (1220 ^{O}F), but the oxide layer is extremely hard (some types approach the hardness of diamonds) and melts at 2000 ^{O}C (3,600 ^{O}F). The difficulty in welding anodized aluminum lies in removing the oxide layer without burning through the aluminum base. The four types of anodized aluminum are standard, bright-finish, colored, and hardened. Bright-finish anodized aluminum can be visually distinguished from standard anodized aluminum by its shiny, chrome like finish.

This type of material has a thicker layer of oxides than standard anodized aluminum, making it more difficult to TIG weld, and is used primarily for cosmetic reasons. Colored anodized aluminum is also used for cosmetic purposes. This material uses dyes in the anodization process, which allow the material to take on different hues, but also introduce potential contaminants into the weld. Hardened anodized aluminum is almost as hard as a diamond and is very difficult to weld. This type of material is usually used only in highly specialized industrial applications. Welding procedure: look under TIG welding.

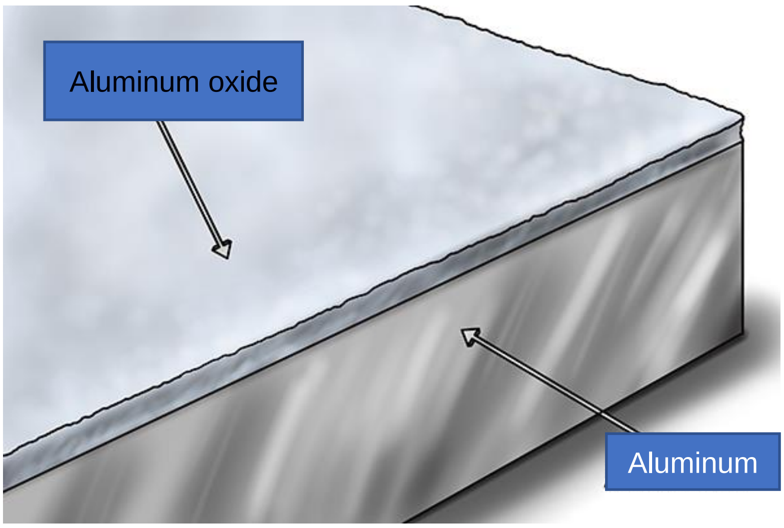
How to identify aluminum?

Magnetic Test:	Non-Magnetic
Spark Test:	No Spark (use angle grinder)
Color:	White
Relative weight:	Light (compared to other components of same size and shape)

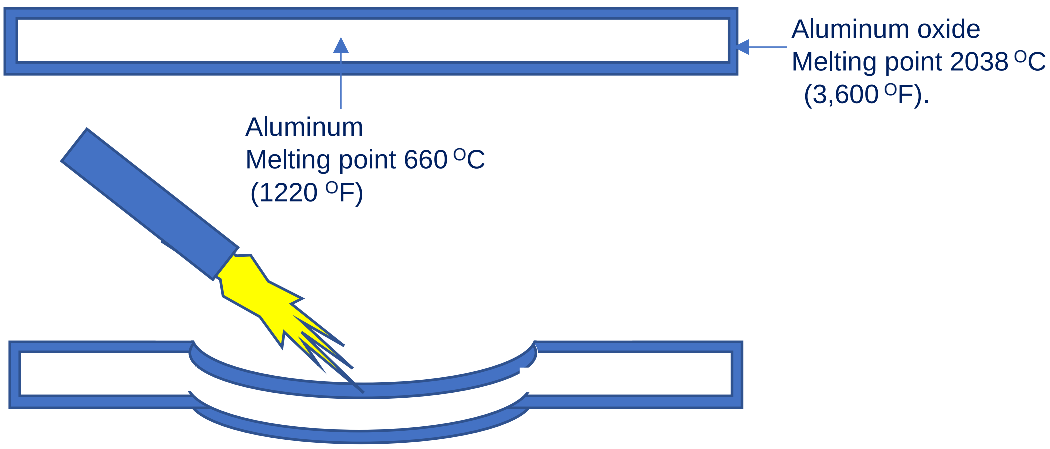
The difficulty can be to identify Aluminum and Aluminum alloys from Magnesium and Magnesium alloys. A simple test to find out is to file some shavings of the component onto a paper. Hold the paper over an oxy- acetylene flame and let the shavings fall into the flame. If the shavings glow the metal is aluminum. If some of the shavings spark in the flame the aluminum is alloyed with magnesium (seawater resistant aluminum). If all the shaving spark in the flame, the metal is magnesium and must not be welded.

What makes it so difficult to weld aluminum?

The oxide coating on aluminum alloys causes difficulty in relation to its weld ability. It also has high thermal conductivity and a very short temperature range between liquidus and solidus and when liquid its viscosity is very low. During fusion welding, the aluminum would oxidize so readily that special fluxes or protective inert-gas atmospheres must be employed.



Aluminum quickly forms a more or less invisible coating of aluminum oxide. Aluminum oxide melts at three times the temperature of aluminum. When you try to weld uncleaned aluminum, the aluminum under the aluminum oxide coating will melt but the aluminum oxide coating will stay solid and act as a membrane, much like a water balloon. When you finally succeed in penetrating the coating, the very runny aluminum inside will flow out all at once, much like a bursting water balloon. The oxide is also heavier than aluminum and, when melted, tends to sink or be trapped in the molten aluminum. For these reasons, it is easy to see why as much as possible of this oxide "skin" must be removed before welding.



Whatever welding methods you use: Clean the aluminum.

This is probably the most important part of welding aluminum. EVEN ALUMINUM THAT LOOKS BRAND NEW AND CLEAN IS ACTUALLY DIRTY. IT'S NOT LIKE STEEL. This is how to prepare aluminum for welding:

- First, clean the aluminum with acetone. Don't use brake cleaner unless it is 100% acetone. NB: Acetone is highly flammable so be careful, and remove it from the weld location after use. Also make sure to have adequate ventilation/ fume extractor during the cleaning process.

- Then, rinse the aluminum using **distillated** water, just in case there is any residues. In tap water there might be free iron that will contaminate the surface. The aluminum should be completely dry before welding.

- Then, use a stainless-steel brush (make sure the brush is stainless) and scrub the aluminum shiny clean around the area to be welded. Avoid touching the cleaned surface with your bare hands.

  Start welding as soon as possible after cleaning. If you do not weld on the aluminum immediately after cleaning, you should give it a touch up cleaning before you start to weld.

Clamp your work to a heatsink made of copper or aluminum whenever possible. Aluminum transmits heat very well. Once the area you weld gets hot enough to melt, the rest of the work is likely to be so hot that it is shrinking and warping. Using a heat sink under the area being welded will absorb some of the heat and help keep the work from warping.

