WLD 153
Innershield Certification Practice

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

Course Assignments

Reading

Welding Principles and Applications 7th edition By Larry Jeffus
Chapter 24, Welder Certification

Recommended assignments

Complete review question following each assigned chapter

Welding Projects

FCAW- Innershield
3 - Vertical Groove (3G)
3 - Overhead Groove (4G)

Final exam - closed book written
Final Practical - 3G and 4G 6" plates

Standard Welding Terms and Definitions: ANSI/AWS A3.0-94
AWS D1.1 Structural Steel Welding Code
The Procedure Handbook of Arc Welding: By The Lincoln Electric Company.

Timeline

Open-entry, open-exit instructional format allows the students to work their own pace. It is the student's responsibility for completing 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 development of course outcomes. The methods of assessment may include one or more of the following: oral or written examinations, quizzes, written assignments, visual inspection techniques, welding tests, safe work habits, task performance and work relations.

Helpful Hints for Wire Welding

Wire Stick out

When welding with the FCAW process it is essential to keep the required stick out. This length should be between ¾" and 1". This length can and should be adjusted while welding to ***OPTIMZE THE ARC***. This stick out provides electrical resistance heating to the electrode. This is important because the flux inside of the wire is preheated so it will react more efficiently in the puddle that will provide for more aggressive scavenging by the flux.

First and Second Layers of Groove Welds

When completing the first and second layers of a groove weld it is important to have a well-set machine. The parameters (volts & amps) may need to be changed because of the need for a "crisp" arc to reach the bottom of the groove. One of two things need to change to achieve this:

REDUCE WIRE FEED SPEED FOR ROOT PASSES SO THAT THE FLUX DOES NOT CROUD THE JOINT AND FORCE YOU TO TRAVEL TOO QUICKLY - HIGHER VOLTAGE (23.5 TO 24'ISH) CAN BE HELPFUL FOR THE ROOT PASS TOO.

MAKE SURE YOU ARE RUNNINNG ENOUGH WIRE TO GIVE A COMPLETE AND CONSISTENT SLAG COVERING TO EACH BEAD

A VERY TIGHT CIRCLE PATTERN HAS HELPED MANY STUDENTS TO CONQUER INNERSHIELD - THIS TECHNIQUE IS ESPECIALLY HELPFUL TO FLATTEN THE EDGES OF BEADS TO IMPROVE BEAD TO BEAD CONTOUR AND ELIMINATE SLAG INCLUSION

Cover Pass Technique

Reduce drag angle for cover - a slight push can be successful to minimize build up

Maximum bead width recommended 1/2"
Reduce WFS and leave the voltage the same
Reduce stick out to 1/2"
Do not fill the groove flush. Leave 1/16"-3/32" shoulder so there is room for the finish beads.
Allow sufficient time between passes for the plate to cool.

Contents of this Packet

- *Importance of Code Qualification*
- *Why Mechanical Properties Testing?*
- *AWS D1.1 Structural Welding Code – Steel*
- *Significance of Bend Testing*
- *Guided Bend vs. Free Bend Testing*
- *Tensile Testing and Charpy V-Notch Impact Testing*

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 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.

Pressure Vessels	ASME Boiler and Pressure Vessel Code (Vol. IX – Welding Qualifications)
Pipe and Pipelines	API Standard 1104; Standard for Welded Pipelines and Related Facilities
Pressure Piping	ASME Code for Pressure Piping B31
All Steel Structures	AWS D1.1 Structural Welding Code – Steel
Buildings	AISC Specification for Structural steel Buildings
Bridges	AASHTO/AWS D1.5; Bridge Welding Code
Ships	ABS Rules for Building and Classing Steel Vessels
Sheet Metal	AWS D9.1; Sheet Metal Welding Code
Automotive Frames	ANSI/AWS D8.8; Specification for Automotive Frame Weld Quality
Aircraft	MIL-STD-1595A; Qualification of Aircraft, Missile and Aerospace Fusion Welders

Why Mechanical Properties Testing?

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 steel structures in accordance with the AWS D1.5 Bridge Welding Code–Steel 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.

AWS D1.1 Structural Welding Code – Steel

When a structure 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 structural welds being fabricated. AWS D1.1 Structural Welding Code – Steel is devised to provide welded joints with acceptable strength, ductility, and CVN impact toughness for the intended application, such as a building, general construction, motorized vehicle, etc. Procedure qualification requirements welder qualification and certification are required. The qualification and certification tests for welders are specially designed to determine the welder's ability to produce sound welds. To achieve these quality standards, the welder qualification and certification provide the means to ensure acceptable welds.

Significance of Bend Testing

Of all the tests prescribed by different welding codes, the bend test provides the best and most reliable measure of ductility of the entire weld joint, including the weld metal, heat-affected zone, and unaffected base metal. Bend tests are one way to determine qualification results. 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 bend test may be have been affected by: (a) hydrogen assisted cracking, (b) micro fissuring 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.

There are three types of bend tests, (1) side bend, (2) face bend, and (3) root bend. Side bend tests are required for welds that are greater than 3/8-inch thick for AWS D1.1 and over ½-inch thick for API-1104. For example, a 2-inch thick butt joint deposited by single-pass electroslag welding could not be tested by face or root bend testing, because the thickness is too great for practical testing. However, a 2-inch thick butt joint can be machined to several 3/8-inch thick side bend specimens and tested easily.

