WLD 113
Shielded Metal Arc Welding: Mild Steel II (E7018)

This project was supported, in part, by the *National Science Foundation*
Opinions expressed are those of the authors And not necessarily those of the Foundation.

PCC/ CCOG / WLD

Course Number:
WLD 113

Course Title:
Shielded Metal Arc Welding: Mild Steel II (E7018)

Credit Hours:
4

Lecture Hours:
0

Lecture/Lab Hours:
80

Lab Hours:
0

Special Fee:
$24.00

Course Description

Develops knowledge and skills in the use of E7018 mild steel electrodes when performing various welds in the vertical and overhead positions. Prerequisites: Department permission required. Audit available.

Addendum to Course Description

discussions, videotapes, and lab demonstrations of technical skills. Course outcomes will include

This is an outcome based course utilizing a lecture/lab format. This course includes classroom theoretical concepts, layout, fabrication, welding, oxy-fuel cutting and safety.

Intended Outcomes for the course

Upon completion of the course students will be able to

- Function safely in the PCC Welding Lab
- Operate oxy-fuel portable and track cutting systems in accordance with industry standards.
- Understand and apply fundamentals of SMAW E7018operations.
- Weld common joint assemblies with the E7018 electrode to AWS D1.1StructuralSteelWelding
- Interpret blueprints to accurately lay out, prepare, and assemble weld joints.
- Apply visual examination principles and practices in accordance with AWSD1.1.
- Operate an CAC-A (Carbon Arc Cutting - Air) system in accordance with industry standards.

Course Activities and Design

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

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

Course Content (Themes, Concepts, Issues and Skills)
Function safely in the PCC WeldingShop.

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

Operate oxy-fuel 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 oxy-fuel cutting with guided practice.
- Describe and demonstrate equipment setup, shut down, and operation

Understand and apply fundamentals of SMAW E7018 Operations.

- Identify Electrode Characteristics
- Demonstrate proper Arc Length and Travel speed
- Demonstrate correct starting, stopping and restarting techniques
- Demonstrate proper bead placement

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

- Interpret lines, symbols, views and notes
- Lay out material per specifications
- Use the oxy-fuel cutting process to cut material to specified dimensions
- Assemble project per specifications

Weld common joint assemblies with the E7018 electrode to AWS D1.1 Structural Steel Welding Code in the following joint configurations and positions.

- Vertical position.
    - Lap joint
    - Single V-groove
- Overhead position
    - T-joint
    - Bead plate
    - Lap joint
    - Single V-groove

Operate a Carbon Arc Cutting - Air system (CAC-A) in accordance with industry standards.

- Demonstrate correct setup and shutdown procedures
- Adjust current and air pressure for size of electrode being used
- Explain CAC-A electrode shapes and their uses
- Demonstrate the effects of the following variables: electrode angle, amperage setting, air pressure, and travel speed
  Demonstrate correct CAC-A gouging techniques on
  Apply visual examination principles and practices in accordance with AWS D1.1
  Evaluate welds using appropriate welding inspection tools
  Assess weld discontinuities causes and corrections

Course Assignments

Reading

The Welding Principles and Applications: By Larry Jeffus

Weld Quality

Arc Gouging

Video Training

Miller #2, Weaving the electrode.

Miller #4, Fillet weld Techniques

Work Sheets

Weld Quality

Arc Gouging

Welding Projects

E7018 Vertical Lap Joint (3F)

E7018 Vertical Single V- Groove Weld(3G)

E7018 Overhead Bead Plate

E7018 Overhead Lap Joint (4F)

E7018 Overhead Tee Joint (4F)

E7018 Single V- Groove Weld (4G)

Final Exam

Part One (Closed Book Exam)

Part Two (Practical Exam)

Required Texts

The Welding Principles and Applications. By Jeffus, Lary

Reference List

Science Packet

Time Line:

Open-entry, open-exit instructional format allows the student to work at his/her own pace. It's 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 test, safe work habits, task performance and work relations.

Low Hydrogen Information Sheet

Low Hydrogen Electrodes

Low-hydrogen electrodes must be dry if they are to perform properly. Electrodes in unopened, hermetically sealed containers remain dry indefinitely in good storage conditions. Opened cans should be stored in a cabinet at 250 F to 300 F. Low-hydrogen electrodes pick up moisture. The moisture, depending upon the amount absorbed, impairs weld quality in the following ways.

- A small amount of moisture may cause internal porosity. Detection of this porosity requires X-ray inspection or destructive testing. A high amount of moisture causes visible external porosity in addition to internal porosity.
- Severe moisture pickup can cause weld cracks or under-bead cracking in addition to severe porosity.
- If the base metal has high hardenability even a small amount of moisture can contribute to under-bead cracking.

Low-hydrogen Electrodes are available with fast fill and fast freeze Characteristics.

When welding out-of-position the molten metal tends to spill out of the joint. To offset this tendency, an electrode with a fast freezing deposit is needed, even though the slag stays molten and has a tendency to spill out.

Applications for low-hydrogen electrodes include:

- X-ray-quality welds or welds requiring high mechanical properties.
- Crack-resistant welds in medium-carbon to high-carbon steels; welds that resist hot-short cracking in phosphorus steels; and welds that minimize porosity in sulfur-bearing steels.
- Welds in thick sections or in restrained joints in mild and alloy steels where shrinkage stresses might promote weld cracking.
- Welds in alloy steel requiring a minimum tensile strength of 70,000 psi or more.
- Multiple-pass vertical, and overhead welds in mild steel.

Vertical Welds:

For multi-pass welds, first deposit a root bead by using a slight weave. Deposit additional layers with either a straight up progression or a slight side to side weave. By hesitating at the sides long enough to insure fusion and to minimize undercut if you use a slight side-side oscillation technique. **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 current range similar to Horizontal position.

Overhead welds:

Deposit stringer beads by using a slight circular motion in the crater. Maintain a short arc. Motions should be slow and deliberate. Move fast enough to avoid spilling weld metal, but do not become alarmed if some slag spills. Use currents in the lower portion of the range.

Helpful Hints

Arc Length for the E7018 (Low Hydrogen Electrodes)

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 too 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. The sound of the arc will help determine the arc length too. It will sound much like, "bacon frying in a pan," a distinct crisp sound.

Remember: The general rule for maximum arc length is the distance and should not exceed the diameter of the electrode at any time. If you remember this you'll never have trouble with porosity.

Heat Control for out of position welding

When welding in the vertical or overhead positions gravity can have an effect on the weld contour. This is important for the welder to understand. The key for successful welding in out of position work is heat control. This can be controlled by the following steps:

1. Use lower amperage range.
2. Use stringer bead technique.
3. Keep the base metal cool. Quench metal every 2 to 3 passes.
4. Use a tight arc technique.

Using these steps in conjunction with practice the welder should have success.

Carbon Arc Gouging

Description

Air carbon arc cutting (CAC-A) is a physical means of removing base metal or weld metal by using a carbon electrode and electric arc process with compressed air. In the air carbon arc process, the intense heat of the arc between the carbon electrode and the work piece melts a portion of the base metal, or weld. Simultaneously a jet of air is passed through the arc, of sufficient volume and velocity to blow away the molten material. This sequence can be repeated until the required groove or cut has been obtained.

Applications

The CAC-A process may be used to prepare plates for welding, to provide a suitable bevel or groove to be welded. It can be used to back gouge a joint prior to welding the second side. Carbon arc provides an excellent means of removing defective welds or misplaced welds.

Back Gouging

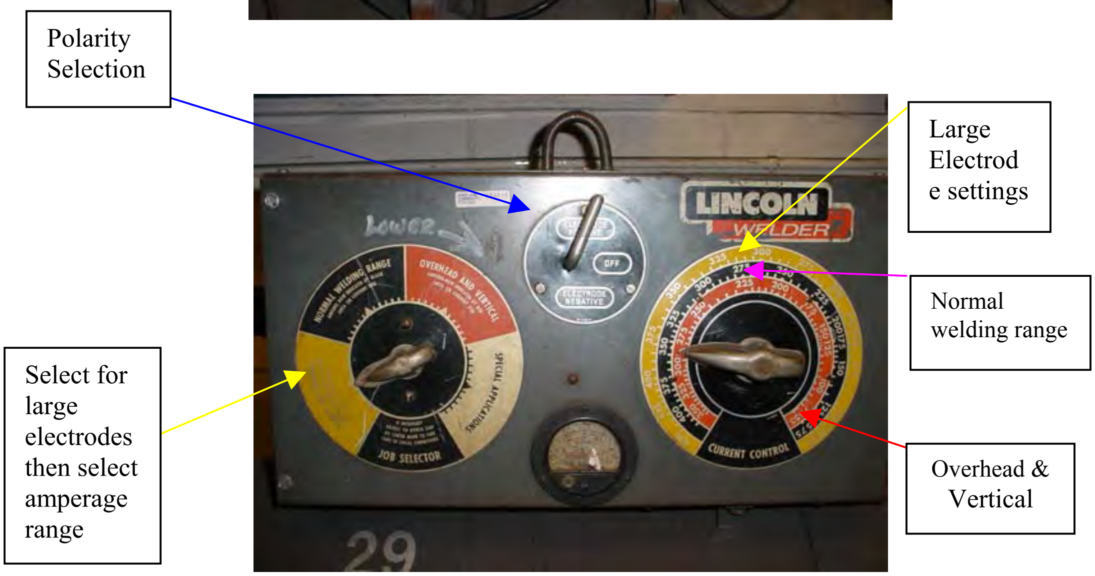
Reasons for Back Gouging:

1. Repairing welds for X-ray quality.
2. When irregular gaps or poor technique produces a poor bead.
3. When a heavy bead is needed to prevent melt-through of semiautomatic fill beads.