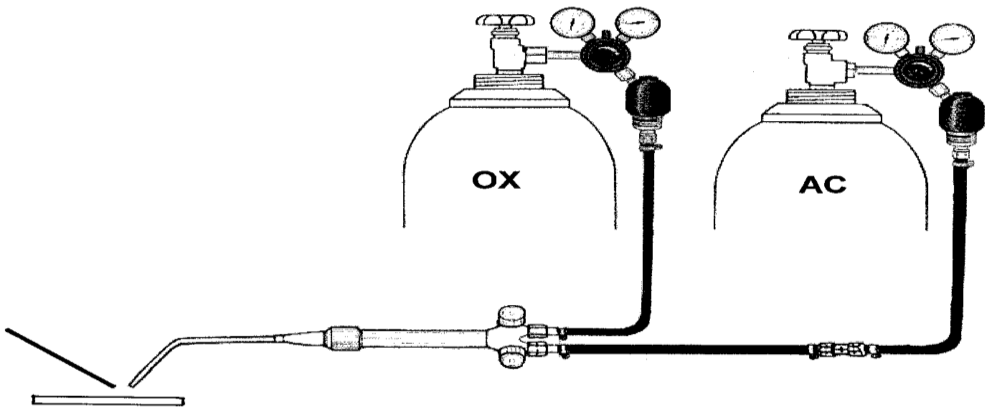
Preheat before welding. This makes it a LOT easier to weld aluminum. Recommended preheating temperatures range from 135 ^{O}C (275 ^{O}F), to 260 ^{O}C (500 ^{O}F). NB. Aluminum does not change colour while being heated.

Welding methods.

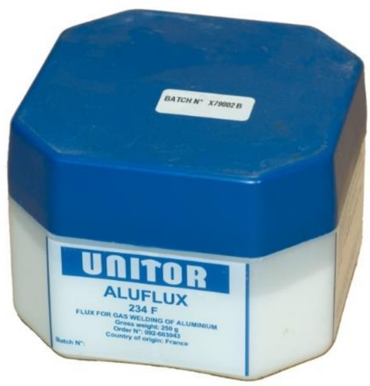
Aluminum can be welded using Gas Welding, Brazing/ Soldering, Electrode/Stick welding, TIG welding or MIG welding. In production welding a number of other welding methods are available. In the following we will only talk about welding methods that are available to the crew onboard in connection with maintenance welding.

Gas Welding

Gas welding aluminum is demanding and require good understanding of the material, skill, proper equipment and consumables. Onboard most vessels Oxy acetylene gas welding equipment will be available. Select a welding neck according to 100L per mm material thickness. As an example, a plate thickness of 6mm require a 600L welding neck (It will consume 600L Oxygen and 600L Acetylene per Hour). Aluminum from 2mm (5/64”) to 10mm (25/64”) thick may be gas welded. Thicker material is seldom gas welded, as heat dissipation is so rapid that it is difficult to apply sufficient heat with a torch. When compared with arc welding, the weld metal freezing rate of gas welding is very slow. The heat input in gas welding is not as concentrated as in other welding processes and unless precautions are taken greater distortion may result.

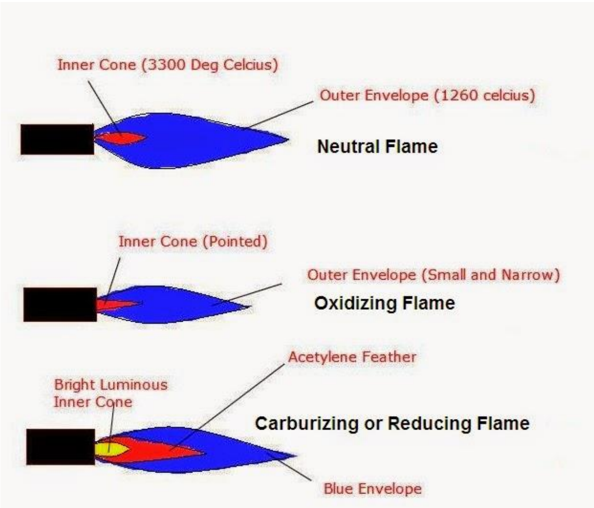


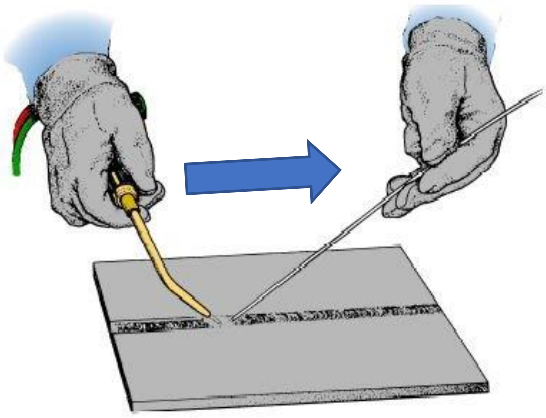
Before you start welding, you need to find yourself the appropriate welding rod. In most cases a TIG rod is a good choice because it is easy to find and its high purity makes for a high-quality weld. It is worth mentioning that some prefer to use flux-cored aluminium welding electrodes (intended for Electrode/stick welding) as it is already having a flux. Aluminum TIG rods comes in a variety of types and diameters and can normally easily be found. In most cases type 1100 or 4043 will work well for most applications encountered. The 1100 has properties that make it suitable for “soft” applications where bending or shaping of metal will occur. At the other end 4043 works well for “hard” applications where the base metal is not intended to flex. Selecting rod diameter is more of a guessing game. Start with 2mm (5/64”) rod and move up or down in size as needed.



As mentioned previously: Clean all dirt, oil, paint, or other residue from the area to be repaired by aluminum Gas Welding. Note previous chapter: “**Clean the aluminum”.**

Aluminum welding flux is designed to remove the aluminum oxide film and exclude oxygen from the vicinity of the puddle. The fluxes used in gas welding are usually in powder form and are mixed with distilled water to form a paste. The flux should be applied to the seam and rod by using a brush.





Direction of travel

A neutral or slightly Carburising flame is recommended for Gas welding aluminum. Oxidizing flames will cause the formation of aluminum oxide, resulting in poor fusion and a defective weld. Start by preheating the joint to be welded. Unlike with other metals there is no change in colour when aluminium is heated to its welding temperature. The following tests should therefore be made to determine if the aluminium is ready to start welding: Using a wooden stick, rub the end of the stick on the metal being heated. At the proper temperatures, the stick will char. Start welding by passing the flame in small circles over the starting point until the flux melts. The filler rod, coated with flux should be scraped into the surface at three or four second intervals, permitting the filler rod to come clear of the flame each time. The scraping action will help removing the oxides and revealing the aluminum. The base metal must be melted before the filler rod is applied. Leftward welding also referred to as forehand welding is generally considered best for welding on aluminum, since the flame will preheat the area to be welded. In welding thin aluminum, there is little need for torch movement other than progressing forward. On material 5mm (3/16") thick and over, the torch should be given a uniform lateral motion. This will distribute the weld metal over the entire width of the weld. A slight back and forth motion will assist the flux in the removal of oxide. The filler rod should be dipped into the weld puddle periodically, and withdrawn from the puddle with a forward motion. This method of withdrawal closes the puddle, prevents porosity, and assists the flux in removing the oxide film.

