# WLD 112
# Shielded Metal Arc Welding: Mild Steel I (E7018)

# *Index*



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by the
*National Science Foundation*
Opinions expressed are those of the authors
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# *Introductory Statement*

Weld 112, ***Shielded Metal Arc Welding: Mild Steel I (E7018)*** is an intermediate welding course offered at Portland Community College. This class will assist the student in developing the techniques needed when using low hydrogen electrodes. This course utilizes a lecture/lab format includes classroom discussions and lab demonstrations. Student will develop knowledge and manipulative skills in the use of E7018 mild steel electrodes when performing various welds in the flat, horizontal and vertical positions. Topics covered will include safety, uses, nomenclature, equipment operation and set-up and shutdown procedures for oxy-acetylene cutting and shielded metal arc welding.

This is an outcome-based course that will allow the student to work at his/her own pace. The student will be required to follow all safety regulations and complete common cutting and welding projects in accordance with industry standards. The student is expected to complete all the exercises within this training packet to receive a grade for this course. Please read the packet and pertaining materials thoroughly and enjoy the course.

# *INTENDED OUTCOMES FOR THE COURSE*

### Function safely in the PCC Welding Shop

- Understand and practice personal safety by using proper protective gear.
- Understand and practice hand and power tool safety.
- Understand and practice equipment safety for welding and oxyacetylene cutting systems.
- Understand and maintain a safe work area.
- Recognize and report dangerous electrical and air/gas hose connections.
- Understand and practice fire prevention.
- Access and explain the importance of Material Safety Data Sheets (MSDS).

### Demonstrate professional work ethics

- Track training hours on time card.
- Perform projects in accordance to specifications and procedures.
- Follow oral and written directions in a positive manner.
- Manage time productively.
- Respects equipment and others.
- Demonstrate skill in problem solving and decision making

### Operate oxyacetylene portable and track cutting systems in accordance with industry standards

- Demonstrate correct setup and shutdown procedures for the hand cutting and track cutting systems.
- Perform oxyacetylene cutting with guided practice.

### Interpret drawing and symbols to accurately layout, prepare and assemble weld joints

- Interpret lines, symbols and verbiage on project drawing.
- Layout material per drawing specifications.
- Use the oxy-acetylene cutting process to cut material to specified dimensions.
- Grind material to meet specifications.
- Assemble weld project per specification.

**Weld common joints with the E-7018 electrode to code quality standards in the flat, horizontal and vertical positions.**

- Use correct terminology.
  Define terms used in the SMAW process.
- Equipment identification, setup, shut down, and principles of operation for SMAW.
  Power source identification and adjustment
  Welding lead, connections, inspection, and use.
  Electrode identification, characteristics, and use
- Know essential variables of SMAW by demonstrating the effects of the following variables: current, travel speed, electrode angle and arc length.
- Demonstrate correct welding techniques with E7018.
  Starting and stopping
  Overlapping welds.
  Follow welding procedure.
- Demonstrate correct welding techniques for the following.
  **Flat Position:**
    Bead Plate
    Corner Joint 1F
  **Horizontal**
    T–Joint 2F
    Corner Joint 2F
    Single V Groove Weld 2G
    Flushing Backing Strip
  **Vertical**
    T-Joint 3F
- Demonstrate visual examination principles and practices.

## *Course Assignments*

### Reading

Welding Principles and Applications, Jeffus, Larry.
Chapter 3, Shielded Metal Arc Equipment, Setup, and Operation
Chapter 4, Shielded Metal Arc Welding of Plate
Chapter 20, Welding Joint Design and Welding Symbols

**Math**

Practical Problems in Mathematics, Robert Chasan
Chapter 5, Introduction to Common Fractions
Chapter 6, Measuring Instruments: The Tape Measure, Calipers, and Micrometer
Chapter 7, Addition of Common Fractions
Chapter 8, Subtraction of Common Fractions

**Recommended assignments**

Complete review question following each assigned chapter

**Cutting Projects**

Complete Bill of Materials

**Welding Projects**

E7018 Bead Plate (Surfacing)
E7018 Corner Joint (1F)
E7018 T-Joint (2F)
E7018 Single V Grove Weld (2G)
E7018 T-Joint (3F)

**Final Exam**

Part One (Closed Book Exam)
Part Two (Practical Exam)

**Reference List**

IPTs Metal Trades Handbook, Garby, Ronald and Ashton, Bruce.

**Time Line:**

Open-entry, open-exit instructional format allows the student to work at his/her own pace. It's the student's responsibility for completing all assignments in a timely manner within your pre-scheduled time. 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 test, 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

# Blueprint

# **Reading**

# **Basics**

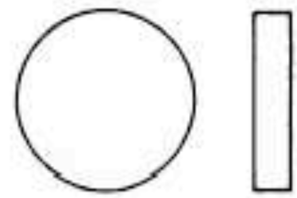
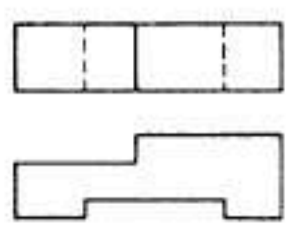
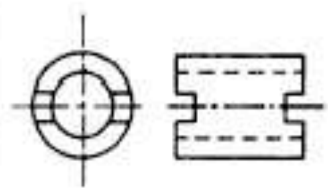
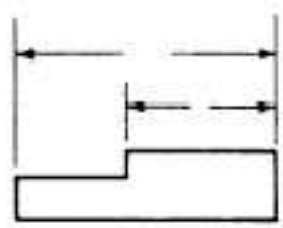
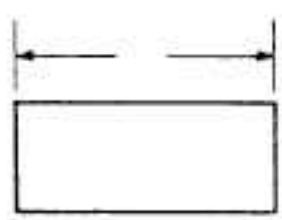
# **for**

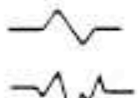
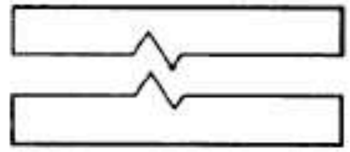
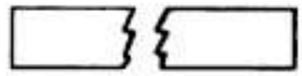
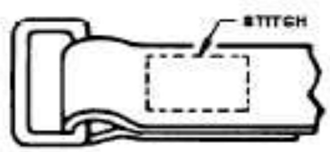
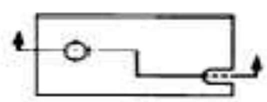
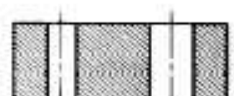
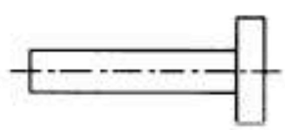
# **Welders**

***Note: your text book has a chapter dedicated to print reading. Make sure you review that too.***

# Definitions of Lines

Lines are the basic communication tool used in blueprints. Listed below are examples of the most common lines used in blueprints today. Take the time to memorize each type of line and know its uses.

| LINE STANDARDS | | | |
|---|---|---|---|
| NAME | CONVENTION | DESCRIPTION AND APPLICATION | EXAMPLE |
| VISIBLE LINES | | HEAVY UNBROKEN LINES<br><br>USED TO INDICATE VISIBLE EDGES OF AN OBJECT |  |
| HIDDEN LINES | | MEDIUM LINES WITH SHORT EVENLY SPACED DASHES<br><br>USED TO INDICATE CONCEALED EDGES |  |
| CENTER LINES | | THIN LINES MADE UP OF LONG AND SHORT DASHES ALTERNATELY SPACED AND CONSISTENT IN LENGTH<br><br>USED TO INDICATE SYMMETRY ABOUT AN AXIS AND LOCATION OF CENTERS |  |
| DIMENSION LINES | | THIN LINES TERMINATED WITH ARROW HEADS AT EACH END<br><br>USED TO INDICATE DISTANCE MEASURED |  |
| EXTENSION LINES | | THIN UNBROKEN LINES<br><br>USED TO INDICATE EXTENT OF DIMENSIONS |  |

| LINE STANDARDS | | | |
|---|---|---|---|
| **NAME** | **CONVENTION** | **DESCRIPTION AND APPLICATION** | **EXAMPLE** |
| BREAK (LONG) |  | THIN, SOLID RULED LINES WITH FREE-HAND ZIG-ZAGS<br>USED TO REDUCE SIZE OF DRAWING REQUIRED TO DELINEATE OBJECT AND REDUCE DETAIL |  |
| BREAK (SHORT) |  | THICK, SOLID FREE HAND LINES<br>USED TO INDICATE A SHORT BREAK |  |
| PHANTOM OR DATUM LINE |  | MEDIUM SERIES OF ONE LONG DASH AND TWO SHORT DASHES EVENLY SPACED ENDING WITH LONG DASH<br>USED TO INDICATE ALTERNATE POSITION OF PARTS, REPEATED DETAIL OR TO INDICATE A DATUM PLANE |  |
| STITCH LINE |  | MEDIUM LINE OF SHORT DASHES EVENLY SPACED AND LABLED<br>USED TO INDICATE STITCHING OR SEWING |   |
| CUTTING-PLANE LINE |  | USED TO DESIGNATE WHERE AN IMAGINARY CUTTING TOOK PLACE |  |
| VIEWING-PLANE LINE |  | USED TO INDICATE DIRECTION OF SIGHT WHEN A PARTIAL VIEW IS USED |  |
| SECTION LINES |  | USED TO INDICATE THE SURFACE IN THE SECTION VIEW IMAGINED TO HAVE BEEN CUT ALONG THE CUTTING-PLANE LINE |  |
| CHAIN LINE |  | USED TO INDICATE THAT A SURFACE OR ZONE IS TO RECEIVE ADDITIONAL TREATMENT OR CONSIDERATIONS |  |

## *Helpful Hints*

### Arc Length E7018

Due to the nature of low hydrogen electrodes it is critical to maintain a short and consistent arc length. This will maximize the shielding gas coverage for the weld puddle. Arc length can be determined by sight and sound.