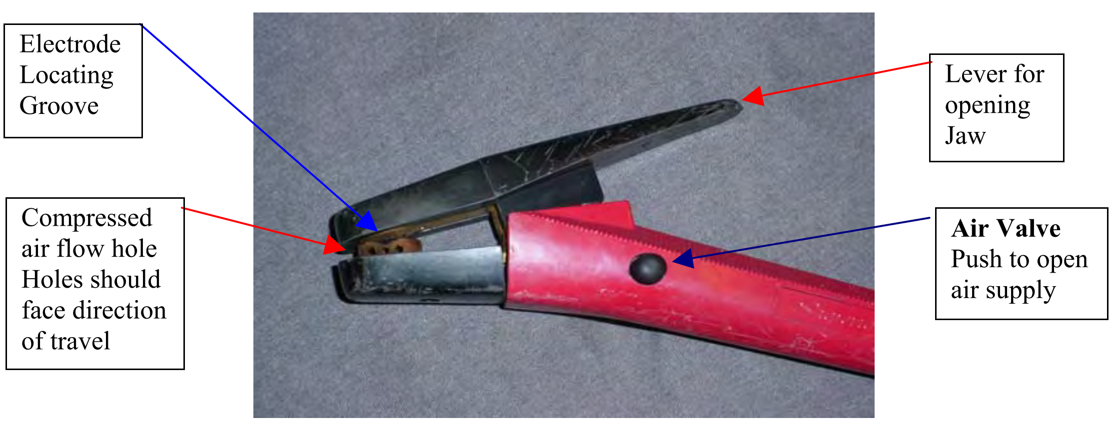
Carbon Arc Torch

Power sources that can be used for Carbon Arc process.

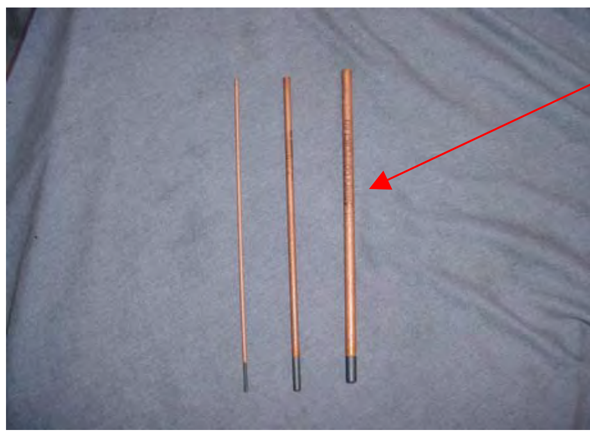
Generator Power Supply



Gouging Torch



Various sizes of Electrodes



Electrodes come in Round, Flat and Semi-Round.
Cross Sections of Carbon electrodes

Caution

Never cut on any material that might produce fumes that would be hazardous to your health without proper safety precautions, including adequate ventilation.

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 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 below:

$$H_2O = 2H + O$$

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" 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 containers must be stored in a baking oven. The oven is set at a temperature recommended by the manufacturer, which 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. A listing of all of the 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 %)	<u>AWS A5.1</u> C: not specified S: not specified P: not specified Ni: not specified Mn: 1.60 max Si: 0.75 max Cr: 0.20 max Mo: 0.30 max	<u>Typical</u> C: 0.05 S: 0.009 P: 0.015 Mn: 1.40 Si: 0.45 Cr: 0.05 Ni 0.05 Mo: 0.03
Mechanical Properties of Weld Metal	Tensile Strength: 72ksi (500MPa) min Yield Strength: 60ksi (420MPa) min % Elongation: 22% min CVN Toughness: 20ft-lbs @ -20°F min	Tensile Strength: 84 ksi (MPa) Yield Strength: 70 ksi (MPa) % Elongation: 30% 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

Codes Requiring E7018 Low-Hydrogen Electrodes

SMAW with E7018 low-hydrogen electrodes is permitted by all welding codes such as API-1104, AWS D1.1 Structural Steel Welding Code, AWS D1.5 Bridge Welding Code, Section IX of the ASME Boiler and Pressure Vessel Code, American Bureau of Shipping (ABS) Rules, MIL-STD-278, Lloyd's, and many others. Instead of cellulosic electrodes like E7010 and E7011, the use of E7018 low-hydrogen electrode is mandatory in many welding codes in order to prevent hydrogen-assisted cracking and to achieve excellent Charpy V-notch (CVN) impact toughness. The low hydrogen characteristic of E7018 electrodes is particularly valuable for welding thick steels greater than ¾ inch (19mm), or steels with tensile strength values greater than 70,000psi (483MPa). For example, the AWS D1.5 Bridge Welding Code allows only E7018 electrodes for SMAW applications in bridge construction and repair, while cellulosic electrodes such as E6010, E6011, E7010, E8010, etc. are absolutely forbidden. Table 2 provides a listing of all the steels that are permitted for welding by E7018 type electrodes. Also, Table 2 provides the preheat/interpass temperatures needed for the steels over 1 ½ inches (38.1mm) thick.

The low-hydrogen capability of the E7018 electrode greatly out-weighs its disadvantages compared to cellulosic electrodes (given above). Cellulose can not be used as an ingredient for low-hydrogen electrodes because of its extremely high moisture and hydrocarbon content. Unlike E7010 electrodes, E7018 low-hydrogen electrodes provide very little gaseous shielding but good slag shielding. DCRP (DCep) should be used whenever possible if the electrode size is 5/32 inch or less. For larger electrodes, AC should be used best operating characteristics (although DCep can also be used). AC provides slightly less penetration than DCRP (DCep).

Hydrogen Designators by AWS

Currently, there is no definition that specifies the amount of hydrogen that is permitted in as-deposited weld metal. To simply state to use low hydrogen electrodes is not enough to prevent hydrogen-assisted cracking in the heat-affected zone of a weld. “Low hydrogen” can actually mean a wide range of hydrogen from 2 to more than 12ml/10g. It has been shown that “low” hydrogen levels as high as 12 ml/100g can cause extensive severe cracking in high strength steels; while, similar welds deposited with electrodes containing only 4ml/100g of hydrogen is crack-free. As a result, the American Welding Society (AWS) developed a new optional Hydrogen Designator System shown in Table 3.

From Table 3, these hydrogen designators are in the form of suffixes added to the end of the electrode classification. To avoid hydrogen-assisted cracking in heat-affected zone of a weld, the hydrogen level produced by the electrode must be held below a certain maximum level. For example, the electrode E7018-H4 must be capable of producing weld metal containing less than 4ml/100g of diffusible hydrogen.

Table 2 Steel Types and Minimum Preheat/Interpass Temperatures for SMAW with E7018 Electrodes specified by AWS D1.1 Structural Welding Code

Steel Specification and Grade	Thickness Range	Minimum Preheating Temperature
ASTM A36; ASTM A53; B ASTM A106; B ASTM A131; A, B, CS, D, DS, E AH-32 & 36, DH-32 & 36, EH-32 & 36	Up to ¾ in. (19mm) Over ¾ in. (19mm) thru 1 ½ in. (38.1mm) Over 1 ½ in. (38.1mm)	None 50° F (10° C) 150° F (66° C)

ASTM A139; B ASTM A242 ASTM A381; Y35 ASTM 441 ASTM A500; A, B ASTM A501 ASTM A516; 55, 60, 65 & 70 ASTM A524; I, II ASTM A529 ASTM A537; 1 & 2 ASTM A570; all grades ASTM A572; 42, 50 ASTM A588 ASTM A595; A, B, C ASTM A573; 65 ASTM A606 ASTM A607; 45, 50, 55 ASTM A618 ASTM A633;A, B, C, D ASTM A709; 36, 50, 50W ASTM A808 API 5L; B, X42 API 2H; 42, 50 ABS; A, B, D, CS, D, DS, E AH-32 & 36, DH-32 & 36, EH-32 & 36	thru 2 ½ in. (63.5mm) Over 2 ½ in (63.5mm)	 225° F (107° C)

Table 3 Optional Hydrogen Designator System developed by American Welding Society for Low-Hydrogen Electrodes

	Diffusible Hydrogen (ml/100g of weld metal)	Example
H2	2	E7018-H2
H4	4	E7018-H4
H8	8	E7018-H8

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

The reason why E7018 is capable of such low diffusible hydrogen content (less than 4 ml/100g) is because of the basic flux coating used. The flux for E7018 electrode contains low-hydrogen ingredients, which include primarily calcium carbonate ($CaCO_3$) and fluorspar (CaF_2). Small additions of rutile, potassium titanate, feldspar and potassium silicate, are added to increase arc stability for AC welding and good slag viscosity for out-of-position welding, as shown in Table 4. Unlike E6010 electrodes, E7018 contains no cellulose, because cellulose decomposes in the arc to produce large volumes of hydrogen and CO_2 during welding. The CO_2 and hydrogen provide gas shielding and excellent penetration, but the hydrogen also causes severe cracking in high strength steels and even mild steels which are over ¾ inch (19mm) thick. To eliminate and replace the hydrogen gas evolution, calcium carbonate (lime) is added to the E7018 flux to produce a limited amount of $C0_2$ shielding gas by the decomposition of lime ($CaCO_3$) during welding, as follows:

$$CaCO_3 = CaO + CO_2 \text{ gas}$$

Thus, low-hydrogen E7018 electrodes must be used with a minimal arc length since the primary means to protect the molten weld pool is by a thick slag cover. The flux ingredients and binding agents used for E7018 must also be free of moisture, hydrocarbons and other hydrogen-producing ingredients. Binding agents are needed to cement all of the flux ingredients into a monolithic coating. Potassium silicate and sodium silicate are the primary hydrogen-free binders.