The aluminum welding fluxes contain chlorides and fluorides. In the presence of moisture, these will attack the base metal. Therefore, all flux remaining on the joints after welding must be completely removed. If the weld is readily accessible, it can be cleaned with boiling water and a fine brush. Parts having joints located so that cleaning with a brush and hot water is not practical may be cleansed by an acid dip and a cold or hot water rinse. Use 10% sulfuric acid cold water solution for 30 minutes or a 5% sulfuric acid hot water at 65ºC (150ºF) solution for 5 to 10 minutes for this purpose.

NB. Regarding flux used in Gas welding and brazing processes: According to the European CLP regulation, toxic substances such as boric acid and borax have been re-classified and categorized as toxic to reproduction "can affect fertility and can damage the child in the mother's womb". Flux and flux coated brazing rods are therefore to be boric acid and borax free. (REACH-compliance).

Recommended filler and flux: Unitor Alumag 235 (AWS A5.10 ER 5356) + Aluflux 234F.

Brazing/Soldering

Brazing and Soldering of Aluminum is accomplished with the same type of torch and gases used for Gas welding. Some fillers can also be used using TIG welding. For soft soldering, a soldering iron might be used. Brazing and Soldering are considered easier than Gas welding.

Brazing is a joining method which provides a permanent bond between the parts to be joined with the help of a brazing filler metal. The composition of the filler alloy is such that its melting point is slightly below the melting range of the parent metal of the parts. Brazing is distinguished from welding by the fact that the parent metal does not melt during the process.

First let us clarify the difference between Brazing and Soldering. By accepted general definition of DVS (Deutscher Verband für Schweißtechnik, Düsseldorf) the working temperature for brazing is above 450°C (842°F), whereas it is below 450°C (842°F), in the case of soldering. Soldering is sometime referred to as Soft Soldering. (Note: 800°F, resp. 426°C, by definition of the American Welding Society). Brazing creates a stronger bond, but soldering is preferred for pieces with electrical circuits or other delicate materials.

Also brazing and soldering filler alloys are classified by a number system American National Standards Institute (ANSI). Generally, brazing of the various aluminum alloys is restricted by the available filler alloys which are based on the binary system Aluminum - Silicon. Typical filler alloys are:

Aluminum 86%, Copper 4%, Silicon 10%. Solidus 521°C (970°F), Liquidus 585°C (1085°F). AWS & International standards: BAISi-3, AMS 4184, AA 4184

Aluminum 88%, Silicon 12%. Solidus 577°C (1070°F), Liquidus 582°C (1080°F). AWS & International standards: BAISi-4, AMS 4185, AA 4047

Recommendation:

Castolin Eutectic 190
Low-melting temperature alloy for capillary brazing of aluminium. Profiles, tubes, air conditioning equipment, heat exchangers. Castolin 190 can be used in conjunction with the Oxyacetylene and TIG processes. An aluminium silicon alloy producing good strength joints and good resistance to corrosion. Not suitable for parts requiring anodised finishes or aluminium alloys containing more than 1.5% magnesium. Use together with EutecTor Flux 190. Highly reactive flux for torch brazing of aluminium and aluminium alloys. The flux is particularly suitable when brazing such common grades as 11xx, 4xxx and selected 5xxx alloys

NB. Alloys of type 2XXX and 7XXX are, not normally braze-able as their solidus/liquidus temperature are too low for the filler metals. Alloys with higher magnesium content (> 1 - 2 %) are also difficult to braze due to increased oxide layer formation which cannot effectively be removed by fluxes. Add flux by dipping the filler rod into the flux or paint it on to the filler using a brush. You may also use flux-coated or flux cored rods to eliminate this step. The flux-coated/ flux cored rods apply the flux during the aluminum brazing process. Avoid solders that contain lead and cadmium whenever possible.

As mentioned previously: Clean all dirt, oil, paint, or other residue from the area to be repaired by aluminum brazing. Note previous chapter: "**Clean the aluminum".**

The joint designs used for brazing/ soldering aluminum assemblies are similar to those used with other metals. The most commonly used designs are forms of simple lap and T-type joints (capillary joints). Joint clearance varies with the specific soldering method, base alloy composition, solder composition, joint design, and flux composition employed. However, as a guide, joint clearance ranging from 0.10 to 0.50 mm (0.005 to 0.020 "). Joints must fit snugly, but not so snug that the solder cannot get into the gap.

Use a brush to apply the flux appropriate to the temperatures and the metal. An all-purpose flux covers a wide range of temperatures and is beneficial to have on hand for general purpose brazing. Brazing fluxes can start to melt and dissolve oxides already at 320°C (600°F). Heat the repaired area with an acetylene or propane torch until the aluminum shows an orange bloom. This happens when the metal gets very hot. Once you apply a flux, it should change colors or turn clear throughout.

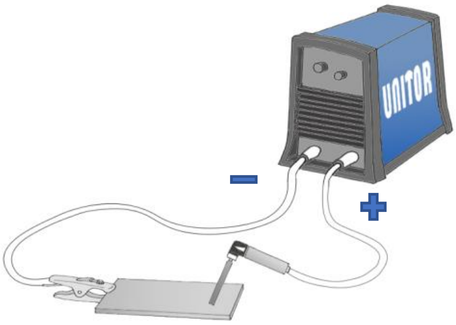
NB. Aluminum parts at brazing temperatures becomes soft. As the assembly to be brazed will be subjected to the pressure of its own weight and to the pressure of the gases emerging from the torch, in particular long horizontal section must be supported, otherwise they will sag.

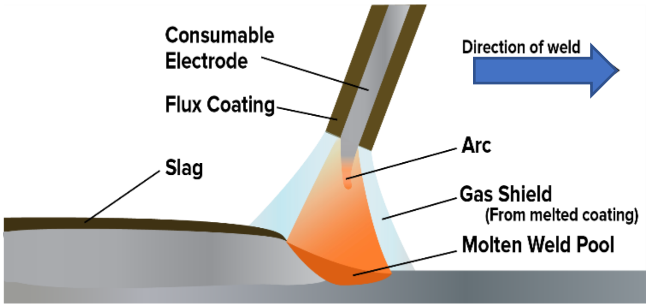
Apply the filler metal by running a brazing rod along the crack or the joint. The heat of the metal will melt the filler into the area needing the repair. Move the flame of the torch on and off as needed to melt the rod.

Remove the flux after the filler material has solidified by dipping the part or pouring hot water on the repair. The flux will flake off. If it does not come off, use a stainless-steel wire brush to gently scrub the brazed area while wet or still in the hot water.

