WLD 211
Gas Metal Arc Welding of Aluminum for Auto Collision Repair

INDEX

Course Information	**3-4**
Information Sheets	**5-26**
Science on Aluminum	**27-29**
Work Sheets	**30-32**
Welding Projects	**33-55**
Final Exam	**56**
Grade Sheet	**57**

Course Assignments

Reading: Texts available in Welding Tool Room for check out.
Required: I-CAR Student Manual, Aluminum Repair Welding
Recommended: Welding Principles and Applications, By Larry Jeffus

Required: Information sheets, included in training packet.

Introduction to GMAW-P
Power Source
Welding Gun
Wire specification and identification
Shielding Gas
Welding procedures
Workmanship Standards
Visual Inspection

Video training:

Required: I-CAR Aluminum Repair Welding
Recommended:

Miller GMAW 1 Process description, safety and equipment set up
Miller GMAW 2 Equipment and process variables
Miller GMAW 10A Aluminum
Miller GMAW 10B Aluminum

Welding projects

Aluminum GMAW-Pulse ----- Skill Development Projects

Flat position	**Horizontal position**	**Vertical position**	**Overhead position**
	T-Joint Lap Joint	T-Joint Lap Joint	T-Joint Lap Joint

Aluminum GMAW-Pulse ---- I-Car Testing Projects

Flat position	**Horizontal position**	**Vertical position**	**Overhead position**
Butt Joint Plug Weld	Lap Joint Plug Weld	Lap Joint Plug Weld	Lap Joint Plug Weld

Timeline

This is a 2 credit lec/lab course. This course provides the student with a maximum of 40 contact hours to complete the course outcomes. Attending a full shift the student is expected to complete the course work in a maximum of 8 class sessions. Outside of class study of materials is required to insure successful completion and best use of in class lecture and lab experiences.
Open-entry, open-exit instructional format allows the students to attend part time or full time as best meets their schedule needs. It is the student's responsibility to complete all assignments in a timely manner. See your instructor for assistance.

Outcome Assessment Policy

The student will be assessed on his/her ability to demonstrate the achievement of course outcomes. The methods of assessment may include one or more of the following: oral or written examinations, quizzes, written assignments, visual inspection techniques, welding tests, safe work habits, task performance and work relations.

Grading criteria

The student's assessment will be based on the following criteria:
15% of grade is based on Safe work habits and shop practices
20% of grade is based on Completion of written and reading assignments
15% of grade is based on demonstrating employability skills
40% of grade is based on completion of welding exercises
10% of grade is based upon final exam

INTRODUCTION TO GMAW
PULSE TRANSFER

Process Description
As defined by the American Welding Society (AWS), Gas Metal Arc Welding (GMAW) is an electric arc welding process that joins metallic parts by heating them with an arc between a continuous fed filler electrode and the work. A shielding gas protects the electrode and the molten weld metal from contamination. The American Welding Society has modified the GMAW classification system to include information to identify the process by the mode of metal transfer. An example GMAW-S is used to identify the short-circuiting mode of metal transfer and GMAW-P is used to identify the pulse spray arc mode. These examples are formal AWS process designations.

GMAW may also be known as Metal Inert Gas (MIG) and Metal Active Gas (MAG). There are also a variety of "trade names" used to describe the process such as "spray arc", "short arc", "hard wire", and "pulse arc". The process was developed in and made commercially available in 1948.

This course will focus on GMAW –P(Gas Metal Arc Welding Pulse spray transfer).

GMAW Advantages
- Used on a variety of metals including: carbon and low alloy steels, stainless steels, aluminum, magnesium, copper, bronze and titanium.
- Capable of producing x-ray quality welds.
- The pulse mode can be used in all positions.
- Produces no slag during welding so there is little post weld clean up and less chance for inclusions.
- High metal deposition rates are available.

GMAW Disadvantages
- Equipment is more advanced and expensive.
- It is not as portable as other welding processes.
- Material must be clean prior to welding.
- Subject to wind drafts that reduce shielding and cause contamination of the weld.
- Shielding gases can be expensive
- Axial Spray transfer is limited to flat and horizontal positions only.

GMAW Uses
- Structural steel assemblies
- Pipelines
- Automobiles and trucks
- Motorcycles & off road vehicles
- Campers and recreational equipment
- Pressure vessels
- Water tanks
- Rockets and missiles
- Lawn and garden equipment
- Ships, barges, boats and submarines

GMAW EQUIPMENT

Identification
The GMAW process can be used either semiautomatic or automatic. The basic equipment required for GMAW consists of the following:

- A welding power source
- A wire feeder
- A welding gun assembly
- A regulated supply of shielding gas
- A supply of electrode
- Interconnecting cables and hoses

The Welding Power Source
For the purpose of this course you will use a Lincoln INVERTEC V350-Pro CC/CV Inverter Welding Power Source.

LN7 and Cobramatic wire feeders mated to the Invertec V350 Pro Power source.

The Invertec V350-PRO is the most powerful inverter power source in its class. Extremely lightweight, the smart design allows it to handle any constant current Stick (SMAW), TIG (GTAW), carbon arc gouging and constant voltage MIG (GMAW) and Flux-Cored welding applications.

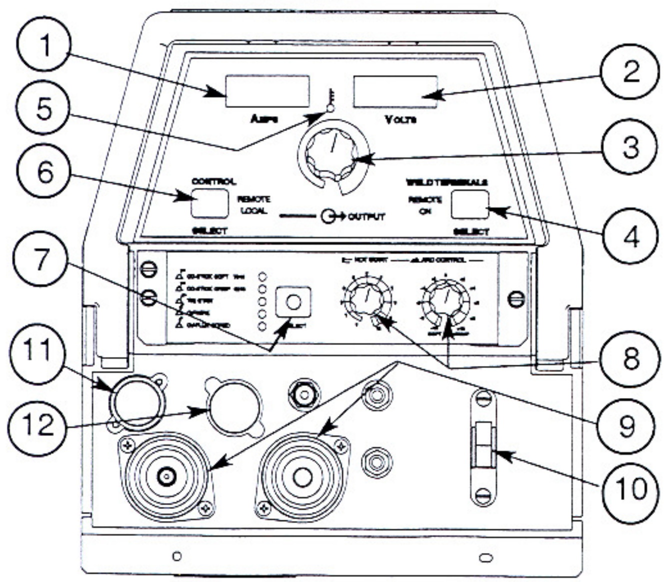
Advanced inverter technology gives you a very portable power source that can be carried to just about any DC welding job needing between 5 and 425 amps.

The V350-PRO can endure the rigors of virtually any work environment. The Invertec V350-PRO is also versatile and well suited for applications that require an extremely smooth arc, process versatility and portability. Examples include: construction sites, shop and maintenance welding applications, welder training schools, technical training centers and pressure and process piping.

The Invertec V350-Pro offers multi-process CV, CC, DC welding and is rated 350 amps, 34 volts at a 60% duty cycle. It is also rated at 275 amps, 100% duty cycle.

The Invertec V350-Pro power source is designed for many applications beyond the scope of this course. It is important however that you have a basic understanding of all the controls available.

FIGURE 1



V350-PRO

LINCOLN ELECTRIC

Operational Features and Controls for the Invertec V350-Pro.

1. Amps Meter	**7. Weld Mode Select**
2. Volt Meter	**8. Hot Start and Arc Control**
3. Output Control (*Volts /Amps*)	**9. Twist Lock Welding lead connections**
4. Weld Terminals – Remote / On	**10. On / Off Switch**
5. Thermal Indicator Light	**11. Brain Cable Connection**
6. Control – Remote / Local	**12. Brain Cable Connection**

Upper Control Panel

1. AMPS meter

- Prior to STICK or TIG operation (current flow), the meter displays preset current value (either 2 amps or +/- 3% (e.g. 3 amps on 100), whichever is greater).
- Prior to CV operation, the meter displays four dashes indicating non-preset table AMPS.
- During welding, this meter displays actual average amps.
- After welding, the meter holds the actual current value for 5 seconds. Output adjustment while in the "hold" period results in the "prior to operation" characteristics stated above. The displays blink indicating that the machine is in the "Hold" period.

2. Volt meter

- Prior to CV operation the meter displays desired preset voltage value.
- Prior to STICK or TIG operation, the meter displays the Open Circuit Voltage of the Power Source or four dashes if the output has not been turned on.
- During welding, this meter displays actual average volts.
- After welding, the meter holds the actual voltage value for 5 seconds. The displays blink indicating that the machine is in the "Hold" period.
- Output adjustment while in the "hold" period results in the "prior to operation" characteristics stated above.

3. Output control

- Output control is conducted via a ***single turn*** potentiometer.
- Adjustment is indicated by the meters as stated above.

4. Weld terminals- remote / on

- Two status lights indicate the location of trigger control as determined by the "WELD TERMINALS" push button.
- If trigger control is local "weld terminals on", the ON display will be lit.
- If trigger control is remote "weld terminals remotely controlled", the REMOTE display will be lit.
- The unit will power up in "pre-determined preferred" trigger modes.

For all versions, these trigger modes can be over-ridden (switched) with the WELD TERMINALS push button. When changed, the unit will power up in the configuration it was in when it was last powered down.

5. Thermal

This status light indicates when the power source has been driven into thermal overload. If the output terminals were "ON", the "ON" light will blink indicating that the out-put will be turned back on once the unit cools down to an acceptable temperature level. If the unit was operating in the "REMOTE" mode, the trigger will need to be opened before or after the thermal has cleared and closed after the machine has cooled down to an acceptable temperature to establish output.

6. Control - remote / local

- Two status lights indicate the location of output control as pre-determined by the power sources auto-configure system.
- The LOCAL display will be lit when control is at the power source.
- The REMOTE display will be lit when a remote pot/control is detected.

These Output Control configurations can be overridden (switched) with the CONTROL push button. When changed, the unit will power up in the configuration it was in when it was last powered down.

7. Weld mode select

The Mode Control button selects from the following welding modes:

CC- stick soft:
The Stick Soft process features continuous control ranging from 5 to 425 amps. This mode was intended for most SMAW applications, and Arc Gouging.

• The Hot Start control regulates the starting current at arc initiation. Hot Start can be adjusted from minimum (0), with no additional current added at arc start, to maximum (10), with double the preset current added for the first second after arc initiation.

• The Arc Control regulates the Arc Force to adjust the short circuit current. The minimum setting (-10) will produce a "soft" arc and will produce minimal spatter. The maximum setting (+10) will produce a "crisp" arc and will minimize electrode sticking.

CC- stick crisp:
The Stick Crisp mode features continuous control from 5 to 425 amps. This mode was intended primarily for pipe welding applications. • The Hot Start control regulates the starting current at arc initiation. Hot Start can adjust starting current up or down by 25% of the preset value.

• The Arc Control regulates the relative Slope of the process. Slope dynamically controls the force the arc has to penetrate an open root. At the minimum setting, Arc Control is very soft and is similar to the Stick Soft mode. At the maximum setting, the slope is reduced, the OCV is reduced, and the operator has full control off the arc force required to penetrate an open root joint. For vertical down, open root pipe welding applications, the recommended setting is between 8 and 10.

TIG GTAW: The TIG mode features continuous control from 5 to 425 amps. The TIG mode can be run in either the TIG touch start or high frequency (optional equipment required) assisted start mode. The Arc Control is not used in the TIG mode.

