WLD 132
Gas Metal Arc Welding
Pulse Transfer on Mild Steel and Aluminum

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Opinions expressed are those of the authors And not necessarily those of the Foundation

Course Number:
WLD 132

Course Title:
Gas Metal Arc Welding-Pulse

Credit Hours:
4

Lecture Hours:
0

Lecture/Lab Hours:
80

Lab Hours:
0

Special Fee:
$24.00

Course Description

Develops knowledge and skills using the gas metal arc welding - pulse transfer process on common mild steel and aluminum joints in all positions. Prerequisites: Department permission required. Audit available.

Addendum to Course Description

This is an outcome based course utilizing a lecture/lab format. This course includes classroom discussion, videos, theoretical concepts, lab demonstrations and technical skills. Course outcomes include; theoretical concepts, lay out, fabrication, oxy-fuel cutting, and safety.

Intended Outcomes for the course

Upon completion of the course students should be able to:

- Function safely in the PCC Welding Lab.
- Interpret blueprints to accurately lay out, prepare, and assemble weld joints.
- Understand and apply fundamentals of GMAW-pulse operations.
- Weld common joint assemblies with the GMAW-pulse to AWS D1.1 Structural Steel Welding Code visual acceptance criteria in the following joints and positions.
- Apply visual examination principles and practices in accordance with AWS D1.1.

Course Activities and Design

Welding lec/lab courses are Open Entry and Open Exit (OE/OE) and are offered concurrently. Courses are designed to meet the needs of the students with flexible scheduling options. Students may attend full time or part time. This is an OE/OE course which does not align with the normal academic calendar.

Outcome Assessment Strategies

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

Course Content (Themes, Concepts, Issues and Skills)

Function safely in the PCC Welding Lab.

- Understand and practice personal safety by using proper protective gear
- Understand and practice power tool safety
- Understand and maintain a safe work area
  - Recognize and report dangerous electrical and air/gas hose connections
  - Understand and practice fire prevention

Interpret blueprints to accurately lay out, prepare, and assemble weld joints.

- Interpret lines, symbols, views and notes
- Lay out material per specifications
- Assemble project per specifications

Understand and apply fundamentals of GMAW-P Operations.

- Describe and demonstrate equipment setup, shut down, and operation
- Identify pulse transfer characteristics
- Demonstrate proper stick out and travel speed
- Demonstrate correct starting, stopping and restarting techniques
- Demonstrate proper bead placement

Weld common joint assemblies with the GMAW-P to AWS D1.1 Structural Steel Welding Code visual acceptance criteria in the following joints and positions:

Flat Position: (mild steel)

- Bead plate

Horizontal Position: (mild steel and Aluminum)

- T-Joint
- Lap Joint

Vertical Position: (mild steel and Aluminum)

- T-Joint
- Lap Joint

Overhead Position:

- T-Joint
- Lap Joint

Apply visual and destructive examination principles and practices in accordance with AWS D1.1.

- Evaluate welds using appropriate welding inspection tools
- Assess weld discontinuities causes and corrections

INTRODUCTION TO GMAW
SPRAY AND PULSE SPRAY TRANSFERS

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.

The purpose of this course our focus will be on GMAW (spray transfer) and GMAW-P. Please refer to course WLD 131 for information on GMAW-S (Short Circuiting transfer and Surface Tension 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

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 the following gas mixtures:

- 98% Argon 2% Oxygen for Axial Spray transfer
- 90% Argon 10% Carbon Dioxide for Pulse Spray transfer
- 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

GUIDE TO AWS CLASSIFICATION OF CARBON STEEL FILLER METALS FOR GAS SHIELDED ARC WELDING

AWS Electrode Wire Classification System

The classification system follows AWS filler metal specifications. The inherent nature of the products being classified has; however, necessitate specific changes that more ably classify the product.

Example = **ER70S-6**

- "**E**" designates an electrode as in other specifications.
- "**ER**" designates a classification indicating that the bare filler metal may be used as an electrode or welding rod.
- "**70**" designates the required minimum tensile strength in multiples of 1000 psi of the weld metal in a test weld made using the electrode in accordance with specified welding conditions.
- "**S**" designates a bare, solid electrode or rod.
- **A suffix** relates to the specific chemical composition. NOTE: Welding position is determined by mode of transfer, not filler composition.

ER70S-2 Classification

This classification covers multiple deoxidized steel filler metals that contain a nominal combined total of 0.20 percent zirconium, titanium, and aluminum in addition to the silicon and manganese contents. These filler metals are capable of producing sound welds in ***semi-killed*** and ***rimmed steels*** as well as in ***killed steels*** of various carbon levels. Because of the added deoxidants these filler metals can be used for welding steels that have a rusty or dirty surface. There is a possible sacrifice of weld quality depending on the degree of surface contamination. Fillers can be used with a shielding gas of argon-oxygen mixtures, C02, or argon-C02 mixtures. These mixtures are preferred for out-of-position welding with the short circuiting type of transfer because of their ease of operation.

ER70S-3 Classification

These filler metals will meet the requirement of this specification with either C02 or argon-oxygen as a shielding gas. They are used primarily on single-pass welds, but can be used on multiple-pass welds, especially when welding killed or semi-killed steel. Small diameter electrodes can be used for out-of-position welding with argon-C02 mixtures or C02 shielding gases. However, it should be noted that the use of C02 shielding gas in connection with excessively high heat inputs may result in failure to meet the minimum specified tensile and yield strength.

ER70S-4 Classification

These filler metals contain slightly higher manganese and silicon contents than those of the ER70S-3 classification and produce a weld deposit of higher tensile strength. The primary use of these filler metals is for C02 shielded welding applications where a slightly longer arc or other conditions require more de-oxidation than provided by the ER70S-3 filler metals. These filler metals are not required to demonstrate impact properties.

ER70S-5 Classification

This classification covers filler metals that contain aluminum in addition to manganese and silicon as de-oxidizers. These filler metals can be used when welding rimmed, killed, or semi-killed steels with C02 shielding gas and high welding currents. The relatively large amount of aluminum assures the deposition of well-deoxidized and sound weld metal. Because of the aluminum, they are not used for the short circuiting type transfer, but can be used for welding steels which have a rusty or dirty surface, with a possible sacrifice of weld quality, depending on the degree of surface contamination. These filler metals are not required to demonstrate impact properties.

ER70S-6 Classification

Filler metals of this classification have the highest combination of manganese and silicon, permitting high current welding with C02 gas shielding even in rimmed steels. These filler metals may also be used to weld sheet metal where smooth weld beads are desired and steels which have moderate amounts of rust and mill scale. The quality of the weld will depend on the degree-of surface impurities. This filler metal is also usable out of position with short circuiting transfer.

ER70S-7 Classification

These filler metals have substantially greater manganese content (essentially equal to that of ER70S 6) than those of the ER70-S-3 classification. This provides slightly better wetting and weld appearance with slightly higher tensile and yield strengths and may permit increased speeds compared with ER70S-3 filler metals. These filler metals are generally recommended for use with argon-oxygen shielding gas mixtures, but they are usable with argon-C02 mixtures and C02 under the same general conditions as for the ER70S-3 classification. Under equivalent welding conditions, weld hardness will be lower than ER70S-6 weld metal but higher than ER70S-3 deposits.

ER70S-G Classification

This classification includes those solid filler metals which are not included in the preceding classes. The filler metal supplier should be consulted for the characteristics and intended use. This specification does not list specific chemical composition or impact requirements. These are subject to agreement between supplier and purchaser. However, any filler metal classified ER70S-6 must meet all other requirements of this specification.

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.

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 depend 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 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 vs. DCSP)
- 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 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, the 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. As a rule, it is not practical to use the reactive gases alone for arc shielding. Carbon dioxide is the outstanding exception. It is suitable alone or mixed with inert gas, or mixed with oxygen for welding a variety of carbon and low alloy steels. Carbon dioxide shielding is inexpensive. All the other gases except nitrogen are used chiefly as small additions to one of the inert gases (usually argon). Nitrogen has been used alone, or mixed with argon, for welding copper. The most extensive use of nitrogen however, is in Europe where little or no helium is available.

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. Resistance heating causes the electrode temperature to rise. There is a need to control electrode extension, because too long an extension results in excess weld metal being deposited with low arc heat. This will cause poor weld bead shape and shallow penetration also, as the contact tube-to-work distance increases the arc becomes less stable. Good electrode extension is ¾" for spray and pulse welding.

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. The effects are greater than those of arc travel angle. Electrode position is described by the relationships of the electrode axis with respect to (1) the direction of travel, (2) the travel angle, and (3) 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. 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 cover gas, to be used in order to achieve optimal welding performance for each given material. Each of the waves is separate and distinct, even if there are only slight changes due to differences in gas type and wire diameter. Waveform Control technology was designed so the best performing weld parameters are easy for the operator to find, and require minimal interaction with the machine to maintain optimal performance throughout the course of a working day. In a pulsing application, a wave is set through adjusting peak amperage, peak time, tailout time, tailout speed, background amperage, background time, frequency, and ramp up rate. 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. In practice, the pulsing package is now simpler and easier to control and much more versatile than any other machine. (See Appendix A-2 and A-3 for waveform examples and diagrams).

Trim

Trim is a control of total heat input. In the past, for a pulsing application, heat input was controlled through a series of adjustments. Due to the development of waveform control technology, trim is a one-knob adjustment that gives you the same control of the same variables that required three to four knobs to adjust in the past. In a constant voltage application, the operator will choose a wire feed speed and adjust the voltage until the wire is transferring smoothly, slightly above the molten pool of weld material. (See appendix A-3). This will establish a distance between the wire and the molten puddle so the wire is up above the puddle, but not so high that the filler material is spraying to the outside of the intended weld area. This is commonly referred to as arc length (see appendix A-4). A good arc length is smooth and relatively focused. In the pulse-welding mode, trim controls the exact same thing as voltage does in the constant voltage mode. Trim can be set from a minimum of 0.50 to a maximum of 1.50. As the factory develops different waves for different materials, the trim setting is automatically calibrated to 1.00 as the optimal setting across the wire feed speed range, according to the most desirable transfer that is achieved in the lab. This is a good setting to start with each time the machine is changed into a different mode. This is not as complicated as it sounds. As the operator adjusts the trim value, he or she will see the arc length get shorter or longer. To set the machine, this is all an operator needs to know.

Arc Control

This is the secondary adjustment for heat input. In constant voltage welding mode this is an inductance control and can adjust arc transfer characteristics to the operator's preference. 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.

Synergic Welding

This is a term that refers to the communication that takes place between the power source and the wire feeder. A synergic system has a direct communication channel between the wire feeder and the power source. In other words, the welding power is set directly proportional to the amount of filler material that is being fed into the weld pool. In a non-synergic system, the wire feed speed controls the tachometer for the wire drive motor. On the power source, the output controls the voltage. The operator must set both controls correctly in order to get a smooth arc transfer. In a synergic system, an increase in wire feed speed automatically increases the welding power output. Since the two settings are now working together, or synergic, the power source is aware of changes in the wire feed speed. In order to gauge this correctly, the machine must also have a very accurate voltage sensing feed back circuit. With this addition, the output characteristics of the machine also improve. Not only does the output of the machine respond to changes in wire feed speed, but since the feedback loop is so quick, the machine maintains a much more consistent power output having the ability to compensate for even small changes in the electrical stick out or operator movement. The resulting benefits to the operator are; decreases in the smoke and spatter levels, one knob wire feed speed adjustment, and a more consistent arc length and metal transfer. Due to the need for a voltage feed back loop in the power source and the wire feeder, older machines are not capable of this type of communication and can not be converted.

V 350 vs. Power Wave 455

The Power Wave system is a synergic system, and the V350 is not. However, both machines have the same capabilities in terms of utilizing waveform control technology. Although the memory storage of the power wave is much greater than the V350, new waves can be downloaded from any computer into either machine. Since the power wave is synergic, in the pulsing mode as described previously, adjusting trim controls the arc length.

Contents of this Packet are:

- **Purpose of Pulsing with GMAW**
- **Gas Shielding for Pulsed GMAW**
- **Plasma Formation in the Arc**
- **Use of Diatomic and Tri-atomic Gases with Argon or Helium**
- **Stabilizing the Arc for GMAW of Steel**
- **Fundamentals of Axial Spray**
- **"Fingerlike" Penetration with Pure Argon Spray GMAW**
- **When to Use Arg0n-Helium vs. Ar-CO_2 vs. Ar-O_2 Pulsed Spray Arc GMAW**
- **Oxidation Potential of Argon-Rich Gas Mixtures**
- **Optimum Gas Flow Rate**
- **Pulsed GMAW of Steel vs. Aluminum**
- **Synergic GMAW with Waveform Control**

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.

