WLD 258
Preparation for Downhill Pipe Welding
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### Video Training

*Pipe Welding Made Easy – SMAW 6010/7018 - 2G*

Located in Welding Resource Room

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**National Science Foundation**

Opinions expressed are those of the authors and not necessarily those of the Foundation.
**Course Assignments**

**Reading Packet Information Sheets**
WLD 258, Information Sheets
*Welding Principles and Applications*, by Larry Jeffus
  - Shielded Metal Arc Welding of Pipe
  - Advanced Shielded Metal Arc Welding

**Writing Work Sheets**
- Welding Steel Pipe
- Welding Vocabulary

**Video Training**

**Welding Projects**
- 2G Butt - Single Vee Grove Weld - Open Root (plate)
- 3G Butt - Single Vee Grove Weld - Open Root (plate)
- 4G Butt - Single Vee Groove Weld - Open Root (plate)
- 2G Butt - Single Vee Groove Weld - Open Root (pipe)

**Final Exam**
- Part One (Closed Book Exam)
- Part Two (Practical Exam)

**Required Texts**
- *Welding Principles and Applications*, by Larry Jeffus

**Outcome Assessment Policy:**
The student will be assessed on his/her ability to demonstrate the achievement of course outcomes. The methods of assessment may include one or more of the following: oral or written examinations, quizzes, written assignments, visual inspection techniques, welding tests, safe work habits, task performance and work relations.
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.
E6010 Pipe Certification

Contents of this Packet
- Introduction
- Importance of Code Qualification
- Mechanical Properties Testing for Pipe Welding Qualification
- Code Requirements
- Significance of Bend Testing
- Concave Root Surface (Suck Back)

Introduction
This packet covers the welder qualification using the combination of E6010 cellulosic electrode. E6010 is the deepest-penetrating, all-position electrode. To achieve such deep penetration, the highest amount of cellulose is used in the flux cover. The cellulose also provides large amounts of gaseous shielding with minimal slag. This allows the welder to have a clear view of the keyhole in open root welding.

Importance of Code Qualification
In all industries, there are applicable codes and standards to assure the quality, reproducibility, and adequacy of welded joints. Depending upon the application, a welded joint may need certain mechanical properties; for example, welds on bridges must pass tests for strength, tensile ductility, bend ductility, and Charpy impact toughness. These codes are based on many years of experience. Changes to codes are ongoing to reflect the dynamic changes that are taking place in the industry. There are many welding codes to ensure quality welding. For example, the following is a list of only a few typical industries and governing codes for welding quality.

<table>
<thead>
<tr>
<th>Pressure Vessels</th>
<th>ASME Boiler and Pressure Vessel Code (Section IX – Welding Qualifications)</th>
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<tr>
<td>Cross Country Pipelines</td>
<td>API Standard 1104; Standard for Welding Pipelines and Related Facilities</td>
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</table>
**Mechanical Properties Testing for Pipe Welding Qualification**

In all codes for welded structures and pipe, various degrees of mechanical testing are performed to assure the quality and integrity of the structure. This includes both procedure qualification and welder qualification. For example, the procedure qualification for pipe as well as steel structures in accordance with the AWS D1.1 Structural Steel Welding Code requires that certain welds undergo all-weld-metal tensile testing, transverse-to-weld tensile testing, side bend testing, Charpy v-notch (CVN) impact testing as well as non-destructive testing. Mechanical testing is very important because it ensures that the welding procedure, welder qualification, consumables, and the resulting metallurgy of the weld and heat-affected zone were all acceptable. Welder qualification generally requires less mechanical testing than the procedure qualification; for example, welder qualification typically includes visual, non-destructive testing, and face bend and root bend testing.

**Code Requirements**

When a pipeline or pressure piping is going to be built, the owner and contractor agree on the appropriate welding code, which will be needed to govern the acceptability or rejection of welds being fabricated. API-1104 and ASME Boiler and Pressure Vessel Code can be used for piping applications. Codes are devised to provide welded joints with acceptable strength, ductility, and CVN impact toughness for the intended application. These codes also provide for procedure qualification requirements and welder qualification. The qualification and certification tests for welders are specially designed to determine the welder’s ability to produce sound welds routinely. To achieve these quality standards, the welder qualification and certification provide the means to ensure acceptable welds.

**Soundness Testing**

Soundness is a term used to describe if a weld is solid throughout with no flaws. Soundness in the welder certification process is usually determined through destructive tests. Below are a few tests that the API 1104 code utilizes to ensure weld soundness.

**Bend Testing**

Of all the tests prescribed by different welding codes, the bend test provides the best and most reliable measure of ductility/soundness of the entire weld joint, including the weld metal, heat-affected zone, and unaffected base metal. Welder qualification tests in API 1104 specify bend testing of welded joints. This is because the bend test is extremely sensitive to all types of metallurgical problems associated with welding. For example, weld joints which have inadequate ductility and fail the requirements of the bend test may be due to: (a) hydrogen assisted cracking, (b) microfissuring due internal solidification cracking, (c) excessive slag inclusions, (d) excessive porosity, (e) wrong filler metal, causing embrittlement, (e) wrong welding parameters, causing embrittlement, and (f) other metallurgical factors affecting the ductility of the weld joint.
**Nick Break Testing**
Break any way – pull apart (tensile), hammer, or bend. The objective is to break in the weld zone so the weld is evaluated for flaws. Essentially one will prepare the Nick Break samples much like a tensile test with the exception that notches (nicks) will be cut into the weld face(s) with a hacksaw to ensure the weld breaks in the weld zone.

