WLD 222
Gas Tungsten Arc Welding
Aluminum

INDEX

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National Science Foundation
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Course Assignments

Reading

Welding Principles and Applications 7th edition By Larry Jeffus
Chapter 16, Gas Tungsten Arc Welding Equipment , Setup, Operation, and Filler Metals

Math

Practical Problems in Mathematics 6th edition by Robert Chasan
Chapter 39, Bends and Stretchouts of Circular and Semicircular Shapes
Chapter 40, Economical Layouts of Rectangular Plates

Recommended assignments

Complete review question following each assigned chapter

Quizzes

Complete Interactive Quiz in CourseMate for each assigned chapter

Information Sheets:

Introduction to GTAW
Power Sources
Welding Torch
Tungsten Electrodes
Shielding Gas
Filler Material
Set up procedures
Craftsmanship expectations
Visual inspection

Video Training:

"*Gas Tungsten Arc Welding*" by Miller
GTAW 1,2,and 3 of the Miller Modular series
Bergwall GTAW video series (4 videos)

Writing Work Sheets:

Power Sources
Welding Torch
Tungsten Electrodes
Shielding Gas

Welding Projects:

Flat Position (1F or 1G)	Horizontal Position (2F or 2G)	Vertical Position (3F or 3G)	Overhead Position (4F or 4G)
Edge Joint	T-Joint	T-Joint	T-Joint
Corner Joint	Lap Joint	Lap Joint	Lap Joint
Bead Plate	Corner Joint	Corner Joint	Butt Joint
T-Joint	Butt Joint	Butt Joint	

Timeline:

Open-entry, open-exit instructional format allows the students to work their own pace. **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.

Accessing the Interactive ebook for Principles and Applications and Practical Problems in Mathematics

Here is a link to the publishers website that goes over some "getting started" procedures with CourseMate.
http://www.cengage.com/tlconnect/client/product/fcis.do?productId=535

For New Students

Your book bundle will contain an access code for both your Principles and Applications book and the Practical Problems in Mathematics.

For Returning Students

If you have the Seventh Edition of the Principles and Applications book you should have an access code. If not see your instructor. For the math book you will have to go to this site **http://www.cengagebrain.com/shop/isbn/9781111313593** and rent the ebook for either a six month or one year option.
Your math quizzes will be accessible through Desire 2 Learn. Your Instructor will assist you in accessing this.

Course Key There will be a master course key containing all of the courses available on CourseMate. You will find the course you are currently taking and enter the corresponding number in the appropriate area in CourseMate.

Note For each class there will be separate Access code and course key for Principles and Applications and Practical Problems in Mathematics

RECOMMENDED PROCEDURES FOR GTAW OF ALUMINUM

Plate Thickness (in)	Welding Position (a)	Alternating Current (amp)	Electrode (b) Diameter (in)	Argon Gas Flow (c) (cfh)	Filler Rod Diameter (in)	Number of Passes
1/16	F	70-100	1/16	20	3/32	1
	H, V	70-100	1/16	20	3/32	1
	O	60-+90	1/16	25	3/32	1
1/8	F	125-160	3/32	20	1/8	1
	H, V	115-150	3/32	20	1/8	1
	O	115-150	3/32	25	1/8	1
¼	F	225-275	5/32	30	3/16	2
	H, V	200-240	5/32	30	3/16	2
	O	210-260	5/32	35	3/16	2
3/8	F	325-400	¼	35	1/4	2
	H, V	250-320	3/16	35	1/4	2
	O	275-350	3/16	40	1/4	2
½	F	375-450	1/4	35	1/4	3
	H, V	250-320	3/16	35	1/4	3
	O	275-340	3/16	40	1/4	4
1	F	500-600	5/16-3/18	35-40	1/4-3/8	8-10

- **F** = Flat; **H** = Horizontal; **V** = Vertical; **O** = Overhead.
- **Diameters are for standard pure or zirconium tungsten electrodes. Thoriated tungsten electrodes not generally used for AC TIG.**
- Helium is not generally used in AC TIG welding aluminum. When Helium is used flow rates are about twice those used for argon.

Many factors affect a welding procedure other than those listed above. These available guidelines are helpful to give the welder a starting point for machine adjustments.

Some operating variables that affect a weld procedure are:

1. Are length
2. Rate of travel
3. Amount of filler added
4. Joint type
5. Material dimensions
6. Material preparation

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.

Contents of this Packet include

A. Weld Cleanliness and Porosity
B. What is the Arc Plasma in GTAW?
C. Causes of Porosity in Aluminum Welds
D. AC Power to Weld Aluminum
E. DC-EP Current to Weld Aluminum
F. DC-EN Current to Weld Aluminum
G. Pure Tungsten vs Zirconiated Electrodes

Weld Cleanliness and Porosity

Aluminum and aluminum alloys are extremely susceptible to porosity resulting from the formation hydrogen gas trapped in the molten weld pool. Unlike other metals, liquid aluminum (and liquid copper) is capable of dissolving large volumes of hydrogen into the molten weld pool. The problem occurs during solidification of the weld. The solubility of hydrogen in solidified aluminum drops precipitously to zero. Thus, all of the hydrogen which was dissolved in the molten weld metal, must now form gas bubbles and float out of the weld pool. Unfortunately, the weld cooling rates are so fast that most of the bubbles are trapped in the solidifying weld, leaving gas porosity. Small, fast-cooling welds produce many small pores while large slower-cooling welds produce fewer but larger pores. In any case, eliminating porosity from aluminum welds can only be achieved by good workmanship and clean welding practice.

Unlike steel, it takes very little hydrogen to cause porosity in aluminum. Of course, if there were no source of hydrogen in GTAW of aluminum, there would be no porosity. As a result, it may seem like the plate, consumables and welding practice are "clean", but, a great deal of porosity can still occur.

Compared to SMAW, FCAW and GMAW, weld metal deposited by GTAW can be free of porosity and contamination of any kind. GTAW is an extremely clean and hydrogen-free process. The tungsten electrode and the molten metal pool are protected by the argon shielding gas used in welding. If the welder uses an extra long arc (higher voltage) on a humid day, moisture from the air can be entrained into the arc particularly if the gas flow through the gas lens is turbulent. Once moisture reaches the high temperature arc, the water molecule immediately dissociates into hydrogen (H) and oxygen (O) as shown below:

$$H_2O \Rightarrow 2H + O$$

Because of the high arc temperature, the hydrogen and oxygen atoms are not only immediately dissociated into monatomic H and O, but also ionized. That is, the hydrogen and oxygen atoms exist as single atoms with their outer valence electron lost to the arc plasma atmosphere (plasmas are discussed in the next section). Ionized H and O are in an activated state. H diffuses into the molten pool, while O forms the chemical stable aluminum oxide, Al_2O_3. The aluminum oxide remains at the top of the weld pool. Since aluminum can never form a stable aluminum hydride compound, the H in the arc atmosphere simply dissolves in the molten aluminum in a liquid solution. Just like salt dissolves in water, the hydrogen gas is dissolved in molten aluminum.

What is the Arc Plasma in GTAW?

In order to have a steady sustained arc during GTAW, electricity must be transferred through an electrical conducting "plasma" between the tungsten electrode and the aluminum work-piece. How can this be accomplished if only argon gas is a non-conducting insulator. Argon and helium are inert gaseous elements, which have a full outer shells of electrons. Because argon and helium are considered "inert", they do not undergo any chemical reaction. Argon and helium will not conduct electricity at room temperature. How then is electricity is conducted across the arc?

Fortunately, at elevated temperatures above about 5,000º C, the electrode generates copious electrons by thermionic emission. These energetic electrons collide with the shielding gas (argon or helium) atoms as well as the aluminum atoms in the workpiece causing the stripping away of their outer electrons. Even though argon and helium are normally inert, high energy electrons from the thermionic emitter provides enough energy to knock out electrons from the outer electron shell of both argon and helium atoms. These gas atoms are now in an "ionized" state. These electrons are now free to contribute to current flow during GTAW. The ease with which a gas can be ionized is called the ionization potential or voltage for welding. For example, argon ionizes more readily than helium, so argon has a lower ionization voltage (potential) than helium. At the same time that free electrons are being produced by collisions with thermionic electrons, positive argon ions are also produced. When argon loses an electron, the argon atom becomes a positively charged ion. Since the electrons are small and mobile (compared to the heavy ions), electrons support most of the current conduction. When GTAW with DC-EN, the flow of electrons is from the tungsten cathode to the anode aluminum work-piece. Conversely, the flow of positively charge ions is from the anode to the cathode. For steady arc characteristics, the establishment of a neutral plasma occurs when the net positive ions and negative electrons are equal. Thus the plasma is the state of high temperature ionized gas in the arc containing a balance of positive and negative charges.

Causes of Porosity in Aluminum Welds

Porosity in aluminum and aluminum alloy weld metal is always caused by hydrogen gas contamination, despite attempts by welders to maintain good workmanship. The common sources of porosity are:

1. Long arc length
2. High heat input
3. Inadequate inert gas shielding
4. High humidity
5. Porous oxide layer in aluminum filler metal and plate
6. Oil, paint, and other hydrocarbons in area to be welded
7. High dew point temperature of the inert gas shielding.

Long arc length provides added opportunity for moisture or humidity in the atmosphere to contaminate the gas stream. As mentioned in the previous section, the water moisture forms hydrogen gas in the arc.

High heat input also provides added opportunity for hydrogen atoms to dissolve in the molten aluminum pool. Because the size or surface area of the weld pool increases with increasing heat input, more hydrogen atoms can come into contact with the top of the molten weld pool.

Inadequate shielding gas can occur because the argon gas line is crimped or there is a hole or leak in the gas line. Very little contamination can cause porosity in aluminum welds. If the torch does not have a gas lens, the gas flow may not be laminar. Instead, the flow may become turbulent which easily permits humid air to contaminate the gas stream.

High humidity means that the amount of water vapor or moisture in the air is very high. As a result, humid air contamination can cause more severe porosity than similar contamination of the gas stream by relatively dry air. In manual welding, the arc length varies depending upon the welder's skill and the opportunity for contamination from the atmosphere is always possible.

The oxide layer on the surface of aluminum is always growing in thickness even at room temperature. This oxide is a dull color and it is porous. In fact, the oxide layer acts like a sponge and absorbs moisture from the air as well as oil, grease, and dirt from the surrounding shop. If these faying surfaces are not adequately cleaned before welding, porosity will develop in the aluminum weld metal.