Plasma Formation in the Arc

This is because electricity is conducted through the arc (from the cathode to the anode) by means of plasma. The plasma consists of ionized gas and ionized metal generated by the hot arc. A plasma can form in any gas or metal vapor if the temperature is high enough. The ionization potential of a substance is the energy required to remove an electron from the outer shell of a gas or metal vapor atom. Large atoms with many shells containing electrons usually have low ionization potentials because the outer electrons (negatively charged) are very far away from the positively charged nucleus. Since argon has three major shells of electrons and helium has only 1 outer electron shell, the ionization potential of helium is much higher than that for argon. So, the heat input for helium gas shielded weld deposits is always higher than similar welds deposited with argon shielding. For example, the heat input (H) for a arc weld by GMAW is:

$$H = E\,I / v$$

Where E is the voltage, I is the amperage and v is the travel speed
For welding aluminum with an argon shielding gas, the voltage is 15V, the current is 250amps and the travel speed is 636 mm/s. The heat input is:

$$H = E\,I / v = (15 \text{ volts})\,(250 \text{ amps}) / 7\text{mm/s}$$

$$H = 536 \text{ J/mm}$$

If the same weld were made with helium shielding gas and 250amps and 7mm/s travel speed, the voltage would be higher (to achieve ionization) at 20 volts. So the heat input would increase to:

$$H = E\,I / v = (20 \text{ volts})\,(250 \text{ amps}) / 7\text{mm/s}$$

$$H = 714 \text{ J/mm}$$

Once the gas is ionized, electricity can pass through the arc just as electricity passes through a wire by obeying Ohm's law. For example, argon in GMAW forms a plasma to conduct electricity through the arc in accordance with ohm's law, where:

$$E = I\,R$$

Where: E is the welding voltage, I is the welding amperage, and R is the resistance across the arc. Once a plasma if formed, it has an average electrical resistance which is a combination of the resistances of the ionized shielding gas and metal vapors. Some ionization potentials for shielding gases and metal vapors are given in Table 1.

Table 1 Ionization potentials for common shielding gases and metal vapors

Gas or Metal Vapor	Ionization Potential (electron-volts)	Density (g/cm^3)	Atomic Number
Argon	15.7	0.00180	18
Helium	24.5	0.00012	2
CO_2	14.4	0.00130	-
O	13.2	0.00095	8
Fe	3.5 – 4.0	7.87	26
Al	3.8 – 4.3	2.7	13

Use of Diatomic and Tri-atomic Gases with Argon or Helium

When a diatomic gas like O_2 is used with Ar or He, the effect is to produce a hotter arc similar to an increase in the welding voltage. Diatomic gas will increase the heat transferred to the molten pool. For example, when H_2 dissociates into 2H atoms in the arc heat is extracted from the very hot arc for this dissociation to take place. When the 2H atoms reach the cooler molten pool, H_2 forms (exothermically) and a great of heat pumped into the weld. This exothermic reaction is helpful when welding thick plates of highly conductive metals like copper. Here again, the use of pure N_2 or Ar + N_2 provide an intensely hot arc for welding copper.

This same principle is true for tri-atomic shielding gas like CO_2. CO_2 is an active gas because it decomposes into CO + O in the arc just under the extremely hot electrode. When the CO+O reaches the cooler weld pool it recombines to CO_2 in an exothermic reaction causing substantial heating of the weld area.

Stabilizing the Arc for GMAW of Steel

Although Oxygen (O) forms oxide inclusions in the weld metal, O must be added to Ar in order to stabilize the arc when welding steel. CO_2 can also be added to Ar for arc stability because during welding CO_2 breaks down to carbon monoxide (CO) plus oxygen as shown below:

$$CO_2 \rightarrow CO + O_2 .$$

If oxygen comes into contact with the molten metal, a metal oxide will form instantly. For example, Ar-2%O is commonly used to weld steel. The 2% O combines with iron to form iron oxide in the molten weld pool as well as on the hot wire entering the weld zone. When GMAW steel, DCEP is used, so the weld pool is the cathode and the filler wire is the anode. In order for an arc to be stabile, it must be rooted to cathode spot on the weld pool closest to the electrode. Similarly, the anode spot must be stable and located at the end of the electrode. If the anode and cathode spots are not stable, the arc will wander all over the weld pool as well as up and down the wire electrode. The presence of 1-5% oxygen in Ar shielding provides enough oxide layer to stabilize the arc by stabilizing the cathode and anode spots. The oxide substantially reduces the "work function" of the cathode, that is the energy required to emit an electron from the cathode and pass through the arc to the stable anode spot. The oxide has this property of stabilizing the anode and cathode spots. As a result, welding gases used for GMAW steel can never be composed of pure Ar, otherwise arc instability will occur. The welding gases must be Ar-1% to 5%O, or various mixtures of Ar and at least 5%CO_2 . Even pure CO_2 can be used. However, the greater the Ar content the less spatter and greater the mechanical properties of the weld metal.

Fundamentals of Axial Spray GMAW

For reasons that are not well understood, argon is the only shielding gas that is capable of producing an axially-propelled spray arc that is quiet, stable, spatter-free, and highly directed. Spray arc produces over 100 droplets/s, and these droplets are smaller than the filler metal diameter. For any diameter of filler metal, there is a threshold value of current, above which a directed axial spray mode of metal transfer occurs. The transition current to spray is proportional to the wire diameter. Despite the fact that helium and CO_2 have much higher ionization potentials than Ar, neither helium nor CO_2 are capable of producing a spray transfer. Although helium and CO_2 can generate a greater heat input than Ar, the mode of droplet transfer is a non-directed globular transfer through the arc.

Fortunately, however, we can take advantage of the high-heat-input characteristics of helium, CO_2, and other gases by mixing these gases with Ar. As long as there is more than a critical amount of Ar present in the gas mixture, a true spray arc can be achieved while the heat-producing effects of helium, CO_2 , O, N, and H are obtained. For example, true spray can be obtained with the following Ar gas mixtures :

- Ar-He mixtures containing at least 80%Ar
- Ar-CO_2 mixtures containing at least 85%Ar
- Ar-O_2 mixtures containing at least 95%Ar

The size of droplets in spray transfer are characteristically smaller than the diameter of the wire. As current increases, drop size decreases but frequency of droplets and deposition rate increase. With increasing current, wire diameter must increase to maintain a smooth and stable arc. Because the heat input for spray arc is high, only flat and horizontal fillets positions are used. Using DCEP with a spray arc, the maximum penetration is obtained for GMAW.

"Fingerlike" Penetration with Pure Ar Spray GMAW

The directed axial flow of over 100 droplets/s produces a visible depression of the molten weld pool under the spray arc. The momentum of the rapid stream of axially directed droplets provides the mechanism for deep penetration directly beneath the arc with very little penetration along the side walls of the weld pool. The kinematic viscosity (defined as the viscosity multiplied by the density) of the shielding gas has a substantial effect of penetration. Since Ar has a greater kinematic viscosity than He, the axially directed penetration of Ar is far greater than that for He even though He has a higher ionization potential than Ar. This is why Ar produces fingerlike penetration and He produces more uniform penetration. Since penetration is affected by viscosity and density of the shielding gas, increasing the ambient pressure during welding can also decrease penetration. Increasing pressure of Ar atoms produces a drag or friction force resisting the speed of droplets streaming into the weld pool. As a result, increasing ambient pressure decreases weld penetration.

Fingerlike penetration of Ar spray GMAW is not desirable in welds. The most effective way to eliminate fingerlike penetration and promote a more uniform penetration pattern is by the addition of small amounts of a second gas. For example, Ar with 2 to 5% O or Ar with 5 to 25% CO_2 greatly reduces and even eliminates fingerlike penetration. As discussed earlier, the primary purpose of adding O_2 or CO_2 to Ar is to establish arc stability. However, a secondary benefit of adding O_2 or CO_2 to Ar is to eliminate fingerlike 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.

Steel is readily welded by the GMAW process, but pure Ar can not be used due to the arc instability problem (discussed above). For high toughness applications, steels used in shipbuilding and bridges are usually welded with Ar-2%O or Ar-5%CO_2 . In this way, only the minimum amount of O or CO_2 is used for arc stability. If more than 2%O or 5%CO_2 are used, excessive oxidation and carburization would severely impair mechanical properties particularly Charpy impact toughness. To ensure good Charpy impact toughness, steel filler metals contain Si, Mn, and/or Al deoxidizers. Oxides of Si, Mn, and Al (such as SiO_2, MnO, and Al_2O_3) are formed in the weld metal. Since the densities of these oxides are much lower than the molten steel weld metal, most of the oxides float to the top of the pool forming very thin islands of glassy slag.

Oxidation Potential of Ar-Rich Gas Mixtures

The addition of CO_2 or O_2 to argon to increase arc stability, which is required for GMAW of steel, also oxidizes the molten steel but to different degrees. The oxidation potential of Ar containing 1 to 3% O_2 is equivalent to about Ar containing 2 to 4% CO_2 . The oxidation potential of Ar containing up to 30% CO_2 is roughly similar to Ar-O_2 mixtures containing O_2 about half the level of CO_2.

Optimum Gas Flow Rate

It is sometimes believed that increasing Ar gas flow rate to higher and higher levels provides increased protection for the weld pool. This is only true up to a certain critical value of flow rate, and then detrimental turbulence occurs. Once turbulence occurs, the air contamination is entrained into the gas column across the arc. The formation of turbulence is dependent upon the Reynolds Number (R) for the flowing gas. R is calculated from:

$R = Dv\rho / \mu$

Where, D is the diameter of the tube or nozzle diameter, v is the average gas velocity, ρ is the density of the gas, and μ is the viscosity of the gas.
If the Reynolds Number exceeds 2300, the flow becomes turbulent. Unfortunately, the larger the diameter nozzle, the lower the critical gas flow velocity is for turbulent flow. So, there is only a limited improvement in Ar gas shielding by using larger diameter nozzles. Since gun design also affects Reynolds Number, the manufacturer's recommendations for gas flow settings are important for best protection of the weld pool.

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.

Synergic Pulsed GMAW with Waveform Control

Since the pulsing unit on a GMAW machine is an electronic control, the waveform can be controlled for optimum performance. Synergic-pulsed GMAW ensures that each pulse will produce one droplet of molten metal. Non-synergic pulsed GMAW produces many droplets per pulse. Although pulsed GMAW are both excellent for out-of-position welding, the synergic pulsed GMAW system allows further control of the metal droplet transfer. Today, pulsed synergic GMAW software is available for the welding engineer and welder to manipulate welding waveforms on their personal computers in order to produce the excellent welds. This is especially needed for welding of aluminum because of aluminum's high thermal diffusivity and low melting point. A modified constant current output is used in very high speed synergic pulsed GMAW. The pulsed current provides consistent penetration profile, reduced spatter, improved fluidity, increased in travel speed, reduced heat input and lower distortion. Manipulation of synergic pulse waveforms have a strong influence over the weld bead shape, spatter, fumes, and welding speed. For example, welding 0.035 inch aluminum is extremely difficult for conventional GMAW. The problem of burn-through is always difficult to overcome. By using synergic pulsed GMAW, the pulsed waveform can be optimized to produce low heat input while maintaining full penetration without spatter, burn-through, or cold laps and with minimum distortion.

Solving Formulas

Solving the formulas that are typically used by welders is easy to do. There are several rules that you need to follow in order to successfully use a formula.

Step #1 Read the formula and understand what it says

a. What do the letters (variables) stand for?

b. What math operations does the formula tell you to perform?

Step #2 Substitute the numbers for the letters

Step #3 Follow the rules for 'order of operation' to solve the problem

Step #1 Read the formula and understand what it says

Example**:** **V = IR**

This formula says: Voltage equals current times resistance

Each letter in a formula is called a **variable.** A letter stands for a word(s). **Make sure you know what the letters in your formula stand for**

In this example of Ohm's law
V =Voltage
I = Amperage (current flow)
R = resistance

Be careful when reading formulas because in different formulas the same letters can stand for something different. In the following formula

V = L x **W** x **H**

V stands for volume (not volts). This formula says volume equals length times width times height.

After you determine what the letters or variables stand for in the formula you must figure out what the formula says to do with them. (Do you add them together, subtract, multiply or divide?)

Let's go back to our original example

V = IR

What this formula says is 'voltage equals current times resistance."

This means you multiply current times resistance.

Anytime you see variables next to each other with no separation between them you multiply them together.

So IR is the same as I x R.

In fact there are several ways to indicate multiplication in a formula. They are:

V = IR
V= I x R
V= I * R
V= I • R
V = I (R)
Each different example above tells you to multiply current times resistance

There are also different ways to indicate division in a formula.

Example: R = V/ I
You would read this formula: Resistance equals voltage divided by current.
The slanted line (/) tells you to divide. It is the same as writing R = V ÷ I
Other ways to indicate division are:
R = V/I

R = V÷I

$R = \frac{V}{I}$ A fraction is just another way of telling you to divide the top number by the bottom number.

Step #2 Substitute numbers for variables. Going back to our original formula:

V = IR

If: Current (I) equals 5 amps and
Resistance equals 4 ohms (Ω)

We replace the letter I with 5 amps and we replace the letter R with 4 ohms

V = 5 amps x 4 ohms Always include the units when you substitute numbers for variables.

We can now solve our equation:
5amps x 4 ohms = 20 volts

Step #3 Follow the rules for order of operation
How do we handle a formula that has more than one mathematical operation in it? You must follow the correct order of operation. (Do anything within parenthesis first, next do

exponents, then multiplication and division and finally addition and subtraction.) For details please see the following page on order of operations.

Example: Let's says we wanted to know the Fahrenheit temperature when we know that it is 28˚Celsius outside?