**Significance of Tensile Testing**
Tensile tests are usually used for both Welding Procedure Qualifications and Welder Qualification Tests. The idea of the tensile test is to ensure that the filler metal is stronger than the parent metal (base metal). As in structural steel there are several types of pipe material available with certain properties. It is essential that the welder not only uses the correct filler metal it is also important that s/he uses the correct welding variables to keep the integrity of the weld, HAZ and parent metal to guarantee the integrity of the final product.

**Concave Root Surface (Suck Back)**
The root pass of an open root weld often exhibits “suck back” or a concave root surface in pipe joints. This is due to a complex set of forces, which simultaneously act upon the molten metal in the bottom of the open root. As the open root pass begins to solidify, the weld shrinks and the remaining liquid is stretched across the root face to form a concave root surface or suck-back. The liquid can actually stretch to some degree without burn-through because surface tension acts to hold the molten metal together.

The three most important forces acting on the root pass are (1) surface tension of the molten metal, (2) gravity, and (3) arc force. None of these forces are easily controlled by the welder. **Surface tension is a beneficial property of the molten weld metal, which tends to hold molten metal together; much like a balloon holds liquid water.** Surface tension forces increase with decreasing temperature of the molten weld metal. Gravity always tries to oppose the beneficial effects of surface tension of molten metal in the open root. The effects of gravity are dependent upon the size and weight of the weld pool as well as the welding position used; for example, flat, compared to overhead, compared to vertical-up. The larger the weld pool size of the root pass, the more difficult it will be for surface tension to hold the molten metal in place. **Arc force increases with increasing amperage. Too high an arc force will burn through the root. With decreasing amperage and decreasing size of root pass, the greater will be the surface tension forces holding the molten pool in place.**

Surface tension is the most important beneficial force, because without surface tension, open root welding would not be possible. Without surface tension, the molten metal in the open root would act like water and flow through the root opening. Surface tension is always trying to keep the molten pool from dripping out of the root area. Imagine a balloon full of water, the elastic polymer provides the restraining forces to keep the water...
in place. If outside forces are too great, the balloon will distort, burst and water will escape. Similarly, in a full-penetration open-root pass, the heat input must be adjusted so that surface tension will hold the molten metal in the root opening. The smaller the root pass, the easier it is for surface tension forces to hold the molten metal in place. When the root pass is deposited by E6010 electrode, just the right amount of heat input is needed to produce a keyhole in the joint for full penetration. With too little heat, full penetration will not be achieved; while, with too high heat input, the arc will blow through the joint. At the optimum level of heat, the molten metal is suspended by surface tension forces in the gap of the open root. Surface tension forces overcome gravity and the root pass is achieved.

How does “suck back” develop in the root and what controls the amount of suck back? Surface tension is necessary to hold and suspend the molten metal in the open root without dropping through like water. Surface tension of molten metal in the open root acts as if the molten metal is in an “impervious bag” which prevents liquid from falling through the open root. Fortunately, the surface tension of molten iron is very high; for example, the surface (tension) energy of iron at its melting point is about twice that for aluminum at its melting point. So during solidification, the shrinkage forces between the two root faces pull on the molten pool substantially to produce a concave root surface or suck back. Suck back can be overcome if the welder can provide additional weld metal into the root. This is dangerous because of the increased chance of drop-through. Fortunately, in welding, the use of fast freezing fluxes and good welder skill reduce the occurrence of excessive concave root surfaces.
Science on Steel Worksheet—WLD 258 #1

Name: __________________________  Date: _________________

Complete each question using complete sentences.

1. List 2 codes that are listed in the science section which apply to welding pipe.

2. What do each of the above codes cover application wise.

3. Why does suck back happen?

4. Define Surface Tension (use any source for this definition)

5. If you are experiencing too much suck back what are 2 adjustments that should be made?
6. Why is mechanical testing in pipe welding important?

7. Why are bend tests significant to the welder qualification and procedure qualification process?

8. What are the three types of bend tests?

9. What is the difference between a Nick break Test and a Tensile Test?

10. What are three factors that affect suck back in pipe welding?
Plate Preparation & Welding Information Sheet

Prepare 1/4-inch-thick plates to be welded using the “keyhole” technique when welding the root and hot passes of an open root groove weld with the E6010 electrode. The fill and cap passes will be welded out with the E6010 electrode.

1. Use the Track burner to cut a 30-degree bevel angle on the 1/4” plate. Triangle protractors are available in the Tool Room to assist in setting the torch angle.