**1st** If the arc is to long you will see the globular transfer.

**2nd** If it is too short you will see slag wanting to explode from the puddle and you'll hear an electrical humming sound.

**3rd** The correct arc length will be between those two indicators.

**Remember:** The recommended Arc Length is equal to electrode diameter. It should not exceed the diameter of the electrode at any time. If you remember this you'll never have trouble with porosity.

### Starting/Restarting Technique

When starting or restarting the arc it is important to obtain a sound weld. Therefore, the following technique should be employed.

**1st** Locate where you want to start. This is important so that you do not have arc strikes all over the parent material.

**2nd** Utilize the tap or scratch method to initiate the arc.

**3rd** Start the arc directly ahead of the crater.

Once arc is started establish a long arc with an upward stroke initiation. It is here where an extra quick movement is necessary because the E7018 has a high likelihood of sticking, you will need to pull the electrode away quickly but yet maintain a short enough arc to keep it going. This balance is difficult at first, but will come with time.

The purpose of this is as follows:

A. Preheats the parent metal
B. Allows gaseous shield to be established
C. Allows the amperage to flow so the heat will build up
D. Gives off light to find the crater

**4th** Precede back to the crater. Once there, drop the electrode into its normal arc length and circle in the crater and then start to travel with the normal travel speed. By circling in the crater you accomplish two things:

A. Its a timing device used to fill the crater flush with the weld bead.

B. It will help drive out any slag/porosity that may of other wise it becomes entrapped.

The E7018 is easier to initiate with a new rod than a used rod. However, when restarting a used rod, it is important to note that the flux surpasses the core wire. The core wire also tends to have a slag covering on it as well. These two items make it more difficult to initiate the arc. Hence, if you scrap the end of the rod off before striking it will light up easier. Take care not to break away any excessive coatings off the end of the rod. The flux coatings helps stabilize the arc without the flux it will make arc initiation troublesome.

Quick flick technique when terminating your arc will allow a globular ball to fly off the end of the electrode. This glob will take the slag off the end of the rod. Thus allowing an easier restart.

**5th** **REMEMBER:**

The quality of welds produced depends largely upon the skill of the welder. Developing the necessary skill level requires Practice. However, practicing the welds repeatedly without changing techniques will not aid in developing the required skills. Each time a weld is completed it should be evaluated, and then a change should be made in the technique to improve the next weld.

## *Vertical Up Welding Information Sheet*

There are several things to consider when welding in the vertical position. When traveling vertically up, heat control is very important. The following list should be considered when welding vertically up.

### Vertical Welding Technique

1. Controlling your heat
   - Amperage—lower range
   - Plate temperature—cool every 2-3 passes

2. Establishing a puddle (shelf)
   - The width of puddle should be 1/8" larger than electrode diameter measure at the flux

3. Keep a "tight arc"
   - Too long of an arc you'll see globs transfer across arc
   - Too short you'll see slag "bubble ahead of arc

4. Keeping electrode on leading edge of puddle top of flux coating should be at the leading edge of the puddle

5. Travel speed
   - Travel fast enough to keep puddle from "falling out" but slow enough to maintain correct puddle size (see #2).

# *Science*

# *on*

# *Steel*

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



## Characteristics of E7018 Low-Hydrogen Electrodes compared to E7010

Although an all-position electrode, the E7018 electrode provides moderate penetration and build-up. The slag layer is heavy and hard, but easily removed. The iron powder in the flux coating provides about double the deposition rate compared to E7010 electrodes. The molten weld metal is protected from the surrounding air primarily by the molten slag layer and not by the rapidly expanding gases, which is the primary shielding for E7010 cellulosic electrodes. Since E7018 provides only limited gaseous protection and less penetration compared to cellulosic electrodes (for example: E7010), E7018 is not suited for open root passes. Without substantial gaseous protection the open root is susceptible to both hydrogen contamination and porosity because of air and moisture contamination from the back-side of the root. In addition, the weld starting location of an E7018 weld deposit is very susceptible to porosity because of the time-lag associated with the build-up of the thick slag shielding. A short starting tab is recommended when using E7018.

## Why "Low-Hydrogen" prevents Cracking in Welds

Hydrogen is in undesirable impurity in weld metal. The primary source of hydrogen contamination is moisture content ($H_2O$) of the flux coating. Unfortunately, hydrogen is very difficult to eliminate in any flux welding process, such as SMAW, FCAW or SAW, because all fluxes absorb moisture to some extent. When moisture passes through the arc, it dissociates into hydrogen and oxygen as shown:

$$H_2O = 2H + O$$

Other sources of ***hydrogen*** contamination, which are avoidable with good workmanship practices, include: ***oil, grease, paint, dirt, moisture-absorbing rust*** and other hydrogen-containing materials. ***Oil and grease*** are hydrogen-carbons, which dissociate into free hydrogen and carbon dioxide during welding. Although hydrogen does not impair arc stability, it does cause serious cracking in the heat-affected zones of welds deposited on thick and/or high strength steels.

Hydrogen is the smallest atom in the universe and is an "interstitial" (a crystalline lattice containing smaller atoms of a different element within its interstices, voids or holes between the atoms and the lattice) in iron, so hydrogen can diffuse in steel rapidly even at and below room temperature. Interstitial atoms like hydrogen are so small compared to iron that they can diffuse between the iron atoms. That is, the iron atoms do not move while the hydrogen atoms diffuse between the iron atoms. Because the flux coating can absorb moisture from the air, E7018 electrodes that have been removed from their hermetically sealed, moisture/water tight containers must be stored in a baking oven. The electrode exposure to the atmosphere shall not exceed: Four (4) hours maximum. (Table 5.1. AWS D1.1. The oven is set at a temperature recommended by the manufacturer, which is within the temperature range specified by the welding code of interest. For example, the D1.5 Bridge Welding Code specifies baking temperature for E7018 in the range from 250°F to 500°F. Generally, the manufacture's recommendation will fall within this range. The reason for baking the electrodes is to effectively evaporate all traces of water or moisture from the flux coating.

### *Advantages of E7018 Electrode for SMAW*

The E7018 electrode for SMAW is often called "lime" electrode, "basic" electrode and "low-hydrogen" electrode. The three primary functions of E7018 electrodes are to provide (1) all-position capability, (2) weld metal with low hydrogen content for greatest cracking resistance, and (3) Charpy impact toughness typically required for all code work. Outstanding features of E7018 electrode include:

- All-position welding
- Low hydrogen weld deposits
- Tough weld metal (having high Charpy V-notch (CVN) impact toughness)
- Iron powder addition for improved deposition rate
- Required for all welding codes to join thick steel and high strength steels to prevent hydrogen-assisted cracking
- Sound weld deposits (X-ray quality)
- Reduced preheating requirements
- Either DCEP (reverse polarity) of AC can be used
- Moderately heavy slag which is easy to remove

### *Disadvantages of E7018 Electrodes for SMAW*
Compared to the cellulosic Exx10 electrodes such as E6010, the E7018 electrodes have the following disadvantages:
- Can not deposit the root pass on an open root steel pipe as well as E6010
- Can not penetrate as deep as E6010
- Porosity can occur during arc starting
- Susceptible to undercut in up-hill welding

### *Mechanical Properties of Weld Metal deposited by SMAW with E7018*
The specified composition and mechanical properties of weld metal deposited by E7018 are listed in Table 1. Weld metal deposited by SMAW using E7018 electrodes provides excellent strength, ductility, soundness, and most importantly resistance to hydrogen-assisted cracking.

**Table 1** Composition and Mechanical Properties of Weld Metal deposited by SMAW using modern E7018-H4 electrodes

| | | |
|---|---|---|
| E7018 Composition of Weld Metal (wt %) | AWS A5.1<br>C: not specified<br>S: not specified<br>P: not specified<br>Ni: not specified<br>Mn: 1.60 max<br>Si: 0.75 max<br>Cr: 0.20 max<br>Mo: 0.30 max | Typical<br>C: 0.05<br>S: 0.009<br>P: 0.015<br>Mn: 1.40<br>Si: 0.45<br>Cr: 0.05<br>Ni 0.05<br>Mo: 0.03 |
| Mechanical Properties of Weld Metal | Tensile Strength: 72ksi (500MPa) min<br>Yield Strength: 60ksi (420MPa) min<br>% Elongation: 22% min<br>CVN Toughness: 20ft-lbs @ -20°F min | Tensile Strength: 84 ksi (MPa)<br>Yield Strength: 70 ksi (MPa)<br>% Elongation: 30%<br>CVN Toughness: 120ft-lbs @ -20° F |
| Radiographic Soundness per AWS A5.1 | Grade 1 (highest level of integrity) | |
| Diffusible Hydrogen | H4 (4 ml/100g max) | 3 ml/100g |

## *Flux Composition of E7018 Electrode*

E7018 is a low-hydrogen electrode containing a completely different flux coating composition compared to the E6010, E6011 cellulosic electrodes and the E6012 and E6013 rutile electrodes. The mineral flux coating on low-hydrogen E7018 electrodes does not produce much gas shielding but does produce a thick slag that primarily consists of calcium carbonate and calcium fluoride to provide:

- A thick basic slag to cover the molten weld pool with adequately high melting temperature and viscosity to:
    - Protect the molten pool from air contamination, and
    - Assist with out-of-position welding
- Only limited gas shielding to protect against air contamination
- Very low contamination by moisture and hydrogen; for example 4ml/100g (that is: 4ml of hydrogen gas in 100grams of deposited weld metal).
- Low density slag which quickly floats to the top of the weld pool
- Directional mass transfer through the arc for out-of-position welding
- Alloying elements, as needed
- Deoxidizers and desulfurizers to improve weld metal toughness
- Capability to use either DCEP or AC
- Readily detachable slag
- Smooth flat to slightly convex weld contour
- Nearly spatter-free and light fumes

## *Alloy Variations of E7018 Electrodes*

Although all E7018 electrodes possess the same essential properties shown in Table 1, electrodes designated as E7018-1, E7018M, E7018-A1 and E7018-B2L have specific enhancements. Compared to E7018 electrode, weld metal deposited with E7018-1 must provide greater Chary V Notch impact toughness than that shown in Table 1; namely, a minimum of 20ft-lbs (27 J) at -50° F (-10° C). E7018-M is designed for extra low levels of diffusible hydrogen as specified in military code MIL-E-0022200/10. Typical diffusible hydrogen content in weld metal will be less than 4 ml/100g (of deposited weld metal). E7018-A1 contains 0.5Mo for added yield strength and is designed for welding high yield strength steels used in the boiler and pressure vessel industry. Finally, E7018-B2L is a Cr-Mo alloyed electrode with extra low carbon content. It is designed to welding the 1%Cr-.5%Mo steels in boilers, pressure piping, castings and forgings.