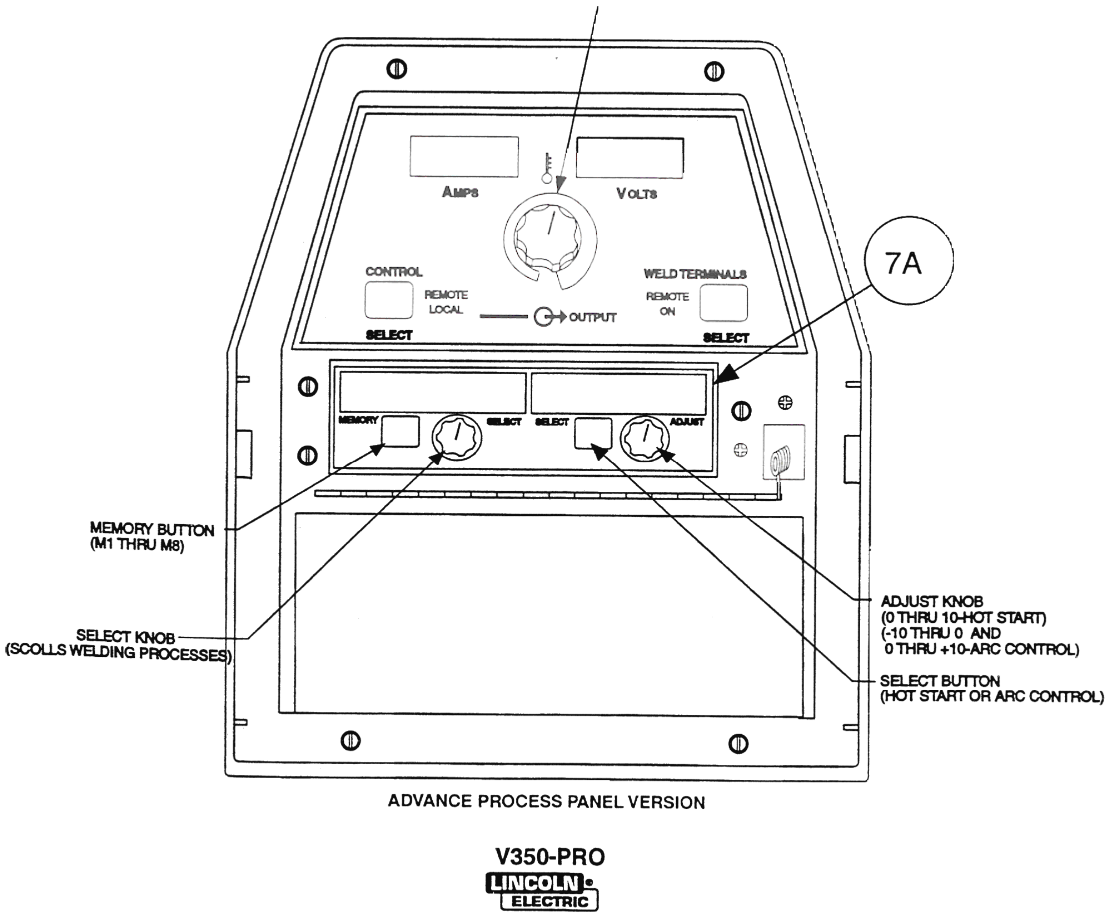
CV-Wire: The CV-WIRE mode features continuous control from 10 to 40 volts. The mode was intended for most GMAW and FCAW applications. The Hot Start control is not used in the CV-WIRE mode.

• The Arc Control regulates pinch effect. At the minimum setting (-10), minimizes pinch and results in a soft arc. Low pinch settings are preferable for welding with gas mixes containing mostly inert gases. At the maximum setting (+10), maximizes pinch effect
and results in a crisp arc. High pinch settings are preferable for welding FCAW and GMAW with CO_2.

CV-Flux cored: The CV-FLUX CORED mode features continuous control from 10 to 45 volts. This mode was designed for self-shielded flux cored wires that require tight voltage control. The Hot Start control is not used in the CV-FLUX CORED mode.

• The Arc Control regulates pinch effect. At the minimum setting (-10), minimizes pinch and results in a soft arc. At the maximum setting (+10), maximizes pinch effect and results in a crisp arc. Most self-shielded wires work well at an Arc Control setting of 5.

V 350 Pro Advanced Process Panel



To program Welding modes use the Select knob is used to scroll through all Welding modes. The Memory button is used to store and access Welding modes into locations M1 thru M8.

Modes

In addition to the 5 welding modes described above the Advance Process Panel allows you to select the following additional modes.

Constant Power mode

In the Power Mode, the work point will be in the Volts window. The Amp window will have **CP** displayed indicating Constant Power. Once current starts flowing and during the 5 second "Hold" feature the displays will show Volts and Amps respectively.

Gouge

Air Carbon Arc Cutting (CAC-A) is a physical means of removing base metal or weld metal by using a carbon electrode, an electric arc and compressed air. Although the equipment is capable of this option you will **not** be using the power source for this application.

Pulsed Modes

In Pulse Modes, the work point will be in the Amps window and should be set close to the wire feed speed of the wire feeder in inches per minute. The Volts window will have **SPd** displayed indicating Wire Feed Speed. Once current starts flowing and during the 5
second "Hold" feature the displays will show amps and volts. Pulse Mode features that are displayed while selecting a Welding pulse mode are listed below;

Steel - .030, .035, .045, .052 – Argon Blends.

Stainless Steel - .030, .035, .045 – Argon Blends & Helium/Argon Blends

Aluminum - .035, 3/64, 1/16 – 4043 & 5356**. – Pure Argon shielding gas. The mode you will choose for the pulse aluminum exercises in this course is the 4X Pulse on Pulse mode.**

Metal Core - .045, .052 – Argon Blends

Nickel - .035, .045 – Argon/Helium blends

The Memory button and Select knob are used together to select a welding process and store it in (M1thru M8). **The SELECT knob** scrolls through the, welding process modes and memory modes M1 thru M8. The **MEMORY button** stores the welding process in memory.

Select Button" (The right button) selects between the "Hot Start" or "Arc Control". The panel will indicate the active feature shown below. Right Digital Window "Hot Start" (-10 to 0 +10) "Arc Control" (0 to 10) .

The Adjust knob adjusts the desired settings for the Hot Start or Arc Control feature that is active.

Pulse Programs V350-PRO

The V350 non synergic pulse programs allow independent control of the wire feed speed and the arc length. The V350 Output Control Knob adjusts the arc length similar to other processes. When operating in a pulse mode, the V350 displays a reference number as the relative arc length. Setting this reference number to the actual wire feed speed of the feeder will produce close to the right arc length. The V350's output knob can then be adjusted to dial in the correct arc length. The Arc Control knob will fine tune the arc length to obtain the desired results.

Lower Case Panel

The output studs, line switch and remote connector are located on the lower case front. Both STUDS contain "Twist-Mate" connector inserts. The Negative stud is configured to accept the pass through gas system.

The ON-OFF switch is a 3-phase circuit breaker rated at 100 amps per leg.

The METER POLARITY switch is located above the output connectors. The switch provides a work connection for wire feeder voltmeters. Place the switch in the position of the electrode polarity indicated by the decal. **The switch does not change the welding polarity.**

Remote control of the Output Control and Weld Terminals

The Invertec V350-Pro has auto sensing of remote output controls. If after connecting or removing a remote, the Invertec V350-Pro did not configured the way you would like the local or remote control settings can be changed by pushing the OUTPUT CONTROL or WELD TERMINAL button.

Summary

This completes the review of adjustments and controls as presented in the Operators Manual produced by Lincoln Electric for the INVERTEC V350-PRO. It is helpful to understand the capabilities and limitations of the equipment you are using.

Wire Feeders

The wire feeder houses all the electrical controls and a variable constant feed motor to move the wire from the supply spool through the gun to the contact tip where it is energized. The feeder also contains solenoids for operating shielding gas flow valve and water coolant flow valve when used. You will use the Lincoln Cobramatic feeder equipped with Lincolns' Prince XL gun system for all aluminum welding exercises.

Cobramatic Wire feeder –A Push Pull wire feeder system

There are a wide variety of wire feeders available today. The basic types of wire feeders include:

Push-type. This method is used to push the wire from the spool to the welding gun. The LN-7 feeder is an example of a push type system.

Pull type. This method is used to pull the wire from the supply spool to the drive rollers in the welding gun.

Push–pull type. This method is used to push the wire from the wire feeder to a set of drive rollers in the welding gun. This type of system is used for welding with soft wires, since these wires may buckle in the cable if pushed for long distances. The Cobramatic feeder with the Prince XL gun is a push-pull system.

Spool gun type. This type of unit has a small spool of wire located on the welding gun and is often a choice for soft wire applications such as aluminum.

Wire feeder controls

The number and types of controls will vary depending on the model of the feeder. The major controls include the **power switch** (off/on control), The **wire feed potentiometer** (wire feed speed control) and the **spool brake control** (stops the wire spool at the end of welding).

Auxiliary wire feeder controls may include:

Trigger lock-in control. This control allows the welder to weld without the need to depress the gun trigger during the entire operation.

Burn back (anti-stick) control. This control prevents the wire from sticking in the weld pool. It sets the time that the arc power is on after the trigger is released to burn the wire back from the weld pool.

Purge control. This control allows the welder to open the gas solenoid. The amount of gas can be set on the flow meter without activating the welding circuit.

Wire inching (jog) control. Moves the wire through the system with out activating the welding circuit. It may be used in setting up the equipment or to determining wire feed speed.

Wire reel brake control. The reel brake control should be adjusted so that the spool will stop rotating at the same time the wire stops feeding. If the wire is allowed to over spool and touch the feeder housing it may cause a short circuit or the wire may "bird nest" (tangle).

Other auxiliary controls may be available on some units. Consult the owners manual for specific functions of special controls.

Wire Feeder Drive Roll System

The drive rollers are grooved for specific types and sizes of wire. The drive roller used must be designed to fit the diameter of wire you are using Wire drive rollers have different groove designs for hard and soft wires. A smooth U groove is the best choice for soft wires such as Aluminum. Smooth V grooved rollers are used for hard wires such as steel or Stainless Steel. A knurled type is often the choice for flux-cored wires.

To insure smooth consistent movement of the wire "wire guides" are installed to guide the wire from the spool into the drive rollers and out of the rollers into the gun. The amount of pressure applied to the drive rollers can be adjusted. The pressure should be set so the wire feeds smooth and consistently. Too little pressure will result in slippage of the wire and may cause a burn back. Too much pressure will deform the wire and cause it to become stuck in the contact tip.
Get in the habit of checking the operation of all the components of a system before using it.

Welding guns

Welding guns are available in a wide variety of types and sizes. In this course you will be using a Prince model push pull for the Aluminum exercises.

The wire feed speed adjustor knob will rotate 3 3/4 revolutions. Due to this, you will need to calculate a six second wire length into inches per minute (IPM) by multiplying the 6 second length by 10 seconds to determine the IPM.

