CIGWELD

WELDING OF ALUMINIUM

1) "Atmospheric Conditions" the Affect on Weld Quality:

Many fabricators experience welding problems at different times of the year. Moisture (H_2O) is a prime source of hydrogen. At arc temperatures, water breaks down releasing hydrogen atoms that cause porosity in weldmetal. Shielding gas supplies are controlled to very low moisture content (-57°C dew point or lower). Likewise, the atmospheric conditions in a fabricating facility need to be controlled to prevent moisture condensation from forming on the aluminium welding wire or base metal.

Aluminium which is allowed to repeatedly come into contact with water will eventually form a hydrated oxide (AlOH) coating. Moisture from condensation present on either the welding wire or the base metal can cause two problems during welding:

- Porosity caused by hydrogen generated from the breakdown of water or from the breakdown of hydrated oxide (AlOH) present on the metal surfaces.
- Entrapment of the actual oxide (AlOH), present on the metal surfaces, in the weld metal.

Terms:

Relative Humidity -
The ratio of the quantity of water vapour present in the atmosphere to the quantity which would saturate the air at the existing temperature. Relative humidity is expressed as a percentage number and needs to be monitored in the welding area. Dip tanks, cleaning stations, etc. affect relative humidity.

Dew Point - The temperature at which condensation of water vapour in the air takes place. Moisture will condense on metal surfaces when their temperature is equal to or below the dew point. For each relative humidity percentage, there is a corresponding dew point.

Air Temperature -
The temperature of the air in the welding area at any given time.

Base Metal or Aluminium Welding Wire Temperature -
The temperature of the welding wire or base metal at any given time.

General:

In an aluminium welding shop, the uniformity of air and metal temperatures is important especially when the relative humidity is high. Aluminium welding wires and the base metal should be allowed to stabilise to the weld area temperature. The aluminium welding wire should not be opened in the welding area for 24 hours after entry from a cooler storage area. The base metal should be cleaned and brushed with a clean stainless steel brush prior to welding. CIGWELD recommends mild alkaline solutions and commercial degreasers that do not evolve toxic fumes during welding. Welders should wipe joint edges with a clean cloth dipped in a volatile petroleum based solvent. All surfaces must be thoroughly dried after cleaning.

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Dew Point Conditions Versus Relative Humidity (RH):

(T_{air} - T_{metal})° - Temperature of the air minus the temperature of the metal shown in °C and °F.

The chart below shows the relative humidity at which detrimental water condensation will form for a number of given differential temperatures.

*** Example -** If the relative humidity in the weld area is 70%, the base metal and aluminium welding wire must be no colder than 5°C below the air temperature to prevent moisture condensation.

(T_{air} - T_{metal})°		RH	(T_{air} - T_{metal})°		RH
°C	(°F)	%	°C	(°F)	%
0	(0)	100	12	(21.6)	44
1	(1.8)	93	13	(23.4)	41
2	(3.6)	87	14	(25.2)	38
3	(5.4)	81	15	(27.0)	36
4	(7.2)	75	16	(28.8)	34
5*	(9.0*)	70*	18	(32.4)	30
6	(10.8)	66	20	(36.0)	26
7	(12.6)	61	22	(39.6)	23
8	(14.4)	57	24	(43.2)	21
9	(16.2)	53	26	(46.8)	18
10	(18.0)	50	28	(50.4)	16
11	(19.8)	48	30	(54.0)	14

2) Aluminium Storage & Preparation for Welding:

One of the most frequently asked questions in the process of welding aluminium is "Should the base metal be cleaned before welding?" To answer this question correctly, one must first determine the finished welded product requirements. If consistent, porosity free, high strength, high quality welds are desired, then the base metal must be thoroughly cleaned using a properly designed and executed procedure. Welding wire quality is a subject of constant concern among designers, engineers, and welders, however, base metal preparation and cleanliness if of equal or even greater importance and is often ignored.

Producers of aluminium sheet, plate, rod, bar, and other fabricated shapes generally ship their products with a protective coating of oil or other hydrocarbon to protect the surface. Depending on storage conditions and storage time, aluminium products are covered with oil, ink, grease, dirt, moisture, and a variable layer of hydrated oxide. These contaminants contain hydrogen and are broken down by the arc during welding, releasing atomic hydrogen which is absorbed by the molten aluminium in the weld puddle. During solidification, this hydrogen comes out of solution and coalesces into bubbles in the aluminium which we see as porosity.

The general melting temperature of aluminium alloys is around 650°C (1200°F) while the melting temperature of aluminium oxides is 2040°C (3700°F). Aluminium oxide is not melted during the welding process and if it is present to an excessive degree, it can easily cause lack of fusion and oxide inclusion type defects.

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With this in mind, CIGWELD suggest the following guidelines for the proper storage, joint preparation, cleaning, and welding of aluminium be adhered to:

Storage and Handling:

Base Metal:

- Position base metal vertically and space apart to provide for air circulation and minimise condensation contact points.
- Store inside, preferably in a heated room with as constant a temperature as possible. Humidity control is also desirable, if it can be achieved.

Aluminium Welding Wires:

- Store in a heated room with uniform temperature control and, if possible, with humidity control as well.
- Hold the Aluminium Welding Wire in the welding area for 24 hours before unpacking to allow its temperature to equalise with that of the surrounding area.
- Store unpacked material in a heated cabinet.
- Use dust covers on all welding equipment.

Joint Preparation:

Oxy-fuel Gas Cutting:

- Not recommended for aluminium because it leaves a large heat affected zone with harmful eutectic melting and heavy oxide films.

Carbon Arc Cutting, Bevelling, and Gouging:

- Not widely recommended or used for the same reasons as gas cutting. If it is used, it requires heavy mechanical surface removal before welding.

Plasma Arc Cutting, Bevelling, and Gouging:

- This process is commercially used but has some limitations and must be carefully controlled. If it is used, it requires the power source to be set on DCEN along with the use of a small orifice to gain high velocity and concentrated heat. Heat affected zones will be crack prone particularly for 2XXX, 6XXX, and 7XXX series alloys and will require 3mm or more of mechanical surface removal before welding. Series 1XXX, 3XXX, and 5XXX alloys are not as crack prone and can generally be welded as cut by this process.

Mechanical Machining:

- Drilling, gouging, filing, milling, or router-type cutting produce the best surface for welding. Lubricants or coolants must not be used and tools should be sharp to avoid metal smearing.

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Joint Preparation cont.:

Sawing:

- Blade speed:
  - Circular high-speed steel (8,000 fpm)
  - Circular carbide (12,000 fpm)
  - Band saw (5,000 fpm)

- Tooth shape and spacing:
  - Circular (std. Spacing, high rake angle)
  - Band (3 to 4 teeth per inch)

- Lubricants or coolants must not be used and band saw surfaces should be removed by filing prior to welding.

Grinding:

- Wheel grinding is not recommended since it smears the surface of aluminium and can deposit organic binders from the wheel during grinding.
- Disc grinding can be used with grit size, 30 to 50 preferred, and speeds of 4,000 to 6,000 fpm. Only flexible discs should be used and grinding pressures should be moderate to prevent surface heating or smearing of the aluminium. Lubricants or coolants must not be used.

Base Metal Cleaning:

Moisture:

- Minute traces of moisture on aluminium can produce severe weld porosity. Both the welding wire and the base metal should be brought into the welding area 24 hours in advance to allow all material temperatures to equalise. A dew point test should be done prior to welding. If pre-heating must be used, heat no higher that 65°C (150°F) and remember that oxy-fuel flames produce water as a by-product of combustion.

Lubricants:

- Before oxides can be removed from aluminium, the base metal must be degreased. This is best done with a solvent. Toluene is the best general solvent for this purpose. Acetone is a poor solvent for oils and greases and is less effective than toluene. Chlorinated solvents are also good degreasers but are not recommended for this application because they present environmental problems and their vapours can decompose into toxic or poisonous gases in the presence of heat. Weld joints should be washed with solvent prior to assembly and wiped dry using clean cloth such as cheese cloth. Shop rags should not be used since they contain soaps and other organic compounds from the washing and conditioning processes used to treat them. Do not use compressed air to blow off or dry solvent cleaned areas since it often contains moisture and oil.

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Base Metal Cleaning cont.:

Oxides:

- Wire Brushing:
  Oxide removal must be done after degreasing and is best done with a stainless steel wire brush. Wire brushes must be frequently cleaned with the same solvent as the base metal. Wire brushing can be done by hand or with a power brush. If power is used, keep rpm's and pressures low to avoid heating and smearing the surface metal. Compressed air power brushes should exhaust their air to the rear, not forward towards the brush where the compressed air can contaminate the base metal.