## *Iron Powder in E7018 Electrode*

The use of from 25 to 40% iron powder in E7018 has two very beneficial effects. First, the deposition rate of E7018 is nearly doubled compare to all-position electrodes without iron powder, such as E7010. Second, the beneficial effect is the improved arc behavior and reduced spatter with iron powder additions. The reason why iron powder affects the performance of the E7018 electrode is because the iron powder in the covering causes the covering to become electrically conductive near the arc. As a result, the arc tends to spread out radially and deposits over a wider area. The diffuse arc area provides many conductive paths (to the weld pool), thereby limiting current surges when molten metal globules short circuit between the electrode wire and the weld so that spatter is greatly reduced.

### *Baking of E7018 Electrodes*

Unlike Exx10 and Exx11 cellulosic electrodes, the E7018 low-hydrogen must be kept dry for maximum resistance to weld metal cracking. The electrodes are dried at the manufacturing plant and then immediately packed in hermetically sealed steel cans to preserve the low moisture (low hydrogen) properties. However, as soon as the hermetically sealed can is opened and E7018 electrodes are redrawn for use, humidity in the air slowly deposits moisture in the coating. This is why AWS D1.1 Structural Welding Code allows E7018 electrodes to be exposed to the atmosphere for only 4 hours. After 4 hours, the unused electrodes must be returned to the baking oven for the required re-drying cycle. There is no limit to the number of times that the E7018 electrodes can be taken out for 4 hours and returned back to the drying oven.

### *Arc Length and Arc Voltage*

When using E7018 electrodes, it is important keep a relative short arc since there is very little shielding gas produced by the basic flux coating. Since all SMAW is performed with constant current power sources, variations in arc length will cause variations in arc voltage. For example, as the arc length is increased (by raising the electrode), the arc voltage also increases. This is because all of the electric circuits obey Ohm's Law which states:

$$E = I R$$

Where: E is the arc voltage
I is the arc current in amperes
R is the electrical resistance of the arc

As the arc is lengthened, the arc becomes colder due to radiation to the atmosphere, which in turn increases the electrical resistance of the arc by decreasing the amount of ionized atoms to conduct current. Since the power circuits try to maintain constant current as the arc is lengthened and the resistance is increasing, the resulting voltage also increases.

### *Arc Starting*

Because E7018 electrode is low moisture, low hydrogen electrode, there is very little gas shielding. This is why arc starts or strikes typically contain some porosity and is preferably performed on a run-off tab, if possible. However, when E7018 electrode is started on the work-piece itself, it is advisable to work the puddle to build up the molten pool size and its slag cover. In this way, the initial porosity will have time to float to the top of the pool while the protective slag is thickening. Once the weld pool size and slag cover are established, the porosity problem will disappear. A few electrode manufacturers actually sell electrodes with "starting tips" on their E7018 electrodes to facilitate porous-free arc strikes.

# *Arc Blow*

The welding current flowing through a plate or any residual magnetic fields in the plate will result in uneven flux lines. These uneven flux lines can, in turn, cause an arc to move during a weld. This movement of the arc is called ***arc blow***. Arc blow makes the arc drift as a string would drift in the wind Arc blow is more noticeable in corners, at the ends of plates and when the work lead is connected to only one side of a plate. If arc blow is a problem, it can be controlled by connecting the work lead to the end of the weld joint and making the weld in the direction toward the work lead. Another way of controlling arc blow is to use two work leads, on each side of the weld. The best way to eliminate arc blow is to use alternating current. A very short arc length can help control arc blow.

Arc blow is a phenomenon encountered in DC arc welding when the arc stream does not follow the shortest path between the electrode and the work-piece but is deflected forward or backward from the direction of travel or, less frequently, to one side. Unless the arc blow is controlled arc blow can cause the welder some difficulties in controlling the weld pool and slag. You will have excessive spatter, possibly cause lack of fusion, slower welding speed, excessive undercut and will cause weld pool to boil out and leave a large mound of weld in the center of your weld bead or drip down leaving an ice cycle below your crater.

When electrons flow they create lines of magnetic force that circle around the line of flow. Lines of magnetic force are referred to as magnetic flux lines. These lines space themselves evenly along a current-carrying wire. If the wire is bent, the flux lines on one side are compressed together, and those on the other side are stretched out. The unevenly spaced flux lines try to straighten the wire so that the lines can be evenly spaced once again. The force that they place on the wire or cable is usually small. However, when welding with very high amperages, 600 amps or more, the force may cause the wire or cable to move.

## *Ways to control Arc Blow*

1. Reduce the welding current which may require you to slower travel speed

2. Change angle of electrode with the work opposite the direction of arc blow

3. Weld away from the ground to reduce back blow weld toward the ground to reduce forward blow

4. Wrap ground cable around the work piece and pass ground current through it in such a direction the magnetic field causing the arc blow

**Back blow** is indicated by:

Spatter
Undercut, either continuous or intermittent
Narrow, high bead, usually with undercut
An increase in penetration
Surface porosity at the finish end of welds on sheet metal

**Forward Blow**

A wide bead, irregular in width
Wavy bead
Undercut, usually intermittent
A decrease in penetration

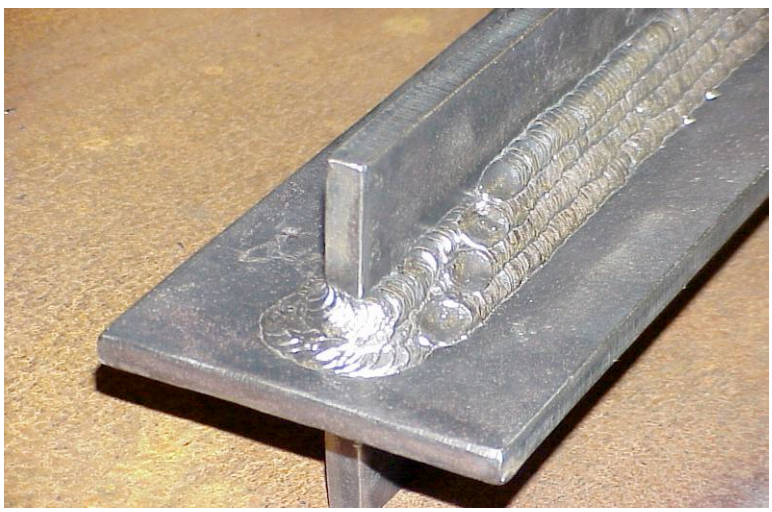
# *Craftsmanship Expectations for Welding Projects*

**The student should complete the following tasks prior to welding:**

1. Thoroughly read each drawing.
2. Make a cut list for each project.(Cut enough material for two projects). Check Oxyacetylene tip for any obstructions clean if necessary for precise cuts.
3. Practice welding scrap to check setting.
4. Assemble the welding project to Blue Print Specifications.
5. Review Welding Procedure in upper right hand corner of print.
6. 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** | Flush to 1/8" |
| **Undercut** | 1/32" deep |
| **Weld Bead Contour** | Smooth Transition |
| **Overlap** | None Allowed |
| **Cracks** | None Allowed |
| **Arc Strikes** | None Allowed |
| **Fillet Weld Size** | See Specification on Print |
| **Porosity** | None Allowed |