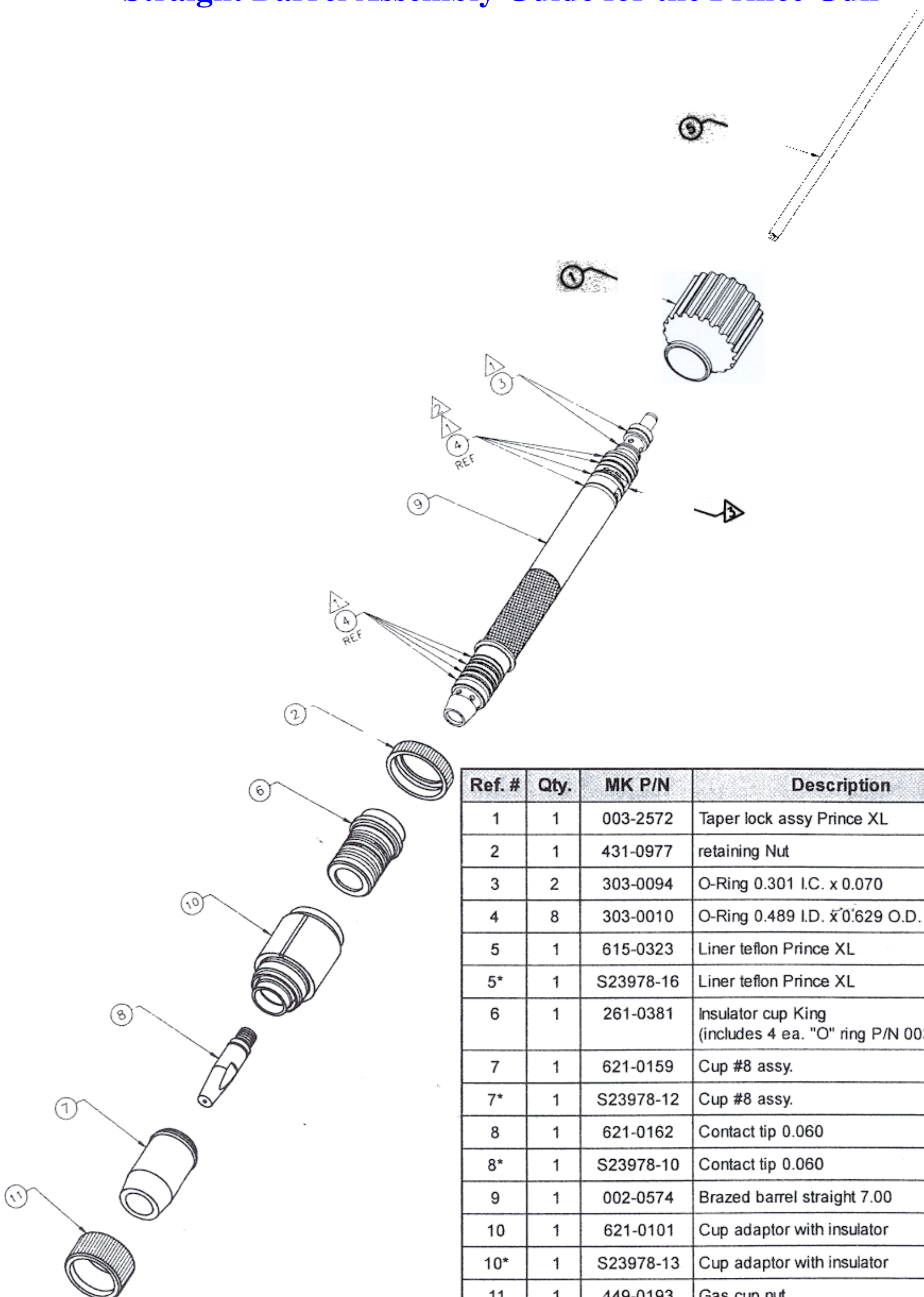
Prince XL Welding Gun

WFS Adjustor

The PRINCE XL gun was specifically designed to operate as both a push-pull gun and a spool gun. You will be using the push-pull system configuration. The model of the PRINCE gun you will be using is a 200 Amp/25 Volt air cooled gun. The drive motor on the gun is controlled by a 3¾ turn potentiometer recessed in the end of the pistol grip. The motor can provide a maximum of 750 inches per minute of wire feed speed.
The PRINCE is designed with a Built-in pre and post gas flow. The trigger is designed so that when it is partially depressed, gas flow starts prior to ignition of the arc. When the trigger is partially released after welding gas flow, continues until the trigger is fully released.

The PRINCE comes with standard knurled drive rollers that will handle from .023 – 1/16 inch diameter wires. Optional grooved drive rollers are available and are preferred for Aluminum wires. Drive roll tension is accomplished by means of a pressure adjusting screw located on the left hand side of the torch. Proper tension is achieved when the wire does not slip if a small amount of pressure is added to the wire as it exits the tip.
All equipment performs better when properly maintained. Maintenance of the gun will normally consist of general cleaning of the wire guide system, including tubes, drive rollers, and conduit at regular intervals.

Straight Barrel Assembly Guide for the Prince Gun



Ref. #	Qty.	MK P/N	Description
1	1	003-2572	Taper lock assy Prince XL
2	1	431-0977	retaining Nut
3	2	303-0094	O-Ring 0.301 I.C. x 0.070
4	8	303-0010	O-Ring 0.489 I.D. x 0.629 O.D.
5	1	615-0323	Liner teflon Prince XL
5*	1	S23978-16	Liner teflon Prince XL
6	1	261-0381	Insulator cup King (includes 4 ea. "O" ring P/N 003-0012)
7	1	621-0159	Cup #8 assy.
7*	1	S23978-12	Cup #8 assy.
8	1	621-0162	Contact tip 0.060
8*	1	S23978-10	Contact tip 0.060
9	1	002-0574	Brazed barrel straight 7.00
10	1	621-0101	Cup adaptor with insulator
10*	1	S23978-13	Cup adaptor with insulator
11	1	449-0193	Gas cup nut
11*	1	S23978-14	Gas cup nut
12	1	751-0011	Round vinyl cap

*Lincoln Electric part number   tb-1973.tbl

Shielding Gases

Shielding gas may be a pure gas or a mixture of several gases. In GMAW gases are used to:

- Shield the electrode and molten metal from the atmosphere.
- Transfer heat from the electrode to the metal.
- Stabilize the arc pattern.
- Aid in controlling bead contour and penetration
- Assist in metal transfer from the electrode.
- Assist in the cleaning action of the joint and provide a wetting action.

The common shielding gases include argon, helium, carbon dioxide, and oxygen. Argon and helium are inert gases (those that are chemically inactive and will not combine with any product of the weld area). They may be used as a single gas or as part of a mixed gas. Carbon dioxide in an active gas. It may be used alone or as part of a mixed gas. Oxygen is always combined with other gases.

For the purpose of this course you will be using pure Argon for Pulse transfer on Aluminum.

Gas Supply

Your gas will be supplied by individual cylinders (pressurized bottles) using a combination regulator and flow meter system. The combination regulator/flow meter reduces the pressure from the cylinder and regulates the flow of gas to the gun. The amount of flow is indicated by reading from the top of the float ball. The flow rate should be set at 35-45 cfh (cubic feet per hour). Remember to open the cylinder valve all the way, and close the cylinder valve fully when you shut down the system.

Cylinder with flow meter

CLASSIFICATION OF ALUMINUM

Aluminum alloys are broadly classified as 1) casting and 2) wrought. Our focus will be on the wrought alloys. This group includes those alloys that are designed for mill products whose final physical forms are obtained by working the metal mechanically, rolling, forging, extruding, and drawing. These products include: sheet, plate, wire, rod, bar, tube, pipe, forgings, angles, structural channels, and rolled and extruded shapes.

It is important to understand the properties of aluminum. Compared to steel, aluminum:

- Is a better electrical conductor.
- Is a better thermal (heat) conductor.
- Cannot be magnetized.
- Has natural corrosion resistance. A hard thin oxide layer protects from further corrosion.
- Is one third the weight of steel.
- Must be handled more carefully because it scratches easily.

Aluminum body parts and panels are not marked to identify the type of alloy. The type of alloy must be identified from the body repair manual. It is important to know the type of aluminum being repaired. The alloy type affects the choice of electrode wire to be used, the strength or hardness of a part, if heat should be used as a straightening method and the safe temperature for heating.

The Aluminum association has designed a four digit index system for designing wrought aluminum and its alloys.

The first digit identifies the alloy group:

Aluminum Alloy	**Designation**
Aluminum - 99.0%	1xxx
Copper	2xxx
Manganese	3xxx
Silicon	4xxx
Magnesium	5xxx
Magnesium and Silicon	6xxx
Zinc	7xxx
Other elements	8xxx
Unused series	9xxx

Second digit indicates modification or impurities, last two digits indicate minimum aluminum percentage, i.e. 1075 is 99.75% pure aluminum.

Example: 6061 Aluminum

6 = Magnesium and Silicon is the major alloy group
0 = no modifications or significant impurities
61 = percent aluminum

MAJOR ALUMINUM ALLOYS AND THEIR APPLICATIONS

Alloy Series	Description of Major Alloying Element	Typical Alloys	Typical Additions
1xxx	**99.00% Minimum**	**1350**	**Electrical conductor**
	Aluminum	1060	Chemical equipment, tank cars
		1100	Sheet metal work, cooking utensils, decorative
2XXX	**Copper**	**(Al-Cu)**	
		2011	Screw Machine parts
		2219	Structural, high temperature
		(Al-Cu-g)	
		2014	Aircraft structures and engines, truck frames and wheels
		2024	
		2618	
3XXX	**Manganese**	**3003**	**Sheet metal work, chemical**
		3004	Equipment, storage tanks
4XXX	**Silicon**	**4032**	**Pistons**
		4043	Welding electrode
		4343	Brazing Alloy
5XXX	**Magnesium**	**5005**	**Decorative, architectural**
		5050	Anodized automotive-trim
		5052	Sheet metal work, appliances
		5657	
		(>3%Mg)	
		5083	Marine, welded structures
		5086	Storage tanks, pressure
		5454	Vessels, armor plate
		5456	Cryogenics
6XXX	**Magnesium and Silicon**	**6061**	**Marine, truck frames**
		6063	Bodies, structures, architectural, furniture
7XXX	**Zinc**	**(Al-Zn-Mg)**	
		7004	Structural, cryogenics, missiles
		7005	(Al-An-Mg-Cu)
		7001	High strength structural
		7075	Aircraft
		7178	

ALUMINUM ALLOYS

A temper designation system is used to indicate the condition of a product. It is based on the sequence of basic treatments used to produce the desired mechanical properties. This designation follows the alloy designation. Subsequent divisions of the basic letter tempers are indicated by one or more digits following the letter. These digits designate a specific sequence of basic treatments.

BASIC TEMPER DESIGNATIONS FOR ALUMINUM ALLOYS

F	As-Fabricated
O	Annealed
H1	Strain hardened only
H2	Strain hardened and partially annealed
H3	Strain hardened and thermally stabilized
W	Solution heat-treated
T1	Cooled from an elevated temperature shaping process and naturally aged
T2	Cooled from an elevated temperature shaping process, cold worked and naturally aged
T3	*Solution heat-treated, cold worked, and naturally aged
T4	Solution heat-treated and naturally aged
T5	Cooled from an elevated temperature shaping process and then artificially aged
T6	Solution heat-treated and then artificially aged
T7	Solution heat-treated and stabilized
T8	Solution heat-treated, cold worked, and then artificially aged
T9	Solution heat-treated, artificially aged, and then cold worked
T10	Cooled from an elevated temperature shaping process, cold worked, and then artificially aged

*Achieved by heating to and holding at a suitable temperature long enough to allow constituents to enter into solid solution and then cooling rapidly to hold the constituents in solution.

Nonheat-Treatable Alloys

The initial strengths of the nonheat-treatable alloys depend primarily upon the hardening effect of alloying elements such as silicon, iron, manganese, and magnesium. These elements increase the strength of aluminum by formation of dispersed phases in the metal matrix or by solid solution. The nonheat-treatable alloys are mainly found in the 1XXX, 3XXX, 4XXX and 5XXX series depending upon their major elements. Iron and silicon are the major impurities in commercially pure aluminum, but they do contribute to its strength. Magnesium is the most effective solution-strengthening addition. Aluminum magnesium alloys of the 5XXX series have relatively high strength in the annealed condition. All of the nonheat-treatable alloys are work harden able.

The nonheat-treatable alloys may be annealed by heating to an elevated temperature to remove the efforts of cold working and improve ductility. The proper annealing schedule to use will depend upon the alloy and its temper. When welding the nonheat-treatable alloys, the heat affected zone may lose the strengthening effects of cold working. Thus, the strength in this zone may decrease to near that of annealed metal.

Heat-Treatable Alloys

The heat-treatable alloys are found in the 4XXX, 6XXX and 7XXX series. The strength of any of these alloys depends only upon the alloy composition, in the annealed condition as do the nonheat-treatable alloys. However, copper, magnesium, zinc, and silicon, either singly or in various combinations, show a marked increase in solid solubility in aluminum with increasing temperature. Therefore, these alloys can be strengthened by appropriate thermal treatments.

Heat-treatable aluminum alloys develop their improved strength by solution heat treating followed by either natural or artificial aging. Cold working before or after aging may provide additional strength. Heat-treated alloys may be annealed to provide maximum ductility with a sacrifice in strength properties. Annealing is achieved by heating the component at an elevated temperature for a specified time, and then cooling it at a controlled rate.

During welding, the heat-affected zone will be exposed to sufficiently high temperatures to overage heat-treated metal. As a result this zone will be softened to some extent.

Reprinted from American Welding Society Welding Handbook, Seventh Edition, Volume 4, Metals and Their Weldability.

Aluminum Filler Metal

Selection of a compatible filler wire is an important step in successful Aluminum welding. The filler metal composition must be compatible with the composition of the base material or cracking will result. Filler for aluminum is classified in the same way as wrought aluminum alloys.

A relatively small number of filler alloys can be used to weld a wide range of aluminum alloys. Certain filler alloys, 5356 or 5183 for example, can be used for practically all aluminum welding.