2. Use a grinder and a file to prepare the groove face and the root land. The groove face should be ground to a shiny appearance with a root face equal to a width of 1/16 of an inch. This is known as a “dime thickness.”
3. Fit the 1/4" thick plates together with a “dime face and dime root opening.”

Note that a 1/16” piece of filler metal is used as a spacer.

Note that the plates are aligned on one plane. This prevents one plate from being higher than the other. This condition would be termed “Hi – Low.”

4. Tack weld the ends of plate. Tacks should average 1/2" to 3/4" in length. The first tack, however, should be approximately 1/4” long to control distortion and shrinkage. Feather back the end of the tack with a hand grinder (notching wheel) to provide access for 100% penetration.

The tack weld is ground at each end to ramp the weld. This technique will ensure complete joint penetration when the welder applies the root pass.

Limit the grinding on the keyhole end because this is a thin area due to the weld profile. Excessive grinding at keyhole end can lead to excessive burn through.
5. After positioning the plate in the desired position, strike the arc and extend the arc length ("long arc") over a tack weld to allow electrode to "warm up." "Pop" into open root and pause slightly, and begin welding. Note that the arc is "burning" through the root opening and obtaining complete penetration. This creates a distinctive “beehive”: type of sound and is one of the indicators that 100% penetration is being obtained.

6. Use the step technique to apply the root pass. The step technique is a modified whip and pause technique and is defined as moving the rod in and out of the puddle in small steps. While using this technique in the root pass, ensure that the majority of the arc’s light ("fire") stays on the back side of the pipe/plate. This creates a distinctive sound to the arc that indicates to the welder s/he is attaining 100% penetration. This small motion will allow the puddle to freeze and easily be worked forward when applying the root pass.
Plate Preparation & Welding Information Sheet Continued

7. While welding the root pass, the electrode should be touching the root land or pushed into it slightly. Pushing the electrode into the root land too far will cause undercut on the backside. Use a drag technique while watching a keyhole develop, then adjust travel speed to fill the crater/keyhole.

8. Note that the electrode can be held at the top of the root face or pushed into it slightly.

Five variables to control when running the open root pass:
- Root land
- Root opening
- Amperage
- Arc length
- Travel speed

Root Bead Suggestions:
- Center stringer when welding, this will help prevent internal undercut or inadequate penetration (IP).
- Keep bead moving forward.
- Vary technique for joint fit up.
The ideal keyhole size is just slightly larger than the electrode.

Adjust Technique for Root Fit Up

Narrow gap techniques:
• Push electrode into opening
• Increase amperage
• Grind root area to reduce root land

Wide gap technique:
• Weld wide section last, hopefully welding the other three quadrants will shrink wide area.
• Reduce Current
• Use U-weave
• Allow pipe to cool.

Internal Undercut:
• Electrode is too deep into groove
• Amperage is too high
• Root opening is too large
• Root land is too thin

Stopping techniques
Use a quick step out of the root bead to decrease keyhole size when terminating the weld. Leaving a large keyhole can cause excessive internal root reinforcement.
Root Pass Inspection

A “Downhill” E6010 (5P) quality root pass
Plate Preparation & Welding Information Sheet Continued

- Remove the slag from the internal root pass side, and inspect the root for complete penetration, undercut and excessive penetration. See Craftsmanship Expectations for inspection criteria.

Applying the Hot Pass, second pass, with an E6010 using the whip and pause technique.

- Grind root pass clean with a hand grinder prior to applying the hot pass.
- Apply the hot pass within 5 minutes of completing the root pass.
- Increase amperage 10 to 20 amps above root bead setting.
- Use the whip and pause technique with a medium arc length. Use a circling technique emphasizing the sides of the puddle ("Paint The Walls") to melt out the slag which is referred to as wagon tracks.

Purpose for the hot pass is to:
- Burn out slag (wagon tracks)
- Re-contour stringer
- Anneal (stress relieve)
- Drive out hydrogen in heat affected zone (HAZ)
**Plate Preparation & Welding Information Sheet Continued**

*Fill and Cover Pass Technique*

A tight arc length is essential when welding with E6010. The puddle relies on the vaporization of the flux and the molten slag for added shielding. Keep electrode in the puddle to produce a sound weld.

Failure to follow these techniques can result in porosity, undercut, slag inclusions, and lower impact strength.

**Oscillation Techniques**
- Straight side-to-side weave for the flat, vertical and overhead positions.
  
  ![Pause slightly at the sides](image)

- Slant Loop for the horizontal welding positions.
  
  ![Pause slightly at the top of the rotation](image)
Fill Pass for 2G

Pause at the top

Note: For a horizontal weld, the maximum bead width should be no more than $\frac{1}{2}$" wide. Excessively wide beads will lead to overlap.
Plate Preparation & Welding Information Sheet Continued

The *Slant Loop* technique is also an excellent choice for fill passes.
(Stringer bead technique used for cap)

Stringer bead cover pass sequence for the horizontal position (2G).
Watts Pipe Cutter Information Sheet

- The Watts pipe beveler uses oxygen and acetylene to flame cut pipe bevels. All safety procedures that apply to the track burners and hand torches apply with this pipe beveler.