## E7018 Bead Plate (Surfacing) ___ _ Project #1

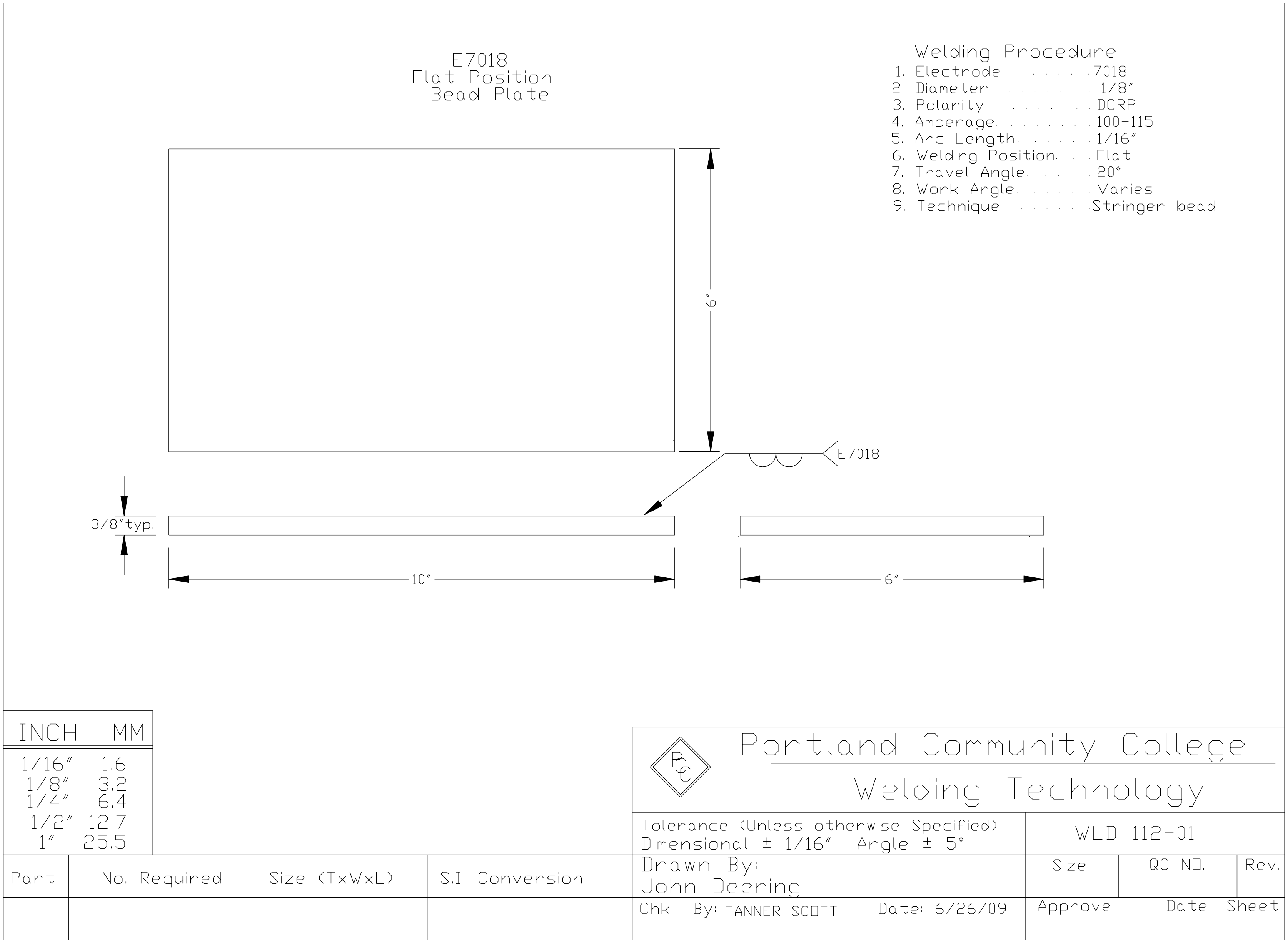
### Technique

Employ a straight stringer bead technique holding a tight arc length. Allow the puddle to obtain a 3/8" to 1/2 " width and adjust travel speed to keep puddle size consistent. See info sheet on ***Striking Arc*** for helpful hints.

**Welding Sequence:** Alternate direction of welding for each pass. Weld full length of plate.

Alternate direction with each pass

| 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** |


E7018
Flat Position
Bead Plate
Welding Procedure
1. Electrode . . . . . . . 7018
2. Diameter . . . . . . . . 1/8"
3. Polarity . . . . . . . . . DCRP
4. Amperage . . . . . . . . 100-115
5. Arc Length . . . . . . 1/16"
6. Welding Position . . . Flat
7. Travel Angle . . . . . 20°
8. Work Angle . . . . . . Varies
9. Technique . . . . . . . Stringer bead
6"
E7018
3/8"typ.
10"
6"
INCH MM
1/16" 1.6
1/8" 3.2
1/4" 6.4
1/2" 12.7
1" 25.5
Portland Community College
Welding Technology
Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
WLD 112-01
Part
No. Required
Size (TxWxL)
S.I. Conversion
Drawn By:
John Deering
Size:
QC NO.
Rev.
Chk By: TANNER SCOTT
Date: 6/26/09
Approve
Date
Sheet

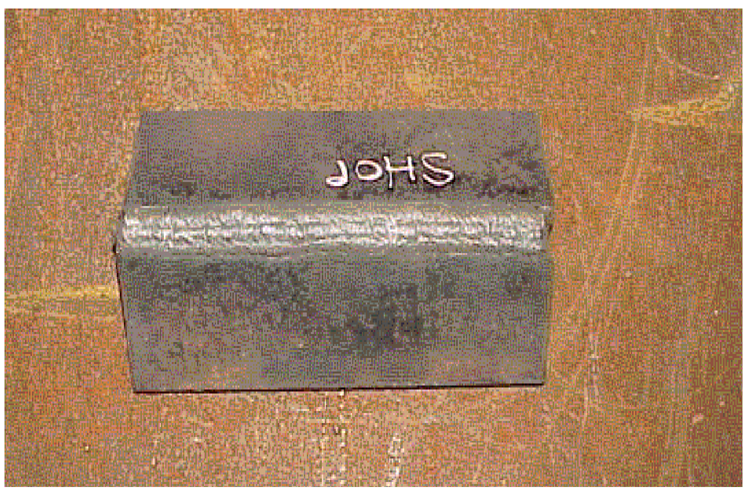
## Corner Joint 1F Best of Two Project #2

### Technique:

Use a stringer bead with tight arc. Center the weld in the first pass (root pass) so that it is equally distributed on to each piece of metal. This is accomplished by adjusting the work angle so that the bead centers itself. The additional passes should then be laid down to allow the weld deposits to flow equally on the previous passes and to the parent material. Desired outcome is to make each individual pass tie into the previous pass(es) and/or parent metal so that a convex weld is achieved.

### Welding Sequence

Alternate directions of welding for each pass.

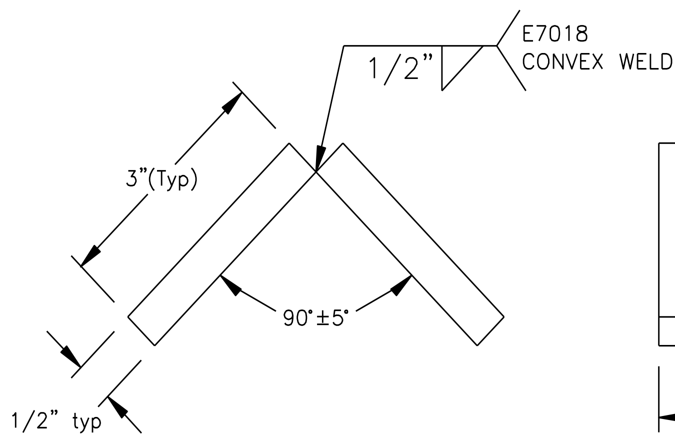


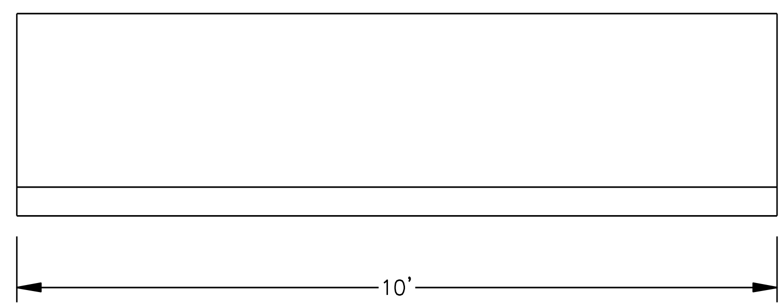
| VT Criteria | Project #1 | Project #2 |
|---|---|---|
| Reinforcement (0” – 1/8”) | | |
| Undercut (1/32”) | | |
| Weld Bead Contour | | |
| Penetration | | |
| Cracks (none) | | |
| Arc Strikes (none) | | |
| Fusion (complete) | | |
| Porosity (none) | | |
| | Grade Date | Grade Date |

# E7018
# Flat Position (1F)
# Corner Joint

**Welded Procedure**

1. Electrode — 7018
2. Diameter — 1/8"
3. Polarity — DCRP
4. Amperage — 100–115 Amps
5. Arc Length — 1/16"
6. Welding Position — Flat (1F)
7. Travel Angle — 20°
8. Work Angle — Varies
9. Technique — Stringer




| INCH | MM |
|---|---|
| 1/16" | 1.6 |
| 1/8" | 3.2 |
| 1/4" | 6.4 |
| 1/2" | 12.7 |
| 1" | 25.4 |

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| Part | No. Required | Size (TxWxL) | S.I. Conversion | Tolerance (Unless otherwise Specified) Dimensional ± 1/16" Angle ± 5° | WLD 112-02 | | |
|---|---|---|---|---|---|---|---|
| | | | | Drawn By: John Deering | Size: | QC NO. | Rev. |
| | | | | Chk By: TANNER SCOTT Date: 4/30/08 | Approve | Date | Sheet |

## E7018 T-Joint 2F — Best of Two — Project #3

### Technique:

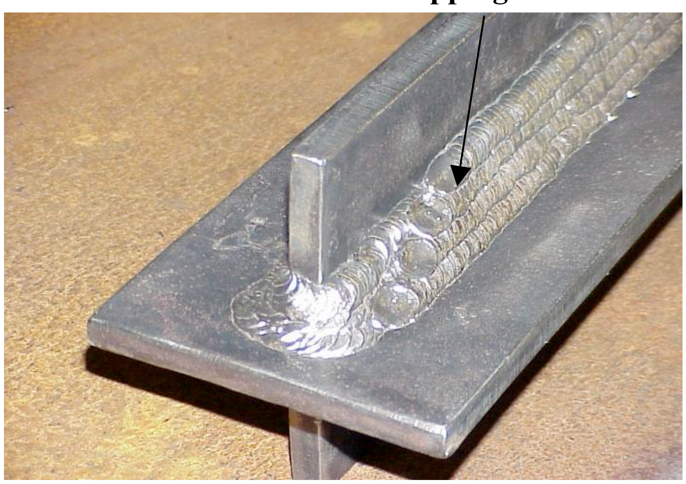
Use a string bead technique with a tight arc length. When running the first pass (root weld) it is important to center the weld so that it has equal distribution onto each piece of metal. This is accomplished by adjusting the work angle so that the bead centers itself. Additional passes should then be laid down to allow the weld deposits to flow equally on the previous passes and to the parent material. The key is to make each individual pass tie into the previous pass(es) and or parent metal so that a flat to convex surface is obtained.