The purity and quality of welding-grade shielding gases are governed by the specification from the American Welding Society, AWS 5.32, as shown in Table 1. This specification not only provides an identification system for shielding gases, but also, it specifies required purity and dew point for individual gases. For example, the required maximum dew point temperature for pure argon is -60°C (-76°F) and the minimum purity of argon gas is 99.997%. The dew point is the temperature below which moisture (impurity) in gas begins to condense into droplets of water. So, argon having a high dew point will contain a large volume of moisture, whereas argon having a low dew point temperature will contain very little water.

Table 1 Purity and Dew Point of Common Shielding Gases per AWS A5.32

	Minimum Purity (%)	Maximum Moisture (ppm)	Dew Point Maximum	AWS Classification
Argon	99.997	10.5	-60°C (-76°F)	SG-A
CO_2	99.8	32	-51°C (-60°F)	SG-C
Helium	99.995	15	-71°C (-57°F)	SG-He

AC Power to Weld Aluminum

For most hand-held GTAW applications, AC power is used for the very practical reason of oxide removal or "cleaning action". If GTAW with DC power is used on aluminum, which has not been chemically and/or mechanically cleaned immediately before welding, the thick and porous oxide layer of Al_2O_3 can have a detrimental effect on both integrity and code-acceptability of the joint. DC welding of aluminum is covered in the next section.

When welding aluminum alloys for both flat and out-of-position GTAW, a strong cleaning action is achieved by using AC power and DC-EP. Although other materials like steel may experience a small cleaning effect when welding with electrode positive, the cleaning action in aluminum is so strong that welding procedures depend upon on it for code work. The reason why this cleaning effect takes place only when the electrode is positive is not fully understood. The cleaning action is possibly due to the presence of the thick refractory Al_2O_3 oxide layer protecting the aluminum acts as a capacitor. During GTAW, electrical charge builds up below and above the oxide layer, which is an electrical insulator. When the Al_2O_3 oxide layer has accumulated sufficient electrical charge, the layer physically explodes leaving a clean surface protected by the argon shielding gas. This action not only takes place above the melting point of aluminum (660°C) but also well below its melting point. In fact, the heat-affected zone of the aluminum weld is usually completely cleaned by this action. This dynamic cleaning action is clearly visible by the welder during the GTAW operation. After the weld is finished, the weld and heat-affected zone areas are smooth and brightly cleaned.

DC-EP Current to Weld Aluminum
Since the cleaning action occurs only during the DC-EP part of the AC cycle, why not used DC-EP exclusively, as it is for GMAW? The great advantage of GTAW of aluminum with DC-EP is the maximum possible cleaning effect. Unfortunately, 70% of the heat generated by the arc in GTAW is delivered to the tungsten electrode when using DC-EP. This results in "spitting" and melting of the tungsten electrode at very low current settings. Furthermore, weld penetration with DC-EP is very shallow. Thus, the only limited used of DC-EP is for welding thin sheet, where the current is low enough to prevent melting of the tungsten electrode. Using a larger diameter electrode is also helpful in keeping the tungsten electrode from melting.

DC-EN Current to Weld Aluminum
Although the great majority of GTAW is conducted using AC power, aluminum can be welded with DC-EN current using 100% helium and thoriated tungsten electrodes. The disadvantage of DC-EN current is the total absence of cleaning action. The great advantage of GTAW with DC-EN current is the substantial increase in penetration. DC-EN has become particularly beneficial for automatic GTAW of thick aluminum plate. A further advantage is that smaller diameter electrodes can be used, because only 30% of the heat is used to heat the tungsten electrode with DC-EN.

Compared to AC welding, DC-EN can provide a deeper and narrower weld pool. Unlike AC welding, preheating of thicker aluminum sections is not necessary. In addition, less edge preparation is needed and the groove can be reduced in size so that less filler metal is consumed. Since the heat intensity is greater with DC-EN, the weld pool is formed faster resulting in less distortion of the base metal than with AC. Not only does DC-EN have substantial advantages for GTAW thick aluminum plate, but also DC-EN can also be used for welding thin aluminum at significantly faster travel speeds than with AC.

Pure Tungsten vs Zirconiated Electrodes
When welding with DC-EP or DC-EN, thoriated tungsten electrodes (EWTh-1 or EWTh-2) are always used. However, when GTAW of aluminum with AC current, it is important that the tip of the electrode have a hemispherical shape for better arc action. Both pure tungsten (EWP) and zirconiated tungsten electrodes (EWZr) are used for GTAW with AC power. The addition of zirconium oxide to tungsten (EWZr) electrodes provides several advantages over pure tungsten electrodes. The zirconiated electrodes are capable of higher electron emissivities because the zirconium oxide is a better thermionic emitter than pure tungsten. As a result, zirconiated electrodes produce higher welding currents without spitting. Because the thermionic emission temperature for EWZr electrode is lower than that for EWP, a more stable arc can be achieved by using zirconiated electrodes especially of thicker section AC welding.

Set Up Procedure for Welding Aluminum

Material preparation
Cleanliness of material is a critical factor of success in GTAW. All surface contamination must be removed. Use a wire brush to loosen the surface oxides on Aluminum.

You will need

- EWP - (size selected according to material thickness and current range, available in sizes 1/16", 3/32", and 1/8").
- Collet - same size as tungsten.
- Collet holder - same size as tungsten.
- Ceramic cup - size will vary with joint type and tungsten diameter.
- Filler metal

Tungsten Preparation
A "balled" or rounded taper is used for welding aluminum. This is done because it allows for a wider cleaning action during welding.

During the reverse polarity half cycle of the A.C., the ionization of the gas bombards the weld surface. Direction of current flow during the reverse polarity half cycle is from the work (-) to the electrode (+). This direction of flow lifts the oxides from the weld surface, resulting in the "cleaning action."

The ball my be formed in two ways:

A. Increasing the amperage range to the maximum recommended for the tungsten diameter and initiating the arc will cause the tungsten to consume itself forming the rounded tip. Too much amperage will cause the ball to enlarge or melt off. Vibration of the ball and enlarging of the ball are indications that the current range is too high for the electrode diameter, or the electrode is too small for the current required.

  The ball on the tip of the tungsten **should not exceed 1-1/2 times the tungsten diameter**. The smaller the ball the better because this helps focus the arc.

B. The ball my also be formed by adjusting the polarity switch to DC + DCRP (Direct Current Reverse Polarity) and initiating an arc. In critical applications this is sometimes done on a clean copper bar to avoid contamination of the tungsten. The condition of the tungsten is an important factor in successful weld results. If the tip becomes contaminated during welding, the contaminated portion should be broken off and the tip redressed.

- Ball Tungsten Grind to a point using the grinder designated for tungsten only in GTAW area. Do not grind the end with the red band on it.

Torch Assembly

- Loosen cap of torch until "0" ring is visible.
- Insert tungsten in collet and collet into collet holder. Screw this assembly into front of torch, ***finger tight only.***
- Screw on ceramic cup and adjust tungsten stick out (the distance the tungsten extends beyond the cup). Tungsten stick out will vary with joint type. Stick out should be long enough to insure proper arc length but should not exceed your cup diameter to insure proper shielding
- Tighten torch cap to secure tungsten position ***finger tight only.***
  Machine Adjustment
- Polarity switch should be set on alternating current with high frequency on continuously (ACHF).
- Current range is adjusted by setting coarse adjustment and fine adjustment according to electrode diameter, material thickness and weld joint requirement.
- Remote/Standard switch - set on remote.
- Post flow timer adjusted to sufficiently shield tungsten and weld crater.
- High frequency switch should be in continuous or "on" position.
- Turn power switch on.
- Turn on gas and water supply at service lines.
- Depress foot control to initiate gas flow and water (if water cooled torch).
- Make sure torch is not in contact with grounded surface or it will arc. Set gas flow rate at 10 - 15 c.f.h. by adjusting knob on flow meter. Check water return line to see that water is flowing.
- Test machine adjustments on a piece of scrap.

Craftsmanship Expectations for Welding Projects

Your instructor will be evaluating your welding projects by the following standards. Read carefully and apply these standards to your project before asking for the instructor's approval.

Steps in completing welding projects:

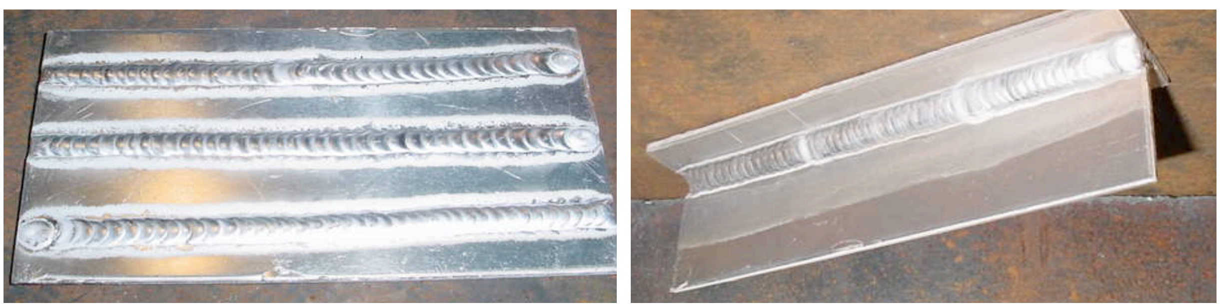
1. Thoroughly read each drawing.
2. Utilize scrap material to adjust machine.
3. Assemble the welding projects per drawing specifications.
4. Review the Welding Procedure portion of the prints to review welding parameter information.
5. Complete welding project. Practice as needed to meet acceptance criteria listed below.
6. Complete the student assessment piece on the project sheet.
7. Submit project to the instructor for the final grading.

Factors for grading welding projects are based on the following criteria

Metal Preparation	***Project Layout***	***Weld Quality***
Thoroughly clean metal	Correct joint assembly (+/- 1/16”)	See chart below

Weld Quality per AWS D1.1

VT Criteria	**Cover Pass**
Weld Size	See specification on drawing
Undercut	1/32” deep
Weld Contour	Smooth Transition
Penetration	N/A
Cracks	None Allowed
Arc Strikes	None Allowed
Fusion	Complete Fusion Required
Porosity	None Allowed
Overlap	None Allowed



Example of a High Quality Weld

GTAW Flat Position Edge Joint (Autogenous/Fuse Weld) Project #1

Objectives of this welding exercise are:

- To learn how to set up and adjust the equipment.
- To develop your ability to control travel speed and arc length.
- Your goal is to fuse the edge surfaces resulting in a smooth rounded contour on all sides of the joint. Note that when "fuse" welding no filler material is added.