The electrode wire commonly used for collision repair includes alloys in the 4000 series, usually 4043 electrode wire, 4043 is softer than 5356 electrode wire, 5000 series usually 5356 electrode wire. Matching the wire to the base material helps insure good weld quality. Consult the vehicle maker's body repair manual for the type of electrode wire to use

The chart below lists filler selection based on base material. Those listed under the "strength" group produced stronger and harder weld composite. The group "elongation" produce softer, more ductile welds.

Recommended filler for various Aluminum Alloys

	Recommended Filler Metal	
Base Metal	**For Maximum As-Welded Strength**	**For Maximum Elongation**
EC 1100	1100 1100,4043	EC, 1260 1100, 4043
2219	2319	(2)
3003	5183, 5356	1100, 4043
3004	5554, 5356	5183, 4043
5005	5183, 4043, 5356	5183, 4043
5050	5356	5183, 4043
5052	5356, 5183	5183, 4043, 5356
5083	5183, 5356	5183, 5356
5086	5183, 5356	5183, 5356
5154	5356, 5183	5183, 5356, 5654
5357	5554, 5356	5356
5454	5356, 5554	5554, 5356
5456	5556	5183, 5356
6061	4043, 5183	53563
6063	4043, 5183	53563
7005	5039	5183, 5356
7039	5039	5183, 5356

Notes:

1. Recommendations are for plate of "0" temper.
2. Ductility of weldments of these base metals is not appreciably affected by filler metal. Elongation of these base metals is generally lower than that of other alloys listed.

3. For welded joints in 6061 and 6063 requiring maximum electrical conductivity, use 4043 filler metal. However, if both strength and conductivity are required, use 5356 filler metal and increase the weld reinforcement to compensate for the lover conductivity of 5356.

GMAW Welding Variables

"Essential Variables" is a term used in the welding codes to identify the critical components of a welding application that if changed would require re-qualification. The essential variables for GMAW are:

- Current (DCRP)
- Wire type and size
- Voltage setting
- Amperage (Wire feed speed)
- Shielding gas selection

A change in any of these variables is going to effect a change in the resulting weld. Note that some of the essentials variables are decisions made when setting up to weld. In trouble shooting weld problems most can be traced back to one or more of these essential variables. It is imperative that the welder understands the effect of each of these variables on the weld.

Current Type

The type of current used in GMAW is Direct Current Reverse Polarity. This means the electrode (Gun) is connected to the positive poll and the work or "ground" is negative. Using the wrong polarity can result is such defects as under bead cracking, porosity and excessive spatter.

Wire Type and Size

The type of wire is usually determined by matching the properties and composition of the base material. The choice of diameter of wire is based on mode of metal transfer desired, thickness of base material and position the welding is to be done in.

Voltage

Think of voltage as the source of heat in GMAW. Voltage wets the base metal. High voltage will give a long arc length. Low voltage will give a tight arc length and the weld bead is narrow. Voltage is also one of the factors that determine the mode of metal transfer. Trial runs are necessary to adjust the arc voltage if it is to produce the most favorable filler metal transfer and weld bead appearance. These trial runs are essential because arc voltage is dependent upon a variety of factors, including metal thickness, the type of joint, position of welding, electrode size, shielding gas composition, and the type of weld. From any specific value of arc voltage, a voltage increase tends to flatten the weld bead and increase the fusion zone width. Reduction in voltage results in a narrower weld bead with a high crown. Excessively high voltage may cause porosity, spatter and undercutting; excessively low voltage may cause porosity, cold lap and lack of fusion.

Amperage (Wire Feed Speed – WFS)

The wire feed speed is measured in inches per minute and controls the welding amperage in GMAW. In adjusting the GMAW equipment there must be a balance between the wire feed speed and the arc voltage. Think of wire feed speed as the amount of filler metal you are feeding to a given amount of heat (voltage) to consume the filler. If the wire feed speed is to slow the result will be a longer arc in extreme cases the wire may melt to the contact tip (burn back). If the wire speed is to fast for the amount of voltage the result will be a high crowned bead with a lot of spatter and little fusion.

Shielding Gas

When molten, most metals combine with the basic elements in air, oxygen, and nitrogen to form metal oxides and nitrides contamination of the weld metal can result in low strength, low ductility and excessive weld defects such as porosity and lack of fusion.

The primary purpose of the shielding gas in GMAW is to protect the molten weld metal from contamination and damage by the surrounding atmosphere. However, several other factors affect the choice of a shielding gas some of these factors are as follows:

- Arc and metal transfer characteristics during welding
- Penetration, width of fusion, and shape of reinforcement
- Speed-of welding
- Undercutting tendency

All of the above factors influence the finished weld and the overall result. Cost must also be considered.

Argon and helium, (used most frequently for GMAW of nonferrous metals) are completely inert. The selection of one or the other, or mixtures of the two in various combinations, can be made so that the desirable metal transfer, penetration bead geometry, and other weld characteristics can be obtained.

Although the pure inert gases protect the weld metal from reaction with air, they are not suitable for all welding applications. By mixing controlled quantities of reactive gases with them, a stable arc and substantially spatter-free metal transfer are obtained simultaneously. Reactive gases and mixtures of such gases provide other types of arcs and metal transfer. Only a few reactive gases have been successfully used either alone or in combination with inert gases for welding. These reactive gases include oxygen, nitrogen and carbon dioxide. Although hydrogen and nitrogen have been considered as additives to control the amount of the joint penetration they are recommended only for a limited number of highly specialized applications where their presence will not cause porosity or embrittlement of the weld metal.

Shielding Gas Selection

The choice of a shielding gas depends on the metal to be welded, section thickness process variation, quality requirements metallurgical factors, and cost. Argon, helium and argon-helium mixtures are generally used with nonferrous metals. Argon-oxygen, argon-carbon dioxide, argon-helium mixtures, and also pure carbon dioxide are employed for ferrous metals. The application needs, therefore, determine shielding gas selection.

Non-Essential Variables

These are variables that can be change at the discretion of the welder and do not require re-qualification. Examples of these variables are:

- Travel Speed
- Electrode extension (Stick Out)
- Electrode angle (Work and Travel)

Travel Speed

Travel speed is the linear rate at which the arc is moved along the weld joint. Travel speed effects bead width and level of penetration. The penetration will decrease when the travel speed is increased, and the weld bead will become narrower. To slow of travel may result in excessive penetration and melt through. To large of a bead in the horizontal position can result in roll over and cold lap. To fast of travel speed can result in under cutting and lack of fusion.

Electrode Extension (Stick Out)

The electrode extension is the distance between the last point of electrical contact, usually the end of the contact tube, and the end of the electrode. There is a need to control electrode extension, because the extension affects shielding gas and penetration. Penetration increases when stick out is decreased. Penetration decreases when stick out is increased. A good electrode extension for pulse welding of aluminum is 3/8" to 5/8".

Electrode Angle (Work and Travel)

As with all arc welding processes, the position of the welding electrode with respect to the weld joint affects the weld bead shape and penetration. Electrode position is described by the relationships of the electrode axis with respect to (1) the direction of travel,(travel angle), and (2) the angle between the axis and the adjacent work surface (work angle). When the electrode points opposite from the direction of travel. It is called the backhand welding technique. When the electrode points in the direction of travel, is called the forehand welding technique. **The forehand or sometimes called "lead angle" or "push" technique is always the choice when welding Aluminum**. When the electrode is changed from the perpendicular to the forehand technique with all other conditions unchanged, the penetration decreases and the weld bead becomes wider and flatter. When producing fillet welds in the horizontal position, the electrode should be positioned about 45 degrees to the vertical member (work angle). For all positions, the electrode travel angle normally used is in the range of 5 to 15 degrees for good control of the molten weld pool.

GMAW Pulse Welding

Pulsed current transfer is a GMAW process variation capable of all-position welding at a higher energy level than with the short-circuiting transfer. In this variation, the power source provides two current levels: a steady “background” level, too low in magnitude to produce any transfer; and a “pulsed peak current, superimposed upon the background current at a regulated interval. The combination of the two currents produces a steady arc (background current) with a controlled transfer of weld metal in the spray mode (pulsed peak current)

Terms and Definitions for Pulse Welding

Waveform Control

Waveform Control Technology is a term that is used in conjunction with Lincoln Electric high-tech welding equipment, indicating total control of the arc. The term refers to infinite variability with respect to adjusting amperage and voltage over the output range of the machine. It is most commonly used for the pulse welding application. Most materials that are weldable have different types of reactions to changes in amperage and voltage. For example, some materials that are exposed to rapid or drastic increases in amperage take longer to respond (liquefy), than other materials exposed to the same types of amperage increases (steel vs. aluminum). Waveform control technology allows a custom wave, specifically designed for a particular material with a given wire diameter and type of shielding gas, to be used in order to achieve optimal welding performance for each given material. These variables are all separate and distinct, and they will all change as wire feed speed is adjusted. The design of a wave is relatively complicated, but this approach is simple because Lincoln does the design for you.

Arc Control

This setting ranges from +10 to –10 with the average setting being “off” or 0. For pulse welding, arc control adjusts frequency and background current. As the arc control is increased, the frequency increases while the background decreases, and vice versa as the arc control is decreased. The controls have similar effects on the metal transfer, and resulting weld bead, whether you are in constant voltage or pulsing mode. Increasing this setting leads to a slightly colder or harsher arc, while decreasing softens up the transfer.

Science On Aluminum

The Welding Fabrication Industry needs qualified welder fabricators who can deal with a variety of situations on the job. This portion of the training packet explores science as it relates to industry requirements.

Purpose of Pulsing with GMAW

There are many advantages of pulsing current during GMAW. Perhaps the most important advantage is that out-of-position welding can be performed as a direct result of pulsed GMAW with a spray transfer. Pulsing provides high energy density spray arc during a pulse while maintaining a low overall heat input. Because of this high energy density arc at low heat input, out-of-position welding and thick-to-thin sections welding can be performed much more successfully than with conventional GMAW.

Historically, out-of-position welding using either globular transfer or spray transfer was not practical with conventional GMAW. So, GMAW had to be used in the short circuit arc welding mode to provide a low heat input arc to weld out-of-position. The problem with short arc was that the arc action, such as frequency of short circuit transfer, was too inconsistent and too dependent on welder preferences for most applications. Furthermore, the re-ignition of the arc during the short circuit cycle produced substantial spatter, since the mode of metal transfer was globular. In fact, many modern welding codes such as MIL-STD-278 completely prohibit short circuit arc welding for ships and military structures. Short arc has been completely replaced in the military and many civilian codes with electronically controlled pulsed GMAW. Pulsing provides spatter-free spray transfer for out-of-position welding.

Gas Shielding for Pulsed GMAW

Although gas metal arc welding of steel is performed routinely, it is a very complicated process involving gas-metal reactions affecting the resulting mode of metal transfer and weld quality. The gases commonly used for GMAW include:

- argon (Ar) - Inert
- helium (He) - Inert
- Oxygen (O) - Chemically Active
- carbon dioxide (CO_2)- Chemically Active

As shown above, Ar and He are totally inert because their outer shell of electrons is “full”. Chemical reactions between gases and weld metal can only take place if the gas is active like O_2 because these gases have partially filled outer shells containing “valence electrons” that can bond with other materials. For example, oxygen has an unfilled outer electron shell containing valence electrons, which combine with the valence electrons of the molten iron to form iron oxide. Similarly, CO_2 is an active gas because it dissociates under the arc to CO and O. Such reactions can not happen with Ar or He. Thus, Ar and He provide excellent protection of the molten weld pool because no chemical reaction can occur between Ar, He and molten metal. The shielding gas composition greatly affects the burn-off rate, type of metal transfer (short circuit, globular, or spray), and penetration.

When to Use Ar-He vs. Ar-CO_2 vs. Ar-O_2 Pulsed Spray Arc GMAW

The only gases that can be used to weld reactive metals (like aluminum, magnesium, and others) are either pure Ar or Ar-He mixtures. Since both Ar and He are inert, the reactive metals will not be contaminated during welding. Also, aluminum and magnesium have such thick refractory oxide layers that neither Ar-CO_2 nor Ar-O_2 mixtures are needed to achieve arc stability when welding these metals. In fact, the presence of CO_2 or O_2 would substantially oxidize and deteriorate the weld metal by impairing its mechanical properties. Thus, only pure Ar or Ar-He mixtures can be used to weld aluminum and magnesium. For thin sections, pure Ar is adequate. When high heat input welds are deposited on thick-section aluminum or aluminum alloys, a mixture of Ar and He is needed.