- Chemical Cleaning:
  Chemical cleaning deoxidises and etches the aluminium. These cleaners contain acids and can present problems in handling and disposal. If they are used, the base metal must be thoroughly rinsed and dried and should be milled or wire brushed prior to welding.

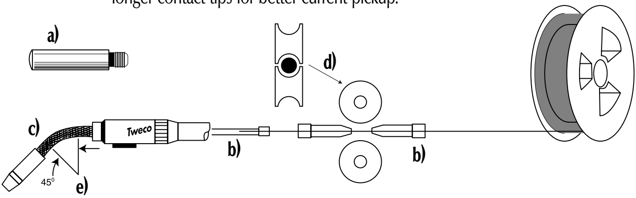
- Etch Cleaning:
  This process uses a hot sodium hydroxide etch and nitric acid rinse. It effectively removes heavy oxides, rough machined, sawn or smeared surfaces and hydrocarbons. However, the process leaves a porous surface containing hydrated oxides that absorb moisture during storage faster than an as-fabricated mill surface. This surface should be milled or wire brushed prior to welding.

3) Feedability of Aluminium Welding Wire:

Performance of GMAW equipment used for welding aluminium significantly affects welding wire feedability. Arcing or burn-backs are often the result of deficiencies in accessory equipment. Such deficiencies can be attributed to improper combinations of accessories, poor care or lack of preventive maintenance. Correcting these deficiencies often improves welding wire feedability markedly. Shown below are important accessory components, each of which is CIGWELD's' recommended equipment for aluminium GMA Welding.

Hints on Feedability:

a) always use the correct size contact tip, or for heavy current work use a tip size 10-15% larger. eg. diameter of the wire 1.2mm = 1.3mm tip. Where possible use longer contact tips for better current pickup.



b) always use where possible, nylon, conduits and inlet and outlet guides. Clean brass inlet and outlet guides are 2nd choice.

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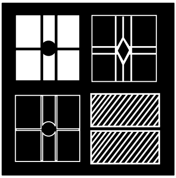
3) Feedability of Aluminium Welding Wire cont.:

Hints on Feedability:

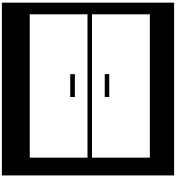
c) use a copper jump liner in the conductor tube (goose neck).
d) always use U-Groove drive rolls.
e) where possible use 45° or straight barrelled conductor tube.
f) keep MIG guns as short as possible (3 metre) when using push type wire feeders.
g) use push pull MIG guns & equipment when welding over longer distances.

Drive Rolls:



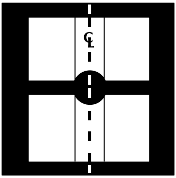
Always use U-Groove drive rolls. Other types distort or shave wire causing more burn backs. Ensure that the U-groove drive roll edges are chamfered, not sharp...The white coloured picture shows the correct drive roll type.

Dust Covers and Wire Storage:



Using dust covers and periodically cleaning the dust and dirt from the liner increases service life. Proper storage is also important in reducing contamination. CIGWELD recommends that aluminium welding wires be stored in a controlled atmosphere below thirty percent relative humidity (30%RH), preferably a temperature and humidity controlled cabinet. Packages containing aluminium welding wire should never be left outdoors or stored in unheated buildings. Aluminium welding wire should never be left on equipment overnight unless protective means are added to the welding machine, such as fully enclosed temperature controlled wire feeders (resistance heater inside the feeder), temperature and humidity controlled workshops, etc.

Proper Alignment of Drive Rolls:



Centre line, misaligned drive rolls will distort the welding wire and cause serious feedability problems. Check your wire feeder for drive roll alignment after each size change of feed rolls. CIGWELD can supply U-groove rollers for most of the TRANSMIG range.

Drive Roll Pressure:

In addition to proper U-type drive roll contours, correct drive roll pressure must be maintained. Excessive drive roll pressure distorts the welding wire increasing frictional drag through the liner and contact tip.

The correct drive pressure can normally be obtained by following these steps;

a) lower the pressure roller down onto the aluminium wire, making sure that all pressure has been backed off.
b) pull the trigger of the MIG gun and slowly wind the pressure roller down until the welding wire starts to feed through the entire length of the MIG gun.
c) once the welding wire has passed through the contact tip, wind the pressure roller down another 1 - 2 turns.

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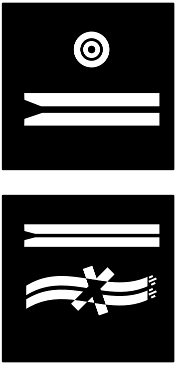
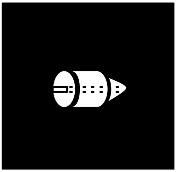
3) Feedability of Aluminium Welding Wire cont.:

Contact Tips:



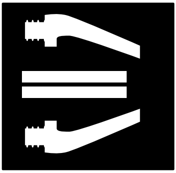
Correct I.D. of the contact tip is of paramount importance. If there is too much clearance between the welding wire and the contact tip, arcing will occur. Continuous arcing causes a build up of particles on the I.D. surface of the tip which increases drag forces and produces burn-backs due to unsteady feed. ▲ Changing contact tips when unsteady feeding is noted eg. pulsing or spiralling of the welding wire, also improves overall performance. ▲ Always use the correct size contact tip, or for heavy current work use a tip size 10-15% larger. eg. diameter of the wire 1.2mm = 1.3mm. Where possible use longer contact tips for better current pickup. ▲ Do not use bent, damaged or crimped contact tips. ▲ Never redrill the I.D. of a genuine Tweco tip as this will soften the tip and cause poor current pick up and severely reduce the tips working life.

Inlet and outlet guides:



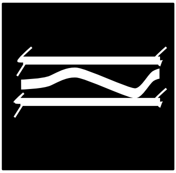
Where possible use, nylon inlet and outlet guides. New, clean brass inlet and outlet guides may be used on aluminium wires but are 2nd choice.

Proper nozzle & contact tip relationship:



The contact tip should be recessed from the edge of the gas shielding nozzle by approximately 1.6mm for lower amperage and voltage settings and up to 5mm for higher settings.

Conduits (liners):



Properly sized flexible conduits with nylon, or plastic liners improves the feeding of aluminium welding wire through long distances by avoiding abrasion of the welding wire. Smooth feeding is also assured by non-metallic connection fittings. Clear total length of the conduit after a burn back.

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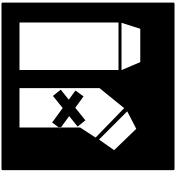
3) Feedability of Aluminium Welding Wire cont.:

Conductor Tubes:



Conductor Tubes (goose necks) are a critical component for successful aluminium welding. CIGWELD recommends the use of either 45° or Straight barrelled conductor tubes. The straighter the tube the better the wire feed. 60° conductor tubes are not recommended. It is advisable to use a copper jump liner throughout the length of the conductor tube, which will aid in current pick up. The copper jump liner replaces the nylon liner between the end of the handle and the gas diffuser.

Water and Inert Gas Leaks:

Check for water and inert gas leaks as these can be a major cause of porosity. Do not interchange water and inert gas lines. Never use old oxy / acetylene hoses for inlet gas lines.

Achieving High Quality Welds:

Although welding equipment is sturdy, the abuses of day-to-day work makes regular maintenance a necessity. Faulty or improperly maintained welding equipment can result in poor welding work. Nevertheless, with proper selection of welding parameters, correct equipment and accessories, an effective program of preventive maintenance and the purchase of CIGWELD aluminium welding wires, high quality welds are attainable.

4) Smoke Testing Aluminium Welding Wire for Surface Contamination:

What Contributes to Weld Porosity?

Weld porosity results from the entrapment of hydrogen gas. This gas entrapment results in lower weld strength and ductility by reducing the cross sectional area of sound metal and by acting as stress risers which cause premature failure. Several variables can produce gas porosity, one of which is the surface condition of the aluminium filler wire. The qualities relating to the surface characteristics of the filler wire include:

1. The removal of surface oxides (hydrated oxides).
2. The absence of any water or water vapour.
3. The removal of hydrogen-containing compounds (hydrocarbons).

Of these three surface conditions, the most common cause of weld porosity is the presence of hydrocarbons. Examples of these compounds include residual wire drawing lubricants, mill dirt or even fingerprints. One relatively quick and inexpensive method of testing aluminium welding wire for freedom from residual hydrocarbons is by means of a "Smoke Test".

What is a Smoke Test?

The "Smoke Test" is a qualitative test performed by heating a sample of wire using an electrical resistance heating machine. While conducting the test, the wire is visually examined for the presence of smoke, caused by the burning of any surface contamination. Minute amounts of contamination, even a fingerprint, will result in smoke.