When welding any of the passes in the T-joint it is critical to not let any of the slag float ahead of the electrode. This will cause slag inclusions because the arc is not forceful enough to remove the slag (see helpful hints section for technique in dealing with this problem). Corners must be wrapped.

### Welding Sequence

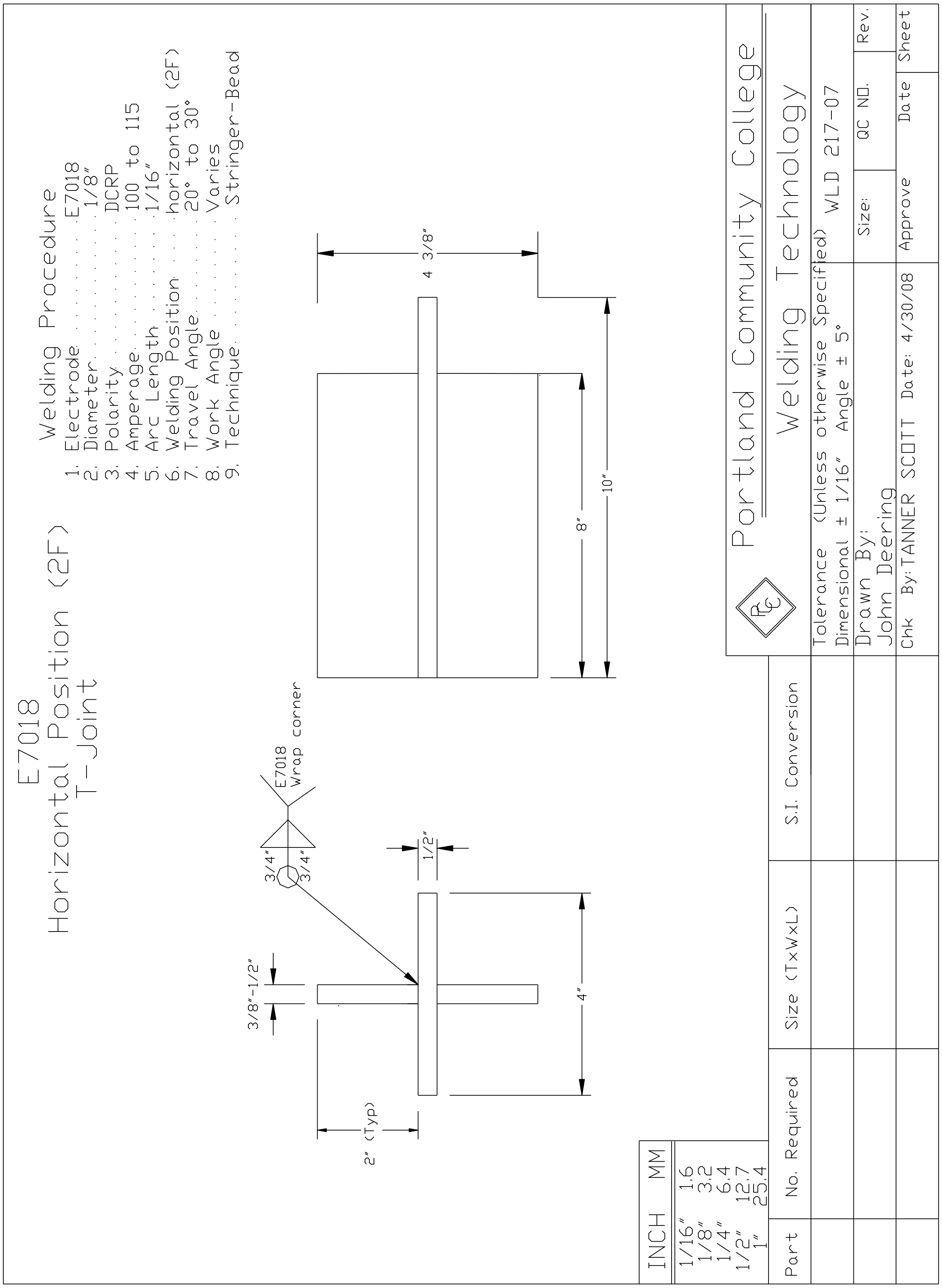
Weld the root pass on all four sides of the joint. Rotate the work so that all the welding is completed in the horizontal position. Notice bead placement starting at the bottom and "stair stepping" towards top of parent metal.

**"Stair Stepping"**



**Do Not Weld Like Photo**
Photo Only Shows Bead Placement

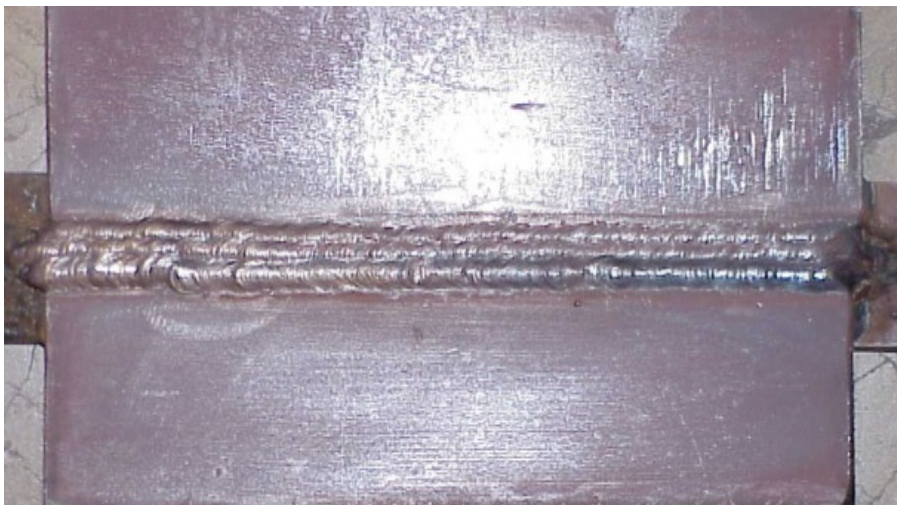
| VT Criteria | Project #1 | | Project #2 | |
|---|---|---|---|---|
| Reinforcement (0" –1/8") | | | | |
| Undercut (1/32") | | | | |
| Weld Bead Contour | | | | |
| Penetration | | | | |
| Cracks (none) | | | | |
| Arc Strikes (none) | | | | |
| Fusion (complete) | | | | |
| Porosity (none) | | | | |
| | Grade | Date | Grade | Date |


E7018
Horizontal Position (2F)
T-Joint
Welding Procedure
1. Electrode .......... E7018
2. Diameter .......... 1/8"
3. Polarity .......... DCRP
4. Amperage .......... 100 to 115
5. Arc Length .......... 1/16"
6. Welding Position .......... horizontal (2F)
7. Travel Angle .......... 20° to 30°
8. Work Angle .......... Varies
9. Technique .......... Stringer-Bead
E7018
Wrap corner
3/4"
3/4"
1/2"
3/8"-1/2"
4"
2" (Typ)
4 3/8"
8"
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 217-07
Drawn By:
John Deering
Size:
QC NO.
Rev.
Chk By: TANNER SCOTT Date: 4/30/08
Approve
Date
Sheet

## E7018 Horizontal V Groove (2G) Project #4

### Welding Sequence

When running the first pass (root weld) it is important to center the weld so that it has equal distribution into each piece of metal. This is accomplished by adjusting the work angle so that the bead centers itself. It is important to drop the angle enough to prevent undercut from happening on the top toe of the weld bead. Additional passes should then be laid down to allow the weld deposits to flow equally on the previous passes and to the parent material. Start with the bottom pass first and use the previous pass as a shelf. This approach is much like walking up a set of stairs-start at the bottom first. The key is to make each individual pass tie into the previous pass(es) and or parent metal so that a flat to convex surface is obtained. Don't let your welds develop "cold lap" because this can cause slag to be trapped. .