Pulsed GMAW of Steel vs. Aluminum

Because has much higher thermal, electrical conductivity, low melting point, greater chemical reactivity, less solid solubility of hydrogen than steel, conventional GMAW of aluminum is much more difficult-to-control than welding steel. When similar welds are deposited on aluminum and steel, the aluminum weld metal is more susceptible to porosity and more sensitive to changes in welding parameters. For example, in comparing similar welds of aluminum and steel, the aluminum weld is over 10 times more sensitive to changes in wire feed rate than is steel. Unlike steel, small changes in wire feed rate causes a substantial change in arc length. In addition, because aluminum is so much more electrically conductive than steel, the use of "stick out" to control arc characteristics such as deposition rate are not as effective as that for steel.

Pulsed GMAW provides many advantages for both steel and aluminum welding. Although pulsing provides out-of-position capability with spray transfer for both aluminum and steel welding, pulsing is particularly beneficial for aluminum welding. The high energy density during a pulse helps to overcome the heat-draining effect cause by the high thermal diffusivity of the aluminum.

The thermal diffusivity is defined as: Thermal diffusivity = thermal conductivity / (density x specific heat).
The thermal diffusivity of aluminum alloys is about 10 times higher than aluminum, because aluminum alloys have both high thermal conductivity and low density. The thermal diffusivity of aluminum is 0.85 cm^2/s while that for steel is only 0.09 cm^2/s. Combined with aluminum's low melting point of only 660º C (melting temperature of iron is 1539º C. This property of aluminum limits the conventional welding. Because molten aluminum readily dissolves hydrogen during welding and then rejects all of it during solidification, aluminum welds are extremely sensitive to porosity. Workmanship for welding aluminum must include extreme cleanliness in both the wire and work piece. Any source of hydrogen (moisture, oil, grease, paint, etc) is immediately converted to porosity. Steel welds are much less sensitive to porosity.

GMAW Work Sheet

Name: ________________________________ Date: __________________

1. What are the four main components of a GMAW system?

2. What welding current is used for GMAW?

3. How do you confirm that the system is set up for the type of current you need?

4. List the modes of metal transfer available in GMAW.

5. List two primary factors that determine your choice of shielding gas.

6. What is the required travel angle for welding Aluminum with GMAW?

7. List three advantages of the GMAW process.

8. List three disadvantages of the GMAW process.

9. Using the select knob what “mode” do you choose for the pulse aluminum exercises?

10. What two types of aluminum fillers can be used for practically all aluminum welding?

11. List four essential variables of GMAW.

12. Identify the type of current required for GMAW and explain the electrode and work connections.

13. Describe the affect of voltage on arc length.

14. What is the affect of slow and fast wire feed speed?

15. Describe the affects of travel speed.

16. Define the terms “backhand” and “forehand” welding techniques.

17. Define the term “work angle.

18. List four problems that may occur when the molten metal combines with the basic elements in air.

19. In pulse welding what does the adjustment “arc control” do?

20. What type of shielding gas is used for GMAW of Aluminum?

Aluminum Welding Projects

Aluminum GMAW-Pulse ----- Skill Development Projects

Flat position	**Horizontal position**	**Vertical position**	**Overhead position**
	T-Joint	T-Joint	T-Joint
	Lap Joint	Lap Joint	Lap Joint

Aluminum GMAW-Pulse ---- I-Car Testing Projects

Flat position	**Horizontal position**	**Vertical position**	**Overhead position**
Butt Joint	Lap Joint	Lap Joint	Lap Joint
Plug Weld	Plug Weld	Plug Weld	Plug Weld

Welding Technology Equipment Supported by The Lincoln Electric Company

NOTE: Before you begin welding practice you must complete your reading and video viewing assignments, including complete study of this training packet. All students must also complete the welding orientation and Safety Test before working in the welding lab. See your instructor for assistance.

Preparation for Welding Project Practice

1. Inspect your personal protective equipment and your work area for any potential safety hazards.

2. Review the following welding procedure and confirm equipment settings and connections comply with the recommendations.

3. Wire brush all Aluminum coupons to remove surface oxides prior to welding. Prepare enough material for at least three assemblies of each welding project. One for demonstration by instructor, one for practice and one for final project and destructive testing. Practice should be repeated as needed to perfect your technique.

4. Adjust your equipment and "warm up" using scrap from the Aluminum scrap bin.

Information Sheet Aluminum Pulse Spray Arc Welding using the V350 Pro Welder

The Pulse spray arc on Aluminum of this packet will require the "welder" to follow the following welding procedure.

Program mode	*Pulse Mig Al. .035" 4043, 4X Pulse on Pulse*
Arc Control	This controls the fluidity of the puddle. Recommended setting +7.2
Current DCRP (Direct Current Reverse Polarity), Electrode Positive, Work Negative	
Volts	read off power source meter - SPd
Amps	read off power source amp meter. 260 to 280 recommended
WFS	WFS – The wire feed speed adjustor knob will rotate 3 3/4 revolutions. Due to this, you will need to calculate a six second wire length into inches per minute (IPM) by multiplying the 6 second length by 10 seconds to determine the IPM. 260 to 290 IPM recommended
Shielding Gas	100% Argon flow rate of 35 to 45 cfh
Stick out **Electrode** **Travel Angle** **Travel Speed**	Recommended 3/8 inch .035 diameter ER4043 Push angle of 5 to 15 degrees recommended. Travel at a rate that results in bead width as specified by I-CAR visual inspection criteria.

GMAW Pulse Aluminum Transfer T Joint (2F) Project #1

Technique

Use a slight step technique and push gun progression.

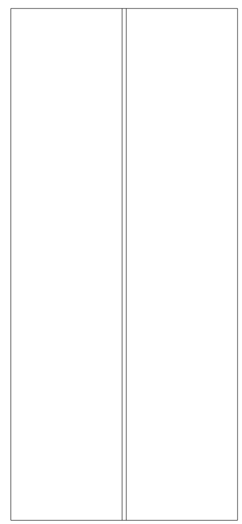
Welding Sequence

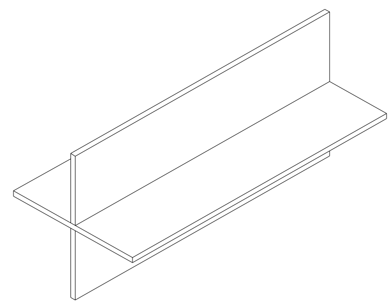
VT Criteria	Student Assessment	Instructor Assessment
Reinforcement (0" –1/8")		
Undercut (1/32")		
Weld Bead Contour		
Penetration		
Cracks (none)		
Arc Strikes (none)		
Fusion (complete)		
Porosity (none)		
		Grade Date

WLD 132

GMAW Pulse, Aluminum

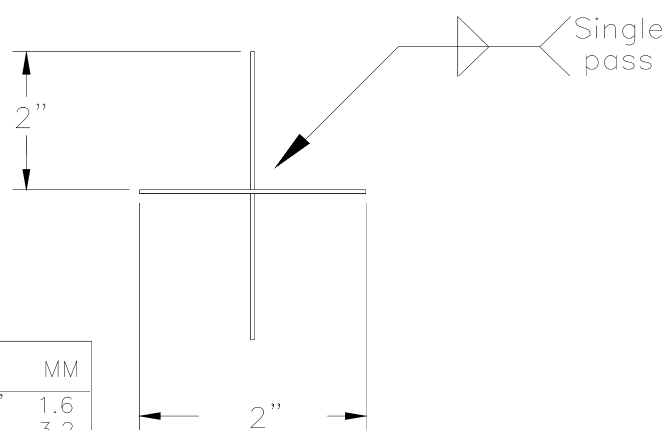
Horizontal Position T-Joint (2F)

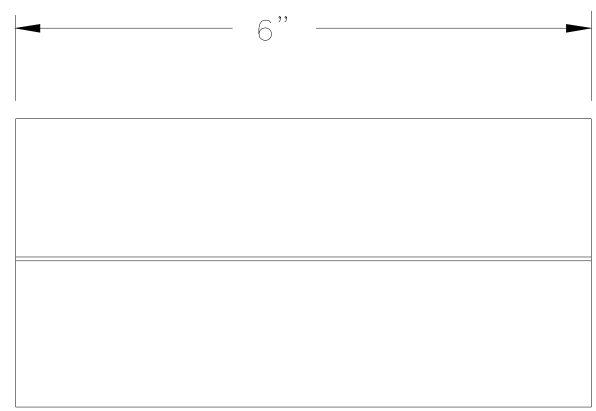




Welding Procedure

1. Volts	SPd
2. Amps	260-280
3. WFS (Actual)	260-290 IPM
4. Polarity	DCRP
5. Gas	Argon
6. Gas Flow	45 cfh
7. Welding Position	Horizontal (2F)
8. Material Thickness	10 gauge
9. Stick Out	3/8"
10. Electrode Diameter	.035"
11. Electrode	4043
12. V350Pro Program	Pulse Mig Al. .035" 4043
13. Arc control	+7.2





Inch	MM
1/16"	1.6
1/8"	3.2
1/4"	6.4
1/2"	12.7
1"	25.4

Part	No. Required	Size (TxWxL)	S.I. Conversion

Portland Community College Welding Technology			
Tolerance (Unless otherwise Specified) Dimensional ± 1/16" Angle ± 5°	WLD 132-09		
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: TANNER SCOTT Date: 8/13/08	Approve Date		Sheet

GMAW Pulse Aluminum Transfer Lap Joint (2F) Project #2

Technique
Use a slight step technique and push gun progression.

Welding Sequence

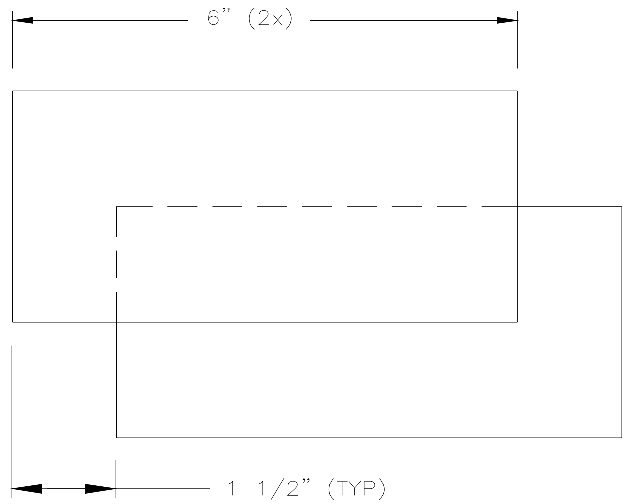
VT Criteria	Student Assessment	Instructor Assessment
Reinforcement (0" –1/8")		
Undercut (1/32")		
Weld Bead Contour		
Penetration		
Cracks (none)		
Arc Strikes (none)		
Fusion (complete)		
Porosity (none)		
		Grade Date

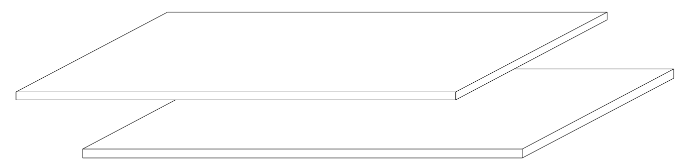
WLD 132

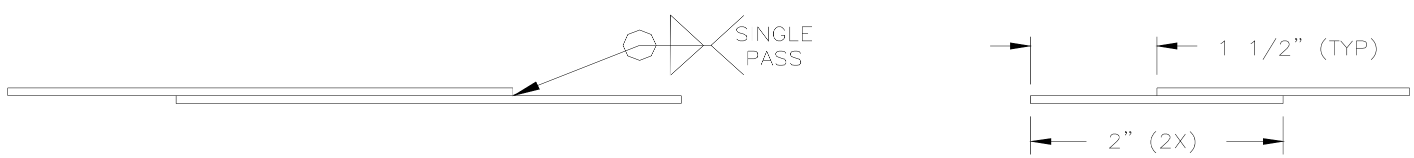
GMAW–Pulse Aluminum
Horizontal Position (2F)
Lap Joint

Welding Procedure

1. Volts — SPd
2. Amps — 260–280
3. WFS (actual) — 260–290 IPM
4. Polarity — DCRP
5. Gas — Argon
6. Gas Flow — 45 cfh
7. Welding Position — Horizontal (2F)
8. Material Thickness — 10 gauge
9. Stick Out — 3/8"
10. Electrode Diameter — .035"
11. Electrode — 4043
12. 350Pro Program — Pulse Mig Al. .035" 4043
13. Arc Control — +7.2







Inch	MM
1/16"	1.6
1/8"	3.2
1/4"	6.4
1/2"	12.7
1"	25.4

Part	No. Required	Size (TxWxL)	S.I. Conversion

Portland Community College
Welding Technology

Tolerance (Unless otherwise Specified) Dimensional ± 1/16" Angle ± 5°	WLD 132–10		
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Chk By: TANNER SCOTT Date: 8/13/08	Approve	Date	Sheet

GMAW Pulse Aluminum Transfer T Joint (3F) Project #3

Technique

Use a slight step technique and push gun progression.