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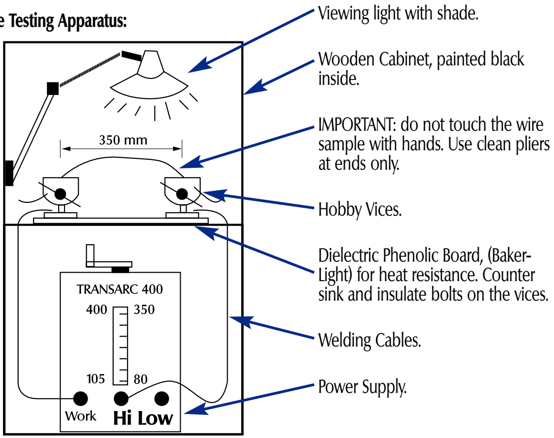
The schematic shows a typical smoke tester machine. Just about any commercial welding power source will suffice. The weld cables are connected to two hobby vices. The wire sample completes the circuit. A light with a dark viewing background is recommended to aid in observing any smoke as the test is performed. Care must be taken in selecting and placing the sample in the vice grips so that the wire does not come in contact with any contamination, including human hands.

4) Smoke Testing Aluminium Welding Wire for Surface Contamination:

CAUTION: Do not touch the wire after testing since it becomes extremely hot.

Typical amperages settings based upon the alloy and diameter of the sample to be tested are listed below. The amperage is chosen to control the melt rate of the sample and allow adequate time to detect the presence of any smoke. The amperage should be sufficient to melt the sample in 3 to 5 seconds.

Smoke Testing Apparatus:



Suggested Amperage Settings By Alloy Series

Sizes (mm)	1XXX 2319	4XXX, C355 A356 & A357	5XXX
0.8	45	40	40
0.9	50	50	50
1.0	60	60	60
1.2	90	90	70
1.6	140	120	120
2.4	225	225	225

What Can I Interpret From the Smoke Test?

A direct correlation exists between smoke test results and weld porosity. Zero smoke should indicate minimal weld porosity. A small amount of smoke will indicate some evidence of weld porosity generated by contamination. A large amount of smoke will indicate severe contamination and the filler wire should be further examined before continuing production welding.

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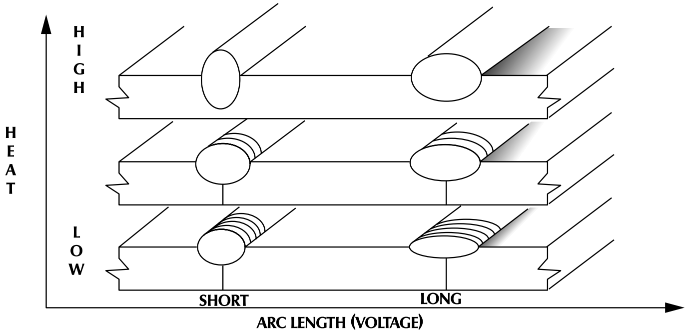
5) Arc Length & Heat (volts x amps) the Affect on Weld Bead Characteristics:

The visual characteristics and mechanical properties of aluminium welds are controlled by weld bead penetration and shape. A number of variables affect the end properties of the weld bead and they can be controlled by the welder. Presented here is a description of those variables and how they can be used to achieve the desired end results.



Note: **Because 5XXX series alloys conduct heat significantly less than 4XXX series alloys, shorter arc lengths are required for desired penetration.**

Characteristics	**Short Arc**	**Long Arc**
Penetration	Deep	Shallow
Weld Width	Narrow	Wide
Weld Height	High	Flatter
Molten Pool Surface	Depressed	Flat
Spatter	Less	More
Arc Noise	Crackling	Humming
Porosity - Surface	More	Less
Characteristics	**High Heat**	**Low Heat**
Penetration	Deep	Shallow
Surface	Smooth	Rippled
Smut (soot)	More	Less
Porosity - Root	Less	More
Recommendations		
Root Pass	Shorter Arc	-
Finish Pass	-	Longer Arc
5XXX Alloys	Shorter Arc	-
	Lower Arc Voltage	-
	Higher Amperage	-
	-	Longer Arc
4XXX Alloys		Higher Arc Voltage
		Lower Amperage

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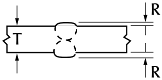
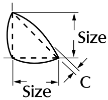
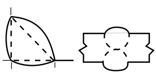
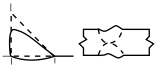
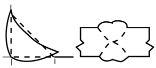
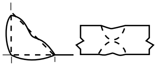
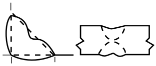
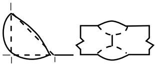
5) Arc Length & Heat (volts x amps) the Affect on Weld Bead Characteristics cont.



CONVEXITY CONTROL SPECIFICATION (USA only)	T	R (max)
	up to 10mm	2.4mm
	10mm to 20mm	3.2mm
	20mm +	5.0mm



CONVEXITY CONTROL SPECIFICATION (USA only)	C (max)
	.07 x face width, plus 1.5mm

	Problem	Solution
	**Excessive Convexity** Reduced fatigue strength	Increase arc length[1] Increase torch angle
	**Insufficient Throat or Leg** Reduced mechanical properties	Change torch angle Change torch position[2] Decrease arc length[1]
	**Insufficient Throat** Reduced mechanical properties	Reduce cooling rate Increase wire feed speed Decrease travel speed Decrease arc length[1]
	**Undercut** Reduced mechanical properties	Change torch position to compensate for: - Dissimilar section sizes - Dissimilar thermal conductivity
	**Overlap** Severe reduction in fatigue strength	Increase welding heat Decrease traverse speed
	**Incomplete penetration** Reduced weld strength and increased sensitivity to crack propagation	Increase heat Decrease arc length[1] Decrease traverse speed Decrease torch forehand angle

Notes:
1) Remember, when changing arc length, arc voltage is changed which also requires a change in arc amperage if constant heat is to be maintained. Watts (heat) = volts x amps
2) For example, the thermal conductivity of 5083 is 32% less than 6061 because of higher magnesium content. This requires more heat input into the 6061 alloy.

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6) Aluminium Welding Problems, Causes and Corrections:

Problem	Causes	Corrections
Porosity	Turbulence of weld pool	Increase welding current to stabilise transfer of metal droplets.
	Hydrogen from hydrated oxide film or oil on wire, base metal, drive rolls & liner.	Keep wire covered. Store wire in a low humidity chamber at a constant temperature. Clean base metal of oil and oxide immediately prior to welding.
	Wet or contaminated shielding gas or inadequate flow. Fast cooling rate of weld pool.	Reject bottles above -57°C dew point. Increase flow rate. Shield from air currents. Use higher welding current and/or a slower speed. Preheat base metal.
Weld Cracking	Improper choice of aluminium welding wire or rod.	Select welding wires with lower melting and solidification temperatures, refer to "W" category of the "Aluminium Alloy Selection Chart".
	Critical chemistry range.	Avoid weld pool chemistry of 0.5 to 2.0% silicon and 1.0 to 3.0% magnesium. Avoid MgSi eutectic problems (5xxx welded with 4xxx).
	Inadequate edge preparation or spacing.	Reduce base metal dilution of weld through increased bevel angle and spacing.
	Incorrect weld technique.	Clamp to minimise stress. Narrow heat zone by increased traverse speed. Produce Convex rather than Concave bead. Minimise super heated molten metal, to control grain size. Proper weld size - not too small. Preheat base metal.
Burn-back or irregular wire feed	Fast run-in wire feed.	Slow run-in wire feed for CV power supply to reduce current surge and arcing in contact tip.
	Insufficient wire feed.	Increase wire feed for CC dropper power supply and reduce arc voltage on CV power supply.
	Electrode too soft, kinked or not level layer wound.	Talk to your local CIGWELD or THERMADYNE Branch Office.
	Flexible conduit too long or kinked.	Cut down or Replace.
	Worn or dirty liner or conduit.	Replace.
	Spatter on end of or eroded interior of the Gas Nozzle.	Replace gas nozzle.
	Aluminium fillings in liner or conductor tube and contact tip, resulting in arcing	Align drive rolls, align the centerline of the drive rolls with the outlet guide, use "U" grooved feed rollers, use only enough feed pressure to prevent slippage.
	Arcing in the Contact Tip	Match contact tip size to wire (or 10-15% above).