The formula to convert Celsius temperatures to Fahrenheit temperature is:

$F = \frac{9}{5}C + 32$ Read the formula and understand what it says;

Fahrenheit degrees equals 9 times Celsius degrees .

Next divided by 5 plus 32.

$F = \frac{9}{5}28 + 32$ Substitute numbers for variables. In this case 28

Degrees is substituted for C

$F = 50.4 + 28$ Follow the correct order of operation: first multiply 9/5 x 28. Hint: use your fraction key to multiply the fraction and the whole number together.

$F = 82.4^{o}$ Finally do the addition

Order of Operation Rules

Excuse My Dear Aunt Sally

PLEASE	= Parenthesis →	Do this first
EXCUSE	= Exponent →	After you have done everything inside the parentheses, then do the exponents. i.e. 5^3
MY	= Multiplication	Do these after you have done every other operation. If you find both of them in a single problem, start with the operation on the left.
DEAR	= Division	
AUNT	= Addition	Do these after you have done every other operation. If you find both of them in a single problem, start with the operation on the left.
SALLY	= Subtraction	

EXAMPLE: $12 \times (8 - 6) - 2^2 \times 0 + 1$

$12 \times 2 - 2^2 \times 0 + 1$

$12 \times 2 - 4 \times 0 + 1$

$24 - 4 \times 0 + 1$

$24 - 0 + 1$

$24 + 1$

25

***REMEMBER:** Your scientific calculator is preprogrammed for the correct order of operation. You can enter the problem from left to right. Remember to include the parenthesis keys. 12 x (8 - 6) - 2 X^2 x 0 + 1 =

Math Lingo

(. . . or when "divided by" doesn't mean "divided into" . . .)

The language of math can be totally confusing at times; there sometimes seems to be a hidden cipher or code needed to magically turn word problems into calculations involving the four operations of multiplication, division, addition and subtraction. It helps to have a small glossary of conversion codes to make sense of it all:

First of all, let's look at some words that mean **addition**:

and, add, plus, more (than), in addition

Examples: *2* ***and*** *4 make/equal 6*
add *4 to 2 and you get 6*
2 ***plus*** *(+) 4 = 6*
4 ***more than*** *2 is 6*
4 (more) ***in addition to*** *the 2*

. . . and some more words signaling addition:

totaling, total, all, altogether, sum, . . .

Examples: *2 eggs and 4 eggs,* ***totaling*** *. . .*
the ***total of*** *2 chickens and 4 chickens*
$2 for this, $4 for that, how much ***in all****?*
$2 today, $4 tomorrow, how much ***altogether****?*
the ***sum of*** *2 and 4*

For **subtraction**, we have:

subtract, less, minus, take away . . .

Examples: *10* ***subtract*** *7 is/equals 3*
10 eggs ***less*** *7 eggs is 3 eggs*
10 ***minus*** *7 is/equals 3*
10 ***take away*** *7 is/equals 3*

Note: *In subtraction, order is important. 10 less 7 is not the same as 7 less 10 (THINK OF YOUR CHECKBOOK, when you're operating in the negative!! UGH!) The same goes for "10 subtract 7" ≠ "7 subtract 10 (= -3)", "10 - 7 ≠ 7 - 10," "10 take away 7" ≠ "7 take away 10," etc.*

Here are some more words signaling subtraction:

the difference between, take out, take from, remainder, left over . . .

Examples: *The **difference between** 10 and 7 is/equals 3*
*What's your **remainder** when you **take** 7 **out** of 10?*
*What's **left over** after you **take** 7 **from** 10?*

Language gets a little more tricky with multiplication and division.

Words signaling **multiplication:**

times, multiplied by, each, of, altogether, for every, . . .

Examples: 3 **times** 5,
3 **multiplied by** 5
3 x 5
3 • 5
2 ***of*** those tickets at $45 ***each***, how much ***altogether***?
$45 ***for every*** ticket, how much for 10 tickets?

Words signaling **division:**

out of, each . . .

Examples:

*3 **out of** 4* becomes ¾ = 3 ÷ 4 = .75 or 75%

$50 total buys how many tickets at $10 ***each***? ⇒ 50 ÷ 10 = 5

AND . . . *divided by, divided into, into, goes into*

6 ***divided into* 18 is 3**

18 *divided by* 6 is 3

Notice these two require the exact opposite order of numbers 6 & 18

6 ***into*** *18 is/equals 3* *Order counts here as well*

*6 **goes into** 18 three times*

Through it all, notice that the word "is" means "EQUALS" ("=") always.

Manipulating simple formulas

As we work on various calculations in welding applications, we will run into quite a few mathematical formulas which follow a certain pattern and therefore can benefit from being taught together. We will not introduce all of them now, but the few shown here will give you an idea of how useful it is to understand their pattern and how to work them.

All of the formulas we present here are of one of these two patterns:

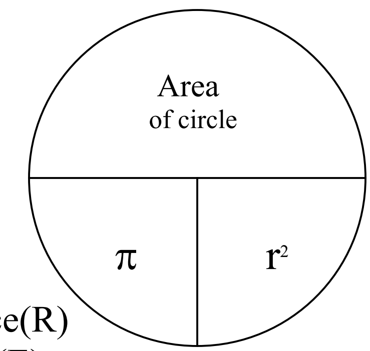
answer = number x number

or

answer = number ÷ number

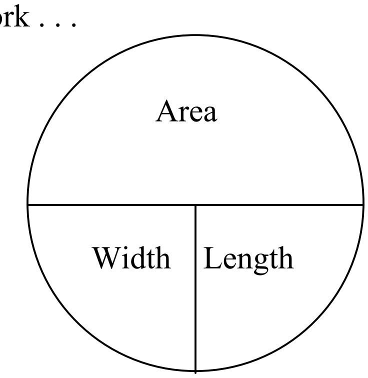
these two are basically the same, just makeovers of each other

Here are some examples:



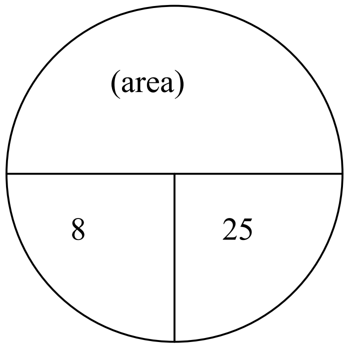
$Area_{rectangle}$ = length x width
$Area_{circle}$ = π x r^2
Distance = Rate x Time
Voltage(V) = Current(I in amps) x Resistance(R)
Power (P in watts)= Current(I) x Voltage(V) or (E)

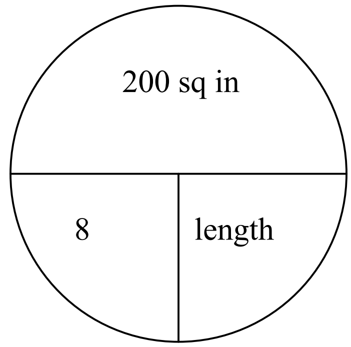
These shop math circles are a good visual aid. Here's how they work . . . The numbers in the bottom two quarter spaces multiply together to get the number in the top space. The number in the top half divided by either of the numbers on the bottom gets you the other number on the bottom. So you can think of the horizontal line as a division sign and the vertical line as a multiplication sign.



Putting your thumb over the information you want is a good way to determine which action to take. If the numbers you have uncovered are separated by a vertical line, you multiply. If they are separated by a horizontal line, then you divide to get your answer.

Suppose you have an area of 25 sq in and a width of 8". Input your numbers as in the following example. If you put your thumb over the information section you want, area, you see that you have the '25' and the '8' both showing and separated by the vertical line indicating multiplication. You multiply them together and get 200 in^3. Now, to check, put your 200 in^3 into the areasection and 8 into the width section; this time you want to calculate the area

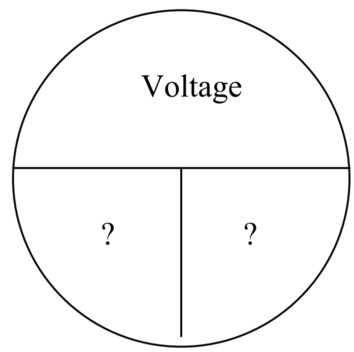




Cover that length with your thumb and see that what is showing is the 200 over and the 8, separated by the horizontal line (like a fraction) indicating you should divide.

200 ÷ 8 = 25 *area ÷ width = Length*

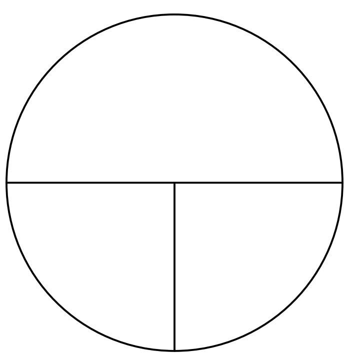
Later we will be introducing the following formulas:

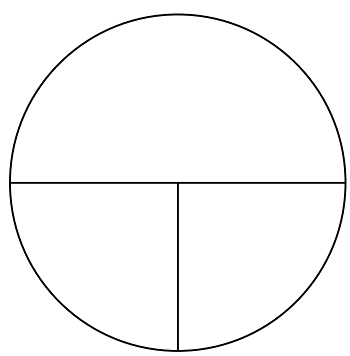


Voltage	=	*Curretn x Resistance*
Power	=	*Voltage x Current*

Can you see that they also follow the same pattern?

Try putting them into these shop math circles and check them to make sure they will work correctly.





Complete the following worksheet on calculating power to practice this circle method of manipulating a formula

Something to Think About

Technical Note on " Dimensional Analysis"

A good way to do a 'sanity check' on a formula is to look at the units for each variable and make sure that the units you end up with match the units you expect to see in your answer.

In the heat input example your answer needs to come out in Joules/inch :

Our original formula was:

Heat input= $\dfrac{\mathbf{V \times I \times 60}}{\mathbf{S}}$

Substituting units for symbols this translates into:

Joules/inch $= \dfrac{\textbf{Volts x Amps x seconds/minutes}}{\textbf{inch/minute}}$

We already know that Volts x Amps = Watts and that Watts are Joules/second

Substituting Joules/seconds for Volts x Amps we get:

Joules/inch $= \dfrac{\textbf{Joules/second x second/minutes}}{\textbf{inch/minute}}$

Note: inches/ minute in the denominator become minutes/inch in the numerator, so:

Joules/inch = Joules/second x second/minute x minutes/inch

Craftsmanship Expectations for Welding Projects

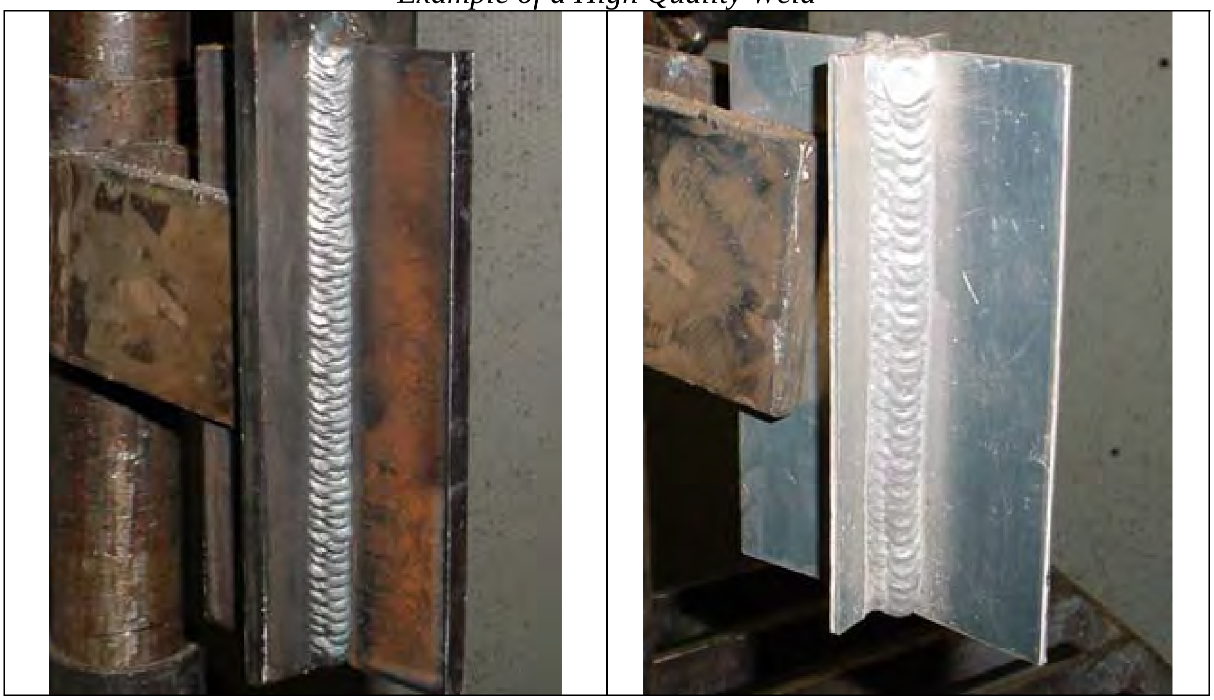
The student should complete the following tasks prior to welding.