- Place pipe in jaws and snug jaws down with T-bar wrench.

- Swivel cutting head over pipe ensuring there is approximately ¾” clearance between the cutting tip and pipe.

- Slowly hand rotate the pipe referencing the cutting tip to pipe wall distance. For a quality cut this variation should not exceed 1/16”. Make adjustments when necessary.

- Tighten jaws after alignment is completed.
Watts Pipe Cutter Information Sheet

- Turn on the manifold and adjust cutting pressures. A good starting point is 5 psi for Acetylene and 40 psi for Oxygen with a cutting tip.

- Turn the Ignite toggle switch ON and open the acetylene needle valve on the back side of the unit. Light the torch and adjust the acetylene flame so the heavy soot disappears.

- Add oxygen, and adjust to a neutral flame.
Watts Pipe Cutter Information Sheet Continued

- Turn the *Cut and Roll toggle switch* ON and adjust to a neutral flame. When adding the cutting oxygen, the fuel gas to oxygen ratio changes, thus requiring the need to readjust to a neutral flame.

- Once flame is adjusted, the manual needle valves do not need to be turned off each time. Use the *Ignite toggle switch* to turn the torch ON and OFF.

![Rotation Speed Control Diagram]

- Light torch and align head over the pipe. Use the *Fast Roll toggle switch* and preheat the pipe by having it rotate 360 degrees. Once pipe is preheated let the torch set idle over one area to heat to the kindling temperature (cherry red).

  *Helpful Hint:* Clamp vice grips at the cutting start point. This is a good visual reference for when the pipe cut will be completed, as well as a tool to catch the pipe coupon.

- Once pipe is cherry red, turn the *Cut and Roll toggle switch* on and the cut will begin.

  *Helpful Hint:* Once flame pierces through the pipe, adjust the torch back slightly to remove the starting flaw.
Watts Pipe Cutter Information Sheet Continued

- Once pipe cut is completed, adjust torch extension arm back to make additional cuts or remove pipe coupon and replace with next coupon and complete the cutting process.
Watt’s Pipe Grinding Station Information Sheet

- Ensure pipe is cool enough to touch before handling it.
- Mount pipe in the rotating fixture ensuring that it is mounted concentrically.
- Tighten the thumbscrew ensuring that the pipe is secure.

Thumb Screws

- Hand start the pipe fixture rotation and then begin grinding the groove face.
- Ensure grinder has enough clearance, so it does not hit or catch on the rotating fixture.
Watt’s Pipe Grinding Station Information Sheet Continued

- Do not let the fixture rotate too fast. Slow it down frequently so that the pipe is not thrown from the fixture.

- Ensure the grinder is placed in such a way that the sparks are shooting downward.

- Ensure screens are in place so no by standers are showered with sparks.

- Grind the groove face clean, and then grind the root face (land). For the down hill root pass technique, use a “dime land” (the land is ground to a thickness of a dime which is approximately 1/16” to 3/32”).
Once grinding is completed, remove pipe coupon, replace with next coupon and complete the grinding process.
Pipe Fitting Information

1. Pre-assemble pipe coupons together and rotate top pipe to determine best fit-up to eliminate high-low condition and excessive root opening. Once the best fit up is determined, draw a soap stone line to indicate placement of pipe coupons after the spacer is put into place.

High Low
A high-low condition refers to the pipe material being offset at the fit up area. This is due to each pipe coupon not being a perfect circle. The ASME Code only allows 1/16” for high low.

2. Place a spacer wire between the pipes for the proper root opening. Rotate the top pipe to minimize a high low fit-up.
3. Make the first tack weld ½” long between the open ends of the spacer wire. The first tack should only be ½” long to help control distortion. The remaining three tacks should be ¾” long.

4. Remove the spacer wire and reposition it as shown, and weld the second tack opposite the first tack (this is referred to as diametrically opposed to the first tack).
5. Tack weld the two remaining sides starting with the wider of the two sides. At this point the pipe should have one tack weld at 12, 3, 6 and 9 o’clock positions.

6. Use a hand grinder with a 1/8” thick notching wheel to feather (ramp) the tacks. The keyhole side of the tack will not need as much grinding. Too much grinding on this end of the tack will potentially cause burn through when welding the root pass.

Minimal grinding at the keyhole end of the tack
6. Place the pipe in the fixture or on a table standing vertically and the weld is in the horizontal position. This is known as the 2G position.

7. Strike the arc and extend the arc length ("long arc") over the tack weld and allow electrode to "warm up." "Pop" the electrode into open root and pause slightly, and begin welding. Note that the arc is “burning” through the root opening getting complete penetration. This is seen by the keyhole that the arc creates.

The “fire” is inside of the pipe. Remember that this creates a distinctive “bee hive” sound.
8. Use the drag technique for the root pass pushing the electrode no more than half way into the root area. Ensure that the "fire" stays on the backside of the pipe. This will create the distinctive sound when obtaining 100% penetration.