Table 4 Composition and Function of Flux Ingredients in E7018 Electrodes

(Olson et al, ASM International Handbook, Vol. 6, pp. 55-63)

Mineral in Coating	Chemical Formula	Primary Function	Composition Range, wt%
Calcium carbonate	$CaCO_3$	Shielding gas	15-30
Fluorspar	CaF_2	Slag former	15-30
Rutile	TiO_2	Slag former	0-5
Potassium titanate		Arc stabilizer	0-5
Feldspar	$K_2O.Al_2O_3.6SiO_2$	Slag former	0-5
Iron powder	Fe	High deposition	25-40
Ferrosilicon	FeSi	Deoxidizer	5-10
Ferromanganese	FeMn	Alloying	2-6
Potassium silicate	$SiO_2.K_2O$	Arc stabilizer	5-10

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 CVN 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, deposition rate of E7018 is nearly doubled compare to all-position electrodes without iron powder, such as E7010. The second 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.

WRONG

RIGHT

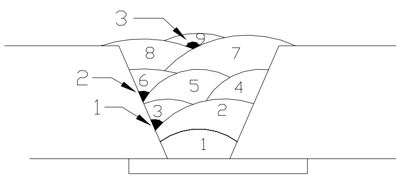


Fig. C

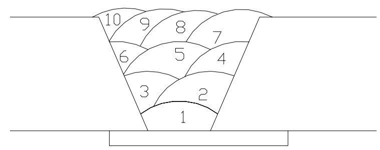


Fig. D

In Figure C, Points 1, 2, and 3 indicate slag and or gas trapped because there was too little space between the sidewall and the bead or as in Point 3 between beads. Undercut must be avoided with any of the beads because this can trap slag. Figure C can be corrected by grinding or air-arc gouging before proceeding with the welding.

STRINGER TECHNIQUE
Flat Groove

WEAVE TECHNIQUE
Flat Goove

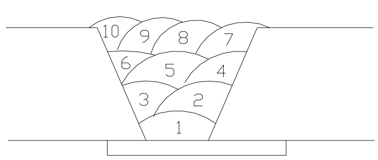


Fig. E

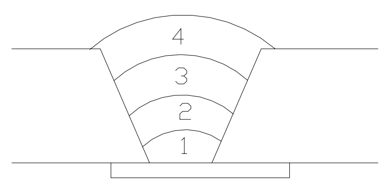
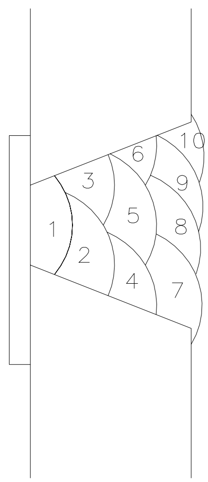


Fig. F

WLD 113 Info sheet 3

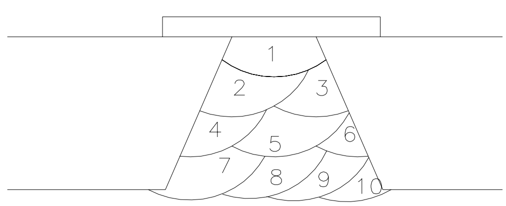
Horizontal Grooves



The Weave Technique is not recommended for the Horizintal Groove.

Over Head Grooves

Stringer Bead Technique



The Weave Technique is not recommended for the Overhead Groove.

WLD 113 Information Sheet 4

Craftsmanship Expectations for Welding Projects

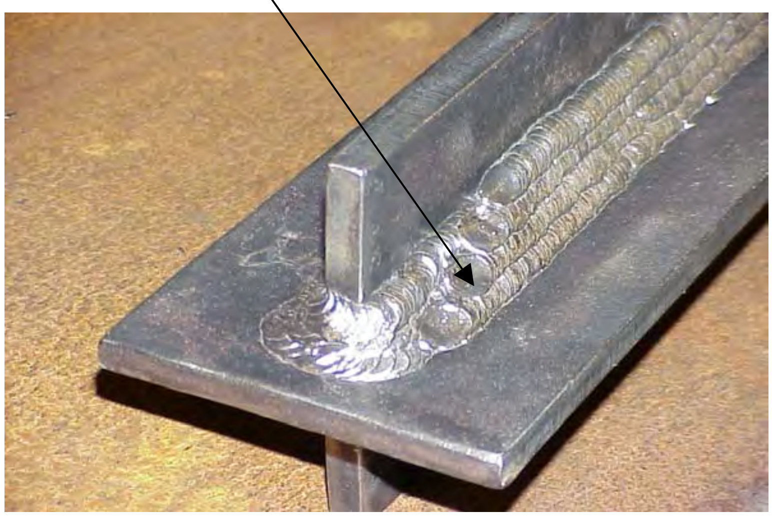
The student should complete the following tasks prior to welding:

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. Assemble the welding project to Blue Print Specifications.
4. Review Welding Procedure in upper right hand corner of print.
5. See the instructor for the evaluation.

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

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

This photo shows Bead Placement



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**

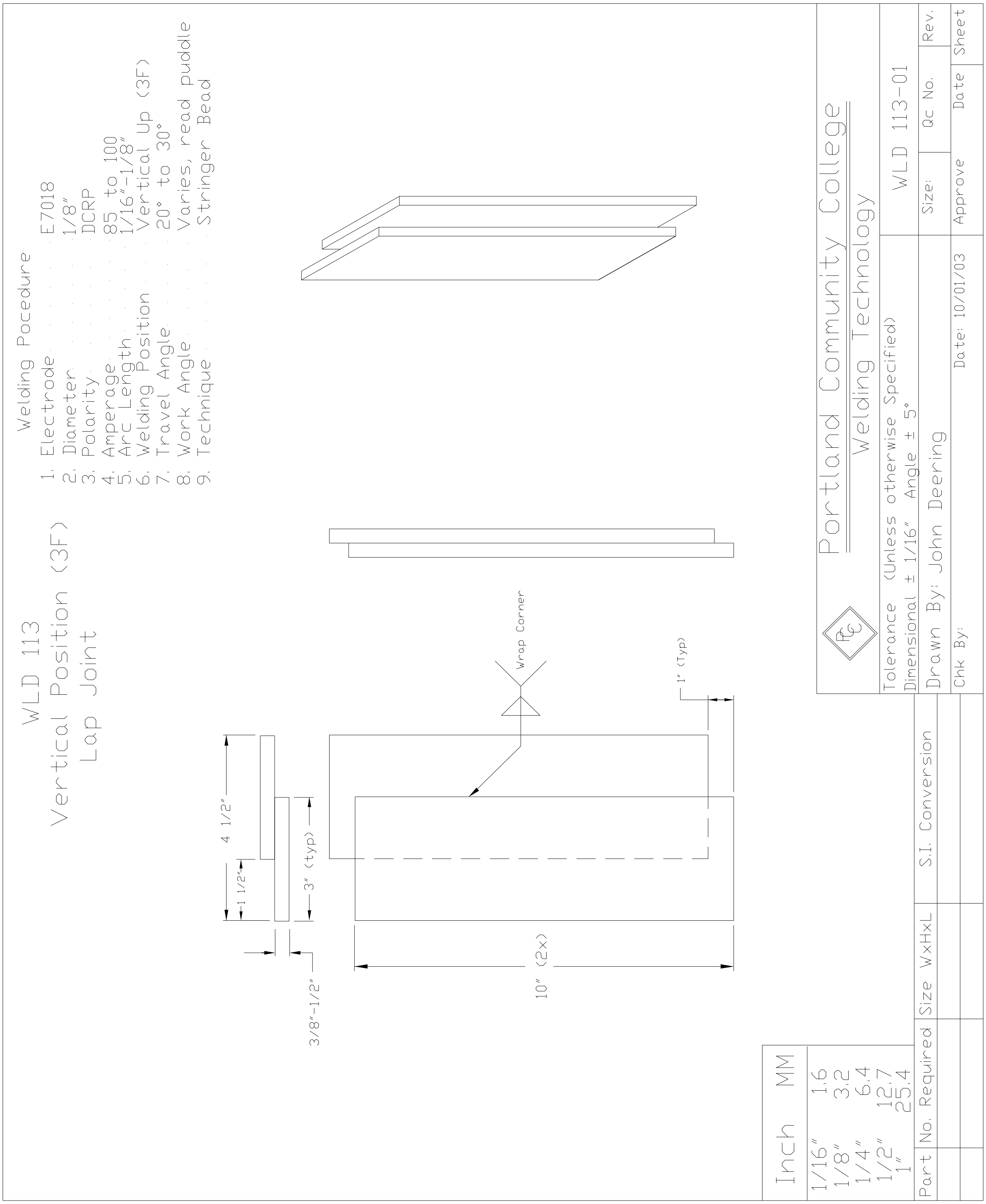
E7018 Vertical Position Lap Joint (3F) Project #1

Technique:
When welding in the vertical position, it is important to control the heat input into the base metal. Two primary ways to accomplish this are by using lower amperages and quenching the project often. For multipass welds, first deposit a stringer bead. Deposit additional layers with a slight side-to-side weave, hesitating at the sides long enough to minimize undercut. Travel slowly enough to maintain the weld without causing metal to spill out.