1. Thoroughly read each drawing.
2. Make a cutting list for each project. Cut at least two project assemblies of metal at a time. This will save a great amount of time.
3. Assemble the welding projects per drawing specifications.
4. Review the Welding Procedure portion of the prints to review welding parameter information.
5. See the instructor for the evaluation.

Factors for grading welding projects are based on the following criteria:

Metal Preparation	**Project Layout**	**Post Weld Clean-up**
Oxyacetylene cut quality	Accurate (+/- 1/16")	Remove Slag/Spatter
Grind all cut surfaces clean	Limit waste	Remove sharp edges

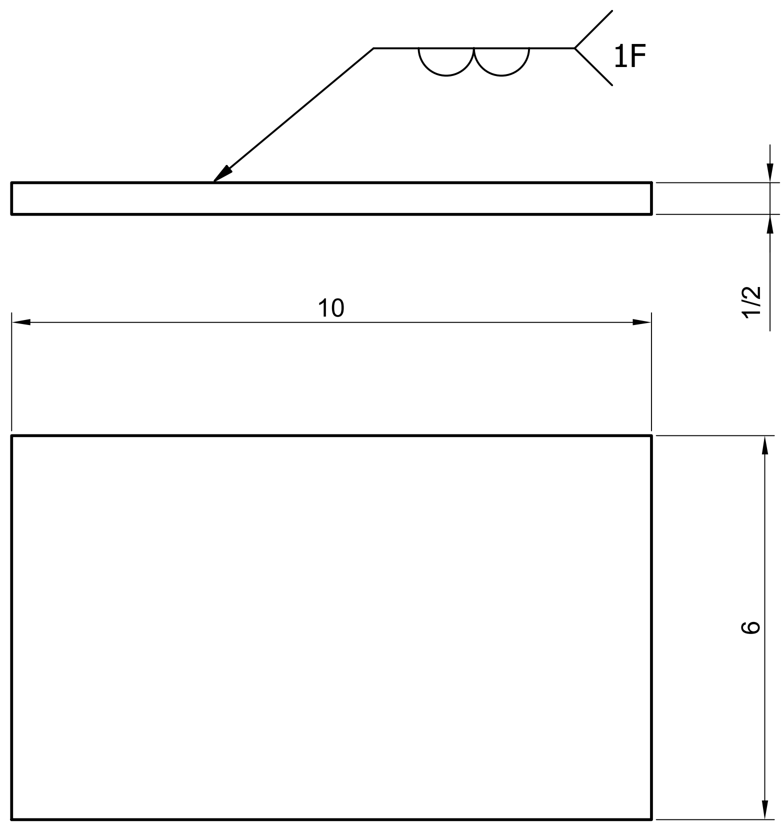
Example of a High Quality Weld

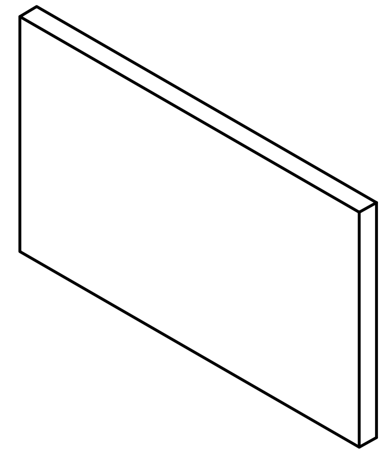


Weld Quality per AWS D1.1

VT Criteria	**Cover Pass**
Reinforcement (groove welds)	Flush to 1/8"
Fillet Weld Size	See specification on drawing
Undercut	1/32" maximum depth
Weld Contour	Smooth Transition
Penetration	N/A
Cracks	None Allowed
Arc Strikes	None Allowed
Fusion	Complete Fusion Required
Porosity	None Allowed
Overlap	None Allowed

WLD 132
Project 1 - Bead Plate





SCALE 1:4

Notes:

Hand cut using oxy-fuel process

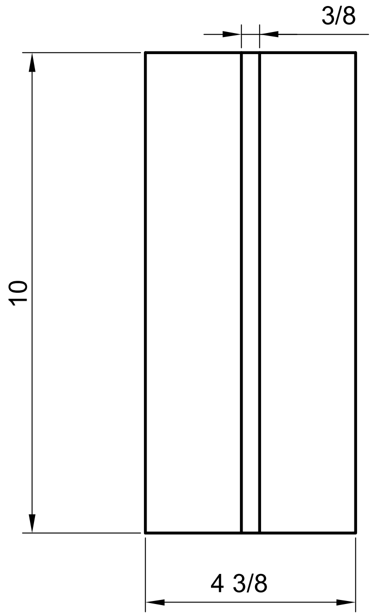
Tolerance for hand cut is +/- 1/8”

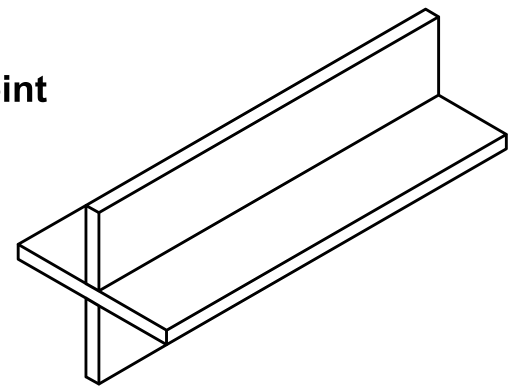
3/8” plate may be substituted for 1/2”

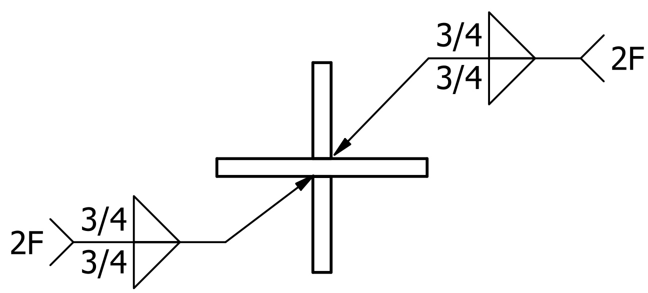
Welding tips:
There should be no valleys between welds.
Make sure you are not aiming your wire anywhere (especially do not “aim at the toe”).
Place the edge of your puddle on the high point of your previous weld.
Following the ridge of you previous weld with the edge of your puddle will ensure flat bead to bead contour.

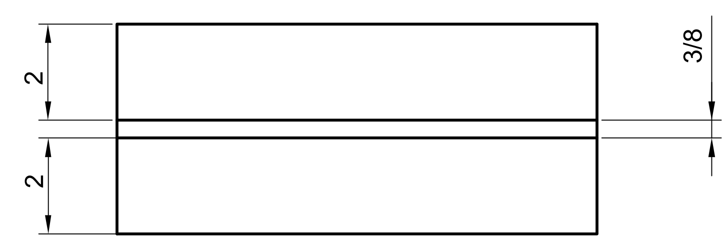
TITLE		
132 Bead Plate		
LAST UPDATED 03/30/22	UNITS in	SHEET 1 / 1
THIRD ANGLE PROJECTION	SCALE 1:3	SIZE A

WLD 132
Project 2 - Horizontal T joint





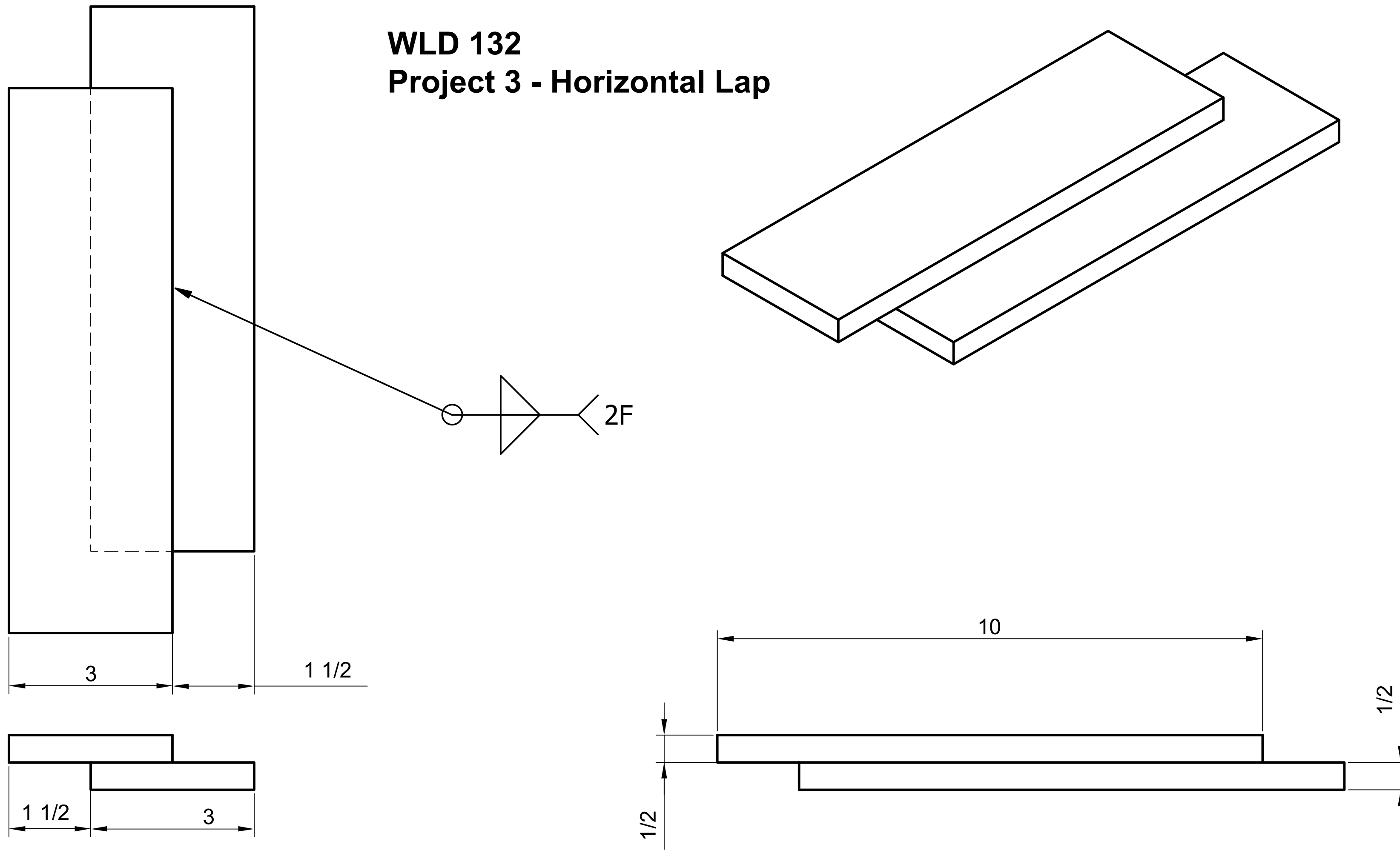




Part	Quantity	Thickness	Width	Tolerance	Length	Tolerance
A				+		+
				–		–
B				+		+
				–		–

TITLE T joint	Linear Tolerances: +/-1/16 Angular Tolerances: 2°30′	
LAST UPDATED 04/01/22	UNITS in	SHEET 1 / 1
THIRD ANGLE PROJECTION	SCALE 1:4	SIZE A

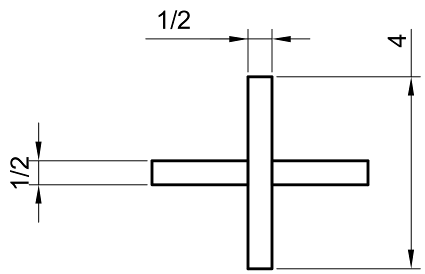
WLD 132
Project 3 - Horizontal Lap

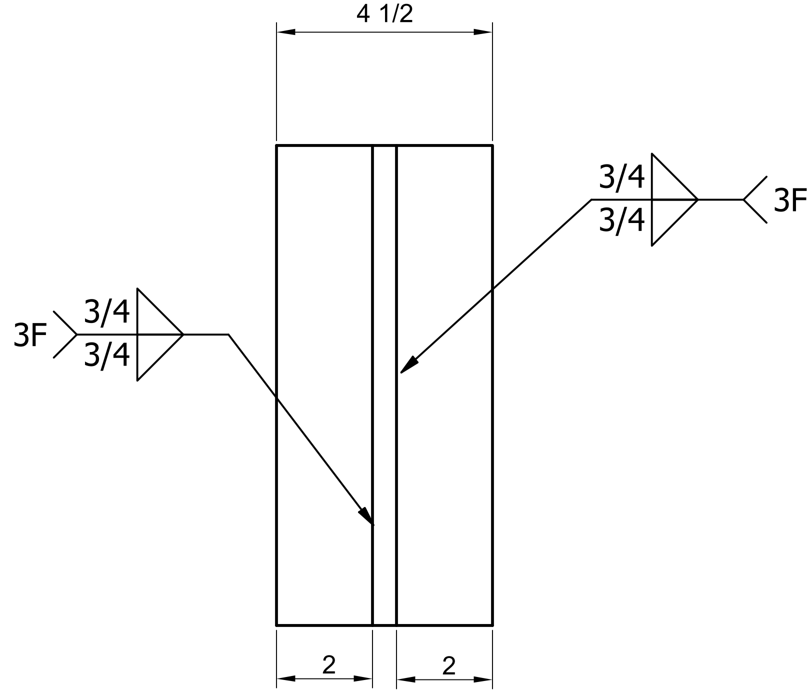


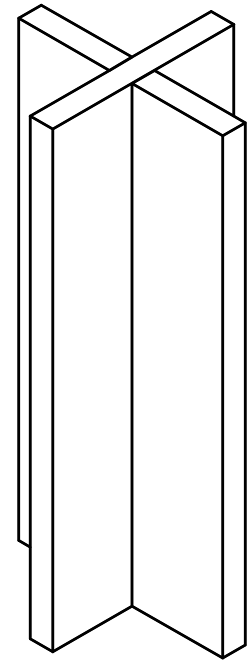
TITLE	Lap
Linear Tolerances:	+/-1/16
Angular Tolerances:	2°30’
LAST UPDATED	04/01/22
UNITS	in
SHEET	1 / 1
THIRD ANGLE PROJECTION	
SCALE	1:3
SIZE	A