Manual Metal Arc Welding (MMAW) Electrode/Stick Welding

Prior to the development of the inert gas welding process (TIG & MIG) the arc welding of aluminum was mainly restricted to the Electrode/Stick Welding (Shielded Metal Arc Welding SMAW) also referred to as the Manual Metal Arc Process (MMA). This welding process uses a flux-coated welding electrode.





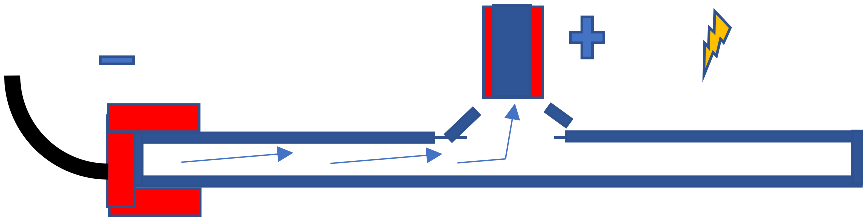
The electrodes are straight lengths of aluminum rod, coated with flux. The flux acts to dissolve the aluminum oxide on both the base alloy and the rod during welding, which is necessary if coalescence is to occur. Some of the flux components vaporize in the arc to form shielding gases that help to stabilize the arc and shield both it and the weld pool from the surrounding atmosphere. There are however a number of problems related to Aluminum Stick/Electrodes. First, they are not 100% effective, so most aluminum shielded metal arc welds suffer from a large amount of porosity. Second, they are very hygroscopic, so they require good storage practices so they do not absorb water vapor from the air. Third, the solidified flux is corrosive to aluminum and other materials. If it is not completely removed from the weld after welding, it can cause corrosion in a short period of time. Fourth, the flux is corrosive and environmentally unfriendly. Last, while aluminum is chemically active, magnesium is even more active, which makes it difficult to shield aluminum/magnesium filler alloys with a flux. In fact, the only available aluminum stick electrodes are of the 4043 types with silicon added. Most common size of stick welding electrodes are 3,2mm (1/8")

There are no electrodes available for the high magnesium content base alloys and electrodes, once exposed to the air, begin to absorb moisture into the flux, which eventually corrodes the aluminum core and produces excessive porosity problems.

Electrode/Stick welding does have an advantage over TIG and MIG welding: The equipment needed is significantly cheaper and less complicated than that used for TIG or MIG welding. All that you need is an inexpensive Direct Current Electrode/Stick welding machine—no gas bottles, torches, regulators, or other related equipment.

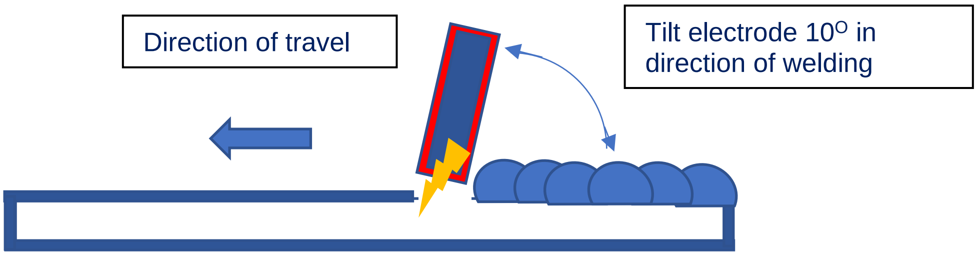
As mentioned previously: Clean all dirt, oil, paint, or other residue from the area to be repaired by welding. Note previous chapter: "**Clean the aluminum".** Preheat before welding. This makes it a LOT easier to weld aluminum. Recommended preheating temperatures to 260 ^{O}C (500 ^{O}F).

The welding machine must be a Direct Current (DC) power source. Connect electrode/ electrode holder to plus (+) polarity on welding machines front panel. The reason for doing this is that electrons moves from minus to plus polarity. If the return (-) is connected to the work peace the electrons will break through the oxides on their way to the electrode tip (+)



Minus polarity and the flux coating on the electrode help to break up the oxides but it is still a difficult task to observe and control the weld pool.

Another thing that helps is to tilt the electrode approximately 10^{O} in the direction of travel. This will make the flux run in forefront of the pool and help dissolving the oxide layer



Aluminum electrodes are not environmentally friendly so make sure to have good ventilation and avoid inhalation of the welding fumes. Preferably have a fume extractor available during welding. Remember to remove all solidified flux (slag) after welding. As mentioned before: If it is not completely removed from the weld after welding, it can cause corrosion in a short period of time.

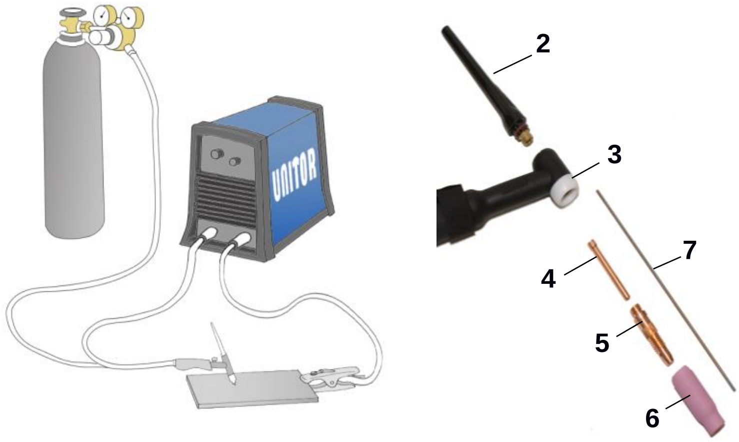
Recommended electrodes: Unitor Alumin-351N in 3,2mm. The electrode is alloyed with 12% silicon. This is an electrode primarily for welding of cast aluminum alloys but can also be used to weld rolled alloys and for joining cast to rolled alloys. If the aluminum base material is of unknown composition this electrode gives the best chance of success.

Aluminum electrodes should preferably be vacuum packed to stop moisture pick up

Esab OK 96.20 is an aluminum electrode alloyed with a 1% manganese addition usually used for welding of rolled weldable aluminum magnesium and aluminum manganese alloys.
Esab OK 96.40 is an aluminum electrode alloyed with 5% silicon. This is suitable for welding AlMnSi alloys such as AWS 6060/6063, 6005 and 6201. It can also be used to weld AlSi5Cu and AlSi7 cast materials.