Drag technique

Keep the arc tight and step no more than 1 electrode diameter in distance.

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Root Pass Arc Length

Keep a tight arc when touching down into the puddle. Try not to push electrode more than ½ way into the root face area.

Remember to keep the puddle moving forward. There is nothing but the puddle to catch itself on the backside of an open root weld.

Five variables to control when running the root pass:
- Root land
- Root opening
- Amperage
- Arc length
- Travel speed

Root Bead Suggestions:
- Center root pass (stringer) in the root opening when welding. This will help prevent internal undercut or inadequate penetration (IP).
- Keep the root pass moving.
- Vary technique for joint fit up.

The soundness of the root pass will be greatly affected by these five variables. The welder will need to learn to control these variables to produce a quality root bead.
Adjust Technique for Root Fit Up

Narrow gap techniques:
• Push electrode into opening
• Increase amperage
• Grind root area to reduce root land

Wide gap technique:
• Weld wide section last, hopefully welding other three quadrants will shrink wide area.
• Reduce current
• Use U-weave
• Allow the pipe to cool.

Internal Undercut:
• Electrode is too deep into groove
• Amperage is too high
• Root opening is too large
• Root land is too thin

Stopping techniques
Use a quick step out of the root bead to decrease keyhole size when terminating the weld. Leaving a large keyhole can cause excessive root reinforcement on the inside.
Applying the Hot Pass with an 1/8” E6010

- Grind root pass clean with a hand grinder prior to applying the hot pass.
- Increase amperage 10 to 20 amps above root bead setting.
- Use the whip and pause technique with a medium arc length. Use a circling technique “Paint The Walls” to remove wagon tracks.

Purpose for the hot pass is to:
- Burn out slag (wagon tracks)
- Re-contour stringer
- Anneal (stress relieve)
- Drive out hydrogen in heat affected zone (HAZ)

**E6010 Fill and Cover Pass Technique**

A tight arc length is helpful when welding with E6010. The puddles relies on vaporization of the flux and the molten slag for shielding.

Failure to follow these techniques may result in undercut since the E6010 series rods have an aggressive arc.

**Fill Pass for 2G**

**Pause at the top**

Note: For a horizontal weld, the maximum bead width should be no more than \( \frac{1}{2} \)” wide. Excessively wide beads will lead to over lap.
Cover Passes (Finish Beads) for the 2G

Finish beads stacked using stringer beads.

- Use the Slant Loop Stringer Bead Technique
- For the 2G weld, the maximum bead width should not be more than \( \frac{1}{2} \)" wide. Excessively wide beads will lead to overlap in the 2G position.
- Remove all slag with a wire wheel. Note that a hand file can be used to smooth out undercut at the weld and the pipe wall interface (toe). Excessive filing will not be permitted because it reduces the pipe wall thickness.
Shielded Metal Arc Welding Pipe—WLD 258 #2

Name: ________________________                 Date: _____________________

Directions:
Use the *Welding Principles and Applications* text book and internet to complete the following questions. Answer the questions using complete sentences, and do not hesitate to reference other sections in the text to find an answer.

1. List 5 variables the "welder" faces in running the first pass in an open root single vee groove weld.

2. List three characteristics of a pipe-welding electrode.

3. What is the name of the first pass in a complete joint penetration pipe weld?

4. Describe the difference between pipe and tubing.
5. What is the purpose of a backing ring?

6. What causes root suck back on a concave root surface?

7. What is the purpose of the "hot pass"?

8. On 5G welds, what usually determines the direction of the root pass?

9. Sketch a pipe in the 2G position

10. Sketch a pipe in the 6G position
11 Sketch the following destructive test samples

Side bend test

Nick Break test

Tensile Test
Welding Vocabulary—WLD 258 #3

Name: ____________________________  Date:  ___________________

Directions:
Define the following terms. Use the Welding Principles and Applications textbook and/or internet.

1. Hot pass

2. Keyhole Welding Technique

3. 5G

4. 6G

5. Tensile strength

6. Yield strength
7. Wagon tracks

8. Soundness Testing

9. Fish Eye

10. Socket weld

11. PQR

12. WPS

13. 5P+ Electrode

14. HYP Rod
Craftsmanship Expectations for Welding Projects

The student should complete the following tasks prior to welding.

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

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

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<th>Metal Preparation</th>
<th>Project Layout</th>
<th>Post Weld Clean-up</th>
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<tr>
<td>Oxyfuel cut quality</td>
<td>Accurate (+/- 1/16”)</td>
<td>Remove Slag/Spatter</td>
</tr>
<tr>
<td>Grind all cut surfaces clean</td>
<td>Limit waste</td>
<td>Remove sharp edges</td>
</tr>
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</table>