Cause and effect factors

Amperage

Too high = undercutting
Too low = lack of fusion on the edges of the joint

Travel Speed

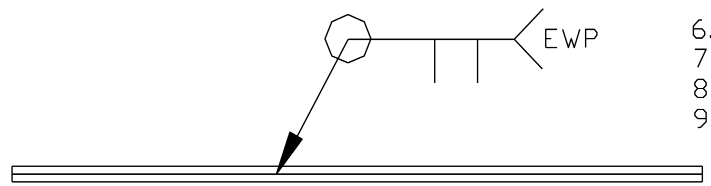
Too slow = excessive heat, irregular shape, burning away of the edge
Too fast = weld does not wrap the edges of the plates leaving them sharp and jagged.

Arc length

Too short = touching the tungsten to the work, contaminating the tungsten and the work.
Too long = undercutting, and can result in loss of gas coverage creating porosity.

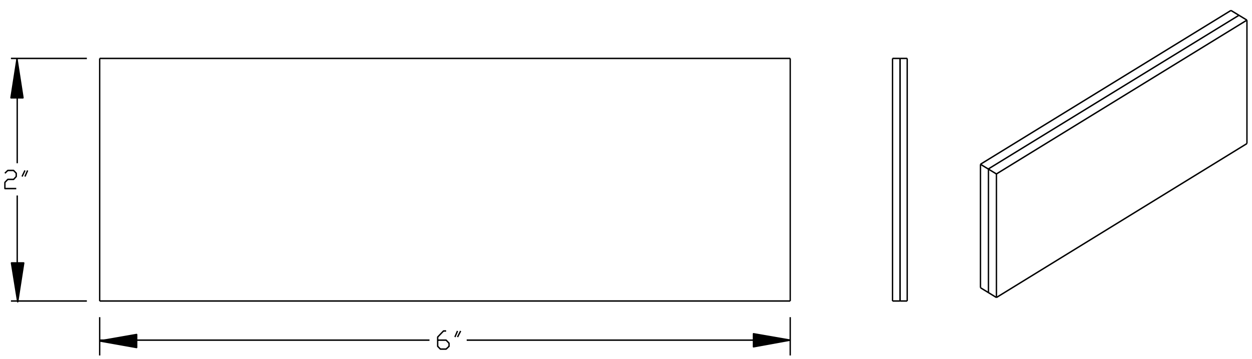
VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	GRADE

WLD 222
Fuse Weld
Flat Edge Joint



Welding Procedure

1. Electrode — EWP
2. Electrode Diameter — 3/32"
3. Current — ACHF
4. Gas — Argon, 15 cfh
5. Material — Aluminum, 16 gage or heavier
6. Filler — none
7. Amperage —
8. Travel Angle — 20° to 30°
9. Work Angle — Varies



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 222-01	
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: TANNER S. 6/30/09	Approve	Date	Sheet

GTAW Flat Position Corner Joint (Autogenous/Fuse Weld) Project #2

Objectives of this welding exercise are:

- To practice set up and adjustment of the equipment.
- To develop consistency in control of travel speed and arc length.
- Your goal is to fuse the edge surfaces resulting in a smooth rounded contour on all sides of the joint. Note that when "fuse" welding no filler material is added.

Cause and effect factors

Amperage

Too high = undercutting, or melting holes through the work
Too low = lack of fusion on the edges of the joint

Travel Speed

Too slow = excessive heat, irregular shape, burning holes
Too fast = weld does not wrap the edges of the plates leaving them sharp and jagged.

Arc length

Too short = touching the tungsten to the work, contaminating the tungsten and the work.
Too long = undercutting, and can result in loss of gas coverage creating porosity.

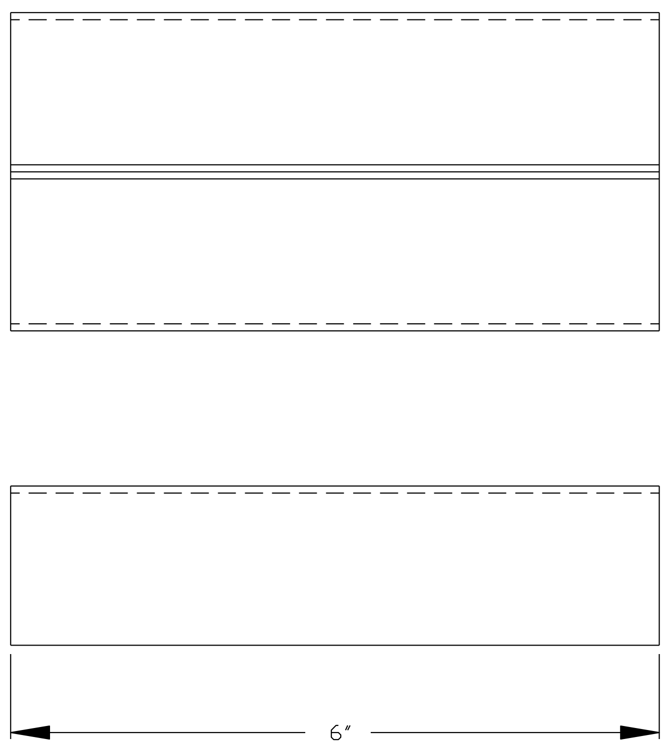
VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	GRADE

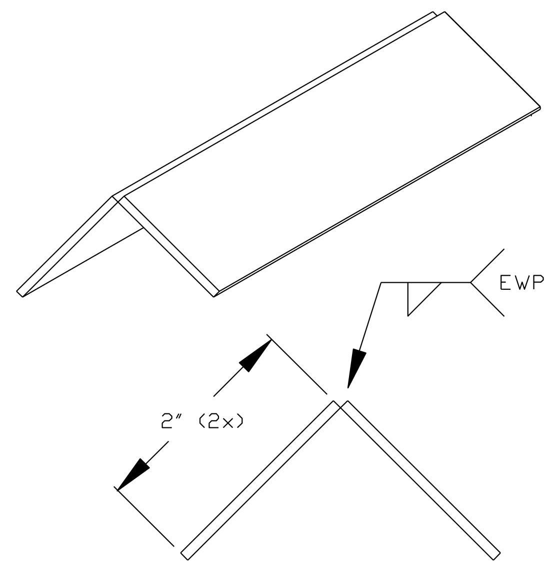
WLD 222

Fuse Weld
Outside Corner (1F)

Welding Procedure

1. Electrode — EWP
2. Electrode Diameter — 3/32″
3. Current Polarity — ACHF
4. Gas — Argon 15 cfh
5. Material — Aluminum, 16 gage or heavier material
6. Amperage — 100-120
7. Travel Angle — 20° to 30° lead
8. Work Angle — Varies





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 222-02

Drawn By: John Deering
Chk By: TANNER SCOTT Date: 6/30/09

Size:	Qc No.	Rev.
Approve	Date	Sheet

GTAW Flat Position Butt Joint — Project #3

Objectives of this welding exercise are:

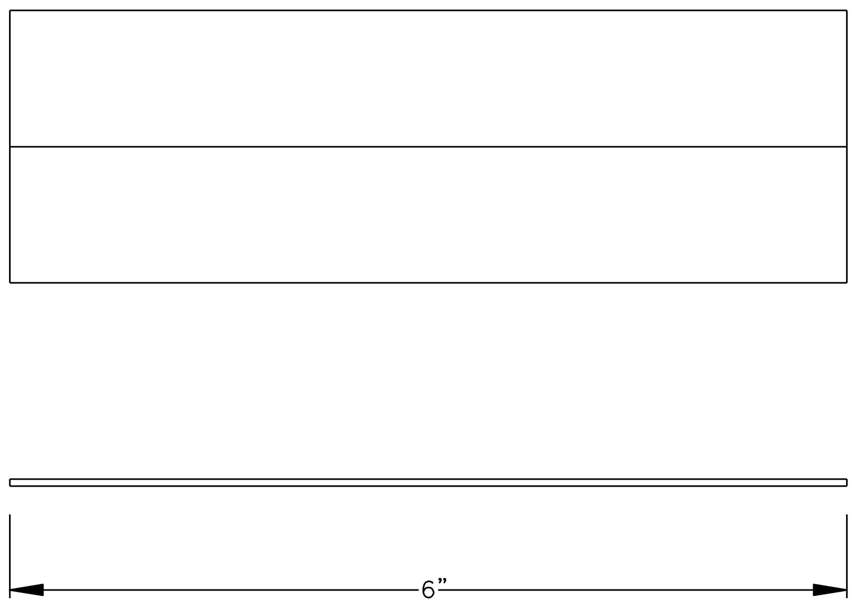
- To practice set up and adjust of the equipment for a different application.
- To develop consistency in your ability to control travel speed and arc length.
- To develop the ability to add filler material to the weld pool.

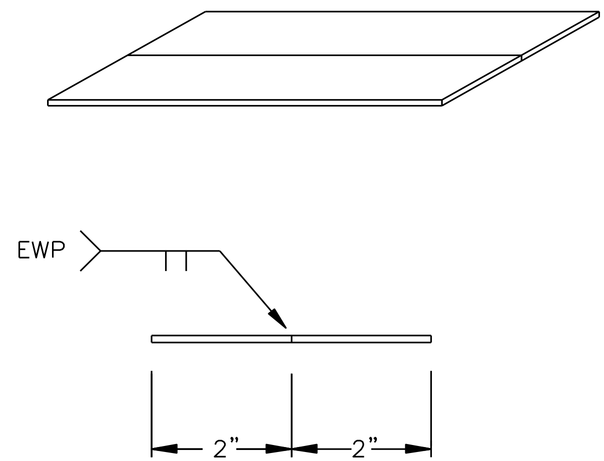
VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	GRADE

WLD 222
Butt Joint
Flat Position (1F)

Welding Procedure

1. Electrode — EWP
2. Electrode Diameter — 3/32"
3. Polarity — ACHF
   Argon, 15 cfh
5. Material — Aluminum, 16 Gage or heaver material
6. Filler — none
7. Amperage — 100-120
8. Travel Angle — 20° to 30°
9. Work Angle — Varies





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 222-03		
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: Tanner Scott Date: 6/30/09	Approve	Date	Sheet

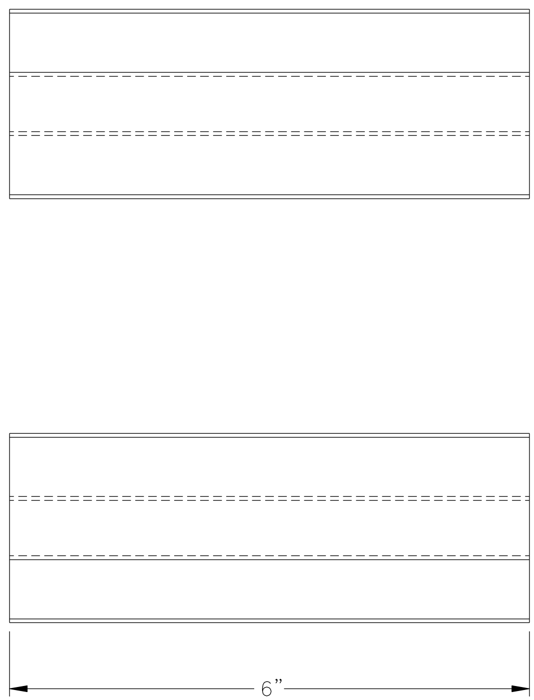
GTAW Flat T Joint   Project #4

Objectives of this welding exercise are:

- To practice set up and adjust of the equipment for a different application.
- To develop consistency in your ability to control travel speed and arc length.
- To develop the ability to add filler material to the weld pool.