TIG Welding

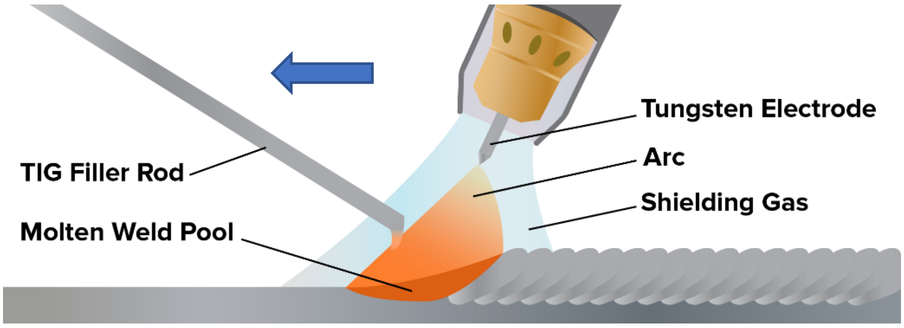
The most applicable and best process for maintenance and repair welding of Aluminum is TIG welding. Tungsten Inert Gas (TIG) welding also known as Gas tungsten arc welding (GTAW), is an arc welding process that uses a non-consumable Tungsten (Wolfram) electrode to produce a weld pool.



1 Short back-cap or...
2 Long back-cap
3 Heat shield
4 Collet 1.6mm
4 Collet 2.4mm
5 Collet body 1.6 mm
  Alternative: Gas Diffuser
5 Collet body 2.4 mm
  Alternative: Gas Diffuser
6 Alumina nozzle 6
6 Alumina nozzle 7
6 Alumina nozzle 8
7 Tungsten electrode 1.6 mm

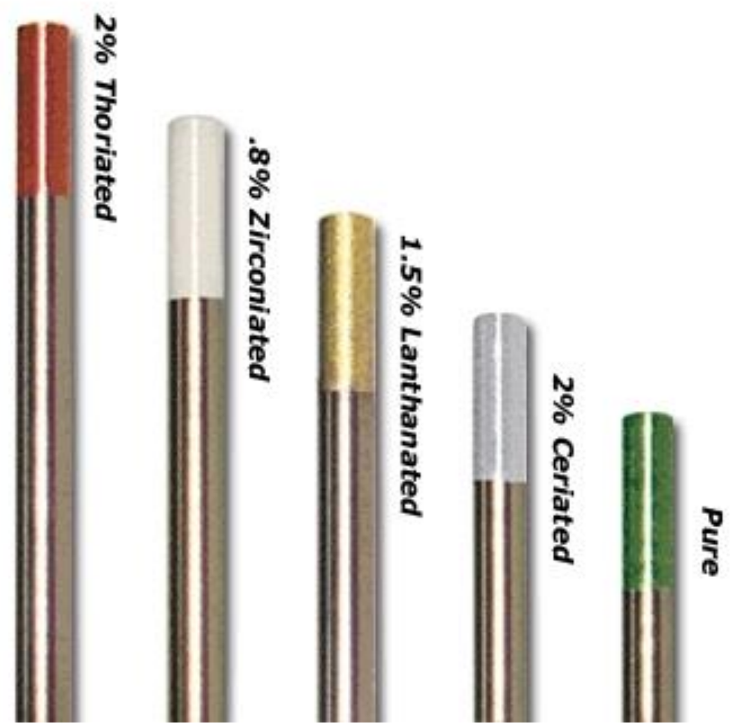
TIG welding is most commonly used to weld thin sections of stainless steel and non-ferrous metals such as Aluminum and seawater resistant alloys like Cunifer and York Albro. The process grants the operator greater control and accuracy over the weld compared to other processes, allowing for stronger and higher quality welds. The welding technique is similar to gas welding (Leftward welding/ forehand welding).

Direction of travel



For TIG welding Aluminum the tungsten electrode tip is grinded to a round shape. The arc and the electrode are shielded by an inert gas (normally Argon) that also surrounds the weld pool and prevents oxidation. TIG welding of aluminum must be performed with an AC current welding machine. The reason for using Tungsten is that it has a very high melting point of 3000°C (5432°F). Tungsten electrodes are normally available in two different diameter sizes, 1,6mm (1/16″) or 2,4mm (3/32″). During TIG welding the tungsten electrode will not melt despite very high temperatures, but it will gradually be consumed during ignition and to some extent during actual work. This is referred to as the burn-off rate. In time, it will be necessary to regrind the electrode.

In order to extend their capacity and performance the manufacturers alloy in any of the following elements: Cerium, Lanthanum, Zirconium or Thorium.



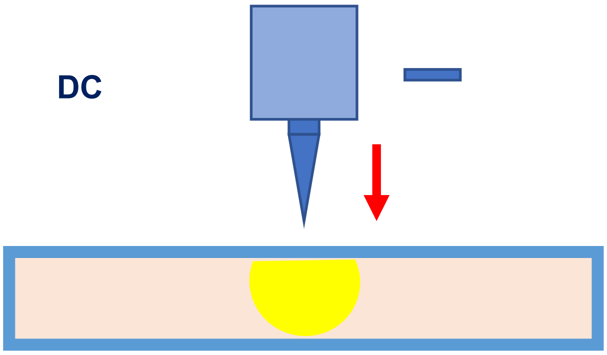
NB. Thoriated TIG welding electrodes with 2% thorium oxide (color code red) are currently the most widely used electrodes worldwide. Thorium is however a radioactive element and as such represents a potential danger to health and environment. Thorium is a so-called “a-emitter,” but when enclosed in a tungsten matrix, the “a” radiation emitted externally is negligible. The danger to the welder arises when thorium oxide gets into the respiratory canals. This problem can occur during welding (vapors) as well as when grinding the electrode tip (grinding dust). It is expected that TIG welding electrodes containing thorium will disappear from the market in the future, especially as an environmentally friendly and technically better solution is already available.

Recommendation: Tungsten electrodes alloyed with Lanthanum (color code gold) can be used for AC and DC welding.

Aluminum is an excellent conductor of heat. It requires large heat inputs when welding is begun, since much heat is lost in heating the surrounding base metal. After welding has progressed a while, much of this heat has moved ahead of the arc and pre-heated the base metal to a temperature requiring less welding current than the original cold plate. If the weld is continued further on to the end of the two plates where there is nowhere for this pre-heat to go, it can pile up to such a degree as to make welding difficult unless the current is decreased. Because of this the TIG torch should be fitted with a hand amperage control so that the welder can gradually reduce the amperage.