Weld Quality per API 1104

<table>
<thead>
<tr>
<th>VT Criteria</th>
<th>Root Pass</th>
<th>Cover Pass</th>
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<tbody>
<tr>
<td>Reinforcement</td>
<td>Flush to 1/16”</td>
<td>Flush to 1/8”</td>
</tr>
<tr>
<td>Undercut</td>
<td>1/32 “deep”</td>
<td>1/32” deep</td>
</tr>
<tr>
<td>Bead Contour</td>
<td>Smooth Transition</td>
<td>Smooth Transition</td>
</tr>
<tr>
<td>Penetration</td>
<td>Complete Joint Penetration</td>
<td>N/A</td>
</tr>
<tr>
<td>Cracks</td>
<td>None Allowed</td>
<td>None Allowed</td>
</tr>
<tr>
<td>Arc Strikes</td>
<td>None Allowed</td>
<td>None Allowed</td>
</tr>
<tr>
<td>Fusion</td>
<td>Complete Fusion Required</td>
<td>Complete Fusion Required</td>
</tr>
<tr>
<td>Porosity</td>
<td>None Allowed</td>
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</tr>
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</table>
**E6010 Butt Joint- Single V (2G)  Project #1**

**Welding Sequence**

E6010--Root Pass  80-90 Amps. Utilize the "key hole" drag technique
E6010--Hot Pass  100-110 Amps. Increase amperage 10 to 20 amps above the root bead setting. “Paint the walls” to burn out wagon tracks.
E6010--Fill and Cap  90-100 Amps. Use a tight arc, keep the electrode stepping in and out of the puddle.

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**Front view of the horizontal groove weld**

### Weld Quality per API 1104

<table>
<thead>
<tr>
<th>VT Criteria</th>
<th>Root Pass/Cover Pass #1</th>
<th>Root Pass/Cover Pass #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforcement</td>
<td></td>
<td></td>
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<tr>
<td>Undercut</td>
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<tr>
<td>Bead Contour</td>
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</tr>
<tr>
<td>Penetration</td>
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</tr>
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<td>Cracks</td>
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<tr>
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<td></td>
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<tr>
<td>Fusion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Porosity</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade and Date</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Welding Procedure
1. Electrodes..............E6010
2. Electrode Diameter.....1/8"
3. Polarity..................DCRP
4. Amperage..............80 to 120
5. Root Face...............1/16" (dime thickness)
6. Arc Length..............Touching
7. Welding Position........Horizontal (2G)
8. Material Size...........1/4" plate
9. Travel Angle............20° to 30°
10. Work Angle..............20° to 70°
11. Root Opening...........1/16" (dime thickness)
12. Technique...............Stringer bead

---

<table>
<thead>
<tr>
<th>Inch</th>
<th>MM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/16&quot;</td>
<td>1.6</td>
</tr>
<tr>
<td>1/8&quot;</td>
<td>3.2</td>
</tr>
<tr>
<td>1/4&quot;</td>
<td>6.4</td>
</tr>
<tr>
<td>1/8&quot;</td>
<td>25.4</td>
</tr>
</tbody>
</table>

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Portland Community College
Welding Technology

WLD 258-01

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

Drawn By: John Deering

CHECKED: TANNER SCOTT Date: 12/15/15

Size: Qc No. Rev.
E6010 Butt Joint- Single V (3G)  Project #2

Welding Sequence

E6010--Root Pass  80-90Amps. Utilize the "key hole" drag technique
E6010--Hot Pass  100-110 Amps. Increase amperage 10 to 20 amps above the root bead setting. “Paint the walls” to burn out wagon tracks.
E6010--Fill and Cap  90-100 Amps Tight arc is essential with a drag technique. Keep the electrode in the puddle and use a side to side weave

Root Pass View   Cover Pass View

Weld Quality per API 1104

<table>
<thead>
<tr>
<th>VT Criteria</th>
<th>Root Pass/Cover Pass #1</th>
<th>Root Pass/Cover Pass #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforcement</td>
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<tr>
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<td>Cracks</td>
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<tr>
<td>Porosity</td>
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<td></td>
</tr>
<tr>
<td>Grade and Date</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
WLD 258
Butt Joint
Vertical Down
1/16" (Typ)

Welding Procedure
1. Electrodes: E6010
2. Electrode Diameter: 1/8" (Typ)
3. Polarity: DCRP
4. Amperage: 80 to 120
5. Root Face: 1/16" (dime)
6. Arc Length: Touching
7. Welding Position: Vertical DOWN (30°)
8. Material: 1/4" plate
9. Travel Angle: 20° to 30°
10. Work Angle: 20° to 70°
11. Root Opening: 1/16"
12. Technique: Stringer and Weave Beads

Portland Community College
Welding Technology

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

WLD 258-02

Drawn By: John Deering

Checked By: Tanner Scott Date: 12/15/15
Approved Date: Sheet

<table>
<thead>
<tr>
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<td>1/2&quot;</td>
<td>12.7</td>
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<tr>
<td>3/8&quot;</td>
<td>19.1</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>25.4</td>
</tr>
</tbody>
</table>
E6010 Butt Joint- Single V (4G) Project #3

Welding Sequence
E6010--Root Pass  80-90 Amps Utilize the "key hole" drag technique.
E6010--Hot Pass  100-110 Amps Increase amperage 10 to 20 amps above the root bead setting. “Paint the walls” to burn out wagon tracks.
E6010--Fill and Cap 90-100 Amps. Tight arc is essential with a drag technique. Keep the electrode in the puddle and use a side to side weave