Part	Quantity	Thickness	Width	Tolerance	Length	Tolerance
A				+		+
				–		–
B				+		+
				–		–

WLD 132
Project 4 - Vertical T joint





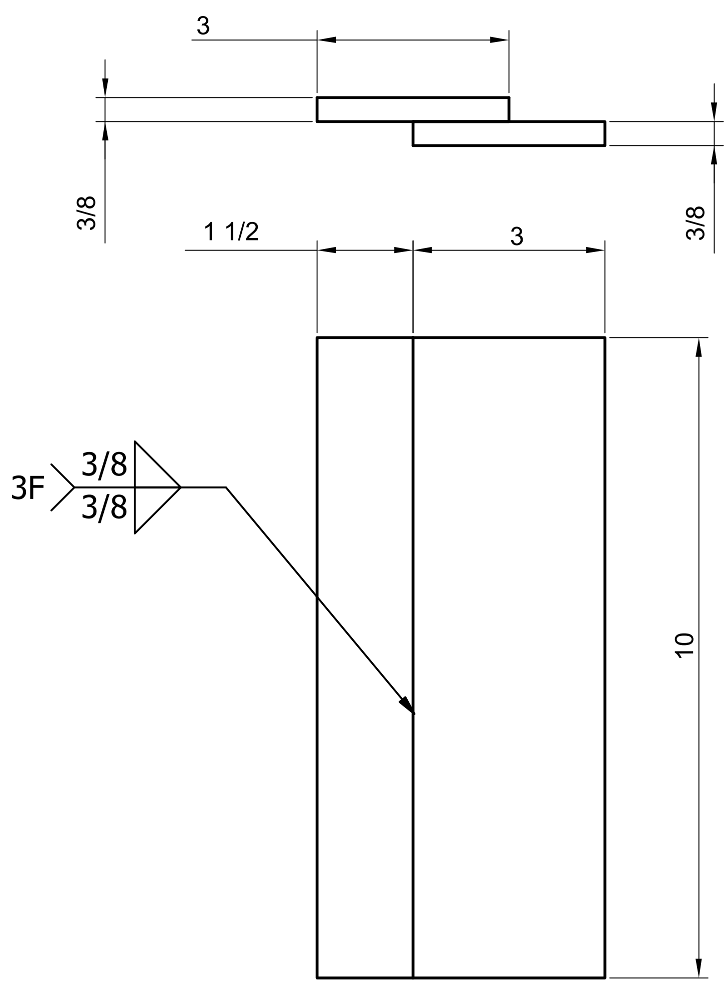


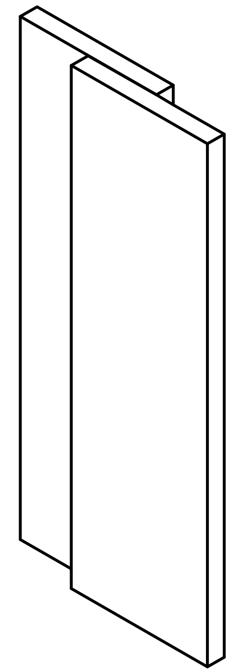
SCALE 1:3

Part	Quantity	Thickness	Width	Tolerance	Length	Tolerance
A				+		+
				–		–
B				+		+
				–		–

TITLE 132 3F T-Joint	Linear Tolerances: +/-1/16 Angular Tolerances: 2°30’	
LAST UPDATED 04/01/22	UNITS in	SHEET 1 / 1
THIRD ANGLE PROJECTION	SCALE 1:4	SIZE A

WLD 132
Project 5 - Vertical Lap





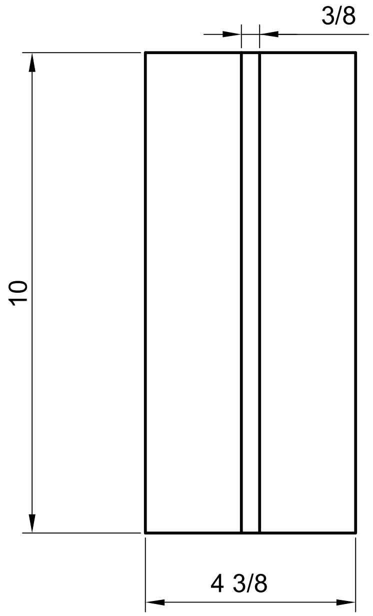
Part	Quantity	Thickness	Width	Tolerance	Length	Tolerance
A				+		+
				–		–
B				+		+
				–		–

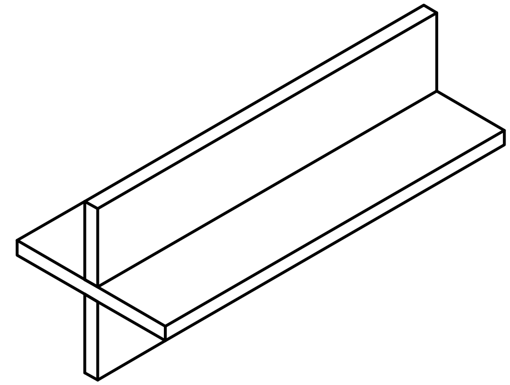
TITLE
3F Lap

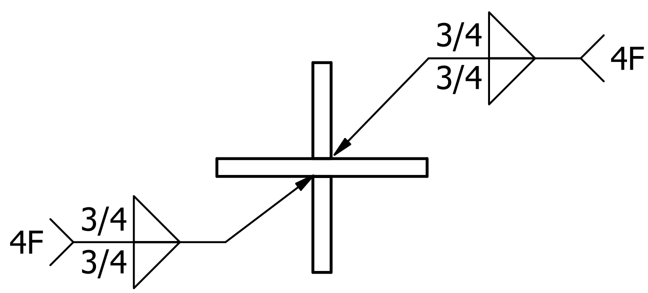
Linear Tolerances: +/-1/16
Angular Tolerances: 2°30′

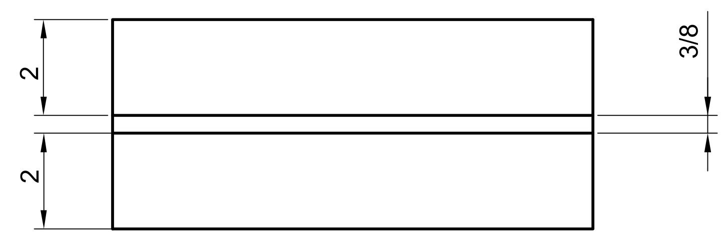
LAST UPDATED	UNITS	SHEET
04/01/22	in	1 / 1
THIRD ANGLE PROJECTION	SCALE	SIZE
	1:3	A

WLD 132
Project 6 - Overhead T joint









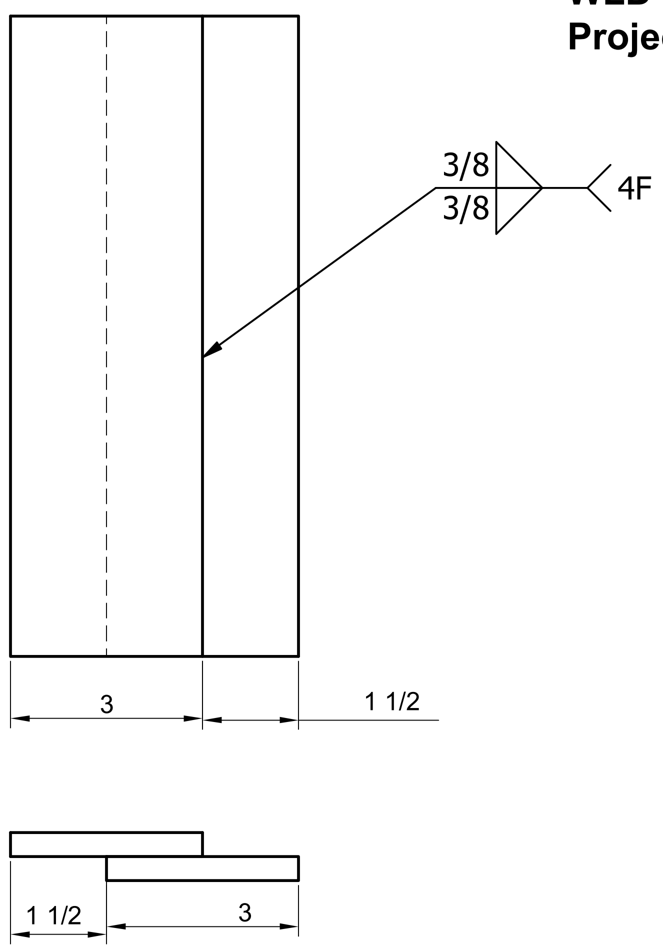
Part	Quantity	Thickness	Width	Tolerance	Length	Tolerance
A				+		+
				–		–
B				+		+
				–		–

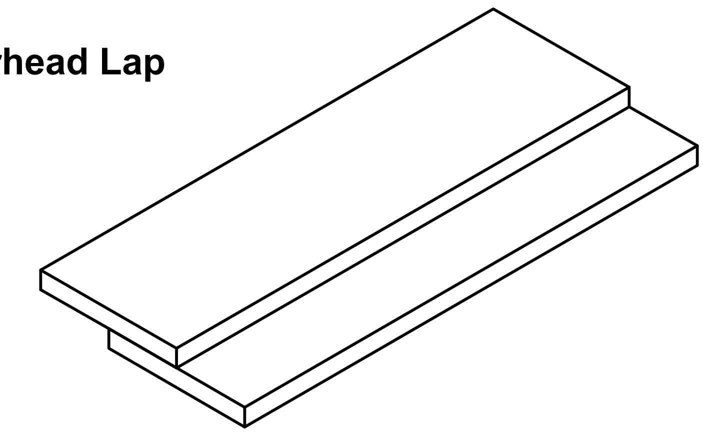
TITLE
T joint

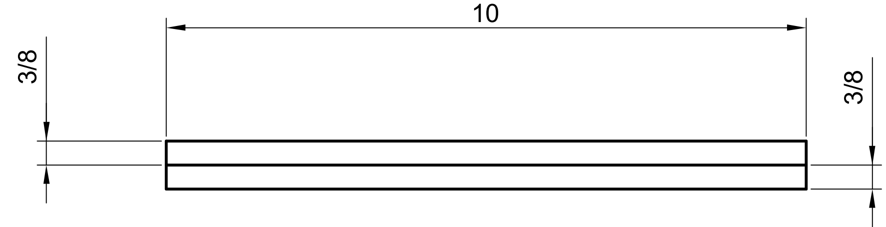
Linear Tolerances: +/-1/16
Angular Tolerances: 2°30'

LAST UPDATED	UNITS	SHEET
04/01/22	in	1 / 1
THIRD ANGLE PROJECTION	SCALE	SIZE
	1:4	A

WLD 132
Project 7 - Overhead Lap







Part	Quantity	Thickness	Width	Tolerance	Length	Tolerance
A				+		+
				–		–
B				+		+
				–		–

Linear Tolerances:	+/-1/16
Angular Tolerances:	2°30′

TITLE Lap		
LAST UPDATED 04/01/22	UNITS in	SHEET 1 / 1
THIRD ANGLE PROJECTION	SCALE 1:3	SIZE A

GMAW Pulse Aluminum Transfer T Joint (2F) Project #8

Technique
Use a stringer technique and push gun progression

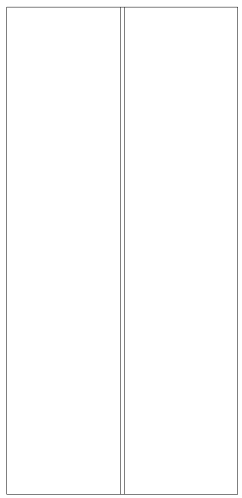
Welding Sequence

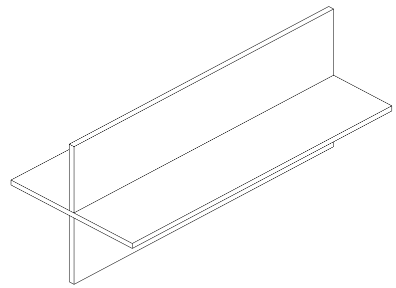
VT Criteria	Student Assessment	Instructor Assessment
Reinforcement (0” –1/8”)		
Undercut (1/32”)		
Weld Bead Contour		
Penetration		
Cracks (none)		
Arc Strikes (none)		
Fusion (complete)		
Porosity (none)		
		Grade Date