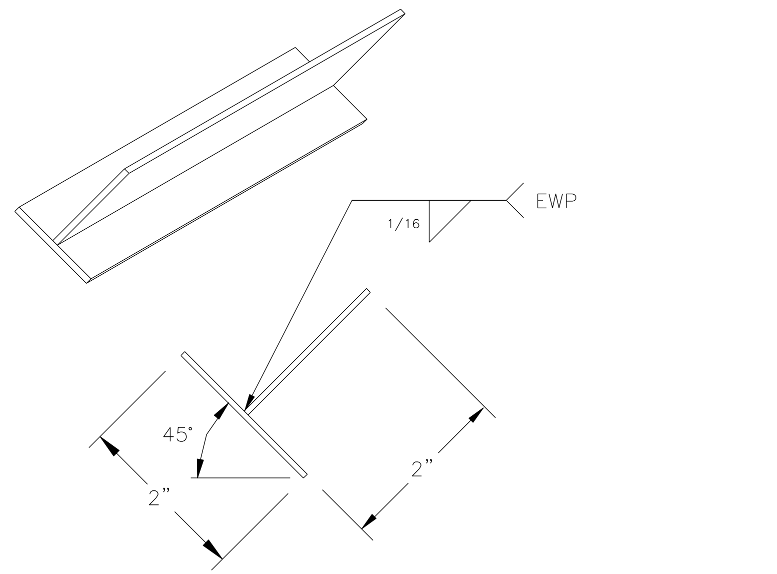
VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	GRADE

WLD 222
T–Joint
Flat Position (1F)



Welding Procedure

1. Electrode — EWP
2. Electrode Diametere — 3/32"
3. Polarity — ACHF
4. Gas — Argon, 15 cfh
5. Material — Aluminum, 16 Gage or heavier
6. Filler — 1/16"–3/32" 4043
7. Amperage — 100–120
8. Travel Angle — 20° to 30° lead
9. Work Angle — Varies



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 222–04			
Drawn By: John Deering	Size:	Qc No.	Rev.	
Chk By: TANNER SCOTT Date: 6/30/09	Approve	Date	Sheet	

GTAW Horizontal T Joint Project #5

Objectives of this welding exercise are:

- To practice set up and adjust of the equipment for a different application.
- To develop consistency in your ability to control travel speed and arc length.
- To develop the ability to add filler material to the weld pool.

VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	GRADE

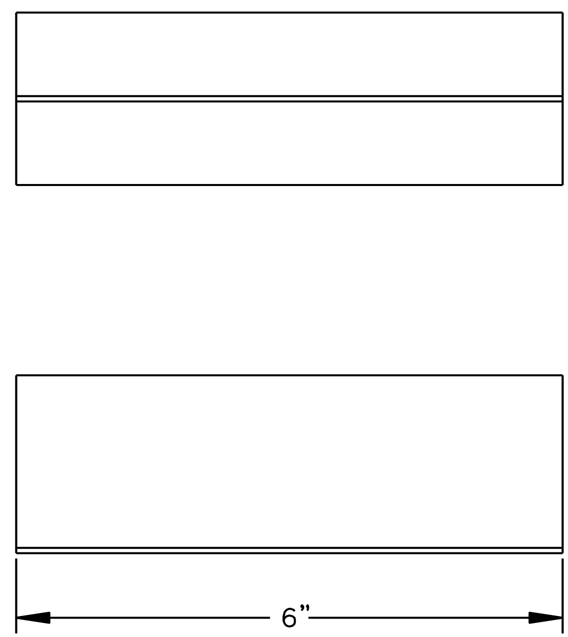
WLD 222

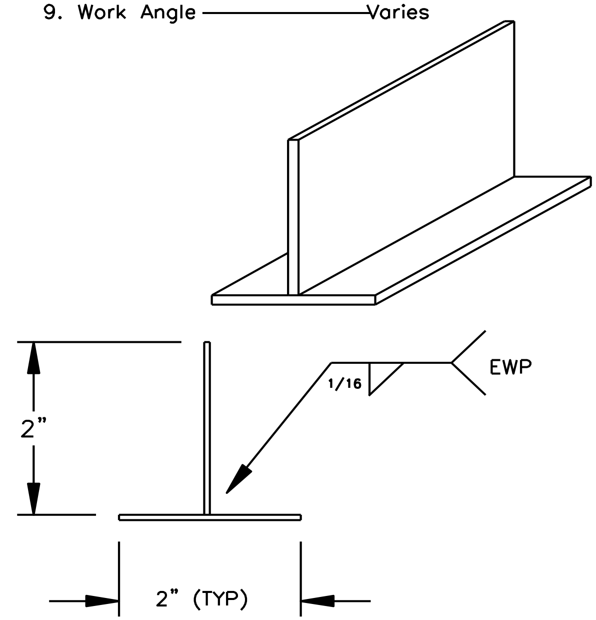
T-Joint

Horizontal Position (2F)

Welding Procedure

1. Electrode — EWP
2. Electrode Diametere — 3/32 or 1/8"
3. Polarity — ACHF
4. Gas — Argon, 15 cfh
5. Material — Aluminum, 16 Gage or lighter material
6. Filler metal — 1/16"-3/32" 4043
7. Amperage — 100-120
8. Travel Angle — 20° to 30° lead
9. Work Angle — Varies





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 222-05		
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: TANNER SCOTT Date: 6/30/09	Approve	Date	Sheet

GTAW Horizontal Lap Joint Project #6

Objectives of this welding exercise are:

- To practice set up and adjust of the equipment for a different application.
- To develop consistency in your ability to control travel speed and arc length.
- To develop the ability to add filler material to the weld pool.

VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	**GRADE**

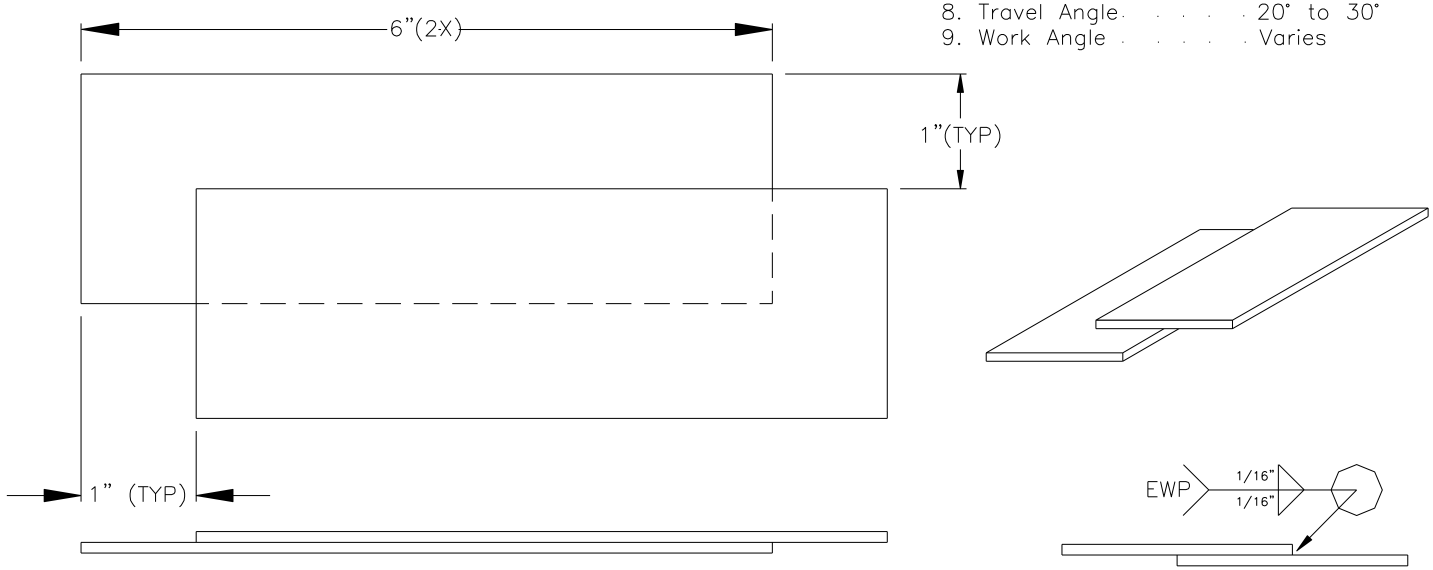
WLD 222

Lap joint

Horizontal Position (2F)

Welding Procedure

1. Electrode . . . . . . EWP
2. Electrode Diameter . 3/32"
3. Polarity . . . . . . ACHF
4. Gas . . . . Argon, 15 cfh
5. Material . . . . . . Aluminum, 16 Gage or heaver material
6. Filler metal . . . . . 1/16"-3/32" 4043
7. Amperage 100-130
8. Travel Angle . . . . 20° to 30°
9. Work Angle . . . . . Varies