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WELDING OF ALUMINIUM

6) Aluminium Welding Problems, Causes and Corrections:

Problem	Causes	Corrections
Poor arc starting	Improper grounding.	Reconnect ground (earth).
	Anodic coating.	Remove anodic coating.
	No shielding gas.	Pre-purge gas shield.
	Wrong polarity.	Change polarity.
Dirty welds	Inadequate gas coverage.	Increase gas flow. Shield arc from drafts. Hold gas nozzle closer to work. Replace damaged gas nozzle. Centre contact tip in gas nozzle. Decrease gun angle. Check gun and leads for air or water leaks.
	Dirty filler wire.	Keep aluminium wire covered when spool is mounted on machine.
	Dirty parent material.	Degrease with toluene, varsol or mineral spirits, etc. to remove oil or grease from joint area. Stainless steel brush to remove other foreign matter from joint area.
	Heavy oxide film or water stain on parent material.	Clean joint area with disc sander, heavy stainless steel brushing or etch.
Unstable arc	Poor electrical connections.	Check electrical connections.
	Dirt in joint area.	Remove all oil, grease, cutting compounds, paints and caulking from joint areas.
	Arc blow.	Do not weld in area of strong magnetic field. Arrange ground clamp to neutralise magnetic field.

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6) Aluminium Welding Problems, Causes and Corrections: Cont.

Problem	Causes	Corrections
Weld bead excessively wide	Welding current too high. Arc travel speed too low. Too long an arc.	Change welding parameters.
Inadequate penetration and incomplete fusion in welds	Insufficient welding current.	Increase weld current.
	Arc travel speed too high.	Reduce arc travel speed.
	Too long an arc.	Decrease arc length through increased wire feed speed.
	Dirty parent metal.	Degrease with toluene, varsol or mineral spirits, etc to remove oil or grease from joint area. Stainless steel brush to remove other foreign matter from joint area.
	Inadequate joint spacing or edge preparation.	Redesign joint.
	Oxide on base metal.	Clean joint area with disc sander, heavy stainless steel brushing or etch.
	Insufficient depth or improper shape of the back-gouge.	Increase depth of back gouge, U-type preferred over V-type.
	Fillet or vee grooves - torch oscillation with CV power supply.	Weld with straight stringer passes without torch manipulation. Switch to CC dropper power supply.
Mismatch of colour after anodising	Improper alloy selection.	Match colour selection in "Aluminium Alloy Selection Chart". Avoid 4xxx and 6xxx match; use 5xxx filler wire with 5xxx and 6xxx base alloys.

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Base Alloys		1070, 1080 1060, 1350	1100	2014, 2036	2219	3303, ALCLAD 3003	3004	ALCLAD 3004	5005, 5050	5052, 5652
Characteristics		WSDCTM	WSDCTM	WSDCTM	WSDCTM	WSDCTM	WSDCTM	WSDCTM	WSDCTM	WSDCTM
	Filler Alloys									
319.0, 333.0, 354.0, 355.0, C355.0, 380.0	2319	-	-	BAAAAA	BAAAAA	-	-	-	-	-
	4043	BAAAAA	BAAAAA	CCBCAA	CCBCAA	BBAAAA	BBAAAA	BBAAAA	BBAAAA	AAAAAA
	4145	AABAAA	AABAAA	ABCBAA	ABCBAA	AABAAA	AABAAA	AABAAA	AABAAA	-
413.0, 443.0, 444.0, 356.0, A356.0, A357.0, 359.0	4043	AAAAAA	AAAAAA	BBAAAA	BBAAAA	AAAAAA	AAAAAA	AAAAAA	AAAAAA	ABAAAA
	4145	AABBA	AABBA	AABAA	AABAA	AABBA	-	-	-	-
	A356.0	-	-	-	-	-	-	-	-	-
	A357.0	-	-	-	-	-	-	-	-	-
	5356	-	-	-	-	-	-	-	-	BABB-A
7005, 7021, 7039, 7046, 7146, 710.0, 7110.0	4043	AACAA	AACAA	BBAAA	BBAAA	ABCAA	ADCBA	ADCBA	ABCBA	BDCBA
	4145	-	-	ABAA	AABAA	-	-	-	-	-
	5183	BABA-A	BABA-A	-	-	BABA-A	BABA-A	BABA-A	BABA-A	AABA-A
	5356	BAAA-A	BAAA-A	-	-	BAAA-A	BBAA-A	BBAA-A	BAAA-A	ABAA-A
	5554	-	-	-	-	-	CCAAAA	CCAAAA	CAAAAA	BCAAAA
	5556	BABA-A	BABA-A	-	-	BABA-A	BABA-A	BABA-A	BABA-A	AABA-A
	5654	-	-	-	-	-	CCAA-B	CCAA-B	CAAA-A	BCAA-A
6061, 6070	4043	AACAA	-ACAA	BBAAA	BBAAA	ABCAA	ADCAA	ADCAA	ABCAA	ADCAA
	4145	AADBA	AADBA	AABAA	AABAA	AADBA	BCDBA	BCDBA	ABDBA	-
	4643*	-	-	-	-	-	-	-	-	-
	5183	BAB--A	BAB--A	-	-	BAB--A	BAB--A	BAB--A	BAB--A	BABC-B
	5356	BAA--A	BAA--A	-	-	BAA--A	BBA--A	BBA--A	BAA--A	BBAC-A
	5554	-	-	-	-	-	-	-	-	CCABAB
	5556	BAB--A	BAB--A	-	-	BAB--A	BAB--A	BAB--A	BAB--A	BABC-B
	5654	-	-	-	-	-	-	-	-	CCAB-A
6005, 6063, 6101, 6151, 6201, 6351, 6951	4043	AACAA	AACAA	BBAAA	BBAAA	ABCAA	ADCAA	ADCAA	ABCAA	ADCAA
	4145	AADBA	AADBA	AABAA	AABAA	AADBA	BCDBA	BCDBA	ABDBA	-
	4643*	-	-	-	-	-	-	-	-	-
	5183	BAB--A	BAB--A	-	-	BAB--A	BAB--A	BAB--A	BAB--A	BABC-B
	5356	BAA--A	BAA--A	-	-	BAA--A	BBA--A	BBA--A	BAA--A	BBAC-A
	5554	-	-	-	-	-	-	-	-	CCABAB
	5556	BAB--A	BAB--A	-	-	BAB--A	BAB--A	BAB--A	BAB--A	BABC-B
	5654	-	-	-	-	-	-	-	-	CCAB-A
5454	4043	ABCCA	ABCCA	-	AAAAA	ABCCA	ADCCA	ADCCA	ABCCA	ADCCA
	5183	BABB-A	BABB-A	-	-	BABB-A	BABB-A	BABB-A	BABB-A	AAAB-A
	5356	BAAB-A	BAAB-A	-	-	BAAB-A	BBAB-A	BBAB-A	BAAB-A	ABAB-A
	5554	CAAAAA	CAAAAA	-	-	CAAAAA	CCAAAA	CCAAAA	CAAAAA	CCAAAA
	5556	BABB-A	BABB-A	-	-	BABB-A	BABB-A	BABB-A	BABB-A	AABB-A
	5654	-	-	-	-	-	-	-	-	BCAB-B
511.0, 512.0, 513.0, 514.0, 535.0, 5154, 5254	4043	ABCC	ABCC	-	AAAA	ABCC	ADCC	ADCC	ABCC	ADCC
	5183	BABB-A	BABB-A	-	-	BABB-A	BABB-A	BABB-A	BABB-A	AABB-B
	5356	BAAB-A	BAAB-A	-	-	BAAB-A	BBAB-A	BBAB-A	BAAB-A	ABAB-A
	5554	CAAA-A	CAAA-A	-	-	CAAA-A	CCAA-A	CCAA-A	CAAA-A	CCAA-B
	5556	BABB-A	BABB-A	-	-	BABB-A	BABB-A	BABB-A	BABB-A	AABB-B
	5654	CAAA-B	CAAA-B	-	-	CAAA-B	CCAA-B	CCAA-B	CAAA-B	BCAA-A
5086, 5056	4043	ABCB	ABCB	-	AAAA	ABCB	ACCB	ACCB	ABCB	-
	5183	AABA-A	AABA-A	-	-	AABA-A	AABA-A	AABA-A	AABA-A	AABA-A
	5356	AAAA-A	AAAA-A	-	-	AAAA-A	ABAA-A	ABAA-A	AAAA-A	ABAA-A
	5554	-	-	-	-	-	-	-	-	CCAA-A
	5556	AABA-A	AABA-A	-	-	AABA-A	AABA-A	AABA-A	AABA-A	AABA-A
	5654	-	-	-	-	-	-	-	-	BCAA-B
5083, 5456	4043	ABCB	ABCB	-	AAAA	ABCB	ACCB	ACCB	ABCB	-
	5183	AABA-A	AABA-A	-	-	AABA-A	AABA-A	AABA-A	AABA-A	AABA-A
	5356	AAAA-A	AAAA-A	-	-	AAAA-A	ABAA-A	ABAA-A	AAAA-A	ABAA-A
	5554	-	-	-	-	-	-	-	-	CCAA-A
	5556	AABA-A	AABA-A	-	-	AABA-A	AABA-A	AABA-A	AABA-A	AABA-A
	5654	-	-	-	-	-	-	-	-	BCAA-B
5052, 5652	4043	ABCAA	ABCAA	AAAAA	AAAAA	ABCAA	ABCAA	ACCAA	ABCAA	ADCBA
	5183	BAB--A	BAB--A	-	-	BAB--A	BAB--A	BAB--A	BAB--A	AABC-B
	5356	BAA--A	BAA--A	-	-	BAA--A	BAA--A	BBA--A	BAA--A	ABAC-A
	5554	-	-	-	-	-	-	-	-	CCAAAB
	5556	BAB--A	BAB--A	-	-	BAB--A	BAB--A	BAB--A	BAB--A	AABC-B
	5654	-	-	-	-	-	-	-	-	BCAB-A
5005, 5050	1100	CBAAAA	CBAAAA	-	-	CCAAAA	-	-	B-AAAA	-
	4043	AACAA	AACAA	BBAAA	BBAAA	ABCAA	ABCAA	ABCAA	ABDAA	-
	4145	BADBA	BADBA	AABAA	AABAA	BBDBA	-	-	-	-
	5183	CAB--B	CAB--B	-	-	CABC-B	BAB--A	BABB-A	BAC--B	-
	5356	CAB--B	CAB--B	-	-	CABC-B	BAA--A	BAAB-A	BAB--B	-
	5556	CAB--B	CAB--B	-	-	CABC-B	BAB--A	BABB-A	BAC--B	-
ALCLAD 3004	1100	DBAAAA	DBAAAA	-	-	CCAAAA	-	-	-	-
	4043	AACAA	AACAA	BBAAA	BBAAA	ABCAA	ADDAA	ADDAA	-	-
	4145	BADBA	BADBA	AADAA	AABAA	BBDBA	-	-	-	-
	5183	CABC-B	CABC-B	-	-	CABC-A	BACC-A	BACC-A	-	-
	5356	CABC-B	CABC-B	-	-	CABC-A	BBBC-A	BBBC-A	-	-
	5554	-	-	-	-	-	CCABAA	CCABAA	-	-
	5556	CABC-B	CABC-B	-	-	CABC-A	BACC-A	BACC-A	-	-
3004	1100	DBAAAA	DBAAAA	-	-	CCAAAA	-	-	-	-
	4043	AACAA	AACAA	BBAAA	BBAAA	ABCAA	ABDAA	-	-	-
	4145	BADBA	BADBA	AABAA	AABAA	BBDBA	-	-	-	-
	5183	CAB--B	CAB--B	-	-	C-BC-A	BACC-A	-	-	-
	5356	CAB--B	CAB--B	-	-	CABC-A	BBBC-A	-	-	-
	5554	-	-	-	-	-	CCABAA	-	-	-
	5556	CAB--B	CAB--B	-	-	C-BC-A	BACC-A	-	-	-
3003 ALCLAD 3003	1100	BBAAAA	BBAAAA	-	-	BBAAAA	-	-	-	-
	4043	AABAA	AABAA	BAAAA	BAAAA	AABAA	-	-	-	-
	4145	AACBA	AACBA	AABAA	AABAA	AACBA	-	-	-	-
2219	2319	-	-	BAAAAA	AAAAAA	-	-	-	-	-
	4043	BAAAA	BAAAA	BCBCA	BCBCA	-	-	-	-	-
	4145	AABAA	AABAA	ABCBA	ABCBA	-	-	-	-	-
2214, 2036	2319	-	-	CAAAAA	-	-	-	-	-	-
	4043	BAAAA	BAAAA	BCBCA	-	-	-	-	-	-
	4145	AABAA	AABAA	ABCBA	-	-	-	-	-	-
1100	1100	BBAAAA	BBAAA	-	-	-	-	-	-	-
	4043	AABAA	AABAA	-	-	-	-	-	-	-
	5356	-	-	-	-	-	-	-	-	-
1060, 1350, 1070, 1080	1100	BBAAAB	-	-	-	-	-	-	-	-
	1188	CCAAAA	-	-	-	-	-	-	-	-
	4043	AABAA	-	-	-	-	-	-	-	-