WLD 132

GMAW Pulse, Aluminum

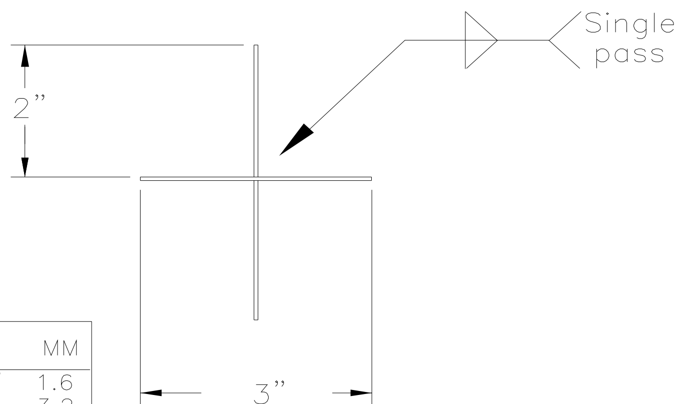
Horizontal Position T-Joint (2F)

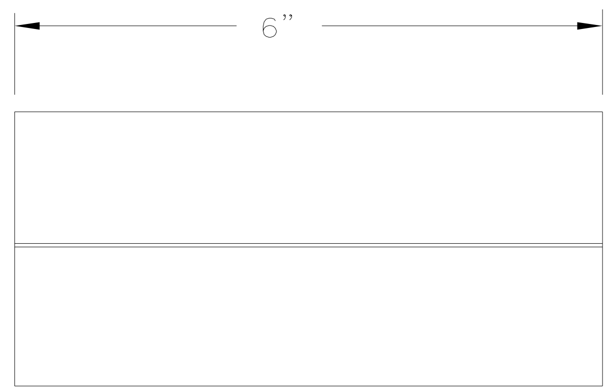




Welding Procedure

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

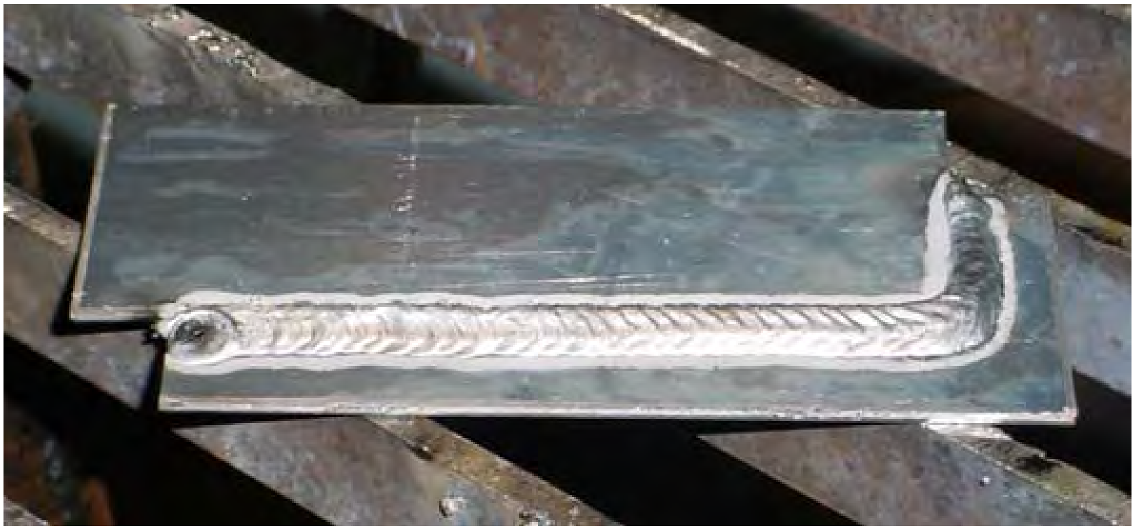
Tolerance (Unless otherwise Specified) Dimensional ± 1/16" Angle ± 5°	WLD 132-09		
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: Date: 7/05/05	Approve	Date	Sheet

GMAW Pulse Aluminum Transfer Lap Joint (2F) Project #9

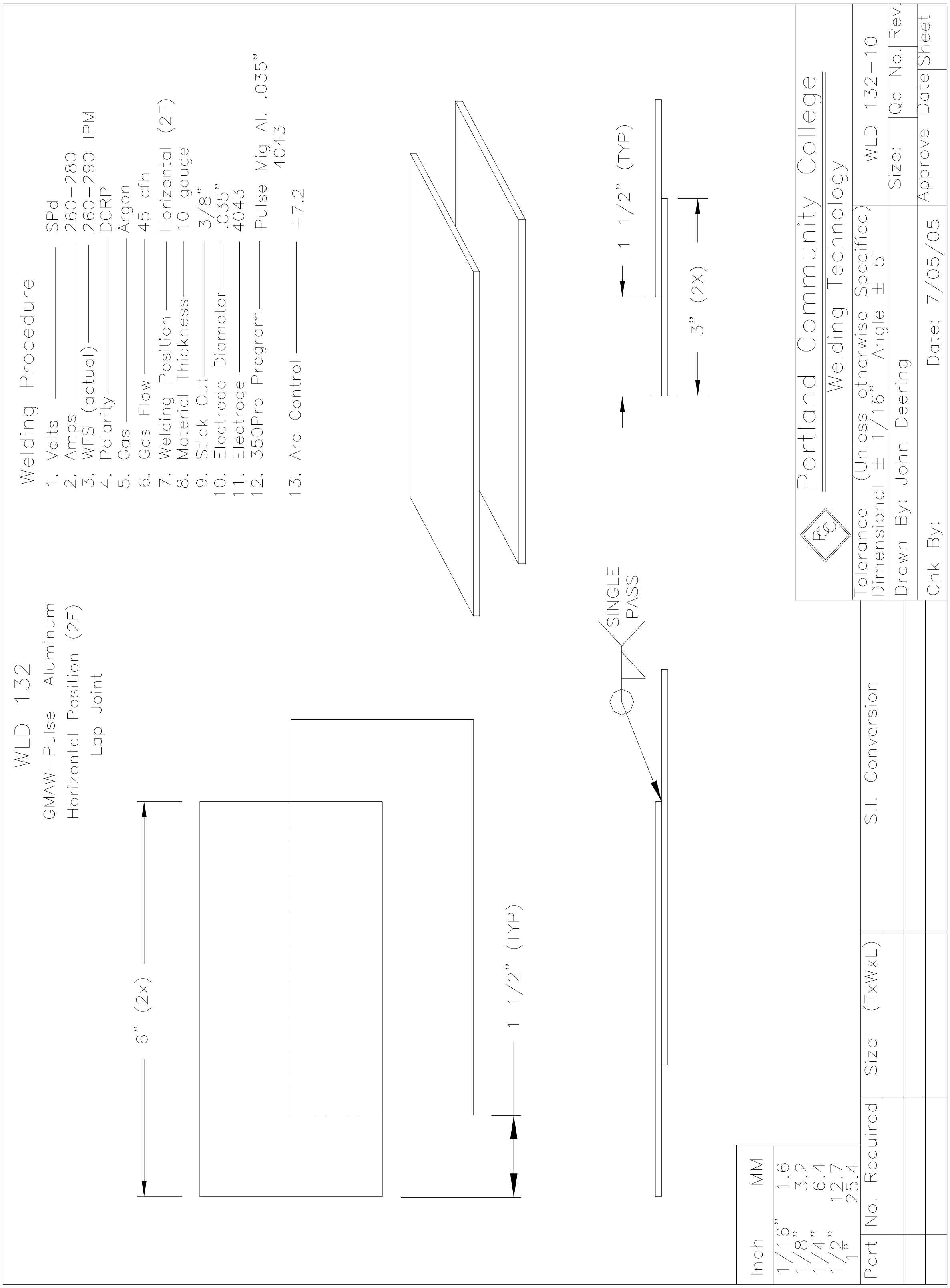
Technique

Use a stringer 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
6" (2x)
1 1/2" (TYP)
SINGLE PASS
3" (2X)
1 1/2" (TYP)
Portland Community College
Welding Technology
Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
Drawn By: John Deering
Chk By:
Date: 7/05/05
WLD 132-10
Size:
Qc No.
Rev.
Approve
Date
Sheet
Part
No. Required
Size (TxWxL)
S.I. Conversion
Inch MM
1/16" 1.6
1/8" 3.2
1/4" 6.4
1/2" 12.7
1" 25.4

GMAW Pulse Aluminum Transfer T Joint (3F) Project #10

Technique

Use a stringer technique and push gun progression

Welding Sequence

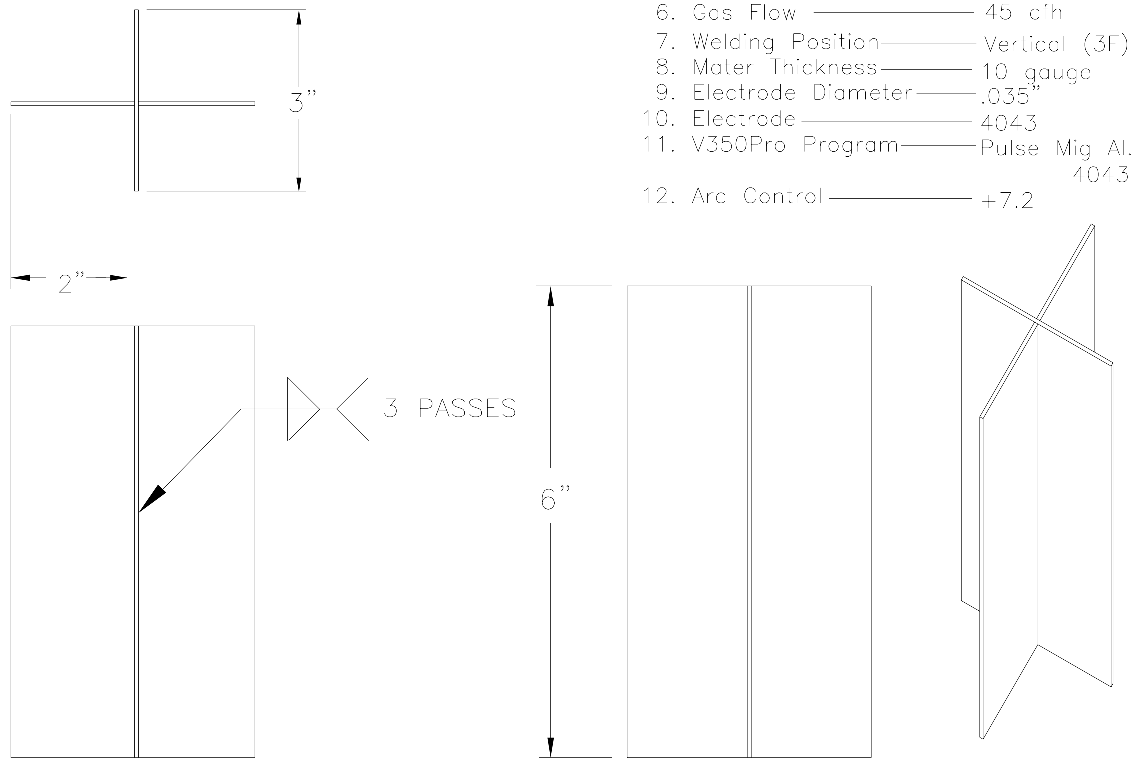
VT Criteria	Student Assessment	Instructor Assessment
Reinforcement (0" –1/8")		
Undercut (1/32")		
Weld Bead Contour		
Penetration		
Cracks (none)		
Arc Strikes (none)		
Fusion (complete)		
Porosity (none)		
		Grade Date

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		
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: Date: 7/05/05	Approve	Date	Sheet