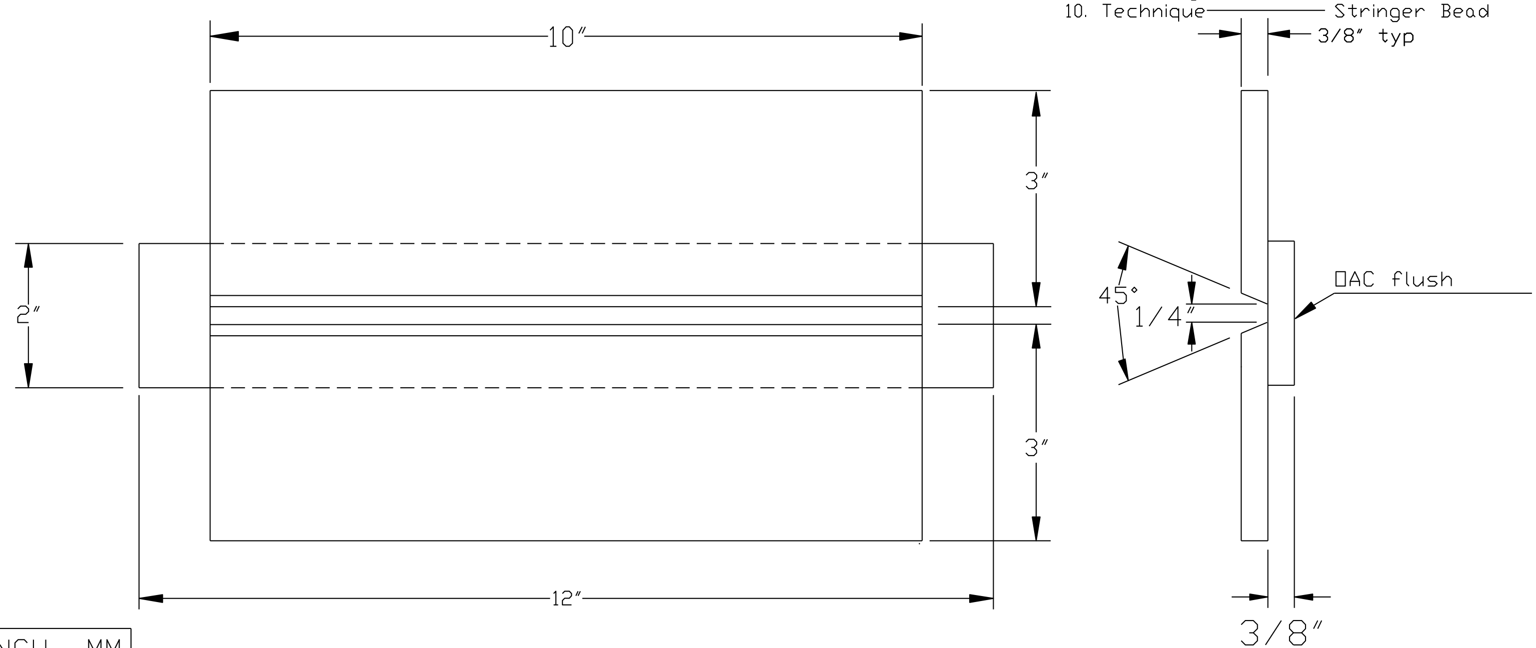


| VT Criteria | Student Assessment | Instructor Assessment |
|---|---|---|
| Reinforcement (0" –1/8") | | |
| Undercut (1/32") | | |
| Weld Bead Contour | | |
| Penetration | | |
| Cracks (none) | | |
| Arc Strikes (none) | | |
| Fusion (complete) | | |
| Porosity (none) | | |
| | | Grade Date |

## E7018 Horizontal Groove (2G)
## Complete Joint Penetration (CJP)

**Welding Procedure**

1. Electrode — E7018
2. Diameter — 1/8"
3. Polarity — DCRP
4. Amperage — 100 - 120 Amps
5. Air — N/A
6. Arc Length — 1/16"
7. Welding Position — 2G
8. Travel Angle — 20° to 30°
9. Work Angle — Varies, read puddle
10. Technique — Stringer Bead




| 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 |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

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| | | | |
|---|---|---|---|
| Tolerance(Unless otherwise Specified) Dimensional ± 1/16" Angle ± 5° | WLD 112-04 | | |
| Drawn By: John Deering | Size: | QC NO. | Rev. |
| Chk By: TANNER SCOTT Date 4/30/08 | Approve | Date | Sheet |

## Oxy-Acetylene Hand Flushing Back Strap                Project #5

### *Setting Up for Flushing Application*

1. Inspect the cutting tip, coupling nut, and torch head for oil, grease, or damaged parts.

> **WARNING:**
> Oil, grease or damage components renders equipment useless, **DO NOT** use the unit until it has been cleaned and/or repaired by a qualified repair technician.

2. Inspect the cutting tip and cutting torch head. All tapered seating surfaces must be free from dents, burns or burned seats. Backfires or flashbacks may occur if damaged tips are used.

> **WARNING:**
> These seating surfaces prevent premature mixing of gases that can cause fires and explosions. If the tapered seats on the tip are damaged, **DO NOT** use it! Wrapping Teflon Tape around the coupling nut will not prevent a leak. The seal is between the "Seating" surfaces on the Tip and the Torch Head.

3. Inspect preheat and cutting oxygen holes on the tip. Splatter can stick on or in these holes. If the holes are clogged or obstructed, clean them out with the proper size tip cleaner.
4. Insert the tip in the cutting attachment head. Tighten the tip nut securely with a wrench (leak tight which is approximately 15 to 20 pounds of torque).
5. Reference to the Tip Flow Chart Data for correct cutting tip size, regulator pressures, and travel speed.
6. Follow cylinder and regulator safety and operating procedures.
7. Adjust the oxygen regulator to the desired delivery pressure.
8. Close the preheat oxygen needle valve.
9. Open the fuel valve on the torch handle. Adjust the fuel regulator delivery pressure.
10. Close the fuel control valve on the torch handle.
11. Close cylinder valves and check system for leaks. (Drop Test) If you have a leak in your system you will see a drop of pressure in the regulator, now you will want to take a soapy solution and spray fittings, regulators, hoses, and torch body to locate leak.

**WARNING:**
If the torch handle and hoses are already connected to the regulators, the system MUST be evacuated (drained) after every shut-down. Open the oxygen valve ½ turn. Allow the gas to flow ten seconds for tips up to size 3 and 5 seconds for sizes 4 and larger for each 25 feet of hose in the system. Close the oxygen valve. Evacuate the fuel system in the same manner.

12. If system is leak free, repeat set-up procedure and prepare to light the torch.

13. Open the fuel valve on the torch handle approximately 1/8 turn. Ignite the gas with a spark lighter. Be sure the spark lighter is away from the tip and not obstructing the gas flow.

**WARNING:**
Wear protective clothing. Use goggles to shield the eyes from bright light.

14. Continue to increase the fuel supply at the torch handle until the flame stops smoking.

15. Slowly open the preheat oxygen control valve and adjust to a neutral flame

16. Since squeezing the cutting oxygen lever changes the gas ratios, further adjustment of the preheat oxygen may be needed to achieve a neutral flame, with the oxygen lever depressed.

**WARNING:**
Inspect the areas where molten metal and sparks will fall. Serious fires and explosions are caused by careless torch operations. Take all possible precautions. Have fire extinguishers available. Remove or protect flammable substances, including oxygen and fuel hoses, before starting to work.

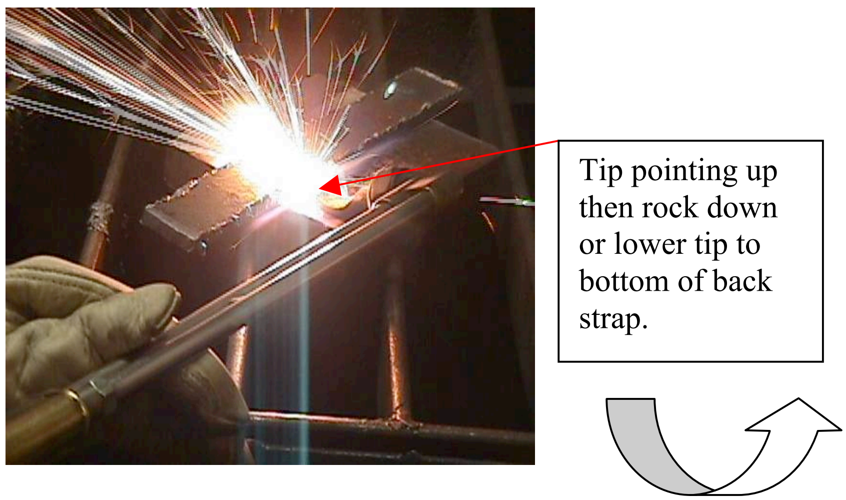
***Step 1***

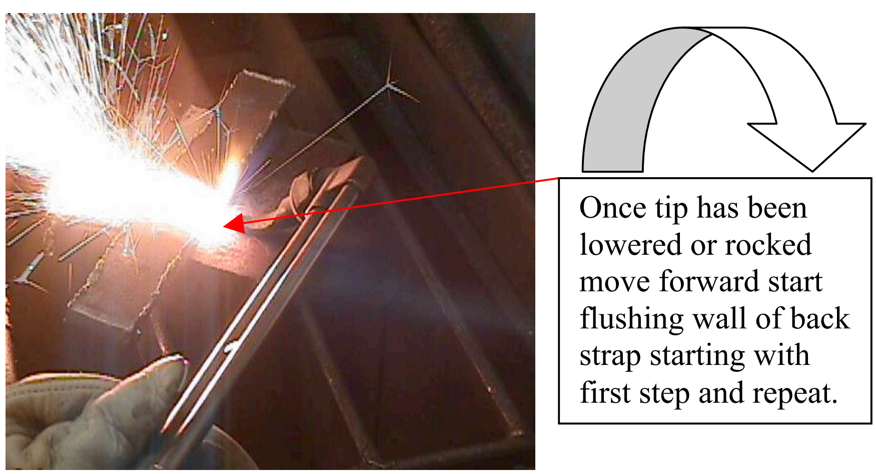
Hold the cutting attachment or torch handle comfortably in both hands. Stabilize the torch with one hand. Position cutting tip preheat flames approximately 1/8" from the base metal (this is known as coupling distance or stand off). The other hand is free to depress the cutting oxygen lever.

***Step 2***

Direct the preheat flame on the spot where you want to start the flushing. Before the cutting action can start, preheat the base metal to a bright cherry red. When the red spot appears, squeeze the oxygen cutting lever slowly and completely.