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Base Alloys		5083, 5456	5086, 5056	511.0, 512.0 513.0, 514.0 535.0 5154, 5254	5454	6005, 6063, 6101, 6151, 6201, 6351, 6951	6061, 6070	7005, 7021, 7039, 7046, 7146, 710.0, 711.0	413.0, 443.0 444.0,356.0 359.0 A356.0, A357.0	319.0, 333.0 354.0, 355.0 C355.0,380.0
Characteristics		WSDCTM	WSDCTM	WSDCTM	WSDCTM	WSDCTM	WSDCTM	WSDCTM	WSDCTM	WSDCTM
	Filler Alloys									
319.0, 333.0, 354.0, 355.0, C355.0, 380.0	2319	-	-	-	-	-	-	-	-	BAAAAA
	4043	AAAA-A	AAAA-A	AAAA-A	AAAAAA	BBAAAA	BBAAAA	BBAAAA	BBAAAA	-
	4149	-	-	-	-	AABAAA	AABAAA	AABAAA	AABAAA	ABBBAA
413.0, 443.0, 444.0, 356.0, A356.0, A357.0, 359.0	4043	ABBA-A	ABBA-A	ABBA-A	ABBAAA	ABAAAA	ABAAAA	ABBAAA	ABAAAA	-
	4145	-	-	-	-	AABBA	AABBA	AABBA	AABBAB	-
	A356.0	-	-	-	-	-	-	-	AAAAAA	-
	A357.0	-	-	-	-	-	-	-	AAAAAA	-
	5356	AAAA-A	AAAA-A	AAAB-A	AAAB-A	-	-	AAAA-B	-	-
7005, 7021, 7039, 7046, 7146, 710.0 7110.0	4043	-	-	-	-	ADCBA	ADCBA	BDCBA	-	-
	4145	-	-	-	-	-	-	-	-	-
	5183	AABA-A	AABA-A	AABA-A	AABA-A	AABA-A	AABA-A	AABA-A	-	-
	5356	ABAA-A	ABAA-A	ABAA-A	ABAA-A	ABAA-A	ABAA-A	ABAA-A	-	-
	5554	-	-	BCAA-A	BCAAAA	BCAAAA	BCAAAA	BCAAAA	-	-
	5556	AABA-A	AABA-A	AABA-A	AABA-A	AABA-A	AABA-A	AABA-A	-	-
	5654	-	-	BCAA-A	BCAA-A	BCAA-A	BCAA-A	BCAA-A	-	-
6061, 6070	4043	ADCA	ADCA	ADCA	ADCBA	ACBAA	ACBAA	-	-	-
	4145	-	-	-	-	-	-	-	-	-
	4643*	-	-	-	-	ACBAA	ACBAA	-	-	-
	5183	AABA-A	AABA-A	BABC-B	BABC-A	BAAC-A	BAAC-A	-	-	-
	5356	ABAA-A	ABAA-A	BBAC-A	BBAC-A	BAAC-A	BBAC-A	-	-	-
	5554	BCAA-A	BCAA-A	CCAB-B	CCAAAA	CBABBA	CBABBB	-	-	-
	5556	AABA-A	AABA-A	BABC-B	BABC-B	BAAC-A	BAAC-B	-	-	-
	5654	BCAA-B	BCAA-B	CCAB-A	CCAB-B	CBAB-B	CBAB-B	-	-	-
6005 6063 6101 6151 6201 6351 6951	4043	ABCA	ABCA	ABCA	ABCBA	ACBAA				
	4145	-	-	-	-	-				
	4643*	-	-	-	-	ACBAA				
	5183	AABA-A	AABA-A	BABC-A	BABC-A	BAAC-A				
	5356	AAAA-A	AAAA-A	BAAC-A	BAAC-A	BAAC-A				
	5554	BAAA-A	BAAA-A	CAAB-A	CAAAAA	CBABBA				
	5556	AABA-A	AABA-A	BABC-A	BABC-A	BAAC-A				
	5654	BAAA-B	BAAA-B	CAAB-B	CAAB-B	CBAB-B				
5454	4043	-	-	-	-	-				
	5183	AABB-A	AABB-A	AABB-A	AABB-A	-				
	5356	ABAB-A	ABAB-A	ABAB-A	ABAB-A	-				
	5554	BCAA-A	BCAA-A	BCAA-A	BCAAAA	-				
	5556	AABB-A	AABB-A	AABB-A	AABB-A	-				
	5654	-	-	BCAA-B	BCAB-B	-				
511.0 512.0 513.0 514.0 535.0 5154, 5254	4043	-	-	-	-	-				
	5183	AABA-A	AABA-A	AABB-B	-	-				
	5356	ABAA-A	ABAA-A	ABAB-A	-	-				
	5554	BCAA-A	BCAA-A	BCAA-B	-	-				
	5556	AABA-A	AABA-A	AABB-B	-	-				
	5654	BCAA-B	BCAA-B	BCAA-A	-	-				
5086 5056	4043	-	-	-	-	-				
	5183	AABA-A	AABA-A	-	-	-				
	5356	ABAA-A	ABAA-A	-	-	-				
	5554	-	-	-	-	-				
	5556	AABA-A	AABA-A	-	-	-				
	5654	-	-	-	-	-				
5083 5456	4043	-	-	-	-	-				
	5183	AABA-A	-	-	-	-				
	5356	A-AA-A	-	-	-	-				
	5554	-	-	-	-	-				
	5556	AABA-A	-	-	-	-				
	5654	-	-	-	-	-				