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

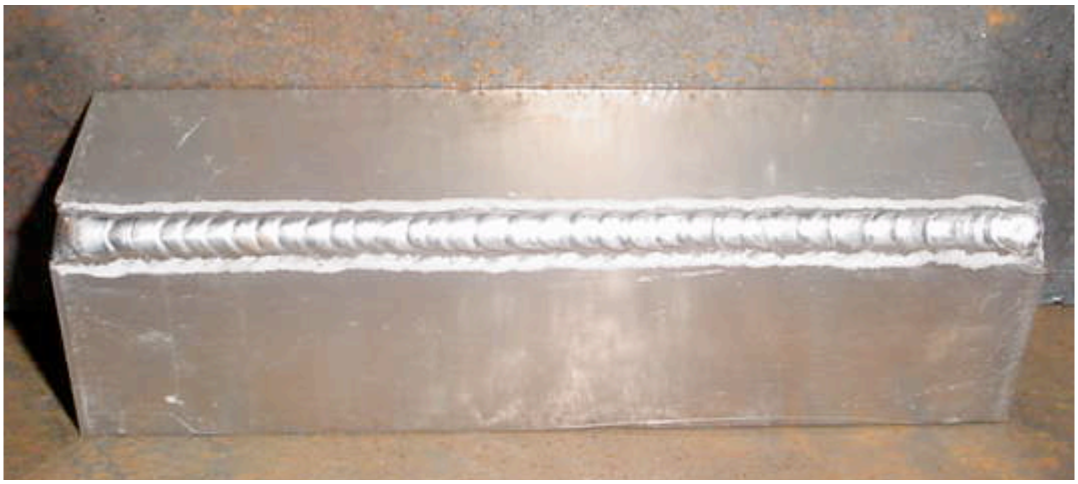
Welding Technology

Tolerance (Unless otherwise Specified) Dimensional ± 1/16" Angle ± 5°		WLD 222-06		
Drawn By: John Deering		Size:	Qc No.	Rev.
Chk By: TANNER S.	Date: 6/30/09	Approve	Date	Sheet

GTAW Horizontal Corner Joint — Project #7

Objectives of this welding exercise are:

- To practice set up and adjust of the equipment for a different application.
- To develop consistency in your ability to control travel speed and arc length.
- To develop the ability to add filler material to the weld pool.



VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	GRADE

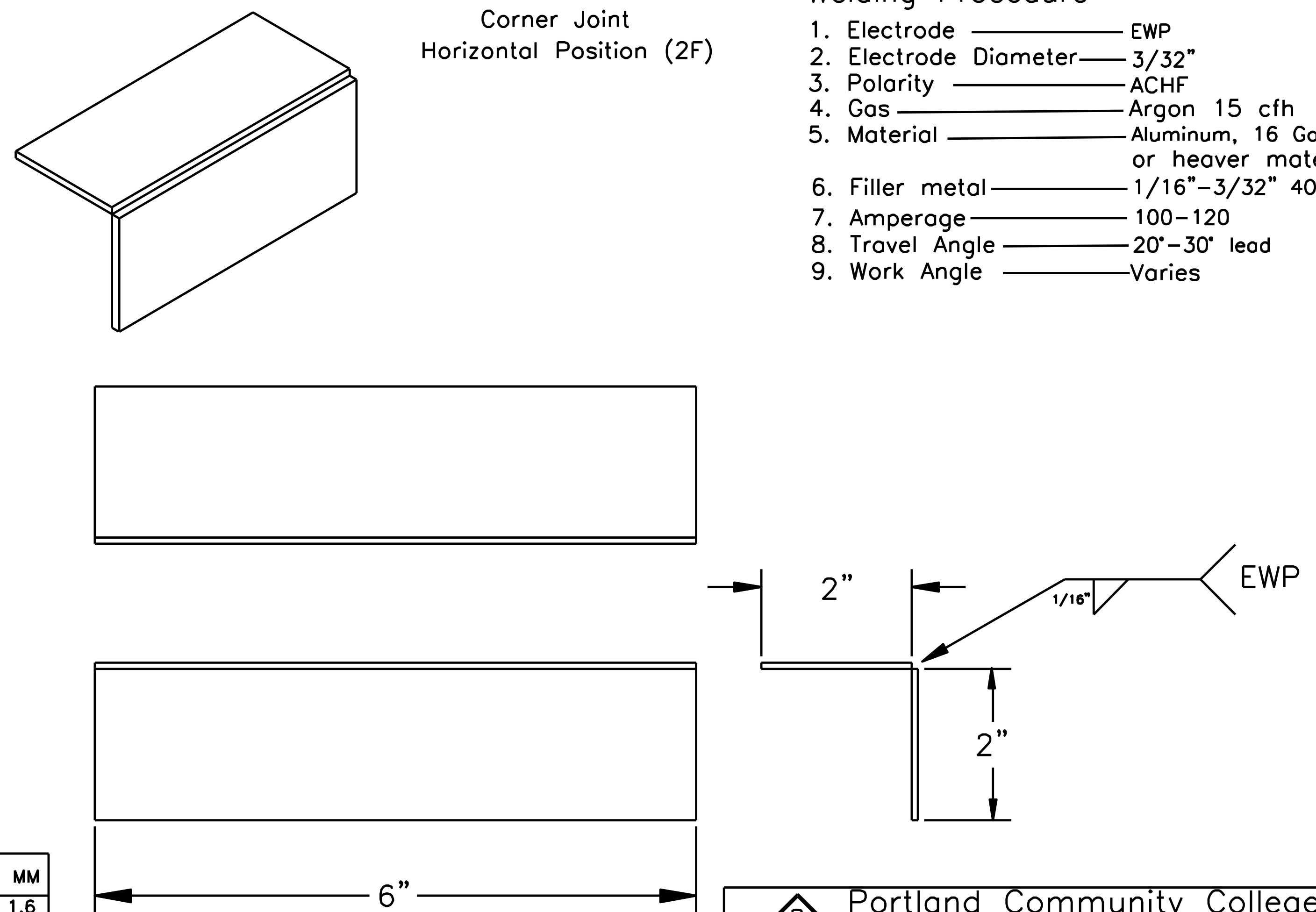
WLD 222

Corner Joint

Horizontal Position (2F)

Welding Procedure

1. Electrode —— EWP
2. Electrode Diameter —— 3/32"
3. Polarity —— ACHF
4. Gas —— Argon 15 cfh
5. Material —— Aluminum, 16 Gage or heaver material
6. Filler metal —— 1/16"–3/32" 4043
7. Amperage —— 100–120
8. Travel Angle —— 20°–30° lead
9. Work Angle —— Varies



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 222-07		
Drawn By: John Deering		Size:	Qc No.	Rev.
Chk By: TANNER SCOTT	Date: 6/30/09	Approve	Date	Sheet

GTAW Horizontal Butt Joint Project #8

Objectives of this welding exercise are:

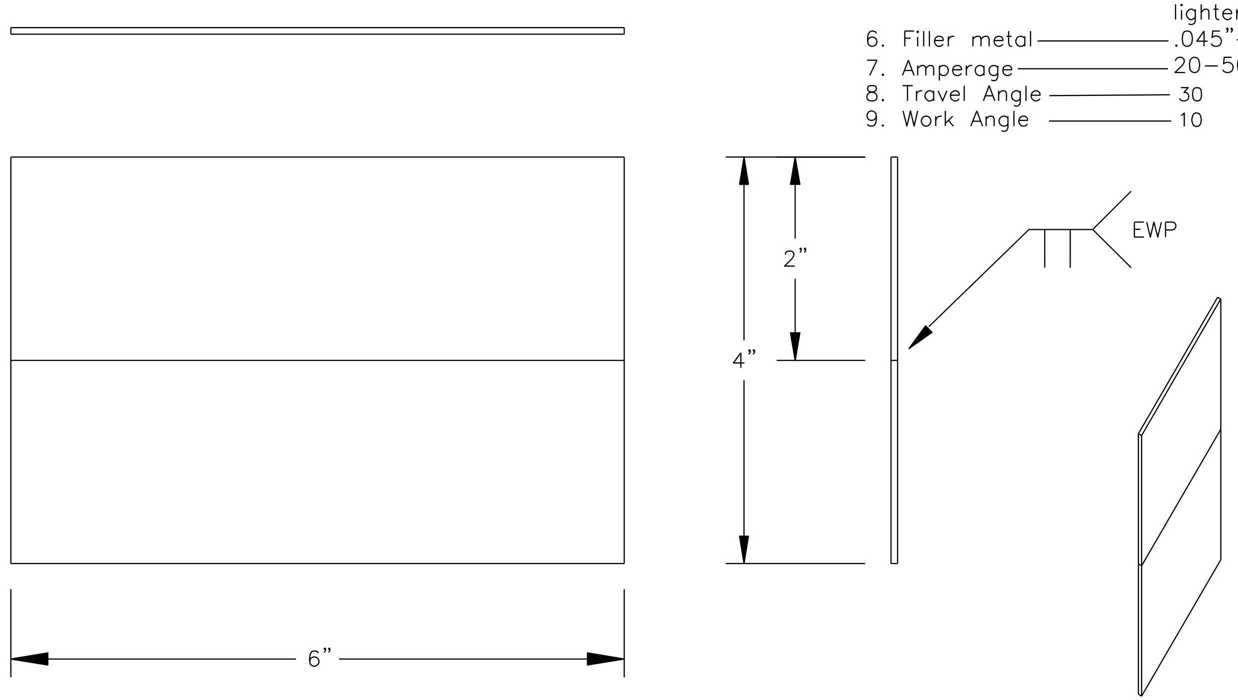
- To practice set up and adjust of the equipment for a different application.
- To develop consistency in your ability to control travel speed and arc length.
- To develop the ability to add filler material to the weld pool.

VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	GRADE

WLD 222
Butt Joint
Horizontal Position

Welding Procedure

1. Electrode — EWP
2. Electrode Diameter — 3/32”
3. Polarity — ACHF
4. Gas — Argon 15 cfh
5. Material — Aluminum, 16 Gage or lighter material
6. Filler metal — .045”–1/16” 4043
7. Amperage — 20–50
8. Travel Angle — 30
9. Work Angle — 10



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 222-08		
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: TANNER SCOTT Date: 6/30/09	Approve	Date	Sheet

GTAW Vertical T Joint — Project #9

Objectives of this welding exercise are:

- To practice set up and adjust of the equipment for a different application.
- To develop consistency in your ability to control travel speed and arc length.
- To develop the ability to add filler material to the weld pool.