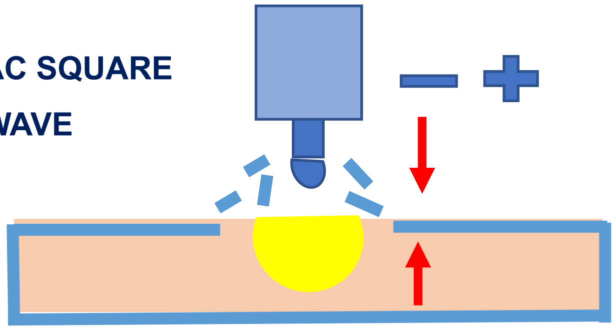
To better understand why, it is necessary to use Alternating current, preferably square wave when welding Aluminum consider the following:

DC

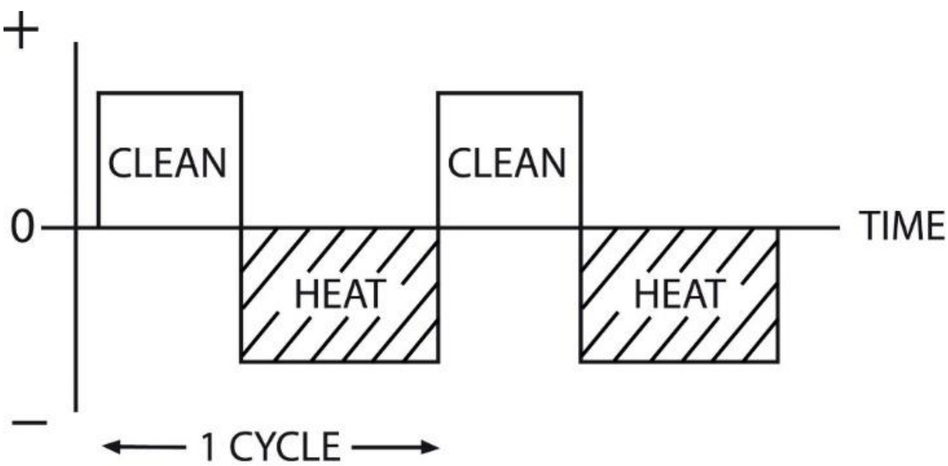


TIG welding using Direct Current (DC) minus polarity the electrons bombard the aluminium melting it, but are unable to break the oxides

AC SQUARE WAVE



TIG welding using Alternating Current (AC) the polarity changes from minus to plus. During minus it melts the aluminium, during plus it breaks up the oxides



So, the Polarity is important

With AC, during the half cycle when the electrode is positive and the workpiece is negative, the electrons coming out of the workpiece break up what is left of the oxide layer: this action is known as **cathodic cleaning** and is essential for successful Welding-aluminium.

To avoid torch overheating new power sources for TIG welding have **square wave** configurations where both the time proportions of electrode positive vs. negative and the relative intensities can be finely adjusted. The effect is a **more stable arc** (than with simple AC), better penetration, and a more balanced heat distribution between torch and workpiece. Recommended machine is Unitor UWI-230 TP AC/DC that provide square wave ability and turbo effect where time proportion of electrode positive is increased thereby increasing the heating period, and hence the welding speed. Avoid using welding machines with Open Circuit Voltage (OCV) above 25V or that depend on High Frequency.

For maintenance welding an air cooled TIG torch will normally be sufficient. If extensive welding considers a water cooled TIG torch. It will be an advantage if the TIG torch is fitted with a thumb control amperage setting so that amperage can be increased or decreased during welding.

Fit the TIG torch with a pure tungsten (color code green) or with Lanthanum (color code gold) electrode for aluminum welding if you have a non-square wave welding machine.

Fit the TIG torch with a Lanthanum (color code gold) tungsten electrode for aluminum welding if you have a square wave welding machine

The TIG torch should preferably be fitted with a gas diffuser (sintered metal) in order to avoid turbulence in the shielding gas as it comes out of the TIG torch.

The TIG torch alumina nozzle must be size 8. This because the aluminum molten pool needs better protection towards oxidation than steel or stainless steel.

Adjust the tungsten to project from the alumina nozzle a distance roughly equal to the diameter of the tungsten.

Use a 1,6mm (1/16″) tungsten electrode for 30 to 80 amps
Use a 2,4mm (3/32″) tungsten electrode for 80 to 180 amps
Use a 3,0mm (1/8″) tungsten electrode for anything above 180 amps

Use Argon quality 4.8 Purity >= 99.998% and flow rate 6 to 9 L/min.

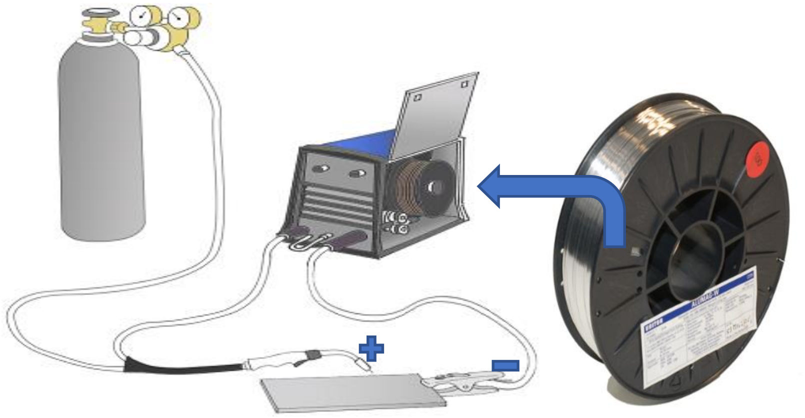
The arc length should be roughly equal to the diameter of the tungsten.

Use a filler rod size equal to the tungsten size. Recommended filler: Unitor Alumag 235 (AWS A5.10 ER 5356).

As mentioned previously: Clean all dirt, oil, paint, or other residue from the area to be repaired by TIG welding. Note previous chapter: “**Clean the aluminum”.**

MIG Welding

Metal Inert Gas (MIG) process, or sometime referred to as Gas Metal Arc Welding (GMAW) are a Wire Welding process. Wire Welding is a process where a wire from a reel is fed through a welding torch passing a contact tip supplying the welding current. The wire melts and is transferred to the pool through the arc. A shielding gas (Argon) is necessary to prevent oxygen oxidising the pool.



Power-source selection: When selecting a power source for MIG welding of aluminium, first consider the method of metal transfer -spray-arc or pulse. Constant-current (cc) and constant-voltage (cv) machines can be used for spray-arc welding. Spray-arc takes a tiny stream of molten metal and sprays it across the arc from the electrode wire to the base material. For thick aluminium that requires welding current in excess of 350 A, cc produces optimum results.

Pulse transfer is usually performed with an inverter power machine. Newer power supplies contain built-in pulsing procedures based on filler-wire type and diameter. During pulsed MIG welding, a droplet of filler metal transfers from the electrode to the workpiece during each pulse of current. This process produces positive droplet transfer and results in less spatter and faster follow speeds than spray-transfer welding. Using the pulsed MIG welding process on aluminium also better-controls heat input, easing out-of-position welding and allowing the operator to weld on thin-gauge material at low wire-feed speeds and currents.

Some of the inherent problems associated with MIG welding of aluminium, compared to the welding of steel, are: feed ability, incomplete fusion at the start of a weld, and crater or termination cracking at the ends of the weld.