---

Root Pass View    Cover Pass View

Weld Quality per API 1104

<table>
<thead>
<tr>
<th>VT Criteria</th>
<th>Root Pass/Cover pass #1</th>
<th>Root Pass/Cover Pass #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforcement</td>
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<tr>
<td>Undercut</td>
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<td></td>
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<tr>
<td>Bead Contour</td>
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<td></td>
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<tr>
<td>Penetration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cracks</td>
<td></td>
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<tr>
<td>Arc Strikes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fusion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Porosity</td>
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<td></td>
</tr>
<tr>
<td>Grade and Date</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Welding Procedure
1. Electrodes: E6010
2. Electrode Diameter: 1/8"
3. Polarity: DCRP
4. Amperage: 80 to 120
5. Root Face: 1/16" (dime thickness)
6. Arc Length: Touching
7. Material Size: 1/4"
8. Welding Position: Overhead (4G)
9. Travel Angle: 20° to 30°
10. Work Angle: 20° to 70°
11. Root Opening: 1/16" (dime thickness)
12. Technique: Stringer and Weave Beads

Portland Community College
Welding Technology

Tolerance: ± 1/16" Angle: ± 5°

Welding Procedure
1. Electrodes: E6010
2. Electrode Diameter: 1/8"
3. Polarity: DCRP
4. Amperage: 80 to 120
5. Root Face: 1/16" (dime thickness)
6. Arc Length: Touching
7. Material Size: 1/4"
8. Welding Position: Overhead (4G)
9. Travel Angle: 20° to 30°
10. Work Angle: 20° to 70°
11. Root Opening: 1/16" (dime thickness)
12. Technique: Stringer and Weave Beads

WLD 258-03

Drawn By: John Deering

CHECKED BY: TANNER SCOTT  DATE: 12/15/15

Sheet
E6010 Butt Joint - Single Vee Pipe (2G) Project #4

Welding Sequence

E6010--Root Pass  80-90 Amps Utilize the “key hole” drag technique
E6010--Hot Pass  100-110 Amps. Increase amperage 10 to 20 amps above the root bead setting. “Paint the walls” to burn out wagon tracks.
E6010--Fill and Cap  90-100 Amps. Tight arc is essential, keep the electrode in the Puddle. Use a stringer bead stepping technique.

Weld Quality per API 1104

<table>
<thead>
<tr>
<th>VT Criteria</th>
<th>Root Pass/Cover Pass #1</th>
<th>Root Pass/Cover Pass #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reinforcement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Undercut</td>
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<td></td>
</tr>
<tr>
<td>Bead Contour</td>
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<tr>
<td>Penetration</td>
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<tr>
<td>Cracks</td>
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<tr>
<td>Arc Strikes</td>
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<tr>
<td>Fusion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Porosity</td>
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<td></td>
</tr>
<tr>
<td>Grade and Date</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
WLD 258
Butt Joint—Single Vee Pipe (2G)

Welding Procedure
1. Electrodes _______ 6010
2. Electrode Diameter _______ 1/8"
3. Polarity _______ DCRP
4. Amperage _______ 80 to 130
5. Root Face _______ 1/16" (dime thickness)
6. Arc Length _______ Teething
7. Welding Position _______ Horizontal Pipe (2G)
8. Travel Angle _______ 20° to 30°
9. Work Angle _______ 20° to 70°
10. Root Opening _______ 1/16" (dime thickness)
11. Technique _______ Stringer bead

NOTE:
Use 6" sch 40 pipe.

NOTE:
Start with 6" long coupons and cut weld cut with Watts beveler to limit waste.

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

WLD 258-04

Tolerance: (Unless otherwise specified)
Dimensional ± 1/16", Angle ± 5°

Drawn By: John Deering

Check By: TANNER, SCOTT Date: 12/15/15
Approve: Date Sheet
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. Complete the exam and write all answers on the answer sheet provided. Once completed, return the exam and answer sheet to your instructor.

Study Guide

Safety
- Oxyacetylene safety
- SMAW safety
- Hand Tool Safety

SMAW and OAC Processes
- Power source specifics
  - Polarity
  - Current output
- AWS electrode classification
- Pipe Welding vocabulary
- Pipe – size and schedule
- 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
Practical Exam

Part Two
This portion of the exam is a practical test where you will fabricate and weld a 6” Schedule 40 pipe test. The evaluation of this portion of the exam will be based on quality requirements set forth in API 1104.

Use the following Diagram to lay out destructive tests.

See the API 1104 Standard for more information if needed.