Welding Sequence:
Wrap the weld around the corner.

Vertical Up Lap Joint

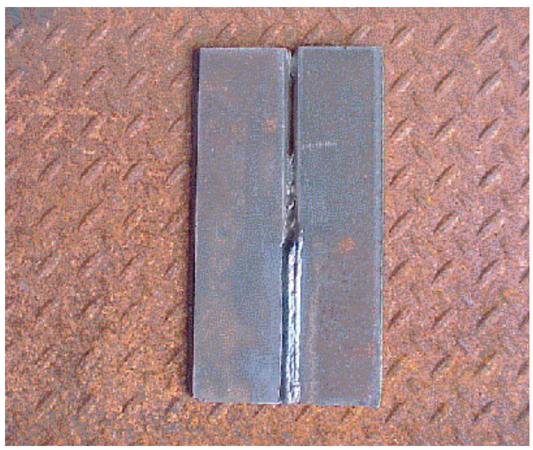
VT Criteria	*Student Assessment*	*Instructor Assessment*
Reinforcement (0” –1/8”)		
Undercut (1/32”)		
Weld Bead Contour (Smooth)		
Penetration		
Cracks (none)		
Arc Strikes (none)		
Fusion (complete)		
Porosity (none)		
		Grade *Date*


WLD 113
Vertical Position (3F)
Lap Joint
Welding Pocedure
1. Electrode E7018
2. Diameter 1/8"
3. Polarity DCRP
4. Amperage 85 to 100
5. Arc Length 1/16"-1/8"
6. Welding Position Vertical Up (3F)
7. Travel Angle 20° to 30°
8. Work Angle Varies, read puddle
9. Technique Stringer Bead
Wrap Corner
1" (Typ)
4 1/2"
1 1/2"
3" (typ)
3/8"-1/2"
10" (2x)
Inch MM
1/16" 1.6
1/8" 3.2
1/4" 6.4
1/2" 12.7
1" 25.4
Part No. Required Size WxHxL S.I. Conversion
Portland Community College
Welding Technology
Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
Drawn By: John Deering Date: 10/01/03
Chk By: Approve Date Sheet
WLD 113-01
Size: Qc No. Rev.

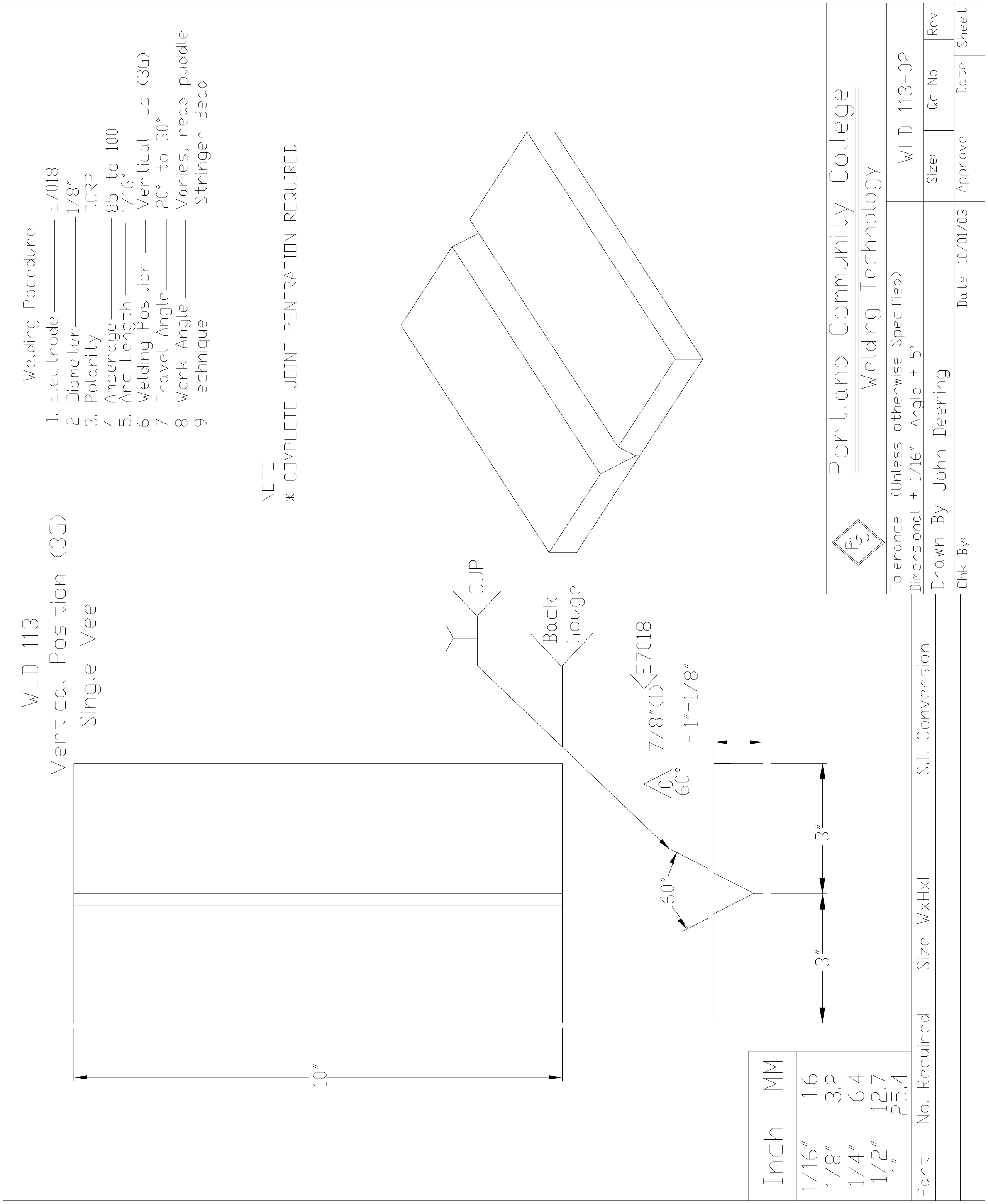
E7018 Vertical Position Single V-Groove (3G) - (1F) Back Gouge   Project #2

Welding Sequence:
When running the first pass (root weld) it is important to center the weld so that it has equal dilution into each piece of metal. Deposit additional layers with a slight sided to side weave and hesitating at the sides long enough to minimize undercut. **Do not use** a whip technique or take the electrode out of the molten pool with the 7018 electrode. Travel slow enough to maintain the weld without causing metal to spill out. Use amperages in the lower portion of the range. You can use a weave or a straight stringer bead technique.

After welding out the front side, back gouge the backside with the air carbon arc gouging process and weld it out. The goal of this project is to achieve complete joint penetration (CJP) so be sure to gouge out deep enough and grind out all slag and rough spots.



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


WLD 113
Vertical Position (3G)
Single Vee
Welding Pocedure
1. Electrode — E7018
2. Diameter — 1/8"
3. Polarity — DCRP
4. Amperage — 85 to 100
5. Arc Length — 1/16"
6. Welding Position — Vertical Up (3G)
7. Travel Angle — 20° to 30°
8. Work Angle — Varies, read puddle
9. Technique — Stringer Bead
NOTE:
* COMPLETE JOINT PENTRATION REQUIRED.
CJP
Back Gouge
E7018
7/8"(1)
60°
1"±1/8"
60°
3"
3"
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 WxHxL
S.I. Conversion
Portland Community College
Welding Technology
Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
WLD 113-02
Drawn By: John Deering
Date: 10/01/03
Size:
Qc No.
Rev.
Chk By:
Approve
Date
Sheet

(1G) Back Gouge U-Groove (Step Two) Project #2

After welding out the front side, back gouge the backside with the air carbon arc gouging process. Arc out un-fused root until seam lines disappear so that when welded you will obtain complete joint penetration. The goal of this project is to achieve complete joint penetration (CJP) so be sure to gouge out deep enough and grind out all slag and rough spots. Weld up area that has been gouged out.