Feed ability is the ability to consistently feed the spooled welding wire when MIG welding, without interruption. Feed ability is probably the most common problem experienced when moving from MIG welding of steel to MIG welding of aluminium. Feed ability is a far more significant issue with aluminium than steel. This is primarily due to the difference between the materials' mechanical properties. Steel welding wire is rigged, can be fed more easily over a further distance and can withstand far more mechanical abuse when compared to aluminium. Aluminum is softer, more susceptible to being deformed or shaved during the feeding operation, and, consequently, requires far more attention when selecting and setting up a feeding system for MIG welding. NB. 4043 filler wire is a softer alloy in the

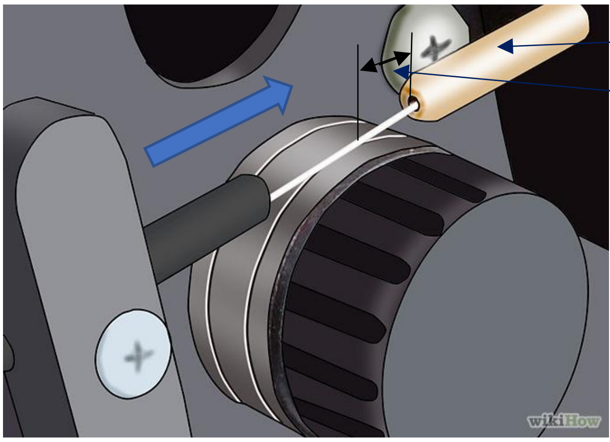
form of spooled wire, compared to 5356. Typically, when MIG Welding, feed ability will become a less critical issue when feeding the more rigid 5356 alloys.

Recommended filler: Unitor Alumag W-235 (AWS A5.10 ER 5356) 1mm

Feed ability problems often express themselves in the forms of irregular wire feed or as burn-backs (the fusion of the welding wire to the inside of the contact tip). In order to prevent excessive problems with feed ability of this nature, it is important to understand the entire feeding system and its effect on aluminium welding wire.

Brake setting tension

Starting with the spool end of the feeding system, the brake settings must be considered first. Brake setting tension, is required to be backed off to a minimum. Only sufficient brake pressure, to prevent the spool from free-wheeling when stopping welding, is required. Electronic braking systems and electronic and mechanical combinations have been developed to provide more sensitivity within the braking system.



Outlet guide

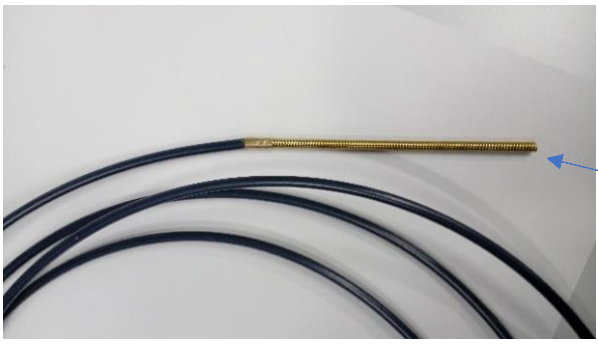
As close to drive roll as possible

Inlet and outlet guides, which are typically made from metallic material for steel welding, should preferably be made from a non-metallic material such as nylon to prevent contamination, abrasion and shaving of the aluminium wire. It is also very important that the outlet guide is placed as close to the drive roll as possible to catch the wire as it comes off the drive roll.

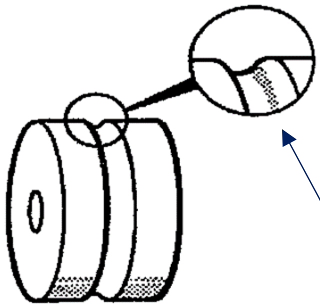
Liners, which are typically made from metallic material for steel welding, must be made from a non-metallic material such as Teflon or nylon to prevent contamination of the aluminium wire. Do not use steel liners that will contaminate the aluminium wire. Change liners with regular intervals to avoid build-up of aluminium oxide that interrupt consistently feed.

Bronze Liner

For a gas cooled MIG torch, it is better use a Teflon liner with a short bronze liner at the end towards the torch neck. This is because a Teflon liner could be overeating near the torch neck/contact tip and melt



Teflon Liner with Bronze end

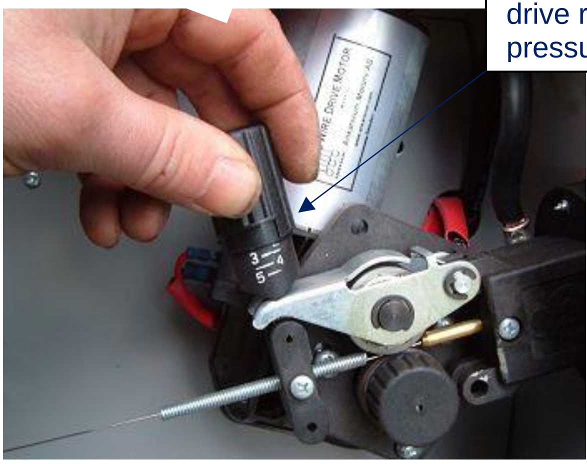


Smooth
U-groove

U-groove for aluminium

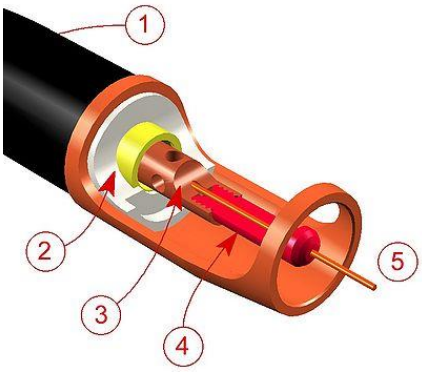
Drive rolls have been developed, often with U-type contours with edges that are chamfered and not sharp, that are smooth, aligned, and provide correct drive roll pressure. Excessive drive roll pressure can deform the aluminium wire and increase friction drag through the liner and contact tip.

Excessive drive roll pressure



Over pressuring soft wire like aluminium can crush and flatten it, resulting in poor feeding and possible bird's nesting (tangling) of the welding wire. Properly adjusting the drive roll pressure is critical when running soft wires.

Contact tip Internal Diameter (I.D.) and quality are of great importance. As current are put to the wire in the contact tip the aluminium wire's thermal expansion (which is about twice that of steel) will make it expand and get stuck in the contact tip. It is therefore important that the contact tips ID is bigger than the wire diameter. For example, a 1mm (0,039") aluminium wire should be used with a 1,2 mm (0.047") contact tip.



(1) Torch handle (Gun)
(2) Insulator
(3) Shielding gas diffuser,
(4) Contact tip,
(5) Gas nozzle

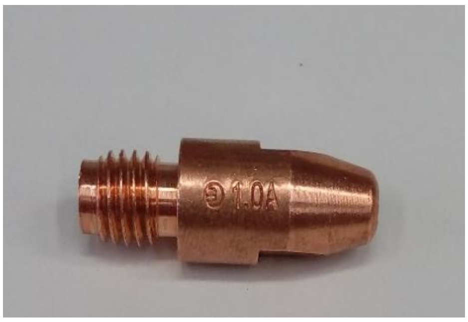
Contact tips made specifically for aluminium welding are available, with smooth internal bores and the absence of sharp burrs on the inlet and outlet ends of the tips which can easily shave the softer aluminium alloys.