*4643 gives higher strength in thick 6xxx series welds after post weld solution heat treatment and aging. 4047 can be used in lieu of 4043 for thin section sheet due to the lower melting point of 4047.

LEGEND

Symbol ***Characteristic***

W Ease of welding (relative freedom from weld cracking).

S Strength of welded joint ("as welded" condition). (Rating applies particularly to fillet welds. All rods and electrodes rated will develop presently specified minimum strengths for butt welds.)

D Ductility. (Rating is based upon the free bend elongation of the weld.)

C Corrosion resistance in continuous or alternate immersion in fresh or salt water.

T Recommended for service at sustained temperatures above 150°F (65.5°C).

M Colour match after anodising.

*A,B,C and D are relative ratings in decreasing order of merit. The ratings have relative meaning only within a given block.

NOTE: Combinations having no rating are not usually recommended. Ratings do not apply to these alloys when heat-treated after welding.

ALUMINIUM ALLOY SELECTION CHART

How to Use:

1. Select base alloys to be joined (one from the side column, the other from the top row).

2. Find the block where the column and row intersect.

3. This block contains horizontal rows of letters (A,B,C or D) representative of the alloy directly across from them in the filler alloy box at the end of each row. The letters in each line give the A-to-D rating of the characteristics listed at the top of each column - W, S, D. C, T and M (see Legend at right for explanation of each letter).

4. Analyse the weld characteristics afforded by each filler alloy. You will find that you can 'trade off' one characteristic for another until you find the filler that best meets your needs.

Example:

When joining base alloys 3003 and 1100, find the intersecting block. Now, note that filler alloy 1100 provides excellent ductility (D), corrosion resistance (C), performance at elevated temperatures (T) and colour match after anodising (M), with good ease of welding (W) and strength (S). However, if ease of welding and shear strength are UTMOST in importance, and ductility and colour match can be sacrificed slightly, filler alloy 4043 can be used advantageously.

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WELDING OF ALUMINIUM

1) Aluminium Base Metals

Aluminium Alloys can be broken up in to the following groups:

Group A - Cast Alloys
Group B - Wrought Alloys

Group A - Cast Alloy System

SERIES No.	MAJOR ALLOY ELEMENTS
100	99% Pure
*200	Copper
*300	Copper & Silicon
400	Silicon
500	Magnesium
*600	Magnesium & Silicon
*700	Zinc
800	Tin

Group B - Wrought Alloy System

SERIES No.	MAJOR ALLOY ELEMENTS
1000	99% Pure
*2000	Copper
3000	Manganese
4000	Silicon
5000	Magnesium
*6000	Magnesium & Silicon
*7000	Zinc

* NB: These alloys are heat-treatable.
Cast aluminium alloys generally contain a higher percentage of alloying elements than wrought alloys.

The higher additions of alloys greatly improve casting qualities, but make machining and working more difficult.

The Different Groups (Features)

- 100/1000 Series: contain 99% AL or greater (iron and silicon are the major impurities).
  - excellent surface finish, high thermal and electrical conductivity and excellent corrosion resistance.
  - excellent weldability.
  - uses: electrical conductors, architectural items and containers.
- 200/2000 Series: contain copper as a major alloying element.
  - limited corrosion resistance, a high strength to weight ratio and superior machinability.
  - very poor weldability.
  - uses: forgings, heavy duty structural work.
- 300 Series: containing copper and silicon have almost replaced the original 200/2000 series due to better casting characteristics, the other features are the same.
- 3000 Series contains manganese which provides approximately 20% more strength than the 100/1000 series. This series has good ductility and retains workability.
  - good weldability.
  - uses: cooking utensils, sheets and panels which are used on storage tanks.

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WELDING OF ALUMINIUM

The Different Groups (Features) cont.

▲ 400/4000 Series: contains silicon as the major alloying element which aids in the metals fluidity and improves strength and machinability. The silicon lowers the melting point and makes the 400 alloys one of the best for casting.

- good to excellent weldability.
- uses: welding wires, castings, decorative gate castings and sheet.

▲ 500/5000 Series: contains magnesium as the major alloying element. The alloys in the group are widely used due to their excellent mechanical properties, high corrosion resistance and excellent anodising characteristics.

- 500 series are difficult to cast.
- good to excellent weldability.
- uses: sheet, plate, angles etc, widely used in the shipping and marine industries, and also in general fabrication.

▲ 600/6000 Series: contain silicon and magnesium making these alloys heat treatable, which allows the mechanical properties to be improved considerably by heat treatment after forming.

- high resistance to corrosion and ease of machining, plus high strength.
- good weldability.
- uses: transportation equipment, engineering structures, bridges etc.

▲ 700/7000 Series: contains zinc which helps to give these alloys very good impact resistance, high strength and excellent ductility.

- not recommended for welding.
- uses: aircraft structures and mobile equipment.

▲ 800 Series: tin is the principal alloy in the group, its chief purpose being to improve anti-friction characteristics in bearing alloys. These alloys have a high resistance to corrosion by engine oils.

- poor weldability.

GTAW Welding Consumables for Aluminium and Aluminium Alloys:

The CIGWELD/Comweld range

* Comweld AL1188
* Comweld AL4043
* Comweld AL4047
* Comweld AL5356

- see product information in the front of this Pocket Guide or the CIGWELD Welding Consumables Technical Reference Manual.

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Filler Metals to AS 1167.2/AWS A5.10

ALUMINIUM ALLOYS		CONSUMABLE (Filler Rod) TYPE		
CAST	WROUGHT	AS1167.2	AWSA5.10	CIGWELD PRODUCT
AP150	1100	R1188	R1188	Comweld AL1188 (Pure Aluminium)
AP170	1200	R1188	R1188	Comweld AL1188 (Pure Aluminium)
AP185	3003	R1188	R1188	Comweld AL1188 (Pure Aluminium)
	3203	R1188	R1188	Comweld AL1188 (Pure Aluminium)
AP403	3004	R4043	R4043	Comweld AL4043 (Aluminium 5% Silicon)
AP601	5005	R4043	R4043	Comweld AL4043 (Aluminium 5% Silicon)
BP601	5050A	R4043	R4043	Comweld AL4043 (Aluminium 5% Silicon)
CP601	6061	R4043	R4043	Comweld AL4043 (Aluminium 5% Silicon)
AS601	6063	R4043	R4043	Comweld AL4043 (Aluminium 5% Silicon)
AP603	6351	R4043	R4043	Comweld AL4043 (Aluminium 5% Silicon)
AP501	5052	R5356	R5356	Comweld AL5356 (Aluminium 5% Magnesium)
AP701	5083	R5356	R5356	Comweld AL5356 (Aluminium 5% Magnesium)
AP703	5086	R5356	R5356	Comweld AL5356 (Aluminium 5% Magnesium)
	5154A	R5356	R5356	Comweld AL5356 (Aluminium 5% Magnesium)
	5251	R5356	R5356	Comweld AL5356 (Aluminium 5% Magnesium)
	5454	R5356	R5356	Comweld AL5356 (Aluminium 5% Magnesium)
	7005	R5356	R5356	Comweld AL5356 (Aluminium 5% Magnesium)
BP401		R4047	R4047	Comweld AL4047 (Aluminium 10% Silicon)
CP401		R4047	R4047	Comweld AL4047 (Aluminium 10% Silicon)
AP303		R4047	R4047	Comweld AL4047 (Aluminium 10% Silicon)
AS303		R4047	R4047	Comweld AL4047 (Aluminium 10% Silicon)
AP309		R4047	R4047	Comweld AL4047 (Aluminium 10% Silicon)

AWS A5.10-92 Specification for Bare Aluminium and Aluminium Welding Electrodes and Rods.