U-Shaped groove by carbon arcing

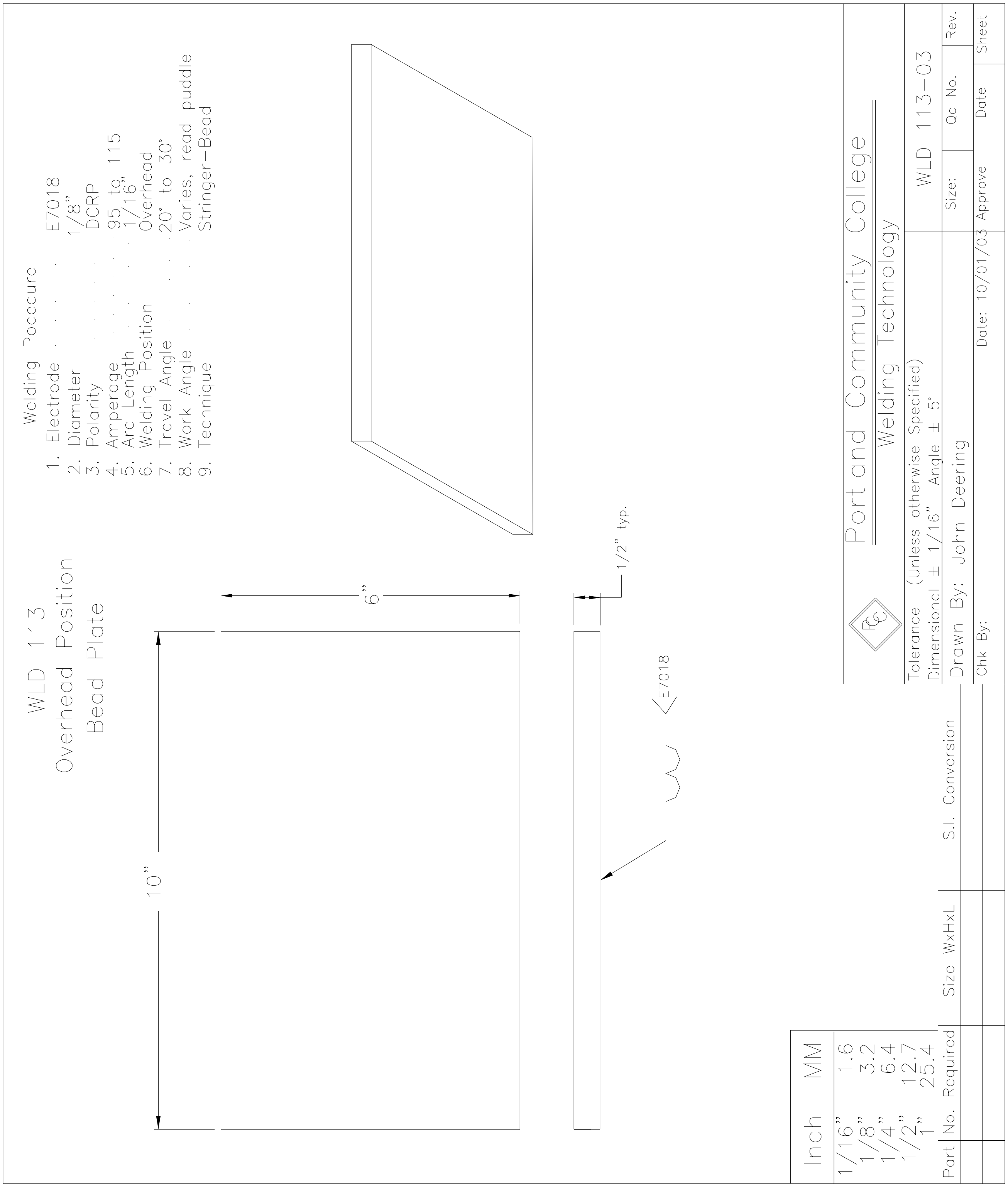
VT Criteria	*Student Assessment*	*Instructor Assessment*
Reinforcement (0" –1/8")		
Undercut (1/32")		
Groove within (+ or - 1/8") of being straight		
Width and Depth of groove within (+ or – 3/32")		
Penetration		
Cracks (none)		
Arc Strikes (none)		
Fusion (complete)		
Porosity (none)		
		Grade ***Date***

E7018 Overhead Bead Plate Project #3

Welding Sequence
Deposit stringer beads by using a slight circular motion in the puddle maintaining a short arc length. Move fast enough to avoid letting the weld metal spill out, but do not be alarmed if some slag falls out. Use amperages in the lower portion of the range. Special care should be taken to clean slag from every bead on multiple pass welds to avoid slag inclusions that would appear on an x-ray. Alternate direction with each pass and weld the full length of the plate. Adjust travel speed to keep puddle size consistent.

NOTE: This photo shows bead placement, there should not be any space left on plate.

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

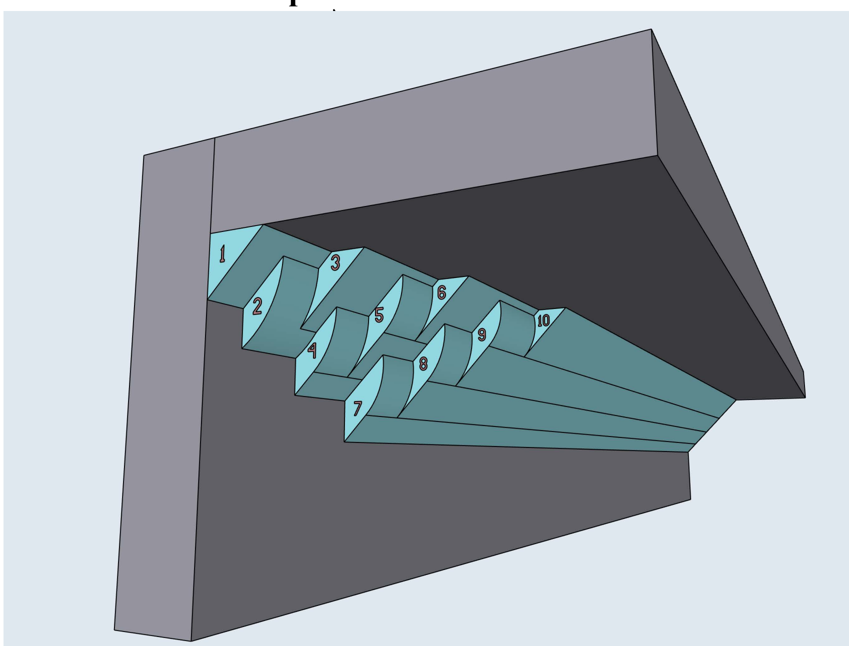

WLD 113
Overhead Position
Bead Plate
Welding Pocedure
1. Electrode E7018
2. Diameter . . . . . 1/8"
3. Polarity . . . . . DCRP
4. Amperage . . . . . 95 to 115
5. Arc Length . . . . . 1/16"
6. Welding Position . . . . . Overhead
7. Travel Angle . . . . . 20° to 30°
8. Work Angle . . . . . Varies, read puddle
9. Technique . . . . . Stringer-Bead
6"
10"
1/2" typ.
E7018
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
PCC
Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
Drawn By: John Deering
Chk By:
Date: 10/01/03
Approve
Date
WLD 113-03
Size:
Qc No.
Rev.
Sheet

E7018 Overhead T-Joint (4F) Project #4

Welding Sequence for Multiple-pass T-Joints
Deposit stringer beads by using a slight oscillation with a short arc length. Oscillation movements should be slow and deliberate. Move fast enough to avoid letting the weld metal spill out of the puddle but do not be alarmed if some slag spills out.

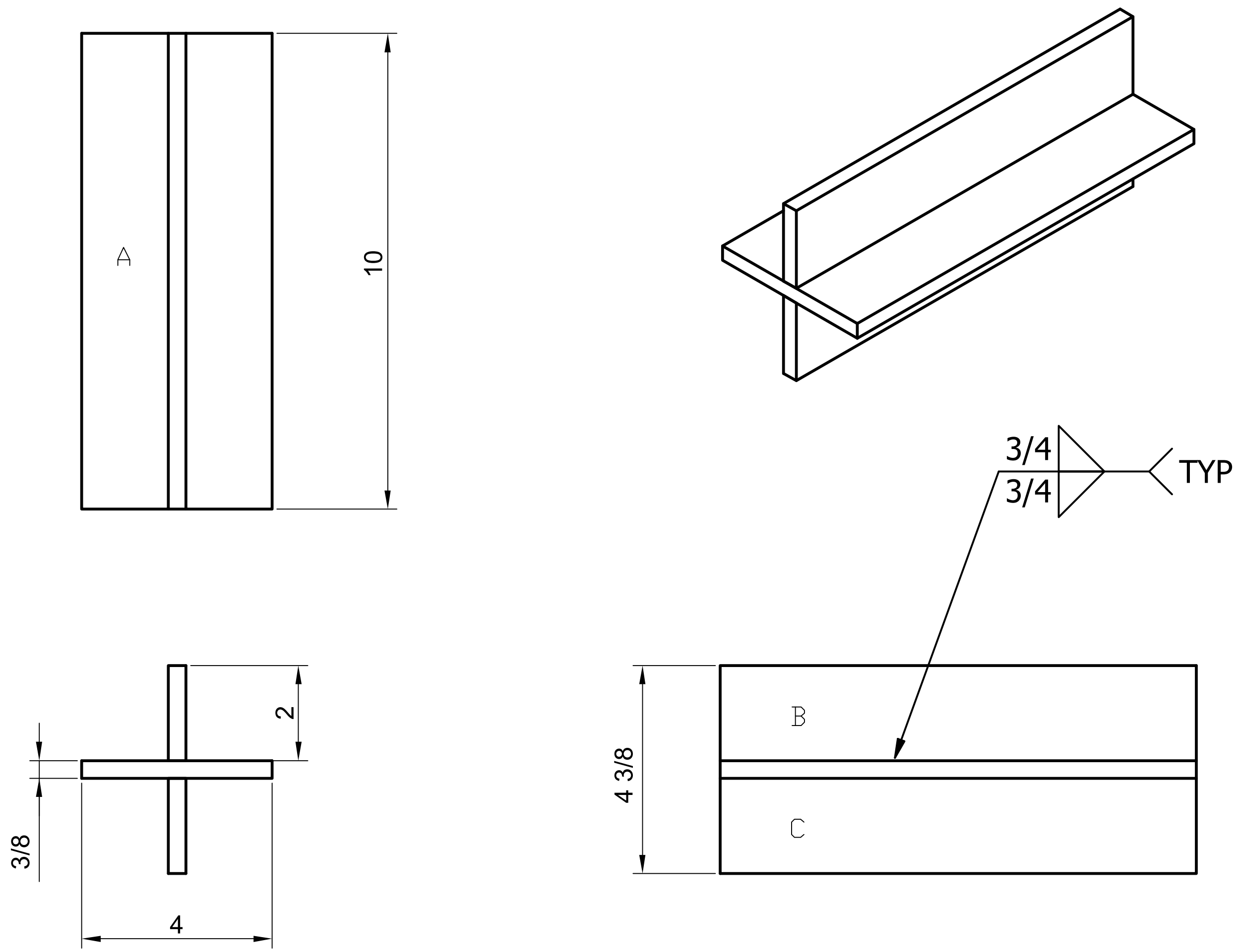
When welding the first pass, the tip of the electrode must touch both legs of the T-joint. After the first bead, the bead placement sequence starts on bottom plate first and you work to the top plate. Clean every bead thoroughly before proceeding to next bead.