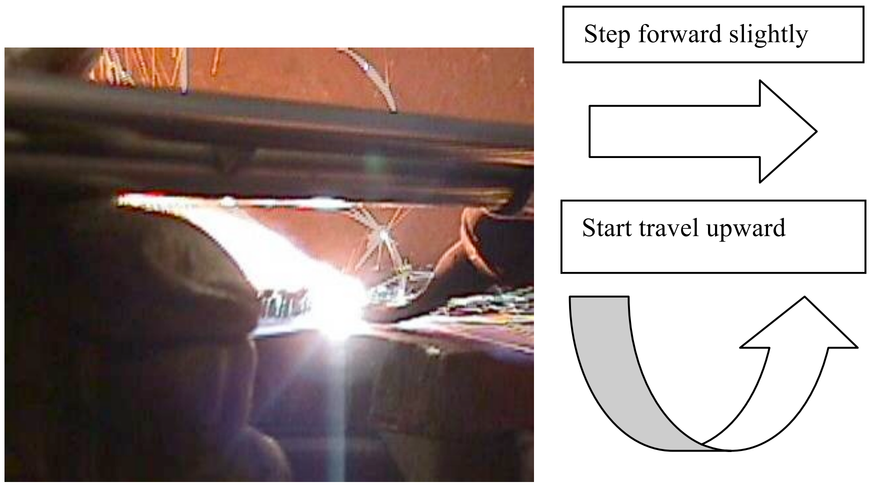
Start flushing with a slow up and down or rocking motion on back strap down to within 1/8 of an inch of base material to prevent gouging into base material.

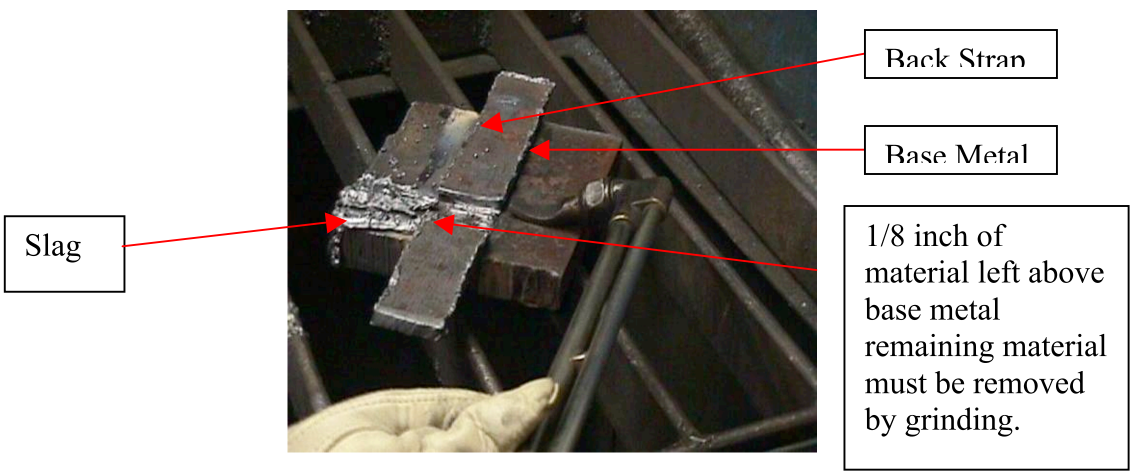


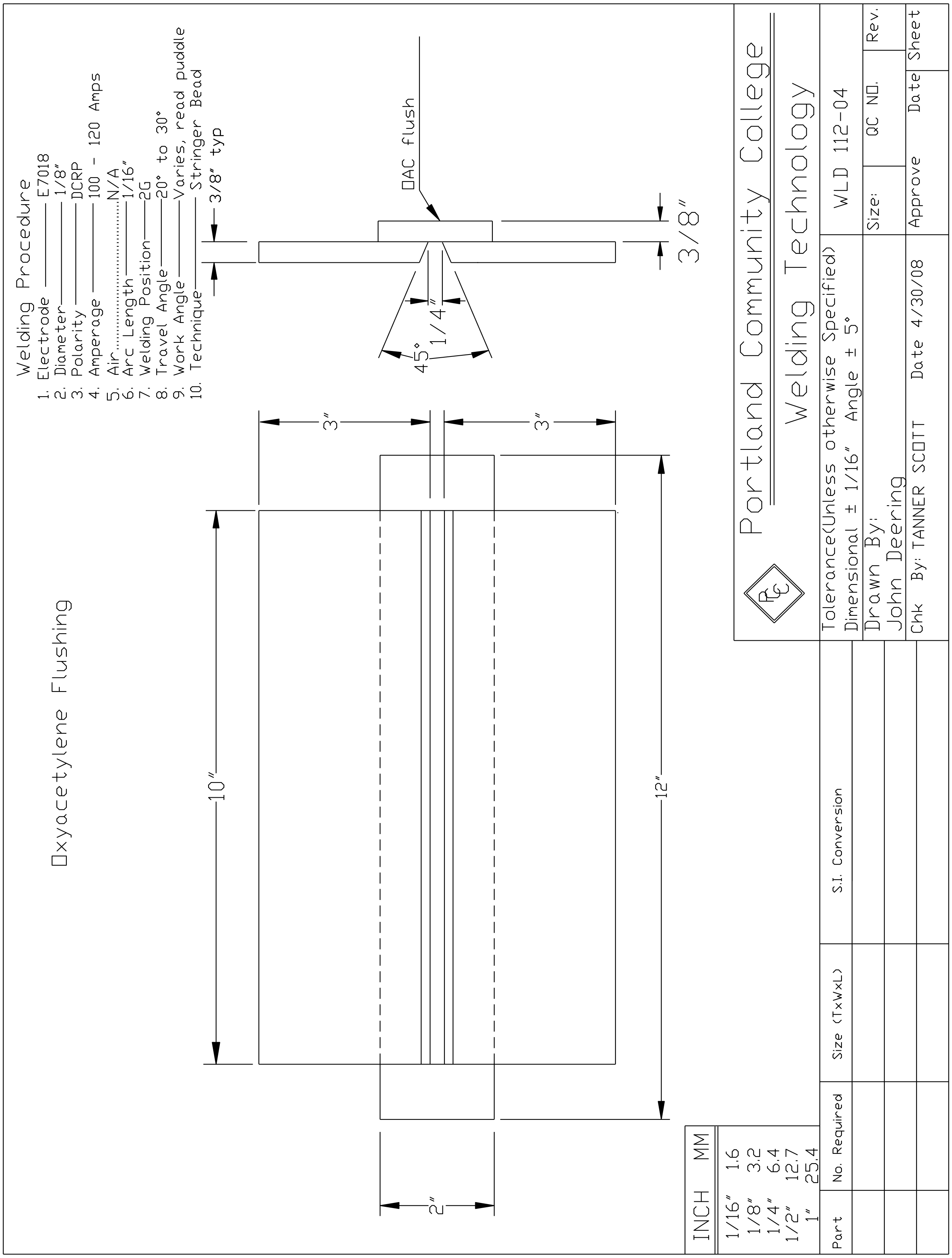
### *Step 3*

While rocking your torch up and down slowly move forward removing about 1/8 to ¼ of an inch of the material stopping about 1/8 of an inch above base metal you are flushing. You want to travel slow enough to allow molten material to be blown away while depressing the oxygen lever. You should try to avoid leaving grooves in the base metal, which could lead to damage




| VT Criteria | Student Assessment | Instructor Assessment |
|---|---|---|
| Reinforcement (0" –1/8") | | |
| | | Grade Date |


Oxyacetylene Flushing
Welding Procedure
1. Electrode — E7018
2. Diameter — 1/8"
3. Polarity — DCRP
4. Amperage — 100 - 120 Amps
5. Air — N/A
6. Arc Length — 1/16"
7. Welding Position — 2G
8. Travel Angle — 20° to 30°
9. Work Angle — Varies, read puddle
10. Technique — Stringer Bead
3/8" typ
OAC flush
45°
1/4"
3/8"
3"
3"
10"
12"
2"
INCH MM
1/16" 1.6
1/8" 3.2
1/4" 6.4
1/2" 12.7
1" 25.4
Portland Community College
Welding Technology
Tolerance(Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
Drawn By:
John Deering
Chk By: TANNER SCOTT Date 4/30/08
WLD 112-04
Size:
QC NO.
Rev.
Approve
Date
Sheet
Part
No. Required
Size (TxWxL)
S.I. Conversion

## E7018 T-Joint (3F) Best of Two Project #6

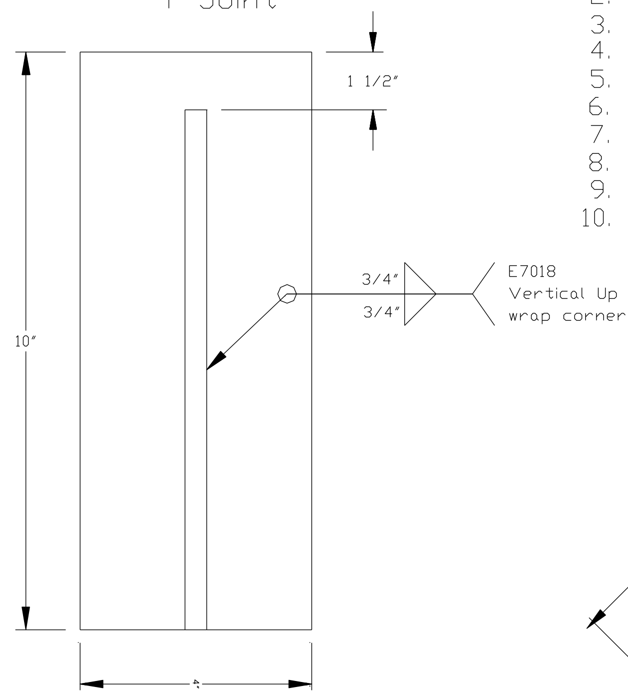
### Welding Sequence

Vertical up welding requires special attention to heat control. See ***Vertical Up Info*** Sheet for helpful hints.