Special contact tips for aluminium:

Without 'A'

For carbon steel and stainless steel

Ø1.0 mm (0,039")



With 'A'

Only for aluminium wire
Ø1.0 mm (0,039")

Without ‘A’

For carbon steel and stainless steel

Ø1.2 mm (0.047”)

With ‘A’

Only for aluminium wire Ø1.2 mm (0.047”)

Generally, when a welding current exceeds 200 A use a water-cooled gun to minimize heat build-up in order to further reduce wire-feeding difficulties.

Special Features for Welding Machines for Aluminum Welding:

The Hot Start Feature: Aluminum has a thermal conductivity about six times that of steel, and because of this ability to rapidly conduct heat away from the weld area, there has always been an inherent problem, particularly when starting a weld on this material. It is not uncommon to experience incomplete fusion at the start of an aluminium weld because of the material's high thermal conductivity. One method which can now be used to help overcome this problem, particularly on thicker sections of aluminium used in structural applications, is the use of equipment that has a hot start feature. This feature may allow the user to program the weld starting current characteristics independently from that of the general welding current parameters, thus providing the user with the ability to start the weld with a higher current density for a predetermined period before moving to the general welding conditions for the remainder of the weld. This allows the use of a higher heat input at the beginning of the weld that can help to overcome the dramatic heat sink associated with this material prior to the weld area becoming heated by the welding operation. The result of this technique is to eliminate, or significantly reduce, the probability of incomplete fusion at the start of the weld and thereby improve the life expectancy of welded components.

Crater Fill Feature: Other characteristics of aluminium that can provide welding problems are associated with its thermal expansion (which is about twice that of steel) and its shrinkage on solidification (which is 6% by volume). This can increase both distortion and weld crater size. One common concern when welding aluminium is crater cracking or what is sometimes called termination cracking. When MIG welding with conventional equipment, once the trigger of the welding gun has been released, the arc is extinguished, and no additional filler metal is added to the weld pool to fill the crater. Consequently, if no further precautions are taken, a large crater will be left which will have a higher probability of cracking. Craters can be serious defects, and most welding standards require them to be filled and free from cracks. Run-off tabs or other methods of locating weld craters on scrap material away from the weld are not usually practical. However, if the weld pool size can be reduced before the arc is fully extinguished, the resulting crater may be very small or almost eliminated and, consequently, the weld may be free from cracks. In the past, a number of welding techniques have been used in an attempt to reduce this termination problem. Reversing the direction of travel at the end of a weld, increasing travel speed to reduce crater size, and providing suitable build-up and remoulding the crater area flush with the weld surface by mechanical means are some of the methods which have been used. These methods are often difficult to control, require specialized training, and are not always successful in their objective. More recently, welding equipment has been developed for aluminium welding which has a built-in crater fill feature. This feature is designed to terminate the weld in a gradual manner by decreasing the welding current over a predetermined period as the weld is completed. This feature may be adjustable to enable the user to select the most favourable termination conditions and thereby prevent a crater from forming at the weld termination. Tests have shown this crater fill feature to be extremely user friendly and very effective in eliminating the crater cracking problem."

Recommended welding machine for MIG aluminium welding: Weco Micro Pulse 302MFK. This is a 3-phase robust designed Inverter for Synergic, Pulse Synergic and Double Pulse Synergic MIG/MAG welding, MMA and TIG Lift Arc welding. Easy to transport, compact and only 24kg, it is a most suitable machine for maintenance and repair welding of aluminum onboard. It can also with good results be used for other metals like steel and stainless steel.

Alternative if only 1 phase 230 V available onboard: Unitor UWW-161 TP. This is a standard all-round welding machine that are not specifically meant for aluminium. It can however be modified for aluminium welding by fitting the machine with a Spool gun. In a Spool gun the wire spool and the wire feed mechanism are moved out on the gun itself thereby creating a short and steady wire feed.

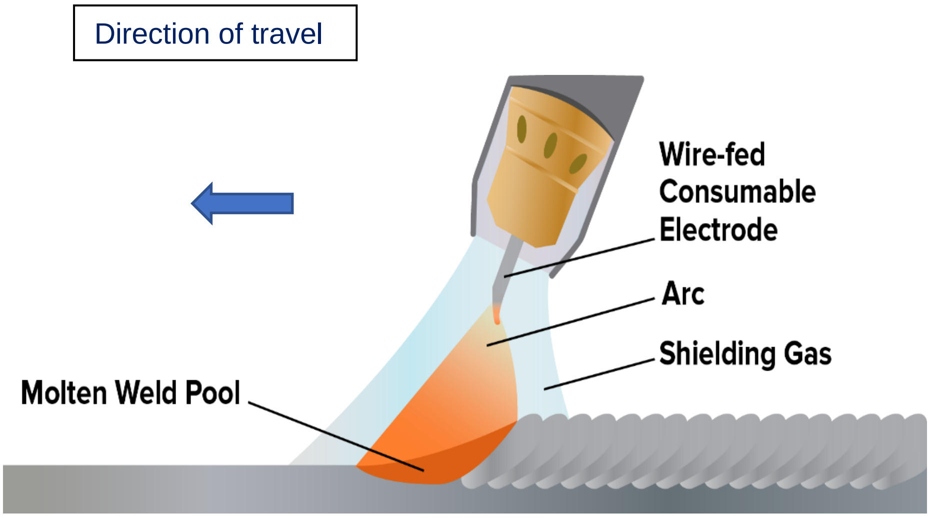
Shielding gas for aluminium: Argon (4.8 Purity >= 99.998%) due to its good cleaning action and penetration profile, is the most common shielding gas used when welding aluminium. Welding 5XXX-series aluminium alloys, a shielding-gas mixture combining argon with helium – 75% helium maximum - will minimize the formation of magnesium oxide. Argon flow rate start at 25 L/min.,

Welding wire: Select an aluminium filler wire that has a melting temperature similar to the base material. The more the operator can narrow-down the melting range of the metal, the easier it will be to weld the alloy. The larger the wire diameter, the easier it feeds.

Clean the aluminum: Clean all dirt, oil, paint, or other residue from the area to be repaired by MIG welding. Note previous chapter: "**Clean the aluminum".**

Welding technic:

Point the gun slightly in the direction of travel.



NB For TIG and MIG Welding: Make sure that the welding location is screened off towards wind and draft that can interrupt the shielding gas and cause porosity.

To sum up:

Clean the aluminum and preheat before welding. TIG welding is undoubtedly the best way for performing maintenance welding of aluminium. MIG welding is easy, fast and efficient but, you need a lot of welding work to justify the investment in equipment. Stick / electrode welding and gas welding can make use of existing and traditional equipment but require a highly skilled welder.