Welding Sequence

VT Criteria	Student Assessment	Instructor Assessment
Reinforcement (0" –1/8")		
Undercut (1/32")		
Weld Bead Contour		
Penetration		
Cracks (none)		
Arc Strikes (none)		
Fusion (complete)		
Porosity (none)		
		Grade Date

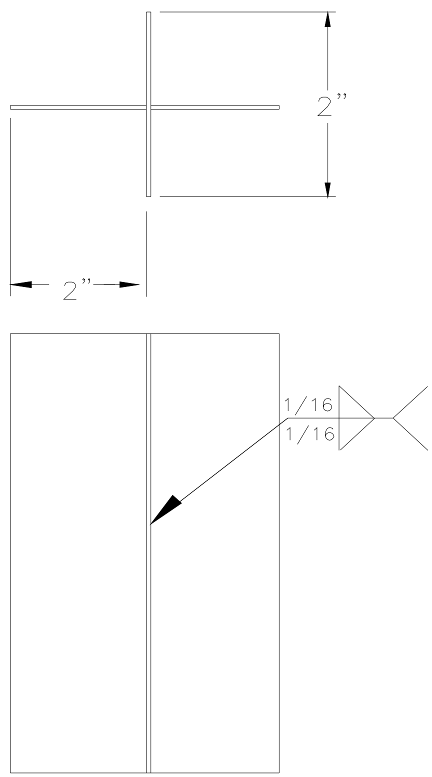
WLD 132

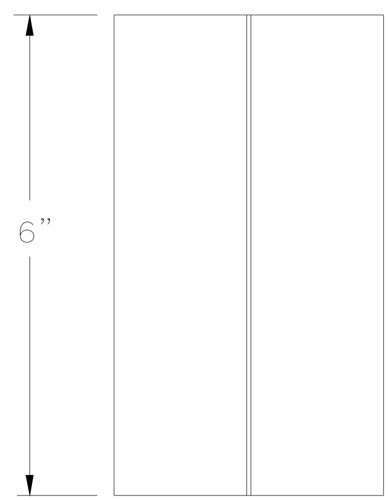
GMAW-Pulse Aluminum

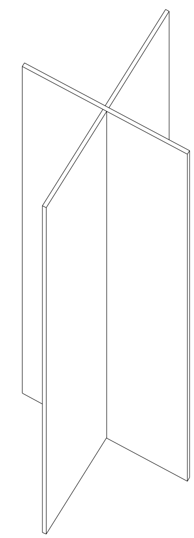
Vertical Position T-Joint (3F)

Welding Procedure

1. Volts —— SPd
2. Amps —— 260-280
3. WFS (Actual) —— 260-290 IPM
4. Polarity —— DCRP
5. Gas —— Argon
6. Gas Flow —— 45 cfh
7. Welding Position —— Vertical (3F)
8. Mater Thickness —— 10 gauge
9. Electrode Diameter —— .035"
10. Electrode —— 4043
11. V350Pro Program —— Pulse Mig Al. .035" 4043
12. Arc Control —— +7.2







Inch	MM
1/16"	1.6
1/8"	3.2
1/4"	6.4
1/2"	12.7
1"	25.4

Part	No. Required	Size (TxWxL)	S.I. Conversion

Portland Community College

Welding Technology

Tolerance (Unless otherwise Specified) Dimensional ± 1/16" Angle ± 5°	WLD 132-11
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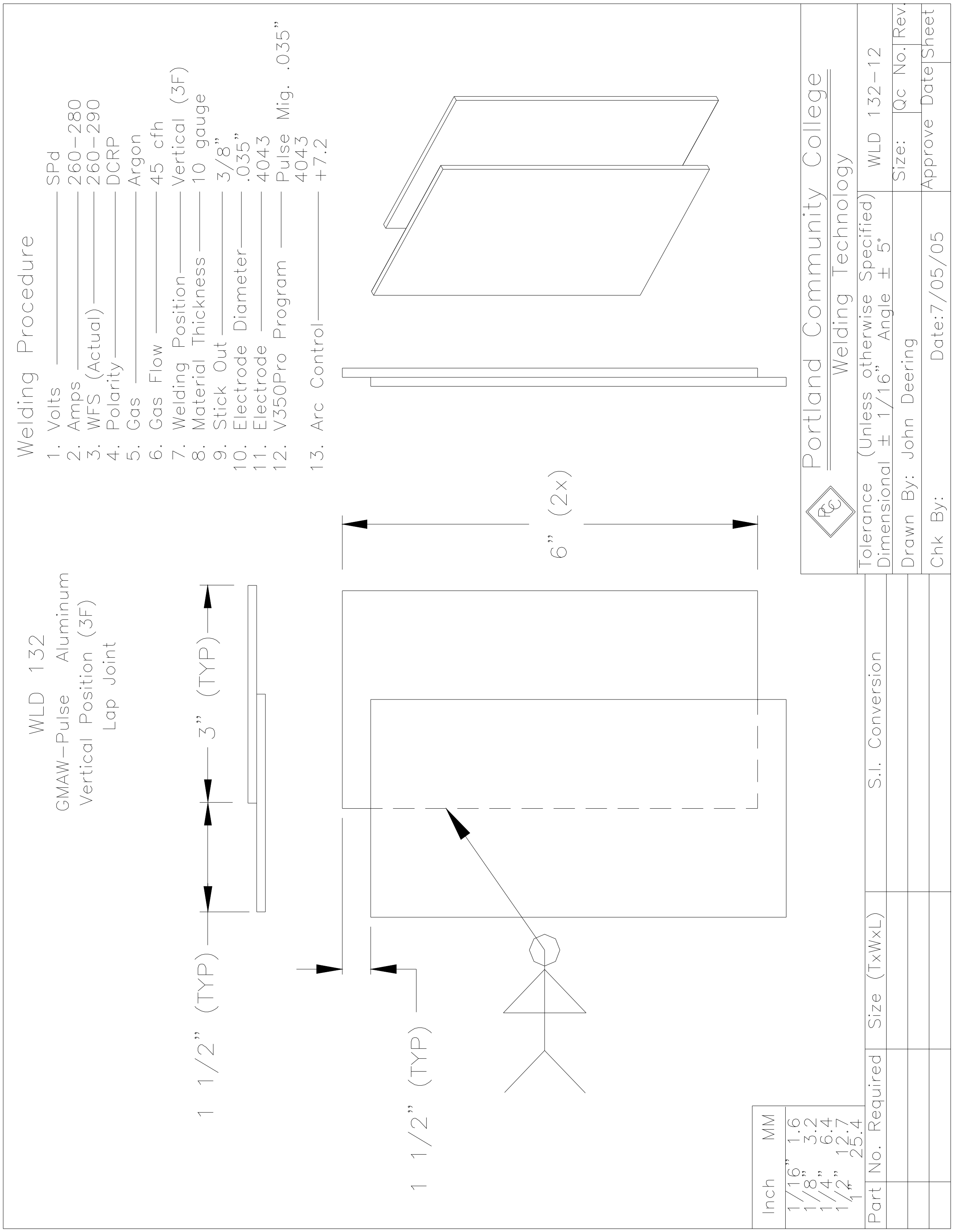
Chk By: TANNER SCOTT Date: 8/13/08	Approve / Date / Sheet

GMAW Pulse Aluminum Transfer Lap Joint (3F) Project #4

Technique
Use a slight step technique and push gun progression.

Welding Sequence

VT Criteria	Student Assessment	Instructor Assessment
Reinforcement (0" –1/8")		
Undercut (1/32")		
Weld Bead Contour		
Penetration		
Cracks (none)		
Arc Strikes (none)		
Fusion (complete)		
Porosity (none)		
		Grade Date


WLD 132
GMAW-Pulse Aluminum
Vertical Position (3F)
Lap Joint
Welding Procedure
1. Volts — SPd
2. Amps — 260-280
3. WFS (Actual) — 260-290
4. Polarity — DCRP
5. Gas — Argon
6. Gas Flow — 45 cfh
7. Welding Position — Vertical (3F)
8. Material Thickness — 10 gauge
9. Stick Out — 3/8"
10. Electrode Diameter — .035"
11. Electrode — 4043
12. V350Pro Program — Pulse Mig. .035" 4043
13. Arc Control — +7.2
1 1/2" (TYP)
3" (TYP)
6" (2x)
1 1/2" (TYP)
Inch MM
1/16" 1.6
1/8" 3.2
1/4" 6.4
1/2" 12.7
1" 25.4
Part No. Required
Size (TxWxL)
S.I. Conversion
Portland Community College
Welding Technology
Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
Drawn By: John Deering
Chk By:
Date:7/05/05
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Size:
Qc No.
Rev.
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GMAW Pulse Aluminum Transfer T Joint (4F) Project #5

Technique

Use a slight step technique and push gun progression.

Welding Sequence

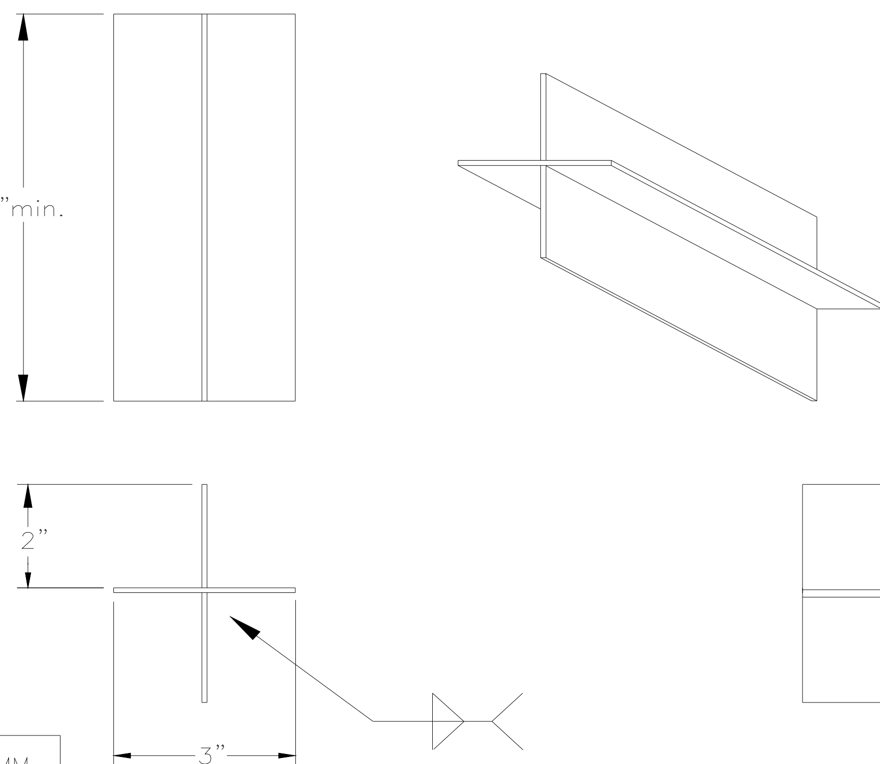
VT Criteria	Student Assessment	Instructor Assessment
Reinforcement (0" –1/8")		
Undercut (1/32")		
Weld Bead Contour		
Penetration		
Cracks (none)		
Arc Strikes (none)		
Fusion (complete)		
Porosity (none)		
		Grade Date