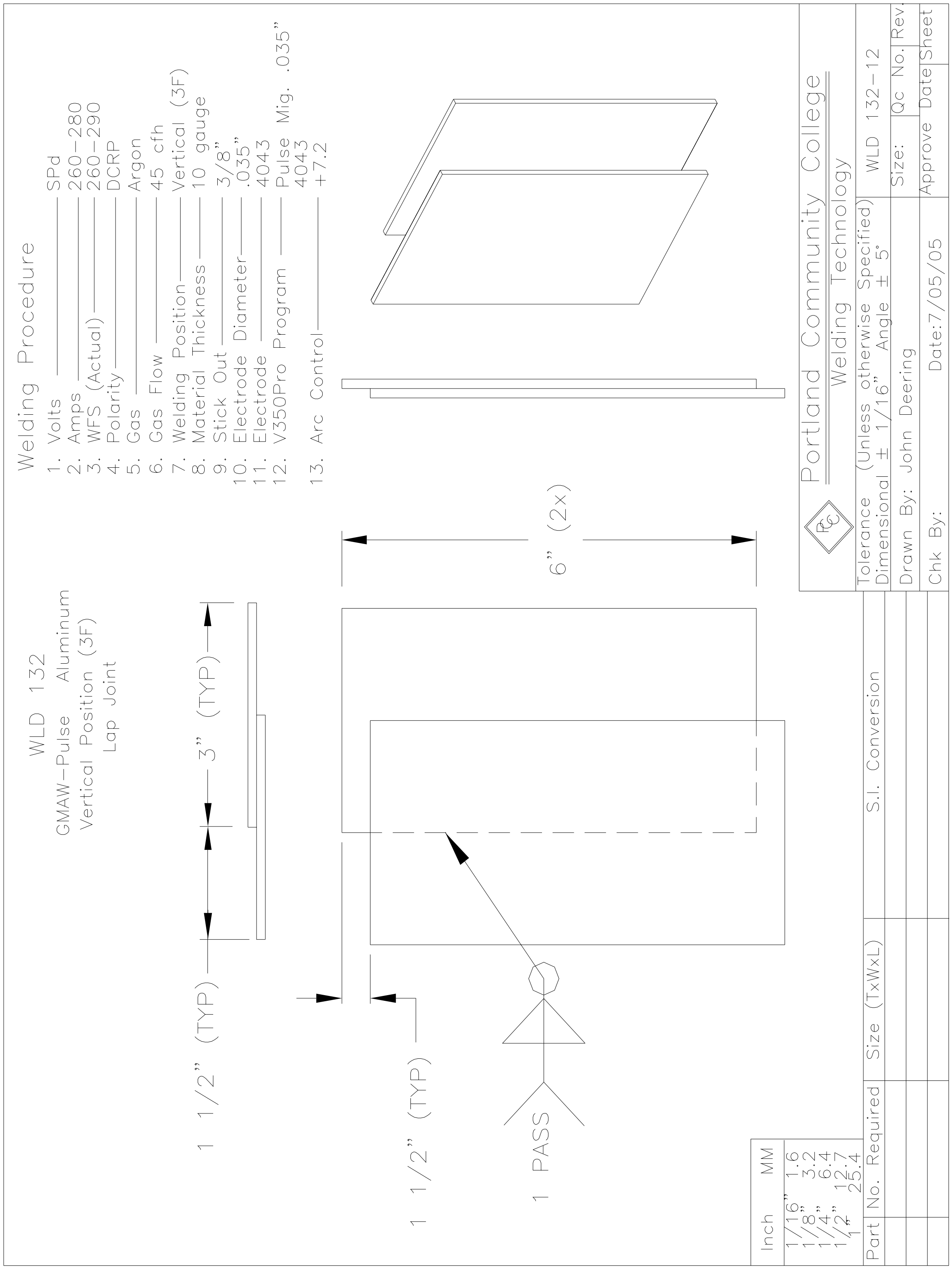
GMAW Pulse Aluminum Transfer Lap Joint (3F) Project #11

Technique

Use a stringer 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
6" (2x)
3" (TYP)
1 1/2" (TYP)
1 1/2" (TYP)
1 PASS
Portland Community College
Welding Technology
Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
Drawn By: John Deering
Chk By:
Date:7/05/05
WLD 132-12
Size:
Qc No.
Rev.
Approve
Date
Sheet
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

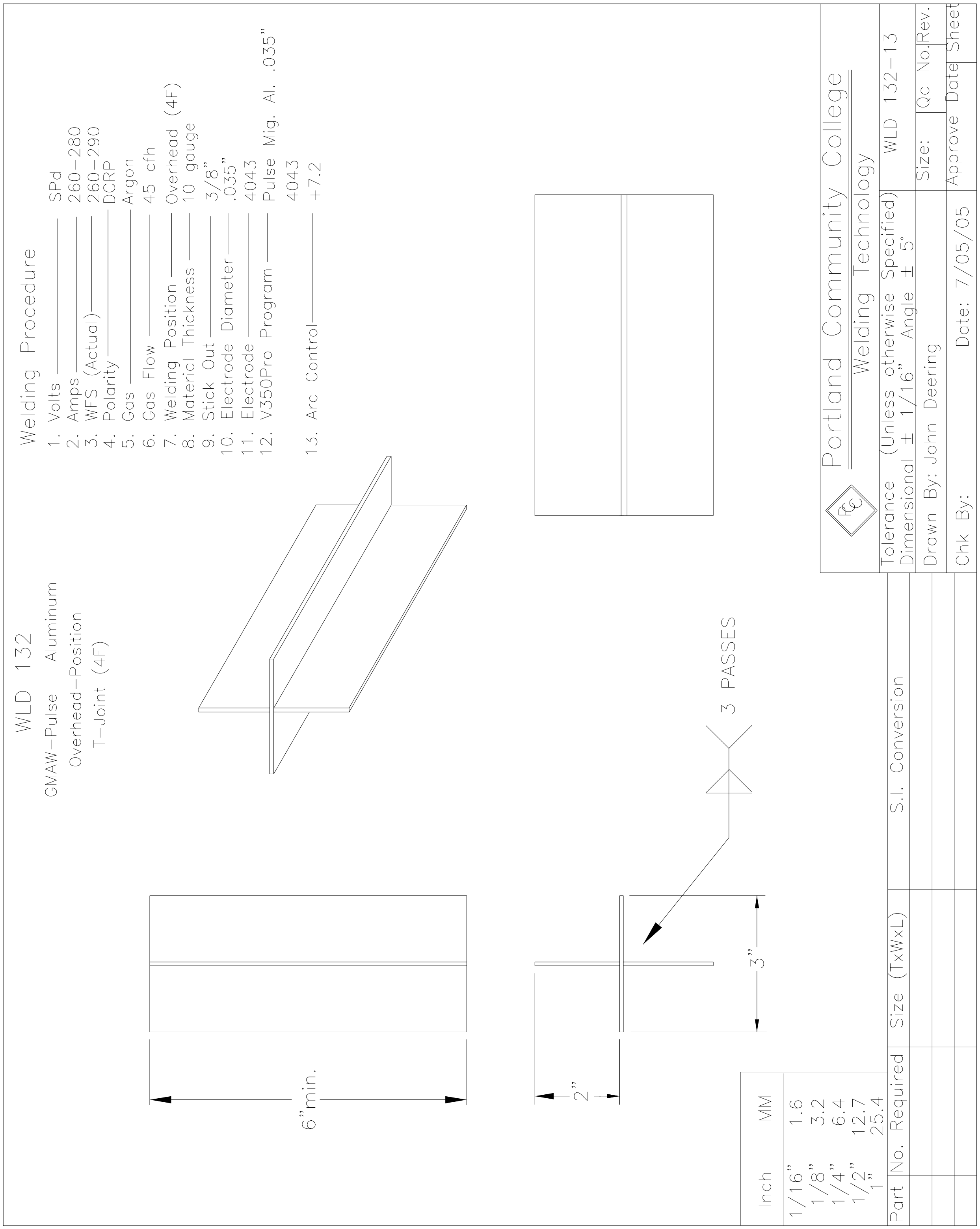
GMAW Pulse Aluminum Transfer T Joint (4F) Project #12

Technique

Use a stringer 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

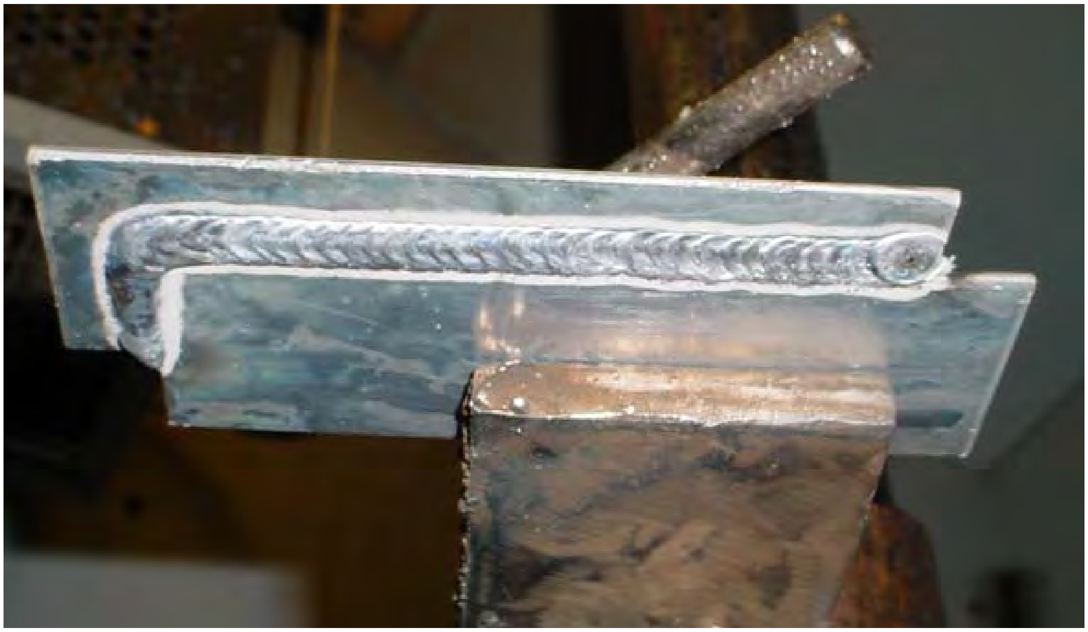

WLD 132
GMAW-Pulse Aluminum
Overhead-Position
T-Joint (4F)
Welding Procedure
1. Volts — SPd
2. Amps — 260-280
3. WFS (Actual) — 260-290
4. Polarity — DCRP
5. Gas — Argon
6. Gas Flow — 45 cfh
7. Welding Position — Overhead (4F)
8. Material Thickness — 10 gauge
9. Stick Out — 3/8"
10. Electrode Diameter — .035"
11. Electrode — 4043
12. V350Pro Program — Pulse Mig. Al. .035"
4043
13. Arc Control — +7.2
3 PASSES
6" min.
2"
3"
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
WLD 132-13
Size:
Qc No.
Rev.
Approve
Date
Sheet

GMAW Pulse Aluminum Transfer Lap Joint (4F) Project #13

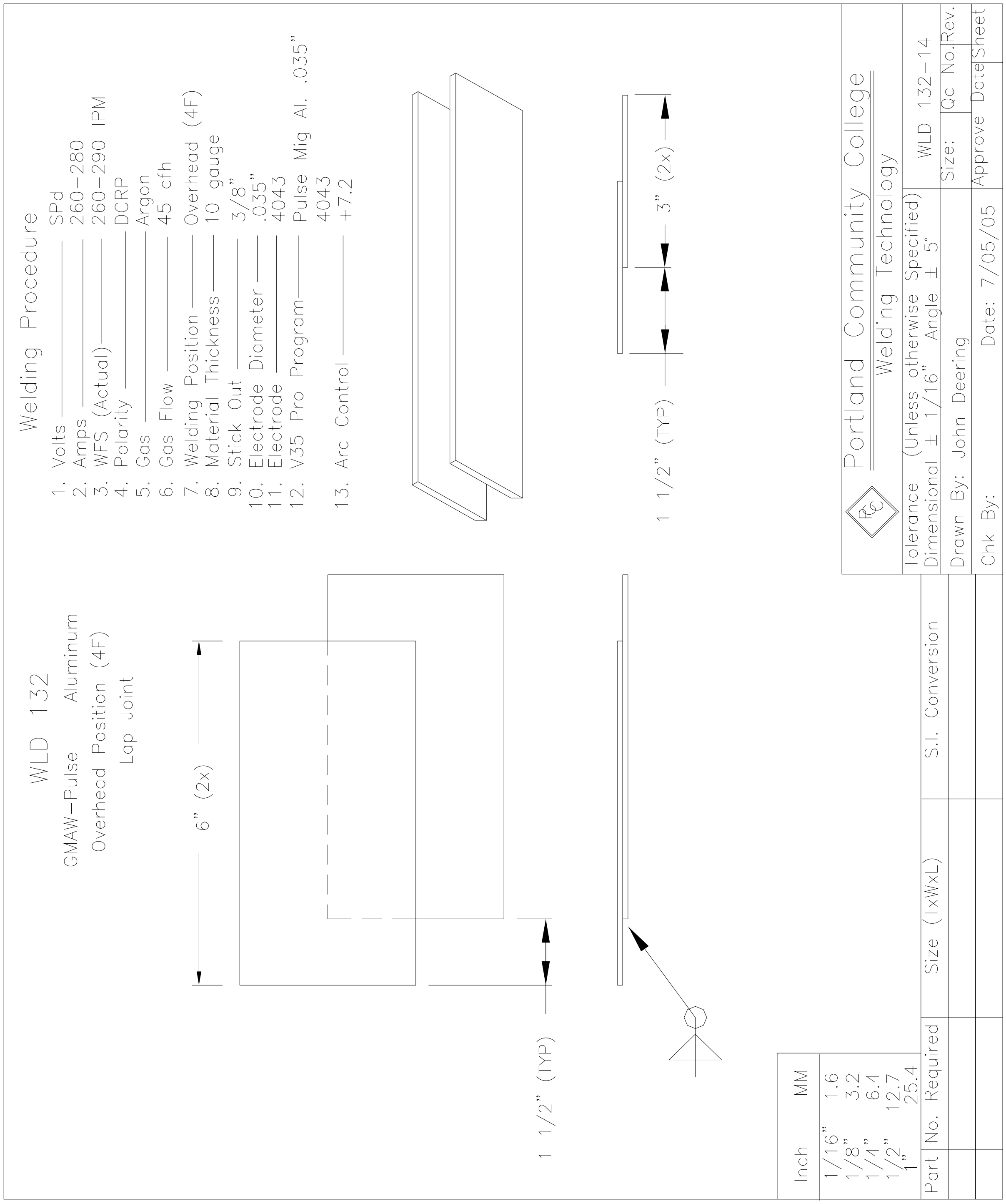
Technique

Use a stringer 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
6" (2x)
1 1/2" (TYP)
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
1 1/2" (TYP)
3" (2x)
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 132-14
Drawn By: John Deering
Chk By:
Date: 7/05/05
Size:
Qc No.
Rev.
Approve
Date
Sheet