2) Tungsten Electrodes

Pure, Zirconiated, and Ceriated are the recommended tungsten welding electrodes for use in A.C. welding. Thoriated welding electrodes are generally reserved for D.C. welding of products such as low alloy steels and stainless steels. Thoriated tungsten will handle a higher current than pure tungsten, although it does not retain the balled shape required for A.C. welding of aluminium.

Pure Tungsten Electrodes:

Pure Tungsten welding electrodes are not often recommended or used for A.C. welding on aluminium and magnesium alloys as Zirconiated, and Ceriated electrodes have gained popularity in recent years. Pure Tungsten electrodes contain a minimum of 99.5% tungsten, with no alloying elements intentionally added. By using high purity tungsten, current carrying capability is diminished, although it maintains a clean, balled end which provides good arc stability.

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WELDING OF ALUMINIUM

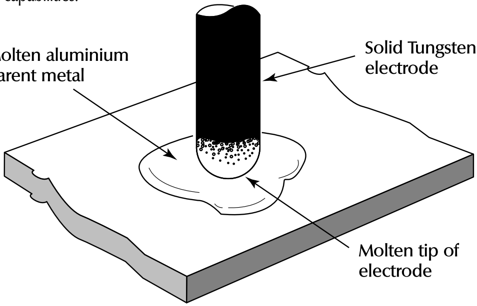
2) Tungsten Electrodes cont.

Zirconiated Tungsten Electrodes:

Zirconiated tungsten welding electrodes have arc stability characteristics that are similar to pure tungsten besides the higher current carrying capability found in the thoriated tungsten. This welding electrode provides a good balance of properties. It is more resistant to contamination than pure tungsten and better for radiographic-quality welding applications than thoriated tungstens.

These electrodes have been designed primarily for use with High Frequency stabilised Alternating Current (AC-HF) and are alloyed with varying percentages of zirconium.
Zirconiated electrodes must be pre-ground to form a tapered tip with a radius end before use.

When current flows through a Zirconiated electrode the end tip which has been prepared with the radius end heats up and becomes slightly molten forming a balled end. This balled end is very important in AC-HF welding as it allows the AC current to obtain arc stability and its arc directional capabilities.



Uses: designed for high quality clean welding of Aluminium and Magnesium alloys.

Advantages:

- high current carrying capacity.
- high resistance to contamination from aluminium oxides (self cleaning action).
- resultant weld metal quality is of high radiographic standard.

Ceriated Tungsten Electrodes:

"The best of both worlds". These electrodes contain varying percentages of cerium and have been designed to function on both AC and DC currents.

Ceriated tungsten welding electrodes have an addition of approximately 2% cerium oxide (CeO_2) which helps to reduce welding electrode burn-off. In performance, the ceriated welding electrode will react much like pure tungsten by providing a stable arc and reducing the amount of tungsten "spitting". These characteristics allow this welding electrode to perform well on aluminium in balanced wave machines (A.C.) and on steel in the D.C. mode.
This electrode can replace both Thoriated and Zirconiated electrodes in most instances.

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2) Tungsten Electrodes cont.

Preparation before welding is dependent upon the current used.
Uses: designed for quality and general purpose work on most metals.

Advantages:

- reduces the number and types of electrodes required to complete different jobs.
- higher resistance to contamination than the thoriated and zirconiated types.
- higher current carrying capacity.
- a longer electrode tip life.
- non-radioactive material.

3) Preparing Tungsten Electrodes:

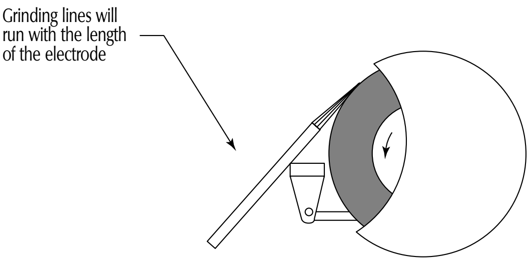
Tungsten electrodes are pre-ground before commencement of welding to allow efficient performance during welding.

Preparation is dependent upon two factors:

- Welding polarity being used (AC-HF or DC)
- The type of Parent Metal being welded.

The Correct Grinding Technique:

- When grinding Tungsten electrodes, it is very important to make sure the grinding lines run longitudinally to the electrodes axis.
- If the grinding lines run around the circumference of the electrode, they may cause the following problems:
  - ridges will be formed around the circumference which can cause tungsten particles to drop off the tip during welding. This will result in tungsten inclusions, a weld defect.
  - these ridges will reduce the stability of the arc and cause "arc wander".



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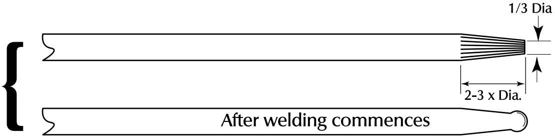
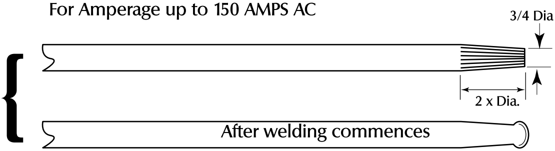
WELDING OF ALUMINIUM

Preparing Zirconiated & Ceriated Tungstens for AC-HF Welding:



For Amperage up to 150 AMPS AC



For Amperage over 150 AMPS AC

Current Carrying Capacities of Tungsten Electrodes:

ELECTRODE DIAMETER	THORIATED	ZIRCONIATED	CERIATED
0.5mm	5-50	5-35	5-60
1.0mm	10-90	15-55	7-95
1.6mm	20-120	35-75	20-130
2.4mm	50-190	45-160	60-230
3.2mm	80-250	50-225	80-320
4.0mm	120-370	90-300	130-450
5.0mm	200-500	150-400	210-600

4) Gas Tungsten Arc Welding - "Process Explanation" and "Power Source Terminology"

The Gas Tungsten Arc Welding (GTAW) process utilises heat generated by an electric arc maintained between the workpiece and a non consumable tungsten welding electrode. The arc is enveloped by a stream of inert gas. GTAW weld quality is primarily controlled by workpiece, filler wire, and tungsten electrode quality, type of power source, and welder technique. Discussed below are several important items that must be addressed in order to produce high quality welds.

High Frequency (HF):

The high frequency mode will initiate and maintain the arc during the zero crossing of the A.C. sine wave. Three positions exist on most GTAW machines eg. TRANSTIG 150:

1. Start - This mode helps arc initiation without making actual contact to the work with the tungsten welding electrode. The "Start" mode is most often used in D.C. welding.

2. Continuous - this also helps initiate the arc and continues throughout the process to maintain the arc during periods when current (amperage) is at the zero crossing point of the sine wave. This mode is most often used in A.C. welding. This type of mode is often a built in feature on most CIGWELD GTAW machines, and occurs automatically when AC current for GTA welding is selected.

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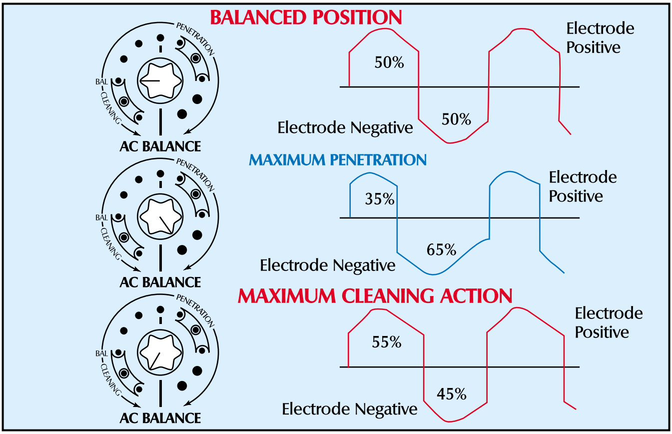
4) Gas Tungsten Arc Welding - "Process Explanation" and "Power Source Terminology" cont.

3. Off - The high frequency system does not engage during any part of the process in this mode. Contact between the tungsten electrode and work surface must occur before the arc can be initiated. A "Touch Start or Scratch Start Practice" to initiate the arc can cause contamination of the the tungsten electrode in the GTAW process. The "Off" mode is often used for DC- TIG or stick welding (MMAW) where scratch starting will initiate the arc.