This photo shows Bead Placement



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

GRADE	
TOLERANCES:	
DIMENTIONAL +/- 1/16 Angle +/- 5°	
ELECTRODE	E7018
DIAMETER	1/8
AMPERAGE	
VOLTAGE	
SHIELDING gas	N/A
POLARITY	DCEP



POSITION	

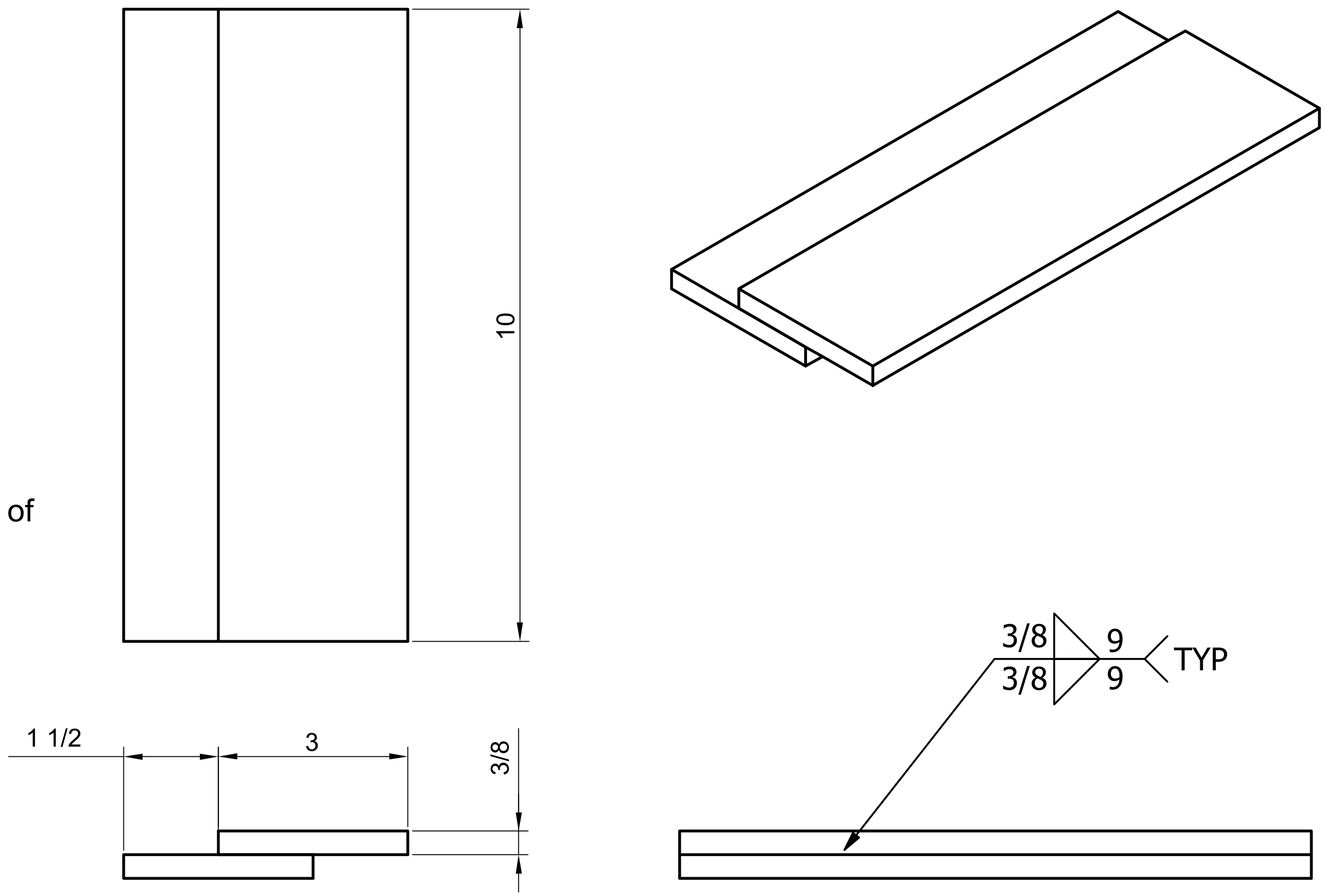
PROCESS	

PART LETTER	THICKNESS	WIDTH	TOLERANCE +/-	LENGTH	TOLERANCE +/-

TITLE		
113 Overhead T-joint		
LAST UPDATED 06/07/21	UNITS in	SHEET 1 / 1
THIRD ANGLE PROJECTION	SCALE 1:4	SIZE A

GRADE	
TOLERANCES:	
DIMENTIONAL +/- 1/16 Angle +/- 5°	
ELECTRODE	E7018
DIAMETER	1/8
AMPERAGE	
VOLTAGE	
SHIELDING gas	N/A
POLARITY	DCEP

Note:
No weld allowed within 1/2" of lap-joint ends.