See API 1104 for destructive test samples
### API-1104 Welding Procedure Specification

**Welding Technology Department**  
**Portland Community College**

**WPS # PCC-API-1104-2016**  |  **Rev # 0**  |  **Process: SMAW**  |  **Date: 09-21-2016**

#### API-1104 Qualified Ranges

<table>
<thead>
<tr>
<th>Diameter: 2.375 od through 12.75 OD</th>
<th>Filler Metal Group: API Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness: .188” thru 7.50”</td>
<td>Joint Type: Sleeve/fillet/butt full penetration</td>
</tr>
<tr>
<td>Material: Yield less than 42 ksi</td>
<td>Progression: Downhill</td>
</tr>
<tr>
<td>Positions: Fixed</td>
<td></td>
</tr>
</tbody>
</table>

#### Weld Joint

| Type: Sleeve/fillet/butt – 30 degrees (+7.5 degrees) | Class: Full and Partial Penetration |
| Joint Description: Single V Groove Weld |
| Sketch Number: See drawing |

#### Filler Metal

<table>
<thead>
<tr>
<th>API Group No: 3</th>
<th>AWS Classification: E6010</th>
</tr>
</thead>
<tbody>
<tr>
<td>SFA Classification: 5.1/5.5</td>
<td>F number: 3</td>
</tr>
<tr>
<td>Size: 1/8” and 5/32”</td>
<td>Number of Beads: 4 passes</td>
</tr>
</tbody>
</table>

#### Base Metal

<table>
<thead>
<tr>
<th>Specification: A53B</th>
<th>Thickness Welded: .154” to .750”</th>
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</thead>
<tbody>
<tr>
<td>Pipe Diameter: 6 inch</td>
<td>Qualification Range: 2.375” to 12.75”</td>
</tr>
<tr>
<td>P number: 1</td>
<td>Group: 1</td>
</tr>
<tr>
<td>Time between passes: 5 mins between root and hot pass</td>
<td></td>
</tr>
</tbody>
</table>

#### Position

<table>
<thead>
<tr>
<th>Position: 2G</th>
<th>Progression: Downhill</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preheat: 70 F</td>
<td>PWHT: None</td>
</tr>
</tbody>
</table>

#### Electrical Characteristics

<table>
<thead>
<tr>
<th>Current: Direct Current</th>
<th>Polarity: Electrode Positive</th>
<th>Amps 90-125</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer Mode: N/A</td>
<td>WFS/IPM: N/A</td>
<td>Volts 17-22</td>
</tr>
<tr>
<td>Electrode size and type: E6010, 1/8” to 5/32”</td>
<td>Travel IPM: 5-13 IPM</td>
<td></td>
</tr>
</tbody>
</table>

#### Welding Technique

| Technique and number of passes: Stringer beads with multiple passes |
| Cleaning: Grind and wire brush as necessary |
Joint Sketch and Bead Number and Sequence

Note: Weld layers are representative only – actual number of passes and layer sequence may vary due to variation in the joint design, thickness and fit-up.

### Typical Welding Parameters

<table>
<thead>
<tr>
<th>Pass #</th>
<th>Filler/Electrode</th>
<th>Diameter</th>
<th>Amps</th>
<th>Volts</th>
<th>Travel Speed</th>
<th>Other</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>E6010</td>
<td>1/8”</td>
<td>70-115</td>
<td>20-25</td>
<td>5-10</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>E6010</td>
<td>1/8”</td>
<td>90-135</td>
<td>20-25</td>
<td>6-12</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>E6010</td>
<td>1/8”</td>
<td>85-120</td>
<td>20-25</td>
<td>6-12</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>E6010</td>
<td>1/8”</td>
<td>85-120</td>
<td>20-25</td>
<td>6-12</td>
<td></td>
</tr>
</tbody>
</table>
Weld 258
Butt Joint—Single V-Groove
Final Exam Pipe (2G)

NOTES:
1. All dimensions are U.S. customary unless otherwise specified.
2. Use 6 inch schedule 40 Pipe.
3. The welder shall prepare a bill of material in U.S. customary and metric units.
4. Fillet weld size 1 times the normal wall thickness of the pipe.
5. Open root angle vee groove weld.
6. Mechanical testing is to be completed according to API 1104 Welder Certification procedure.

Welding Procedure
1. Electrodes . . . . . . . . . . E6010
2. Electrode Diameter . . 1/8”
3. Polarity . . . . . . . . . . . DCSP
4. Amperage . . . . . . . . 80-120
5. Root Face . . . . . . . . . . 1/16”
6. Root Opening . . . . . . 1/16”
7. Arc Length . . . . . . . . Touching
8. Welding Position . . . Horizontal Pipe (2G)
9. Travel Angle . . . . . . . 20° to 30°
10. Work Angle . . . . . . . 20° to 30°
11. Technique . . . . . . . Stinger/Step

6” (2x)

<table>
<thead>
<tr>
<th>Inch</th>
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<tbody>
<tr>
<td>1/16”</td>
<td>1.6</td>
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</tr>
<tr>
<td>1/4”</td>
<td>6.4</td>
</tr>
<tr>
<td>1/2”</td>
<td>12.7</td>
</tr>
</tbody>
</table>

Portland Community College
Welding Technology

Weld 258—Final

Drawn By: John Deering

CHECKED BY: TANNER SCOTT  Date: 12/15/15  Approve  Date  Sheet