For multi pass welds first deposit a fillet weld bead by using a slight weave continue up over the top for a wrap. Deposit additional layers with a slight side to side weave hesitating at the sides long enough to minimize undercut. When " weaving," do not spend time in the middle of the puddle. It takes care of itself. Do not use a whip technique or take the electrode out of the molten pool. Travel slowly enough to maintain the shelf without causing metal to spill. Use currents in the lower portion of the range. You can use a weave or a straight stringer bead.

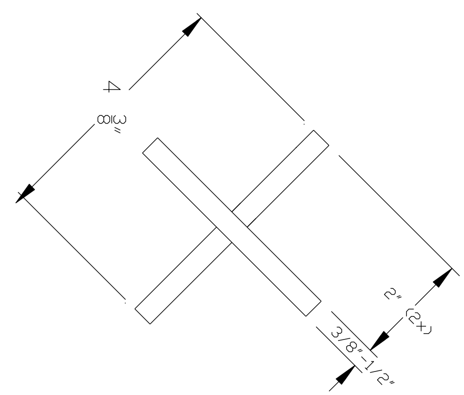
| VT Criteria | Project #1 | | Project #2 | |
|---|---|---|---|---|
| Reinforcement (0" –1/8") | | | | |
| Undercut (1/32") | | | | |
| Weld Bead Contour | | | | |
| Penetration | | | | |
| Cracks (none) | | | | |
| Arc Strikes (none) | | | | |
| Fusion (complete) | | | | |
| Porosity (none) | | | | |
| | Grade | Date | Grade | Date |

# E7018
## Vertical-Up Position (3F)
## T-Joint




## Welding Procedure

1. Electrode — E7018
2. Diameter — 1/8"
3. Polarity — DCRP
4. Amperage — 85 to 100
5. Arc Length — 1/16"
6. Welding Position — Vertical (3F)
7. Travel Angle — 0-15° push angle
8. Work Angle — Varies, read puddle
9. Technique — Stringer
10. Progression — Vertical Up




| 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 |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

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| | | | |
|---|---|---|---|
| Tolerance (Unless otherwise Specified) Dimensional ± 1/16" Angle ± 5° | WLD 112-05 | | |
| Drawn By: John Deering | Size: | Qc No. | Rev. |
| Chk By: TANNER SCOTT Date: 4/30/08 | Approve | Date | Sheet |

## *Final Exam*

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**

- **Oxyacetylene safety**
- **SMAW safety**
- **Hand Tool Safety**

**SMAW and OAC Processes**

- **Power source specifics**
    - **Electricity**
        - **Volts, Amps, Ohms, WATTS**
        - **Transformers/rectifiers etc.**
    - **Polarity**
        - **DCSP, DCRP, Max penetration**
    - **Current out put**
    - **Amperage settings and bead profiles (for different size electrodes too)**
    - **Arc blow**
    - **Duty Cycle**
- **AWS electrode classification**
- **OAC**
    - **Theory of cutting**
    - **Flame types**
    - **Safety**

**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 the ***Traveler***.

Your instructor will evaluate every step of assembly of this part.

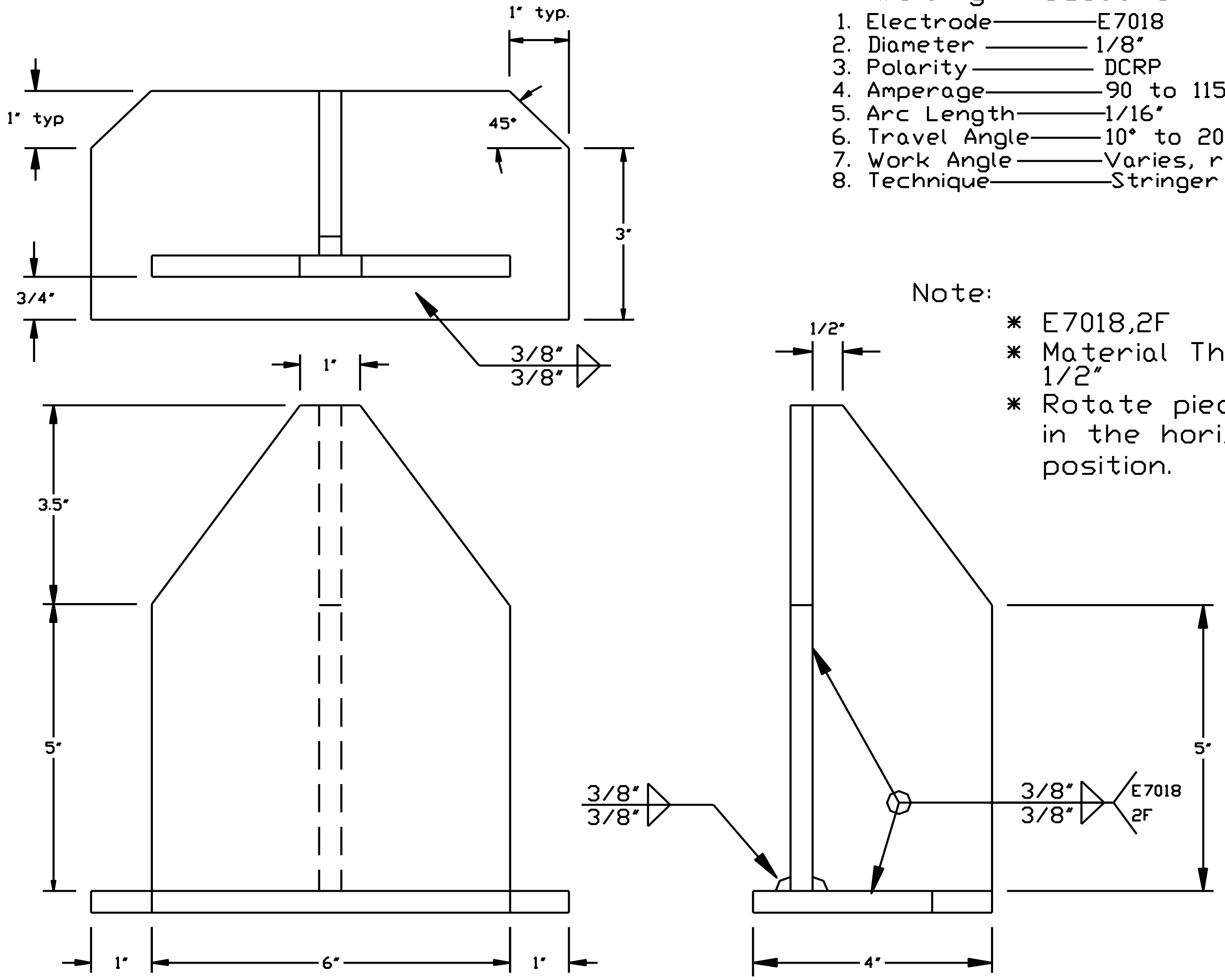
1st step. **Blueprint Interpretation and Material Cut List**

2nd step **Material Layout and Cutting (Tolerances +/- 1/16")**

3rd step **Fit-up and Tack weld (Tolerances +/- 1/16")**

4th step **Weld Quality**

## WLD 112 Practical Final Exam.




### Welding Procedure

1. Electrode——E7018
2. Diameter——1/8"
3. Polarity——DCRP
4. Amperage——90 to 115
5. Arc Length——1/16"
6. Travel Angle——10° to 20° drag angle
7. Work Angle——Varies, read puddle
8. Technique——Stringer

Note:

* E7018,2F
* Material Thickness 1/2"
* Rotate piece to weld in the horizontal position.

| 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 |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

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| | | | |
|---|---|---|---|
| Tolerance (Unless otherwise Specified) Dimensional ± 1/16" Angle ± 5° | Wld 112-Final | | |
| Drwn By: John Deering | Size: | QC NO. | Rev. |
| Chk By: TANNER SOCTT Date: 4/30/08 | Approve | Date | Sheet |

## *Grading Traveler for the WLD 112 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**<br>5 points = 0 errors, all parts labeled and sized correctly<br>3 points = 1 error in part sizing and/or identification<br>2 points = 2 errors or more rework required (max points) | |
| **10 points** | **Material Layout and Cutting (Tolerances +/- 1/16")**<br>10 points<br>Layout and cutting to +/-1/16"<br>Smoothness of cut edge to 1/32"<br>7 points<br>Layout and cutting to +/- 1/8" Smoothness of cut edge to 1/16"<br>5 points (Rework required max points)<br>Layout and cutting to +/-3/16"<br>Smoothness of cut edge to 3/32" | |
| **10 points** | **Fit-up and Tack weld (Tolerances +/- 1/16")**<br>10 points<br>Tolerances +/- 1/16"<br>Straight and square to +/-1/16"<br>7 Points<br>Tolerances +/- 1/8"<br>Straight and square to +/-1/8"<br>5 Points (Rework required - Max points)<br>Tolerances +/- 3/16"<br>Straight and square to +/-3/16" | |
| **15 points** | **Weld Quality**<br>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 112

Name: __________________ Instructor: ____________________ Date: ___________________

**Welding Projects = 40%**

| | | |
|---|---|---|
| Out of 10 | ~~Out of~~ | ~~Out of~~ |
| Out of 10 | ~~Out of~~ | ~~Out of~~ |
| Out of 10 | ~~Out of~~ | ~~Out of~~ |
| Out of 10 | ~~Out of~~ | ~~Out of~~ |
| Out of 10 | ~~Out of~~ | ~~Out of~~ |
| Out of 10 | ~~Out of~~ | ~~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 _________ | |