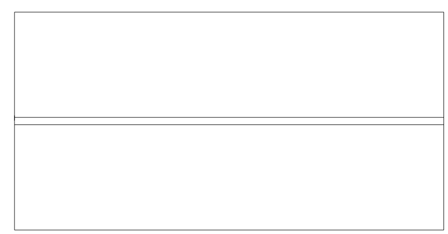
WLD 132

GMAW–Pulse Aluminum
Overhead–Position
T–Joint (4F)

Welding Procedure

1. Volts — SPd
2. Amps — 260–280
3. WFS (Actual) — 260–290
4. Polarity — DCRP
5. Gas — Argon
6. Gas Flow — 45 cfh
7. Welding Position — Overhead (4F)
8. Material Thickness — 10 gauge
9. Stick Out — 3/8”
10. Electrode Diameter — .035”
11. Electrode — 4043
12. V350Pro Program — Pulse Mig. Al. .035” 4043
13. Arc Control — +7.2





Inch	MM
1/16”	1.6
1/8”	3.2
1/4”	6.4
1/2”	12.7
1”	25.4

Part	No. Required	Size (TxWxL)	S.I. Conversion

Portland Community College
Welding Technology

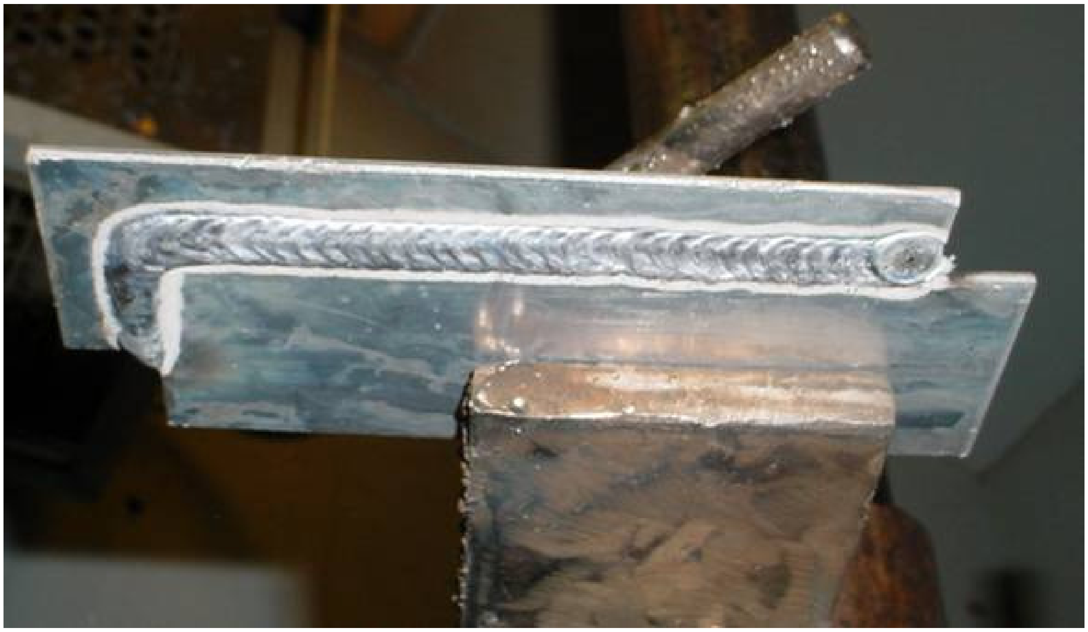
Tolerance (Unless otherwise Specified) Dimensional ± 1/16” Angle ± 5°	WLD 132–13		
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: Date: 7/05/05	Approve	Date	Sheet

GMAW Pulse Aluminum Transfer Lap Joint (4F) Project #6

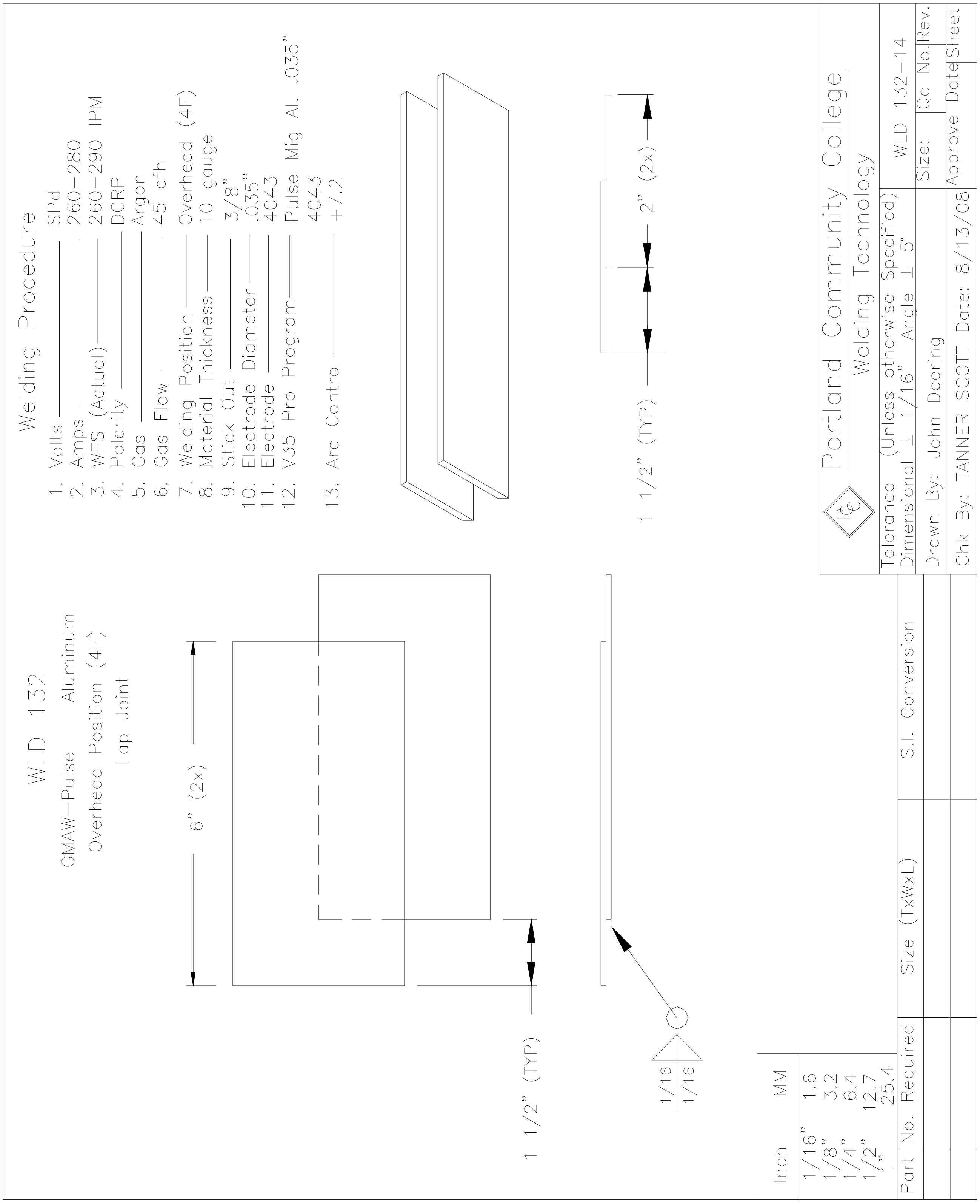
Technique

Use a slight step technique and push gun progression.

Welding Sequence



VT Criteria	Student Assessment	Instructor Assessment
Reinforcement (0" –1/8")		
Undercut (1/32")		
Weld Bead Contour		
Penetration		
Cracks (none)		
Arc Strikes (none)		
Fusion (complete)		
Porosity (none)		
		Grade Date


WLD 132
GMAW-Pulse Aluminum
Overhead Position (4F)
Lap Joint
Welding Procedure
1. Volts — SPd
2. Amps — 260-280
3. WFS (Actual) — 260-290 IPM
4. Polarity — DCRP
5. Gas — Argon
6. Gas Flow — 45 cfh
7. Welding Position — Overhead (4F)
8. Material Thickness — 10 gauge
9. Stick Out — 3/8"
10. Electrode Diameter — .035"
11. Electrode — 4043
12. V35 Pro Program — Pulse Mig Al. .035" 4043
13. Arc Control — +7.2
6" (2x)
1 1/2" (TYP)
2" (2x)
1/16
1/16
Inch MM
1/16" 1.6
1/8" 3.2
1/4" 6.4
1/2" 12.7
1" 25.4
Part No. Required
Size (TxWxL)
S.I. Conversion
Portland Community College
Welding Technology
Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
Drawn By: John Deering
Chk By: TANNER SCOTT Date: 8/13/08
WLD 132-14
Size: Qc No. Rev.
Approve Date Sheet

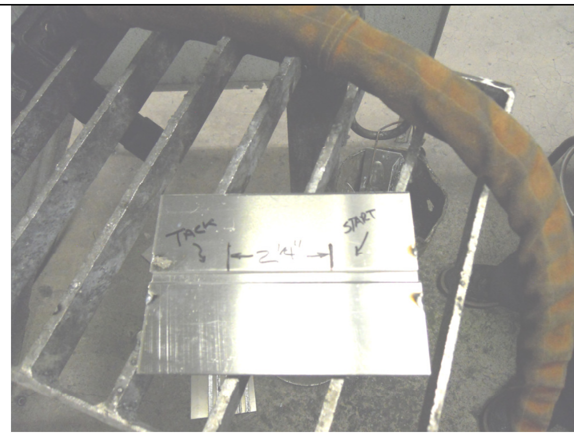
I-Car

Weld

Testing

Preparation

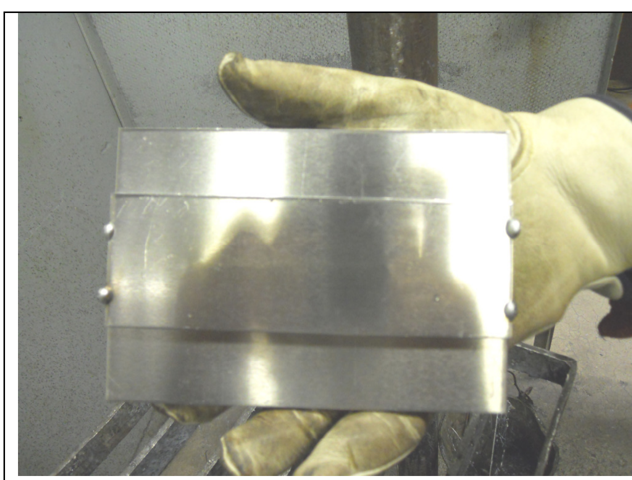
BUTT JOINT WITH BACKING WELD: VISUAL INSPECTION CRITERIA



Project assembly: Butt join 3mm (1/8”) thick to 3mm (1/8”) thick aluminum. Use 3mm(1/8”) thick backing, have a 6mm(1/4”) joint gap.

On the face of the weld:

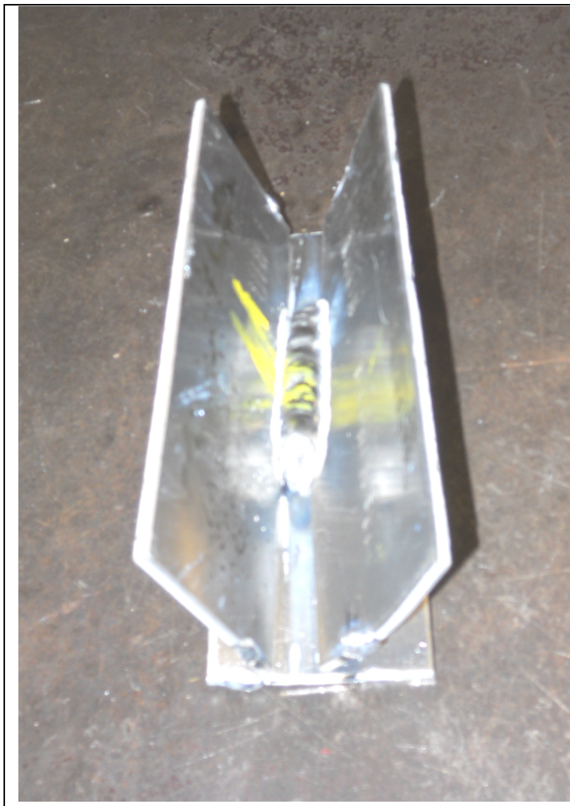
- The bead length must be at least 57mm (2 1/4”), but no longer than 76mm (3”). Use the 1.1 notches on the I-CAR welding gauge.
- The bead width must be at least 10mm (3/8”), but no wider than 16mm (5/8”). Use the 1.2 notches on the I-CAR welding gauge.
- The bead height should not be greater than 2mm (3/32”). Use notch 1.3 on the welding gauge.
- Length
- There should be no porosity larger than 1.5mm (1/16”). The total amount of porosity must not add up to more than 3mm(1/8”) for the entire weld. Use the 1.6 notch on the welding gauge.