POSITION	

PROCESS	

PART LETTER	THICKNESS	WIDTH	TOLERANCE +/-	LENGTH	TOLERANCE +/-

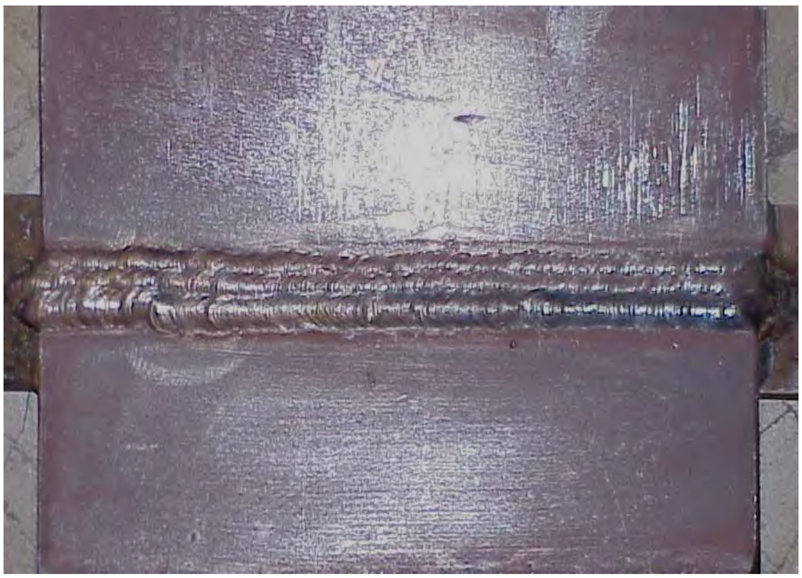
TITLE
113 Overhead Lap Joint

LAST UPDATED	UNITS	SHEET
06/07/21	in	1 / 1
THIRD ANGLE PROJECTION	SCALE	SIZE
	1:3	A

E7018 Overhead V-Groove(4G) Project #5

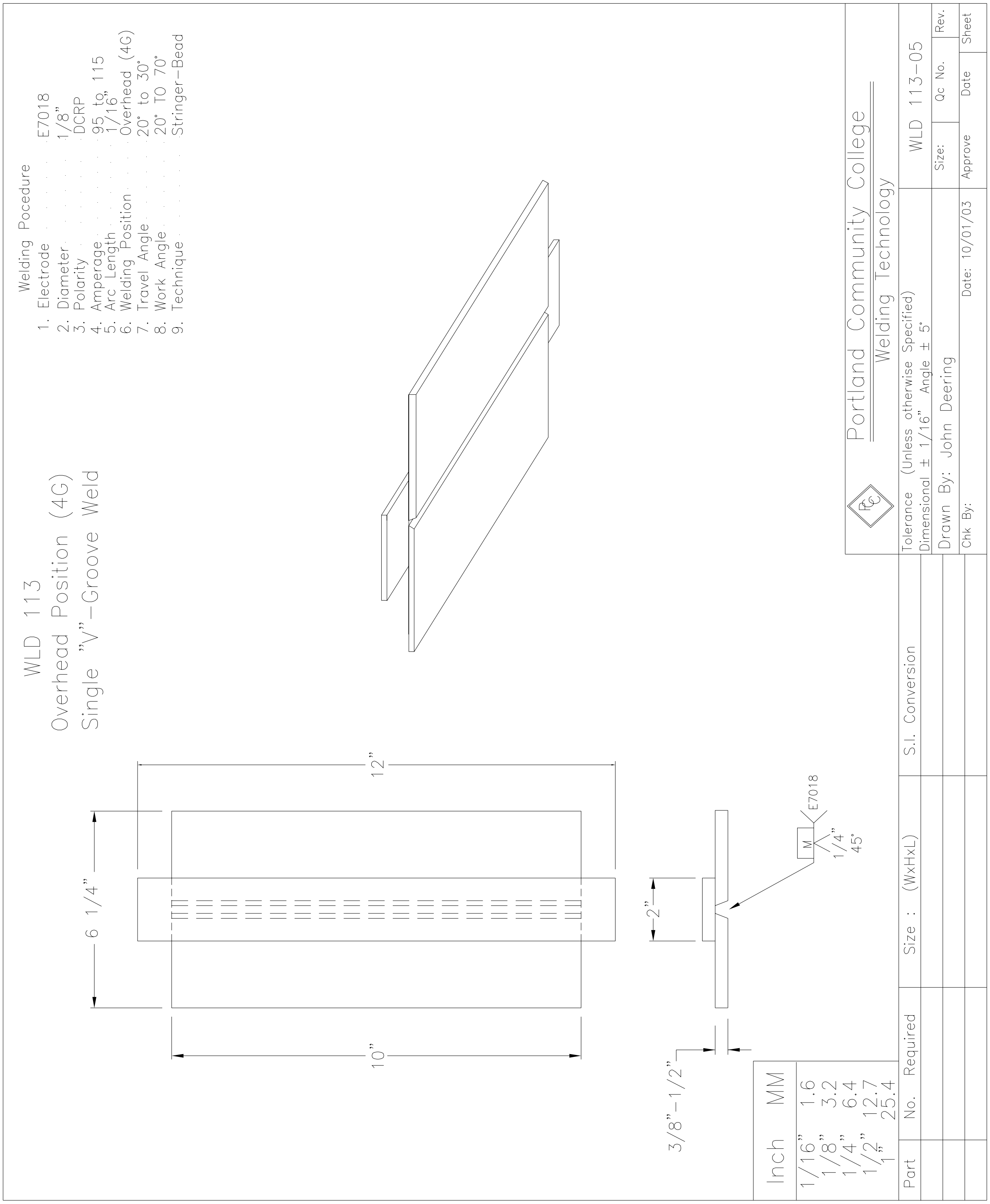
Welding Sequence

Multiple-Pass: Deposit the root pass so that it has equal dilution into each piece of metal using a slight oscillation technique. Weld the second layer using a slight side-to-side weave covering the entire root pass. Be sure to pause at the sides of the puddle long enough to cover the whole root pass and to melt out any small slag pockets and to minimize undercut. From this point, use straight stringer beads filling the groove up to just below the top of the base material before applying the cover pass. Care should be taken to clean slag after every pass to avoid slag inclusions that would appear on X-ray. Use stringer beads for the cover pas.



Overhead V-Groove

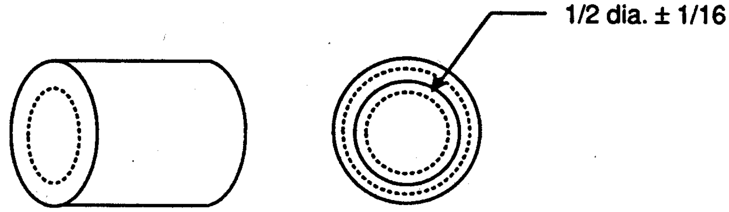
VT Criteria	*Student Assessment*	*Instructor Assessment*
Reinforcement (0" –1/8")		
Undercut (1/32")		
Weld Bead Contour (Smooth)		
Penetration		
Cracks (none)		
Arc Strikes (none)		
Fusion (complete)		
Porosity (none)		
		Grade ***Date***


WLD 113
Overhead Position (4G)
Single "V"-Groove Weld
Welding Pocedure
1. Electrode E7018
2. Diameter 1/8"
3. Polarity DCRP
4. Amperage 95 to 115
5. Arc Length 1/16"
6. Welding Position Overhead (4G)
7. Travel Angle 20° to 30°
8. Work Angle 20° TO 70°
9. Technique Stringer-Bead
6 1/4"
12"
10"
2"
3/8"-1/2"
E7018
M
1/4"
45°
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
PCC
Tolerance (Unless otherwise Specified)
Dimensional ± 1/16" Angle ± 5°
Drawn By: John Deering
Chk By:
Date: 10/01/03
WLD 113-05
Size:
Qc No.
Rev.
Approve
Date
Sheet

Calculating Fractional Tolerances

Often, when a dimension of a part is given on a blueprint, a maximum or minimum allowance is shown. These maximum and minimum allowances are called **tolerances.**

For example, in the part shown below, the hole diameter is shown to be half of an inch plus or minus one-sixteenth of an inch.



This means that the maximum diameter is

$$\frac{1}{2} + \frac{1}{16} \quad \text{or} \quad \frac{8}{16} + \frac{1}{16} = \frac{9}{16}$$

and the minimum diameter is

$$\frac{1}{2} - \frac{1}{16} \quad \text{or} \quad \frac{8}{16} - \frac{1}{16} = \frac{7}{16}$$

So the hole diameter must be between 7/16 and 9/16.

Complete the table below:

DIMENSION	MINIMUM	MAXIMUM
6 ± 1/8		
4 15/16 ± 1/16		
14 5/8 ± 1/32		
5 1/4 ± 1/16		
2 3/8 ± 1/16		
7/8 ± 1/32		

FRACTIONAL TOLERANCES

QUIZ

Give the minimum and maximum for each tolerance below. Then circle all those numbers below each tolerance which fall within that tolerance range. If necessary, use the margin to raise fractions to higher terms so that you can compare to see if the measurements go outside the specified tolerance range.

TOLERANCE:	MINIMUM	MAXIMUM
1. 7 ± 1/16 $7\frac{1}{32}$ 7 $6\frac{13}{16}$ $6\frac{15}{16}$		
2. 5 1/2 ± 1/8 $5\frac{5}{8}$ $5\frac{10}{16}$ $5\frac{11}{16}$ $5\frac{5}{16}$		
3. 6 3/4 ± 1/32 $6\frac{21}{32}$ $6\frac{25}{32}$ $6\frac{10}{16}$ $6\frac{13}{16}$		

Comparing Fractions

Deciding whether measurements are in tolerance or not

When comparing fractions, they must be put in the same terms. In this example we want to know which is larger: $^{3}/_{8}$ or $^{5}/_{16}$?

Put them in the same terms: $^{6}/_{16}$ $^{5}/_{16}$

It is now easy to tell that $^{3}/_{8}$ ($^{6}/_{16}$) is larger.

<u>Circle the larger:</u>

$^{7}/_{16}$ or $^{3}/_{8}$	$^{5}/_{64}$ or $^{3}/_{16}$
$^{3}/_{8}$ or $^{7}/_{32}$	$2\,^{3}/_{8}$ or $2\,^{7}/_{16}$
$^{1}/_{16}$ or $^{3}/_{64}$	$4\,^{6}/_{32}$ or $4\,^{1}/_{4}$
$5\,^{7}/_{16}$ or $5\,^{11}/_{32}$	$13\,^{3}/_{8}$ or $13\,^{25}/_{64}$

<u>Arrange in order from SMALLEST to LARGEST:</u>

$^{3}/_{8}$	$^{1}/_{4}$	$^{3}/_{16}$
$^{5}/_{16}$	$^{3}/_{64}$	$^{5}/_{8}$
$^{3}/_{4}$	$^{3}/_{64}$	$^{11}/_{16}$
$^{7}/_{32}$	$^{11}/_{16}$	$^{1}/_{8}$
$2\,^{3}/_{8}$	$2\,^{7}/_{16}$	$2\,^{1}/_{2}$
$^{3}/_{4}$	$^{3}/_{8}$	$^{3}/_{16}$
$^{1}/_{2}$	$^{9}/_{16}$	$^{5}/_{32}$
$^{13}/_{16}$	$^{7}/_{8}$	$^{3}/_{4}$

Vocabulary Terms

Name: ____________________ WLD______ Date: _________

Directions: Use the glossary in *Welding Principles and Applications* to complete the vocabulary words on this work sheet, using **complete sentences**. Do not hesitate to **reference other sections** in the text to find answers.

1. Coalescence

2. Penetration

3. Root bead

4. Root Penetration

5. Weld Bead

6. Fast freeze

Name: ____________________ WLD_____ Date: _________

Directions:

Chapter 25 in *Welding Principles and Applications:* to complete the questions on this work sheet. Answer the questions using **complete sentences**, and do not hesitate to reference other sections in the text to find answers.

1. What groups have developed electrode identification systems?

2. Referring to Table 25-1 determine the following:

   A. Lincoln Electric Company E6010

   B. Hobart Brothers Company E7018

   C. Teledyne McKay E7024 electrode

3. What types of general information about electrodes may be given by different manufactures?

4. Define Tensile strength.

5. What chemicals and alloys are;
   a. Considered to be contaminants to the weld metal?

b. Used to increase tensile strength in the weld metal?

c. Used to increase corrosion resistance?

d. Used to reduce creep?

6. What should CE be used for?

7. What welding parameters should be used for a metal that has a CE of more than 0.60%?

8. What are the functions of the flux on the SMAW electrode?

9. How does an SMAW welding electrode's flux covering produce the shielding gas to protect the weld?

10. What fluxing agents act as scavengers in the molten weld pool?

11. How can an SMAW welding electrode's flux help with deeper penetration?

12. List the things that must be considered before selecting an electrode for a specific job.

13. Why can there be more than one electrode for each classification manufactured by the same company?

14. What do the following filler metal designations stand for?

    a. E

    b. ER

    c. RG

    d. IN

15. Explain the parts of the AWS electrode classified as E7018.

Arc Gouging

Name: ______________________ WLD_______ Date: _____________________

Directions

Chapter 9 in your Welding Principles and Applications: to complete the questions on this work sheet. Answer the questions using *complete sentences,* and do not hesitate to ***reference other sections*** in the text to find answers.