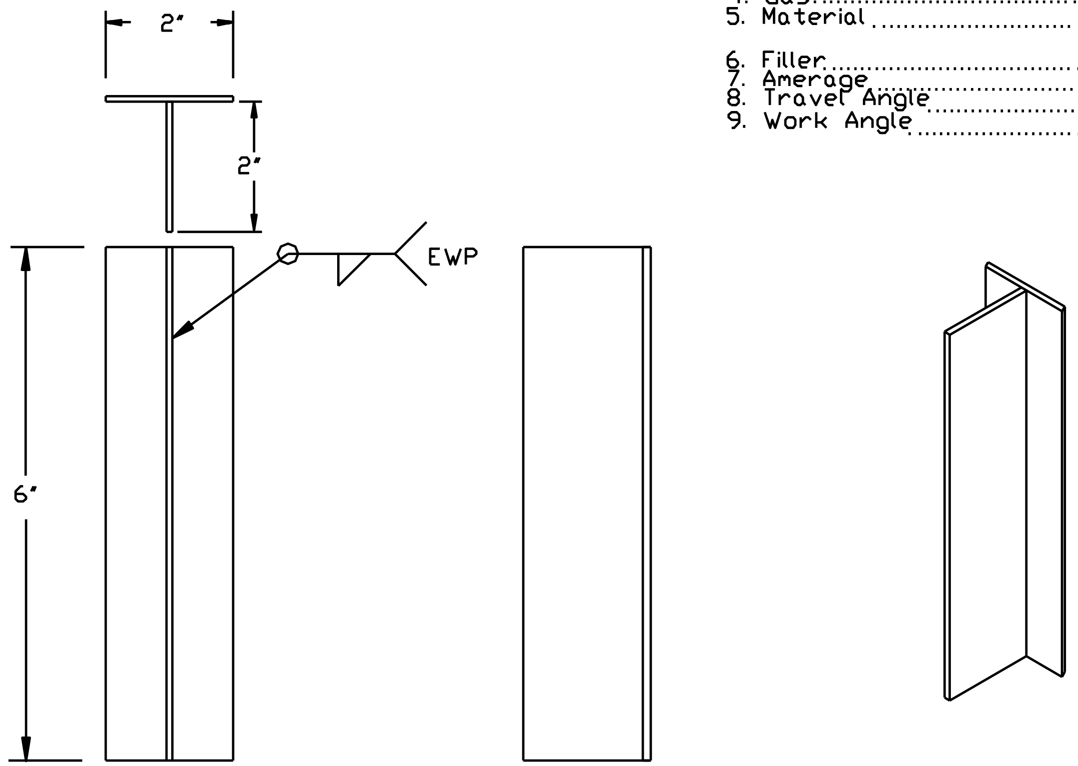
VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	GRADE

WLD 222

T-Joint
Vertical Position (3F)

Welding Procedure

1. Electrode........................ EWP
2. Electrode Diameter........ 3/32 or 1/8"
3. Polarity.............................ACHF
4. Gas.................................. Argon 15 cfh
5. Material .... Aluminum, 16 Gage or heaver material
6. Filler.................................1/16'-3/32" 4043
7. Amerage............................110- 130
8. Travel Angle......................20°-30° lead
9. Work Angle....................... Varies



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 222-09		
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: TANNER SCOTT Date: 6/30/09	Approve	Date	Sheet

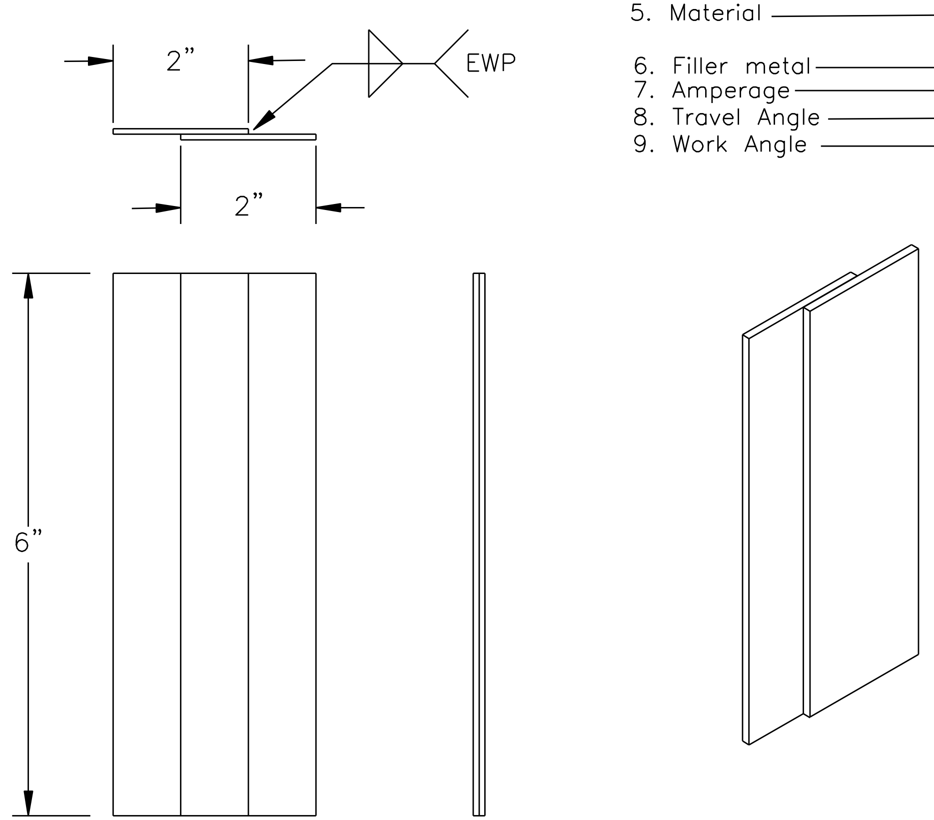
GTAW Vertical Lap Joint Project #10

Objectives of this welding exercise are:

- To practice set up and adjust of the equipment for a different application.
- To develop consistency in your ability to control travel speed and arc length.
- To develop the ability to add filler material to the weld pool.

VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	GRADE

WLD 222
Lap Joint
Vertical Position (3F)



Welding Procedure

1. Electrode —— EWP
2. Electrode Diameter —— 3/32"
3. Polarity —— ACHF
4. Gas —— Argon, 15 cfh
5. Material —— Aluminum, 16 Gage or heaver material
6. Filler metal —— 1/16"–3/32" 4043
7. Amperage —— 100–130
8. Travel Angle —— 20° to 30°
9. Work Angle —— Varies

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 (WxHxL)	S.I. Conversion

Portland Community College
Welding Technology

Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°

WLD 222–10

Drawn By:
John Deering

Size: | Qc No. | Rev.

Chk By: TANNER SCOTT Date: 6/30/09

Approve | Date | Sheet

GTAW Vertical Position Corner Joint   Project #11

Objectives of this welding exercise are:

- To practice set up and adjust of the equipment for a different application.
- To develop consistency in your ability to control travel speed and arc length.
- To develop the ability to add filler material to the weld pool.

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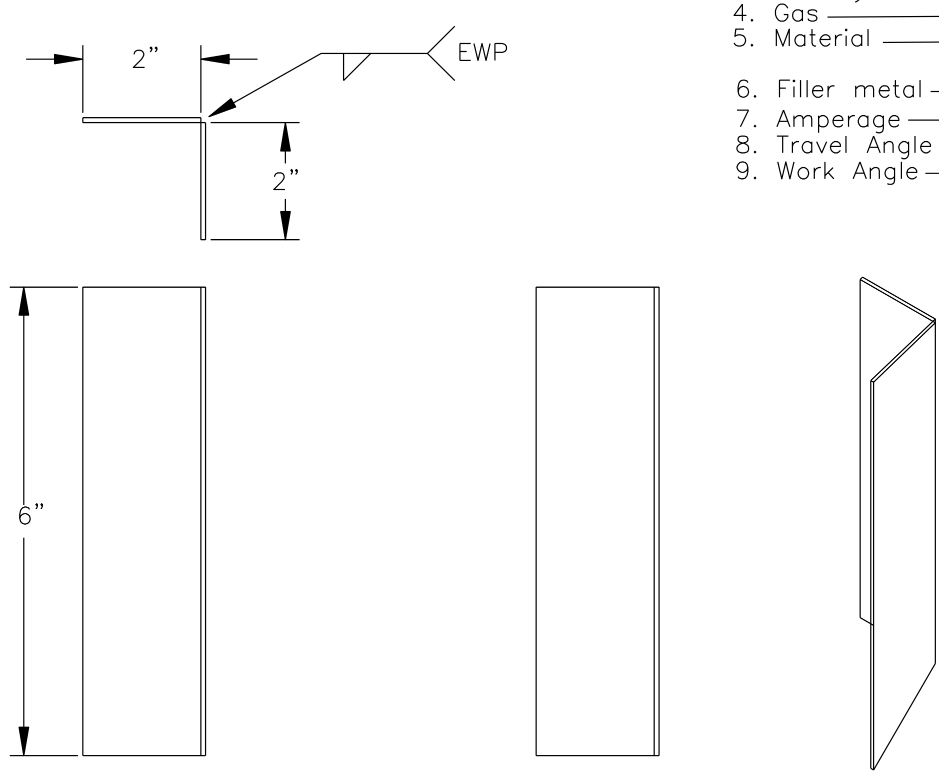
VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	GRADE

WLD 222
Corner Joint
Vertical Position (3F)



Welding Procedure

1. Electrode — EWP
2. Electrode Diametere — 3/32"
3. Polarity — ACHF
4. Gas — Argon, 15 cfh
5. Material — Aluminum, 16 Gage or heaver material
6. Filler metal — 1/16'–3/32" 4043
7. Amperage — 100–130
8. Travel Angle — 20° to 30°
9. Work Angle — Varies

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 222–11		
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: TANNER SCOTT Date: 6/30/09	Approve	Date	Sheet

GTAW Vertical Position Butt Joint   Project #12

Objectives of this welding exercise are:

- To practice set up and adjust of the equipment for a different application.
- To develop consistency in your ability to control travel speed and arc length.
- To develop the ability to add filler material to the weld pool.

VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	GRADE

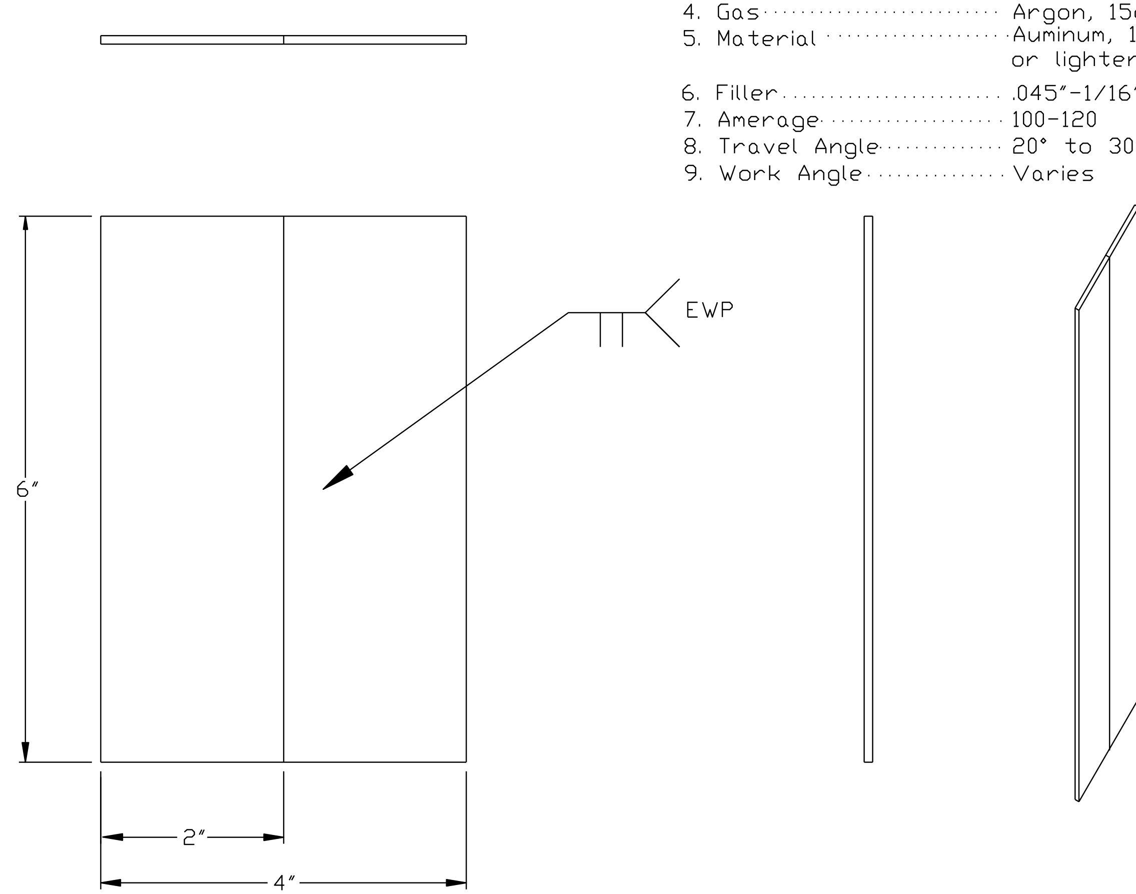
WLD 222

Vertical Position

Butt Joint

Welding Procedure

1. Electrode .... EWP
2. Electrode Diameter ... 3/32"
3. Polarity .... ACHF
4. Gas .... Argon, 15cfh
5. Material .... Auminum, 16 Gage or lighter material
6. Filler .... .045"-1/16" 4043
7. Amerage 100-120
8. Travel Angle .... 20° to 30° lead
9. Work Angle .... Varies



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

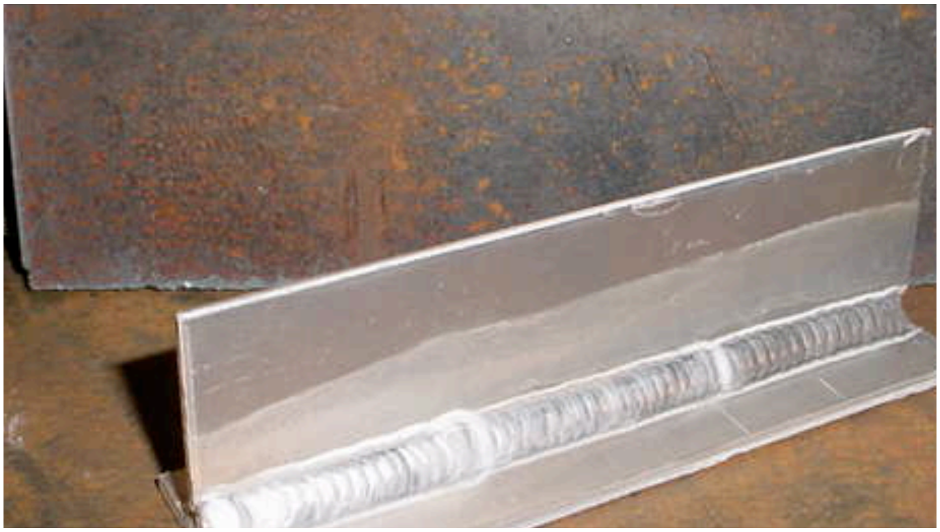
Welding Technology

Tolerance (Unless otherwise Specified) Dimensional ± 1/16" Angle ± 5°	WLD 222-12		
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: TANNER SCOTT Date: 6/30/09	Approve	Date	Sheet

GTAW Overhead Position T Joint   Project #13

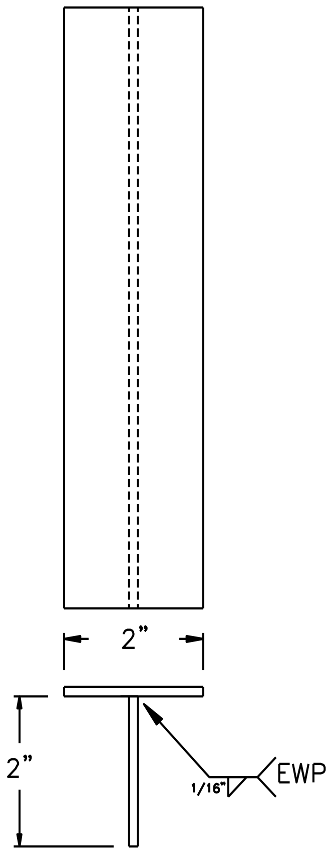
Objectives of this welding exercise are:

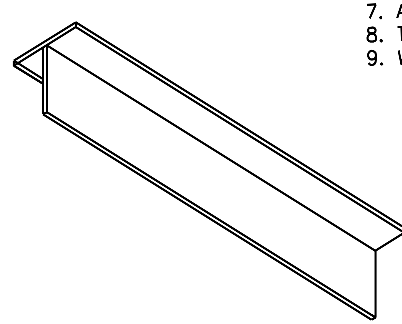
- To practice set up and adjust of the equipment for a different application.
- To develop consistency in your ability to control travel speed and arc length.
- To develop the ability to add filler material to the weld pool.

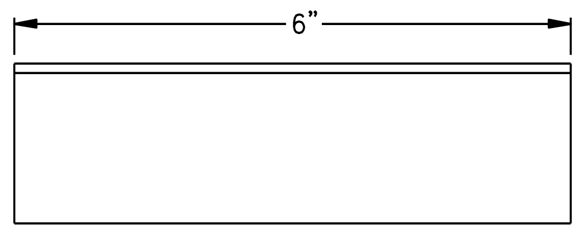


VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	GRADE

WLD 222
T–Joint
Overhead Position (4F)







Welding Procedure

1. Electrode .... EWP
2. Electrode Diameter ..... 3/32"
3. Polarity.................. ACHF
4. Gas .... Argon
5. Material.................. Aluminum, 16 Gage or lighter material
6. Fillermetal .... 1/16"–3/32" 4043
7. Amerage.................. 100–130
8. Travel Angle .... 20° to 30° lead
9. Work Angle .... Varies

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

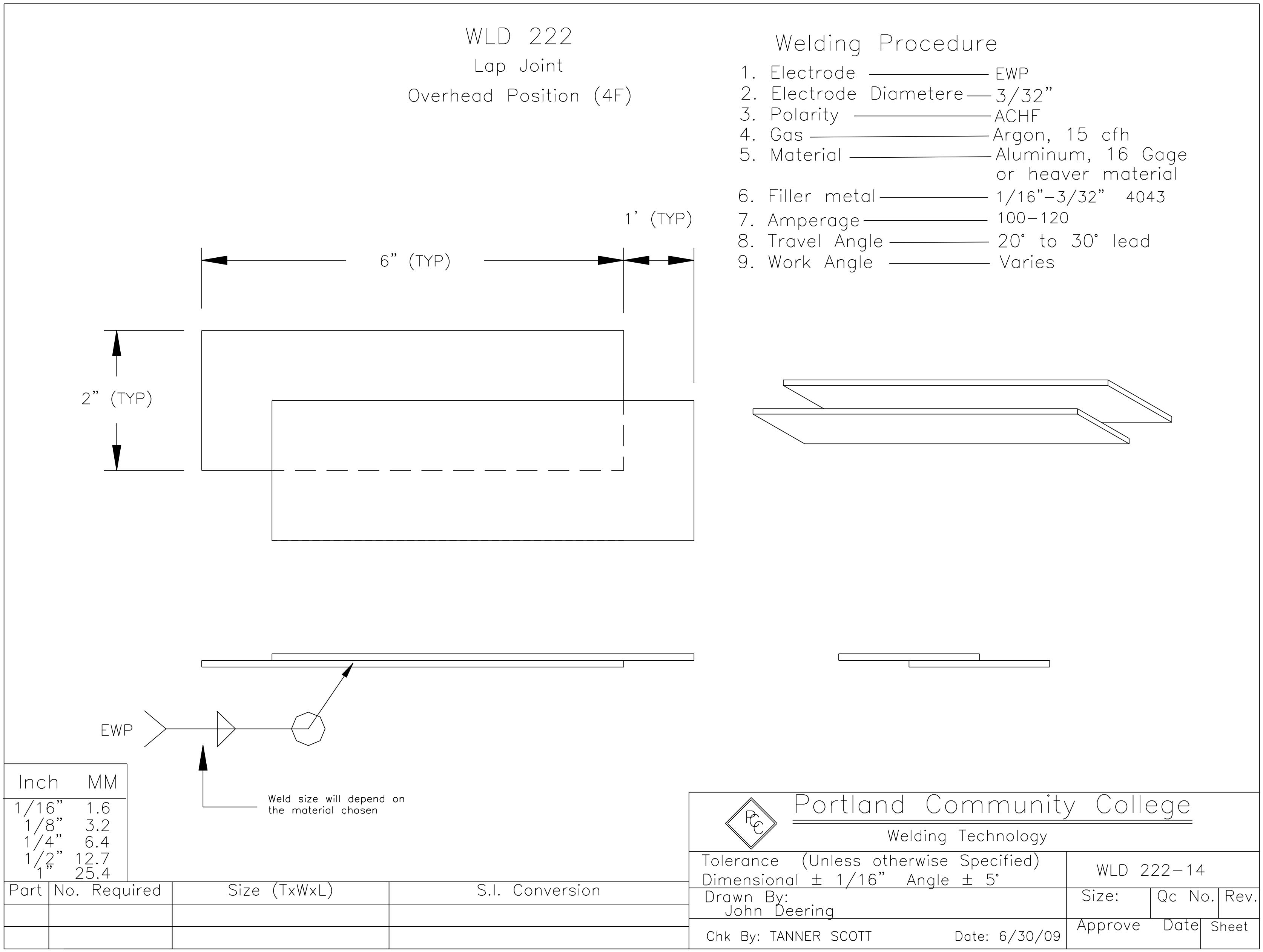
Tolerance (Unless otherwise Specified) Dimensional ± 1/16" Angle ± 5°	WLD 222–13		
Drawn By: John Deering	Size:	Qc No.	Rev.
Chk By: TANNER SCOTT Date: 6/30/09	Approve	Date	Sheet

GTAW Overhead Position Lap Joint Project #14

Objectives of this welding exercise are:

- To practice set up and adjust of the equipment for a different application.
- To develop consistency in your ability to control travel speed and arc length.
- To develop the ability to add filler material to the weld pool.