Using a Balanced Wave Transformer:

The Balanced Wave designation or Square Wave Control indicates that the power supply can alter the current sine wave in the A.C. mode. A normal sine wave will show an even division between each polarity's dwell time. With equipment supported by the Balanced Wave Control, the dwell time can be extended during either the positive or negative cycle.



The CIGWELD Transtig 280 AC/DC/HF Series 2, is a Square Wave GTAW power source.

Square Wave designates the shape of the current wave. It appears in a square, cyclical wave pattern, rather than the standard smooth sine wave cycle. The ability to produce the square wave allows the power supply to utilise the Balanced Wave Control feature to create an arc that can add either more penetration or more cleaning action. Since penetration occurs during the negative side of the wave cycle (tungsten welding electrode negative - DCEN), and cleaning occurs during the positive side of the wave cycle (tungsten welding electrode positive - DCEP), a change in portions of cycle will increase the desired characteristics.

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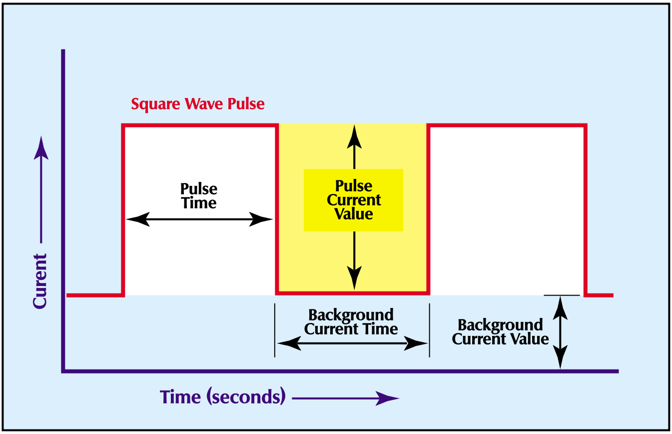
4) Gas Tungsten Arc Welding - "Process Explanation" and "Power Source Terminology" cont.

Pulsed GTAW (TIG) Welding:

In Pulsed Gas Tungsten Arc Welding the current consists of two parts, "see below"

1) the high pulse which melts the metal,
2) the low background current which maintains the arc and allows the weld to cool. The rate of pulse current is usually in the range of 1-10 pulses per second. Pulsed TIG welding offers the following advantages;

a) reduced distortion,
b) reduced heat build up,
c) improved tolerance to joint fit up, and
d) user friendly operation.



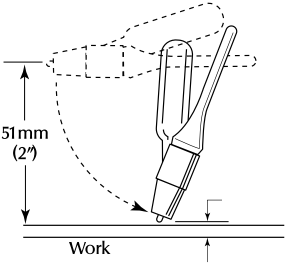
5) GTAW (TIG) Techniques

Starting the Arc:

After gas flow is established and providing HF is used, the electrode does not have to touch the workpiece or starting block to effect arc ignition. The superimposed high frequency current bridges the gap between the electrode and the workpiece or starting block and thus establishes a path for the welding current to follow.

For power sources that do not have a button or foot control start such as the TRANSTIG 150 the following steps are recommended;

a) the torch should first be positioned in a near horizontal position about 50mm above the workpiece or starting block (a piece of copper is recommended for a starting block as it provides less risk of contamination).



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5) GTAW (TIG) Techniques cont.

b) the torch is then moved quickly downwards until the electrode is within approx 3mm of the workpiece or starting block as shown on the previous page. The arc will then be initiated.

c) to stop an arc, the torch should be returned to the horizontal position in a rather rapid manner so that the arc will not mark or damage the weld surface or workpiece. Some care will be necessary, particularly with high quality work and in pipe preparation when breaking the arc. In some instances it is advisable to run off, on to a tab or up the side of the pipe preparation when completing a pass.

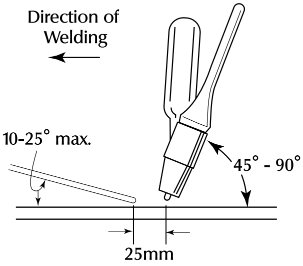
Torch Angles:

The proper manipulation of the welding torch is very important in making a good weld. When welding in the flat position,

- The hand should be placed lightly on a surface, so that the hand can move across the joint evenly. Movement of the torch by the fingers alone, usually results in incorrect torch angles and a poor weld.

- When adding filler wire, the wire should be gripped in the fingers. The hand should be as close as possible to the arc to hold the wire steady. The wire should move in conjunction with the torch movement. When adding wire, move the wire with the thumb through the fingers. The end of the wire should extend 150mm to 200mm from the hand. Too much extension of the filler wire results in a wobbly wire end making the puddle uneven and allowing the filler wire to become contaminated. Adding wire to the puddle requires steadiness and concentration to place the right amount of material at the right place, at exactly the right time.

- Torch angles vary only slightly depending on the welding position. The torch is usually pointed in the direction of travel with a 45-90° angle from the horizontal position. The filler rod is added ahead of the weld pool 10 to 25 degrees from the plane of the weld bead. The filler rod or wire should always be placed within the inert gas shield and at the leading edge of the weld pool. Too large a rod or wire disturbs and often freezes the pool, while a rod too small in size forces the welder to feed too fast for steady operation.



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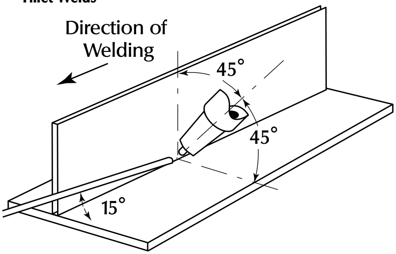
WELDING OF ALUMINIUM

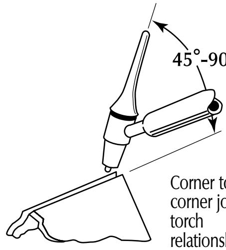
5) GTAW (TIG) Techniques cont.

Torch Angles, for Different Welding Positions:

Fillet Welds



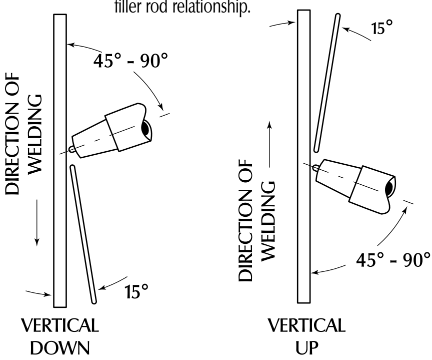
Corner to Corner Weld (Outside Corner)



Corner to corner joint torch relationship.

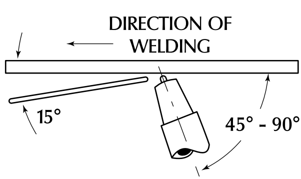
Vertical Welds

Vertical joint torch and filler rod relationship.



Overhead Welding

Overhead joint torch and filler relationship.



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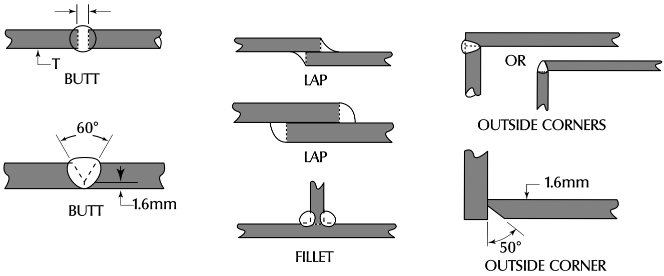
6) Joint Types and Parameters in GTAW

Joints types applicable to the following parameter table: Parameter Table for GTAW (TIG) Welding of Aluminium:



Aluminium GTAW (TIG) Welding - Alternating Current - High Frequency (AC-HF)						
Metal Thickness	Joint Type	Tungsten Electrode Diameter	Filler Rod Diameter (if required)	Amperage	Gas Type	Gas Flow L/min*
1.0mm	Butt/Corner Lap/Fillet	1.0mm	1.6mm	30-45 35-50	Argon	5-7
1.2mm	Butt/Corner Lap/Fillet	1.0mm	1.6mm	40-60 45-70	Argon	5-7
1.6mm	Butt/Corner Lap/Fillet	1.6mm	1.6mm	60-85 70-95	Argon	7
3.2mm	Butt/Corner Lap/Fillet	2.4mm 3.2mm	2.4mm	125-150 130-160	Argon	10
5.0mm	Butt/Corner Lap/Fillet	3.2mm 4.0mm	3.2mm	180-225 190-240	Argon	10
6.0mm	Butt/Corner Lap/Fillet	4.8mm 4.0mm	4.8mm	240-280 250-320	Argon	13

*Flow rates are for argon only, see manufacturers' recommendations for mixtures. Size and shape of gas nozzle has an effect on the flow required for an effective gas cover.

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