1. What is CAC-A?

2. Describe the process of air carbon arc cutting.

3. Give the recommended procedure for air carbon arc gouging of carbon steel, magnesium alloys, low alloy copper.

4. Why are some carbon arc electrodes copper-coated?

5. What are the major differences between an electrode holder and an air carbon arc torch?

6. Air supplied to the torch should be between ________ and ________ psi.

7. Minimum air pressure is around ______ psi.

8. The root of a weld can be back gouged so that a backing weld can be made ensuring what?

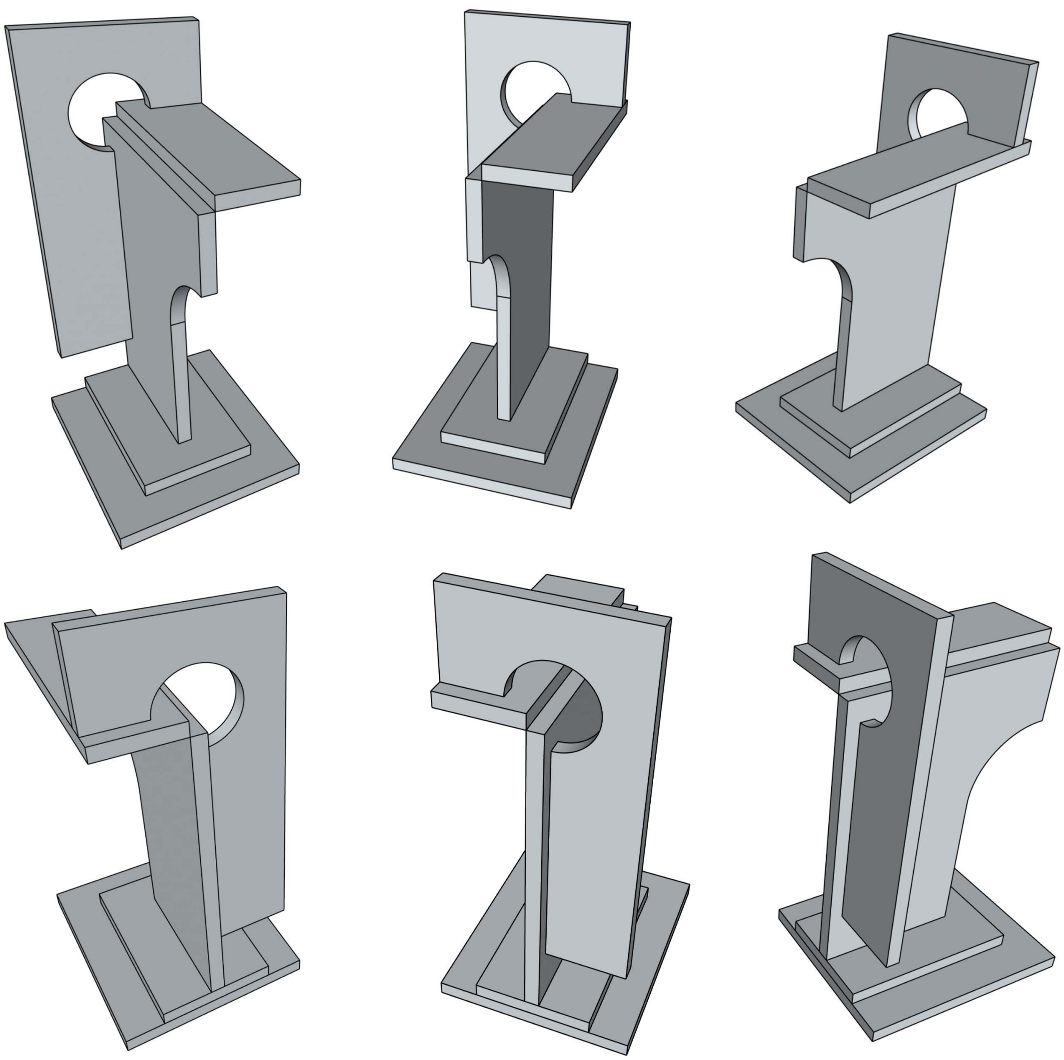
9. What type or types of power sources can be used for Carbon arc gouging?

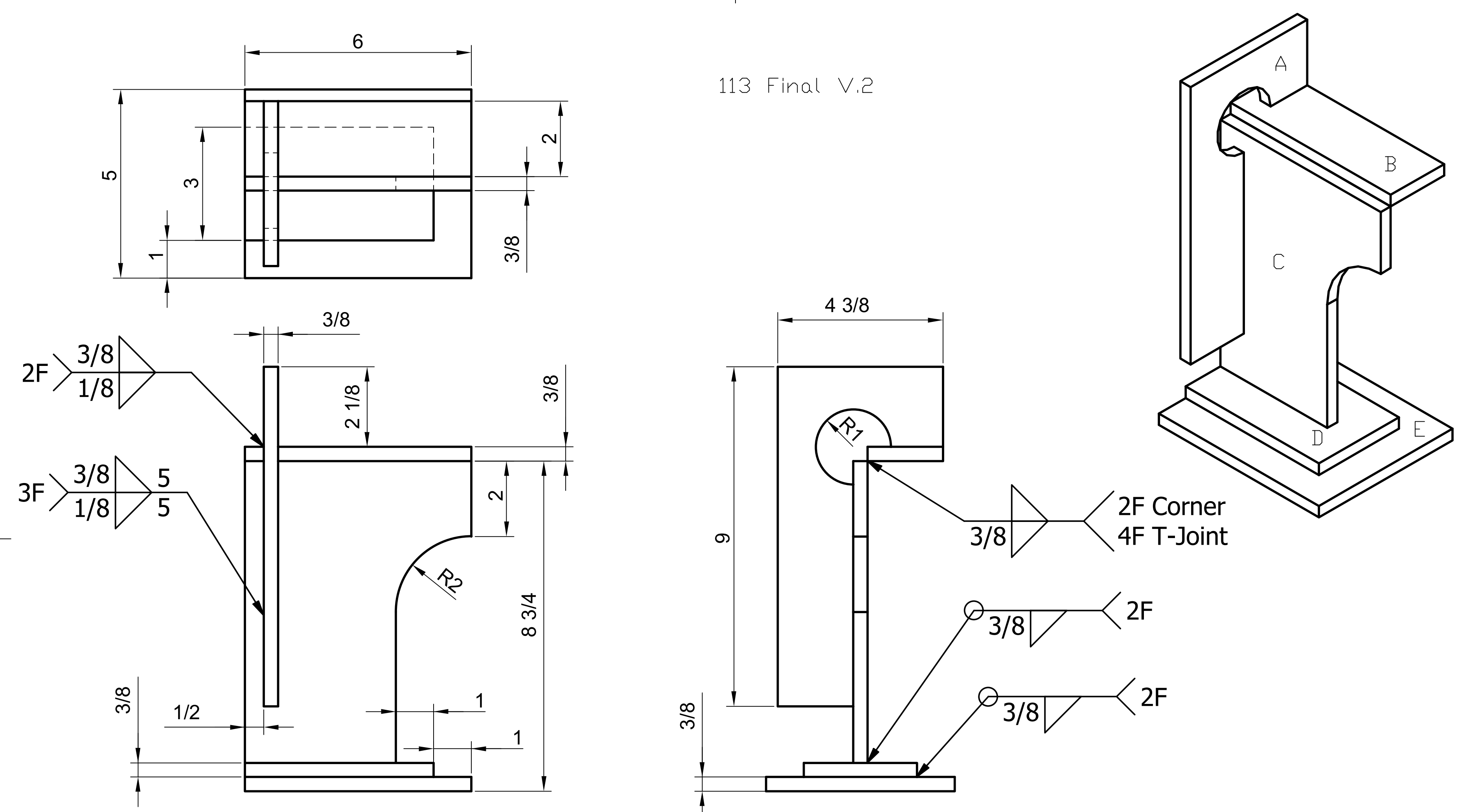
10. What three shapes do carbon electrodes come in?

Final Exam

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

Part Two
This portion of the exam is a practical test where you will fabricate and weld a weldment from a "blue print". The evaluation of this portion of the exam will be based on the Rubric. You will have two class period to construct and weld the project. When completed return the print with the weldment to the instructor.





Part	Quantity	Thickness	Width	Tolerance	Length	Tolerance
A				+		+
				-		-
B				+		+
				-		-
C				+		+
				-		-
D				+		+
				-		-
E				+		+
				-		-

TITLE
113 Final V2

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

LAST UPDATED	UNITS	SHEET
05/09/22	in	1 / 1
THIRD ANGLE PROJECTION	SCALE	SIZE
	1:4	A

Final Grading Rubric for practical exam
Class Name: WLD 113

Name: ________________________________ Date: _______________________

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

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

WLD 113 SMAW: Project Assessment Form

Student Name:________________ Date_________

Vertical Position	Assessment	Instructor Signature/Date
Lap Joint		
V-Groove		
Back Gouge		
U-Groove		

Overhead Position	Assessment	Instructor Signature/Date
Bead Plate		
T-joint		
Lap Joint		
V-Groove		