VT Criteria	Student Assessment	Instructor Assessment
Weld Size		
Undercut		
Weld Contour		
Penetration		
Cracks		
Arc Strikes		
Fusion		
Porosity		
Overlap		
	Completed	Grade


WLD 222
Lap Joint
Overhead Position (4F)
Welding Procedure
1. Electrode — EWP
2. Electrode Diametere — 3/32"
3. Polarity — ACHF
4. Gas — Argon, 15 cfh
5. Material — Aluminum, 16 Gage or heaver material
6. Filler metal — 1/16"-3/32" 4043
7. Amperage — 100-120
8. Travel Angle — 20° to 30° lead
9. Work Angle — Varies
6" (TYP)
1' (TYP)
2" (TYP)
EWP
Weld size will depend on the material chosen
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 222-14
Drawn By: John Deering
Size: Qc No. Rev.
Approve Date Sheet
Chk By: TANNER SCOTT Date: 6/30/09

Final Exam

Part One
This portion of the final exam is a closed book test. You may use the review questions you completed at the end of the assigned chapters as a cheat sheet. Consult with your instructor to determine items that you may need to review. Once you determine that you are ready for the exam, see your instructor.

Study Guide

Safety

- GTAW safety
- Hand Tool Safety

GTAW Processes

- Power source specifics
  - Polarity
  - Current out put
  - High Frequency
  - Shielding gases
- AWS electrode classification

Welding Symbols and Blueprints

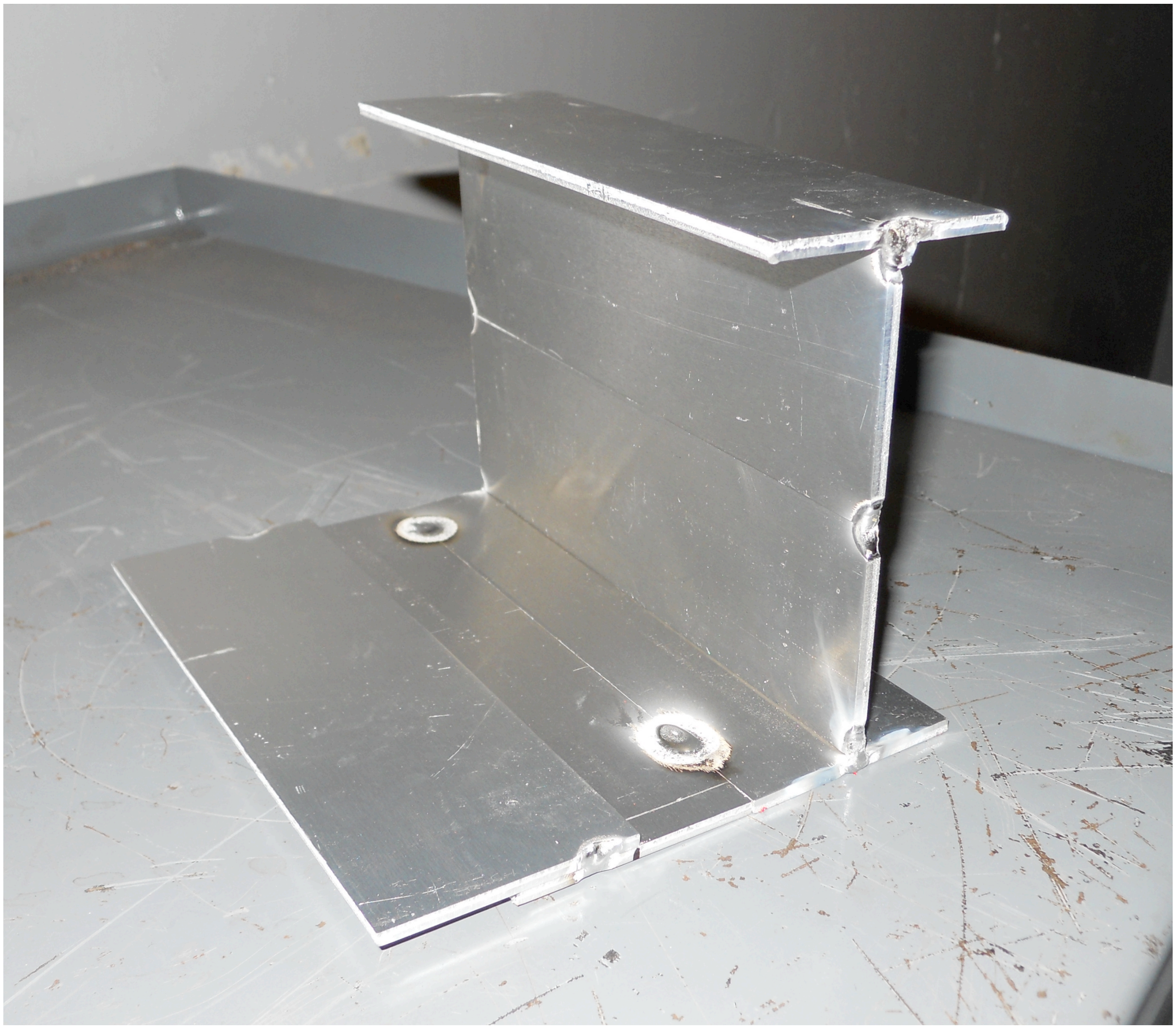
- Orthographic views
- Isometric views
- Welding symbol
  - Weld symbols
  - Reference line
  - Tail

Math and Math conversions

- Adding and subtracting fractions
- Reading a tape measure
- Metric conversions

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 ***Traveler***.



WLD 222

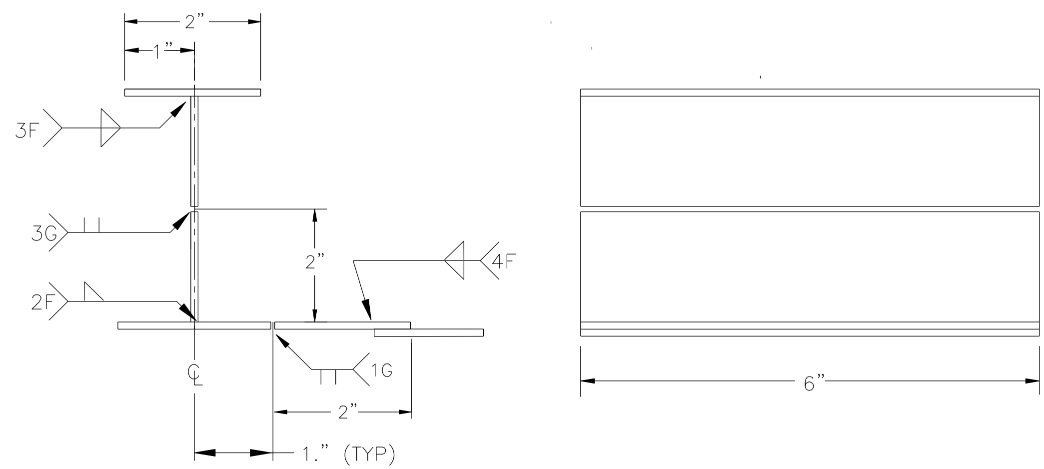
GTAW Aluminum Final

NOTE: UNLESS OTHERWISE SPECIFIED
1. Some hidden lines omitted for clarity.
2. Tack in any sequence and in several spots to control distortion
3. Weld in position specified by welding symbol

1G = Flat Butt
2F = Horizontal Fillet
3F = Vertical Fillet
4F = Overhead Fillet

Welding Procedure

1. Electrode . . . . EWP
2. Polarity . . . . ACHF
3. Gas . . . . Argon 15 cfh
4. Material . . . . 10 gage Alumin.
5. Filler 4043



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: 8/21/08

WLD 222
GTAW Aluminum Final
Size: Qc No. Rev.
Approve Date Sheet

Grading Traveler for the WLD 222 Practical Exam

Name:________________________________ Date______________________

Hold Points are mandatory points in the fabrication process, which require the inspector to check your work. You will have the following hold points that you instructor will check

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 or more rework required (max points)	
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" 5 points (Rework required max points) Layout and cutting to +/-3/16" Smoothness of cut edge to 3/32"	
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" 5 Points (Rework required - Max points) Tolerances +/- 3/16" Straight and square to +/-3/16"	
15 points	**Weld Quality** Subtract 1 point for each weld discontinuity, incorrect weld size and incorrect spacing sequence.	
35 points	***Minimum points acceptable. This equates to the minimum AWS D1.1 Code requirements.***	
	Total Points	**/40**

Final Grades - WLD 222

Name: ________________ Instructor: ___________________ Date: __________________

Welding Projects = 40%

Out of 10	Out of 10	Out of 10
Out of 10	Out of 10	Out of 10
Out of 10	Out of 10	~~Out of~~
Out of 10	Out of 10	~~Out of~~
Out of 10	Out of 10	~~Out of~~
Out of 10	Out of 10	~~Out of~~
A Total Project pts. ________ / Total pts. Possible _______ X 40 = _______ %		

Quizzes = 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 = _______ %		

Attendance = 10% 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 10 = _______ %					

Final Exams 30%

Written Exam	Out of
Practical Exam	Out of
E Total Project pts. ________ / Total pts. Possible _______ X 30 = _______ %	
Add Lines A + B + C + D + E. This will give you your Final Grade TOTAL % _________ FINAL GRADE_________	