On the back of the weld:

- There should be no cracks.
- There should be no suck back
- Melt through width must not exceed 5mm (3/16”). Use the 1.4 notch on the welding gauge.
- Melt through height must not exceed 3mm (1/8”). Use notch 1.5 on the welding gauge.
- Defects shall not exceed 1.5mm (1/16”)

BUTT JOINT DESTRUCTIVE TESTING CRITERIA



To destructively test the butt joint:

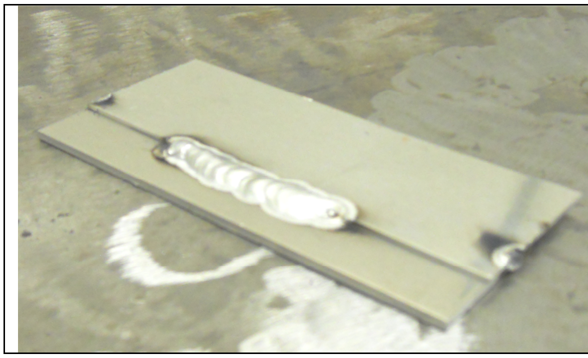
1. Clamp the weld sample in a vise so the weld bead is slightly above and parallel to the vise jaw.
2. Use a hammer to bend the upper coupon away from the backing.
3. Reverse the weld sample in the vise and break the remaining coupon from the backing.
4. Inspect the weld bead on the backing coupon. The cross section on each side of the weld must be even and equal to the cross section of the material being joined (3mm or 1/8")The weld must show root fusion. Lack of fusion appears as a dark oxide line along the base of the weld.
5. Chisel the weld bead from the backing.
6. Inspect the backing for weld penetration along the length of the weld bead. The weld must be penetrated into the backing for a minimum of 25mm (1") in length with no more than a total of 3mm (1/8") of defects within that area.

Welding Project -- Butt Joint with Backing

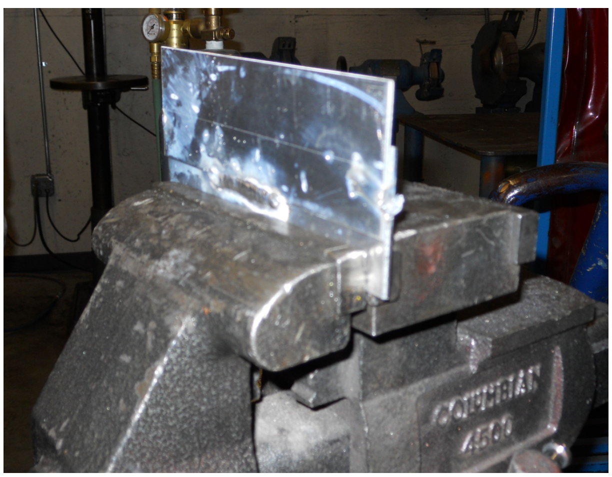
Project assembly: Butt join 3mm (1/8") thick to 3mm (1/8") thick aluminum. Use 3mm(1/8") thick backing, have a 6mm(1/4") joint gap.

Flat Position Butt Joint	*Visual Testing -*	*Destructive Test*
	Pass *Fail*	*Pass* *Fail*

Lap Joint (Fillet Weld) Test Criteria



Project assembly: Lap 1mm (3/64”) thick aluminum over 3mm (1/8”) thick aluminum

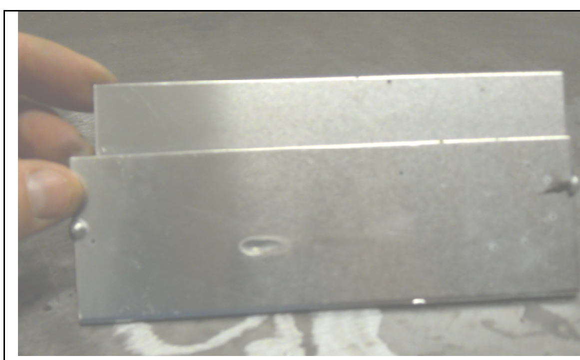


To destructively test a fillet weld:

1. Clamp the 3mm (1/8”) side of weld sample in a vise so the weld bead is above and parallel to the vise jaws.
2. Bend the upper coupon away from the backing.
3. If the face of the 1mm (3/64”) coupon can be bent to contact the face of the 3mm (1/8”) coupon without breaking, the sample passes.
4. If the joint fractures, inspect the weld bead on the 3mm (1/8”) coupon. To pass inspection, the cross section of the weld: must be even or equal to the thinnest metal being joined (1mm or 3/64”). Must show root fusion. Lack of fusion appears as a dark oxide line along the base of the weld.

On the face of the weld:

- There should be no cracks.
- The joint should be completely filled.
- There should be no undercut.
- The bead length should be at least 57mm (2 ¼") in length, but not longer than76mm (3"). Use the 2.1 notches on the welding gage.
- The bead width must be at least 5mm (3/16"), but no larger than 10mm (3/8"). Use the 2.2 notches on the welding gauge.
- The bead height should not be higher than 2mm (3/32") above the top panal. Use notch 2.3 on the welding gauge.
- There should be no porosity or voids larger than 1.5mm (1/16"). The total amount of porosity or voids must not add up to more than 3mm (1/8"0 for the entire weld. Use notch 2.6 on the welding gauge.



On the back of the weld:

- There should be no cracks.
- There should be no suck back.
- Melt through is not required. Maximum allowable melt through is a width of 5mm (3/16"). Use notch 2.4 on the welding gauge, height of 2mm (3/32"), use the 2.3 notch on the welding gauge.

Lap Joint Weld Tests

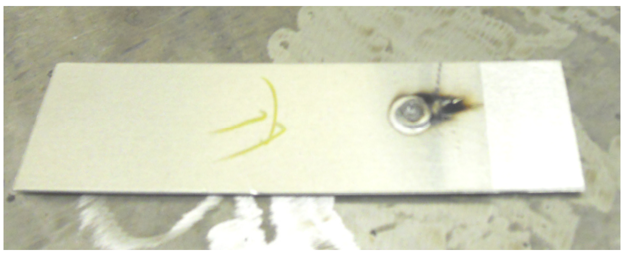
Project assembly: Lap 1mm (3/64”) thick aluminum over 3mm (1/8”) thick aluminum

Horizontal Position Lap Joint	***Visual Testing -*** ***Pass Fail***	***Destructive Test*** ***Pass Fail***
Vertical Position Lap Joint	***Visual Testing -*** ***Pass Fail***	***Destructive Test*** ***Pass Fail***
Overhead Position Lap Joint	***Visual Testing -*** ***Pass Fail***	***Destructive Test*** ***Pass Fail***

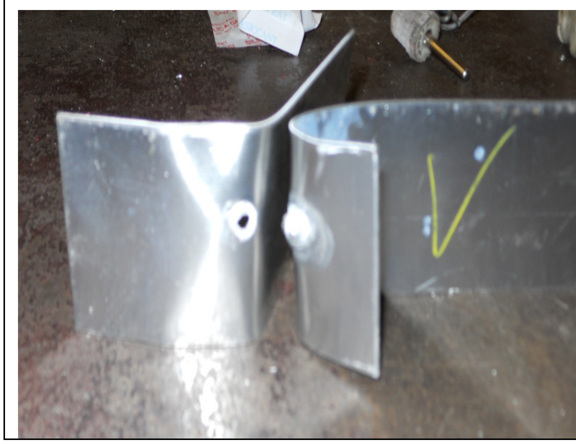
Welding Project -- Plug Welds

Project assembly: Lap 1mm (3/64") thick aluminum over 1mm (3/64") thick aluminum, use an 8mm (5/16") plug weld hole.

PLUG WELD VISUAL INSPECTION CRITERIA

	**On the back of the weld:** • There should be no cracks. • There should be no suck back. • The melt through nugget must be at least 3mm (1/8") in diameter, but not larger than 8mm (5/16"). Use the 3.3 holes on the welding gauge. • The melt through nugget must not be higher than 3mm (1/8"). Use notch 3.4 on the welding gage.

PLUG WELD DESTRUCTIVE TESTING CRITERIA



To destructively test a plug weld:

1. Spread the coupons apart 90 degrees.
2. Clamp the end of the bottom coupon vertically in a vise with the top coupon facing upwards. The weld nugget should face up.
3. Attach a pair of needle nosed vise grips on the end of the top coupon.
4. Roll the top coupon to peel it from the bottom coupon.
5. Inspect the bottom coupon for base metal tear out. The tear- out hole must be a minimum of 5mm (3/16") in diameter. Use hole 3.5 on the welding gauge.

PLUG WELD LIST

Flat Position Plug Weld	***Visual Testing -*** ***Pass Fail***	***Destructive Test*** ***Pass Fail***
Horizontal Position Plug Weld	***Visual Testing -*** ***Pass Fail***	***Destructive Test*** ***Pass Fail***
Vertical Position Plug Weld	***Visual Testing -*** ***Pass Fail***	***Destructive Test*** ***Pass Fail***
Overhead Position Plug Weld	***Visual Testing -*** ***Pass Fail***	***Destructive Test*** ***Pass Fail***

Final Exam

The written final exam is a closed book test. Complete the following test and turn the test and the Final Course Assessment form into your instructor.

Study Guide

Safety

Machine Components
- **Power Source**
- **Wire Feeder**
- **Gun and Ground Clamps**
- **Polarity**

Metal Transfer
- **Pulsed**
- **Spray**
- **Globular**
- **Short Arc**

Gases
- **Mixed gases**

Wire
- **AWS Classification System**

Pulse Vocabulary

Weld Defect Vocabulary

Final Grades - WLD 211

Name: __________________ Instructor: ____________________ Date: ______________

Welding Projects = 40%

Out of	Out of	Out of
Out of	Out of	Out of
Out of	Out of	Out of
Out of	Out of	Out of
Out of	Out of	Out of
Out of	Out of	Out of
A Total Project pts. _________ / Total pts. Possible ________ X 40 = ________ %		

Written Work = 20%

Out of	Out of	Out of
Out of	Out of	Out of
Out of	Out of	Out of
B Total Project pts. _________ / Total pts. Possible ________ X 20 = ________ %		

Safety = 15% Each day of attendance is worth 3 points earned. Any safety violation will result in 0 points for the day.

Out of	Out of	Out of	Out of	Out of	Out of
Out of	Out of	Out of	Out of	Out of	Out of
Out of	Out of	Out of	Out of	Out of	Out of
C Total pts. earned _________ / Total pts. Possible ________ X 15 = ________ %					

Employability Skills = 15% The following attributes will be assessed - attendance, attitude, time management, team work, interpersonal skills, etc.. Daily points (there are no excused absences, hence no points earned for days missed) 3 pts = present and working for the entire shift; 2 pts = late; 1 pt = late and left early; 0 pts = no show.

Out of	Out of	Out of	Out of	Out of	Out of
Out of	Out of	Out of	Out of	Out of	Out of
Out of	Out of	Out of	Out of	Out of	Out of
D Total pts. earned _________ / Total pts. Possible ________ X 15 = ________ %					

Final Exam 10%

Written Exam	Out of
E Total Project pts. _________ / Total pts. Possible ________ X 10 = ________ %	
Add Lines A + B + C + D. This will give you your Final Grade	TOTAL % __________ FINAL GRADE __________