GMAW Worksheet

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

2. Describe the effect of travel angle on penetration in GMAW of steel.

3. What type of shielding gas is required for GMAW Pulse transfer?

4. What determines the type and size of Drive Rollers needed?

5. What is a “burn back”? List three things that may cause a “burn back.

GMAW WORK SHEET

Name: ______________________________Date: ______________________

1. Please define the following abbreviations; GMAW, GMAW-S, GMAW-P, MIG,MAG.

2. List three advantages of the GMAW process.

3. List three disadvantages of the GMAW process.

4. What is the basic equipment required for GMAW?

12. List seven components of a welding gun.

13. Describe the purpose of the insulator.

14. Describe the purpose of the contact tip.

15. Why is a copper alloy the choice for gas cups?

16. How do you know when proper tension is achieved on a drive roll system?

17. List six purposes that shielding gas serves in GMAW.

18. List the three gases / gas mixtures you will be using in this course and identify the application of each.

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

20. List four essential variables of GMAW.

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

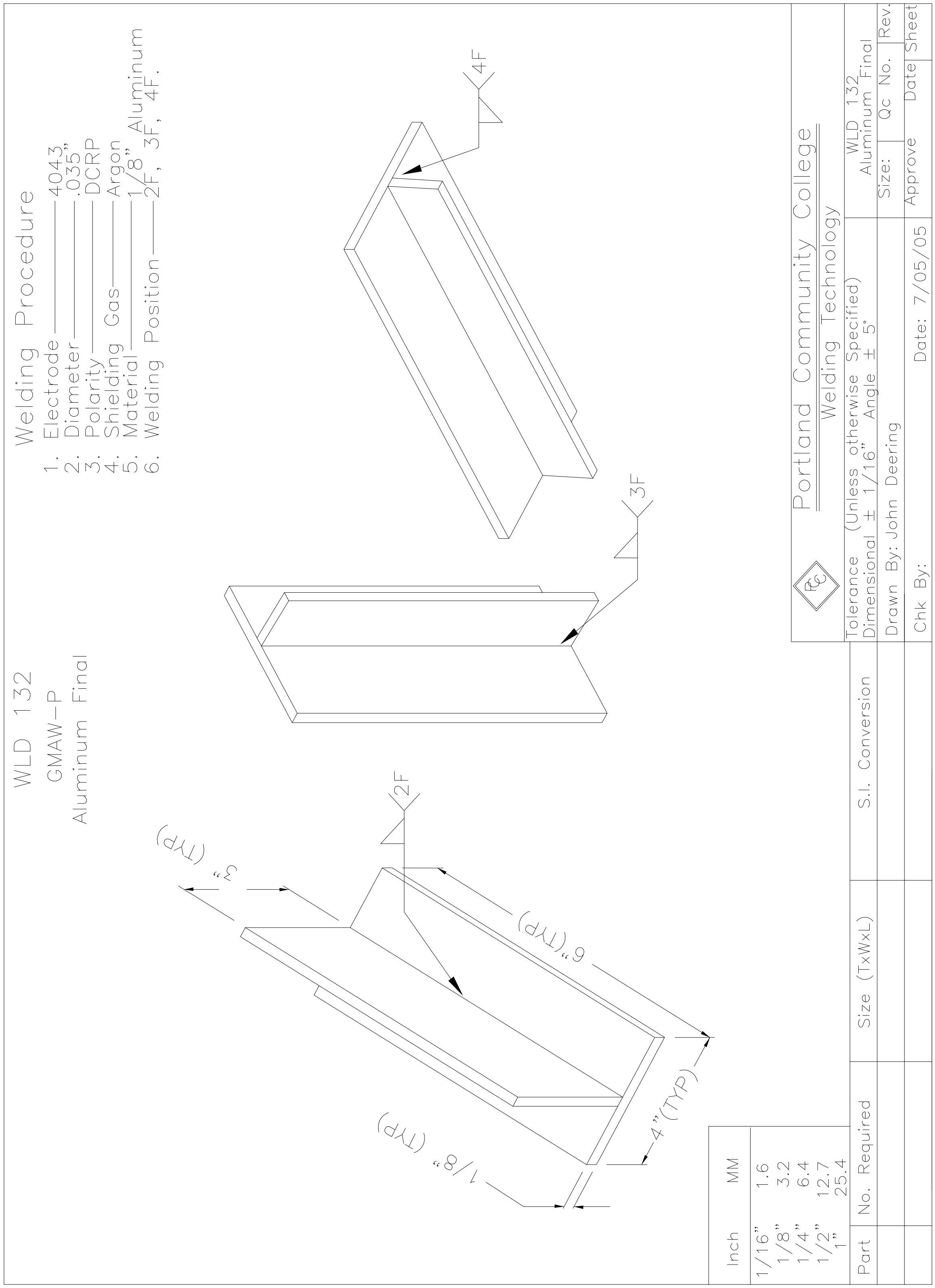
22. What determines the type and size of wire to be used in a welding application?

23. Describe the effect of voltage on arc length.

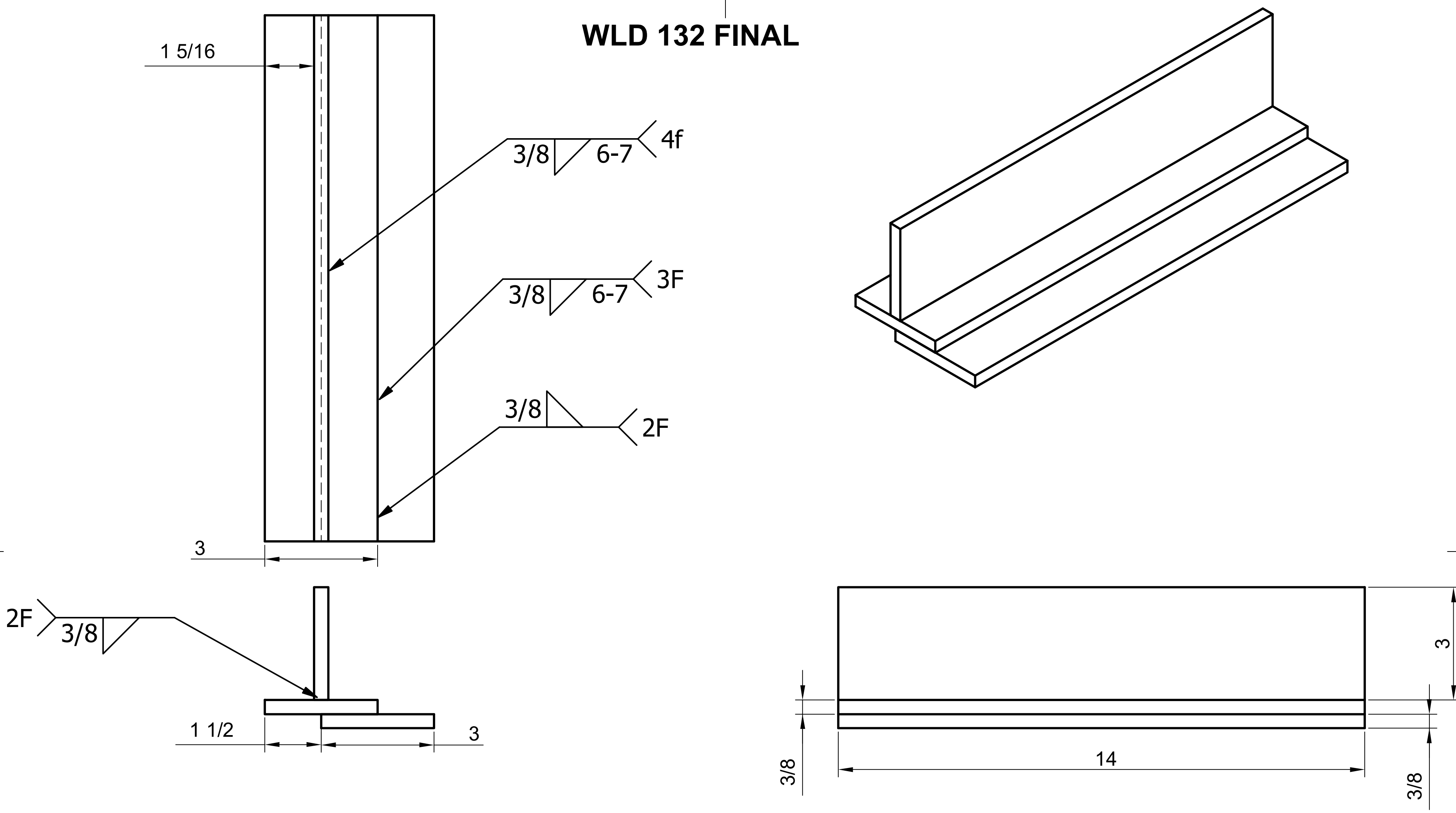
Final Exam

Part One
This portion of the final exam is a closed book test. Consult with your instructor to determine items that you may need to review. Once you determine that you are ready for the exam, request it from your instructor. Complete the exam and write all answers on the answer sheet provided. Once completed, return the exam to your instructor for grading.

Part Two
This portion of the exam is a practical test where you will fabricate and weld a weldment from a "blue print." The evaluation of this portion of the exam will be based on the rubric.


WLD 132
GMAW-P
Aluminum Final
Welding Procedure
1. Electrode — 4043
2. Diameter — .035"
3. Polarity — DCRP
4. Shielding Gas — Argon
5. Material — 1/8" Aluminum
6. Welding Position — 2F, 3F, 4F.
2F
3F
4F
3" (TYP)
6" (TYP)
4" (TYP)
1/8" (TYP)
Portland Community College
Welding Technology
Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
Drawn By: John Deering
Chk By:
Date: 7/05/05
WLD 132
Aluminum Final
Size:
Qc No.
Rev.
Approve
Date
Sheet
Part
No. Required
Size (TxWxL)
S.I. Conversion
Inch
MM
1/16" 1.6
1/8" 3.2
1/4" 6.4
1/2" 12.7
1" 25.4

WLD 132 FINAL



Part	Quantity	Thickness	Width	Tolerance	Length	Tolerance
A				+		+
				–		–
B				+		+
				–		–
C				+		+
				–		–

TITLE
132 Final

Linear Tolerances: +/-1/16
Angular Tolerances: 2°30’

LAST UPDATED	UNITS	SHEET
04/01/22	in	1 / 1
THIRD ANGLE PROJECTION	SCALE	SIZE
	1:4	A

Final Grading Rubric for practical exam
Class Name: WLD 132

Name: ______________________________ Date: ______________________

Hold Points are mandatory points in the fabrication process, which require the inspector to check your work. You are required to follow the hold points.

Points Possible	***Hold Points***	***Instructor's Evaluation***
5 points	**Blueprint Interpretation and Material Cut List** 5 points = 0 errors, all parts labeled and sized correctly 3 points = 1 error in part sizing and/or identification 2 points = 2 errors 1 point = 3 errors 0 points = 4 or more errors	
10 points	**Material Layout and Cutting (Tolerances +/- 1/16")** 10 points Layout and cutting to +/-1/16" Smoothness of cut edge to 1/32" 7 points Layout and cutting to +/- 1/8" Smoothness of cut edge to 1/16 **REWORK REQUIRED IF OUT OF TOLERANCE BY MORE THAN 1/8 INCH**	
10 points	**Fit-up and Tack weld (Tolerances +/- 1/16")** 10 points Tolerances +/- 1/16" Straight and square to +/-1/16" 7 Points Tolerances +/- 1/8" Straight and square to +/-1/8" **REWORK REQUIRED IF OUT OF TOLERANCE BY MORE THAN 1/8 INCH**	
15 points	**Weld Quality** Subtract 1 point for each weld discontinuity, incorrect weld size and incorrect spacing sequence.	
28 points	***Minimum points acceptable. This equates to the minimum AWS D1.1 Code requirements.***	
	Total Points	**/40**

WLD 132 GMAW Pulse: Project Assessment Form
Student Name:________________ Date_________

Mild Steel Pulse		
Flat Position	**Assessment**	
Bead Plate		

Horizontal Position	Assessment	Instructor Signature/Date
T-Joint		
Lap Joint		

Vertical Position	Assessment	Instructor Signature/Date
T-Joint		
Lap Joint		

Overhead Position	Assessment	Instructor Signature/Date
T-Joint		
Lap Joint		

Aluminum Pulse	Assessment	Instructor Signature/Date
Horizontal		
T-Joint		
Lap Joint		

Vertical		
T-Joint		
Lap joint		

Overhead		
T-Joint		
Lap Joint		