Face and root bending are used to test the ductility of butt joints that are 3/8" and thinner. Whether face bends, root bends, or both face and root bends specimens are required depends upon the code used. In AWS D1.1 Structural Welding Code, both face and root bends are required in most cases. The root bend test determines the adequacy of the root penetration and soundness of the root portion of the weld joint. This is particularly important in open root welding applications. Similarly, the face bend test determines the adequacy of the weld metal deposited on the face of the

joint. These specimens must be able to withstand bending strains that are produced when a plunger forces a 3/8-inch thick welded specimen into a guided bend fixture. The plunger, having a specified bend radius, forces the welded bend specimen into a die in order to endure a specified amount of bending (or plastic deformation), that is required by the code for structural applications. From Table 1, the plunger radius and plunger thickness increase with increasing yield strength of the base metal being tested. Bending becomes more difficult with increasing yield strength, because ductility decreases as the strength of the steel increases. Thus, AWS D1.1 permits the bend radius required for welder qualification to increase with increasing yield strength, as shown in Table 1.

Table 1 Specified Bending Parameters for Guided Bend Test for Steel Welds in accordance with AWS D1.1 Structural Welding Code - Steel

Yield Strength Of Base Metal	Plunger Thickness	Plunger Radius	Interior Die Opening	Die Radius
50,000psi and less	1 ½"	¾"	2 3/8"	1 3/16"
Over 50,000psi to 90,000psi	2"	1"	2 7/8"	1 7/16"
90,000psi and greater	2 ½"	1 ¼"	3 3/8"	1 11/16"

Bend Testing of Welds deposited by FCAW using E71T-1, T-8 and T-11 Electrodes

The bend test for steel welds is very sensitive to not only the presence of diffusible hydrogen in the weld, but also high levels of non-metallic inclusions. Typically, these welds will fail in the weld metal. E71T-1 gas shielded welds and E71T-8 self-shielded welds are generally minimally contaminated with non-metallic inclusions and will pass the bend tests prescribed by applicable codes like D1.1 Structural Welding Code. However, the self-shielded E71T-11 electrode contains substantial inclusion content and may be susceptible to reductions in ductility to possibly fail the bend test. In all cases, poor workmanship is the most probable of a bend failure. This may include slag inclusions, lack of fusion, excessive porosity, etc. If workmanship is adequate, then the weld metal deposited with electrodes, which must meet high Charpy impact requirements, will ultimately be the most successful in the bend test.

Guided Bend vs. Free Bend Testing

The most widely used bend test, which is required by most welding codes, is the guided bend test. The benefit of the guided bend test, like that required by the AWS/AASHTO D1.5 Bridge Welding Code and AWS D1.1 Structural Welding Code is that the weld metal, heat affected zone and the unaffected base metal are subject to bending equally. This test requires expensive fixturing and a hydraulic ram to perform the guided bend test.

There is another test called the free bend test. The free bend testing apparatus is less expensive to build and is hand-operated. The disadvantage of this test is that all of the zones of the weld joint (weld metal, heat affected zone and unaffected zone) are not bent equally. In free bend testing, the zone(s) having the lowest tensile strength will bend the most, while the zone(s) having the highest strength will bend the least. This effect may hide potential problems in the weld joint. This is why most codes insist on the guided bend test and not the free bend test.

Tensile Testing and Charpy V-Notch Impact Testing

For welder qualification and certification in accordance with AWS D1.1, tensile testing and Charpy v-notch (CVN) testing of the test weld are not required. However, in other codes, these tests are also used for welder qualification (in addition to bend testing).

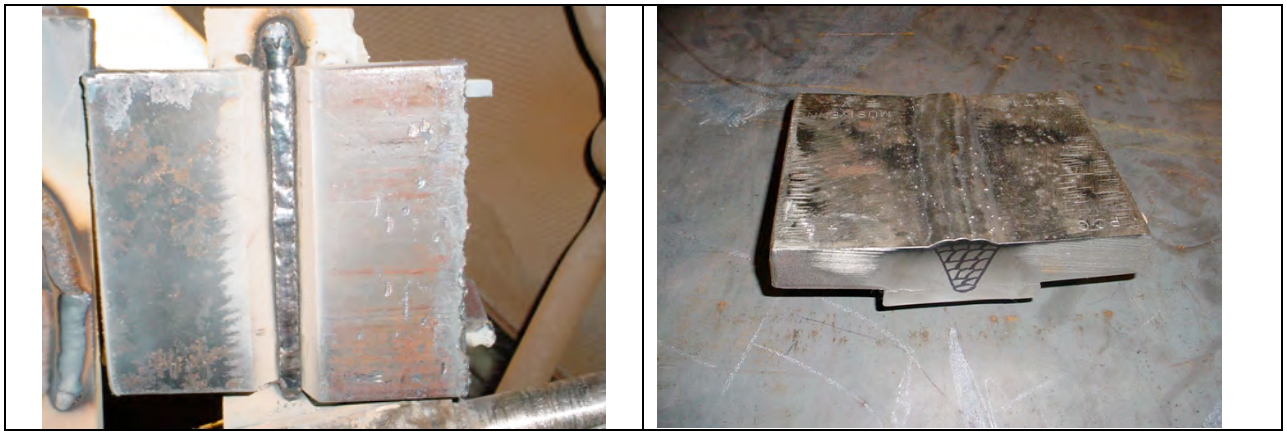
Craftsmanship Expectations for Welding Projects

The student should complete the following tasks prior to welding.

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

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

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



Example of a High Quality Weld

Weld Quality per AWS D1.1

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

Complete Joint Penetration (CJP) Information Sheets

Welding Procedure Specification

AWS D1.1 Job No.:

WPS Number: PCC FCAW - 02
Rev. Number Original
Date:
PQR Number: Prequalified

Title: Flux Cored Arc—Groove with Carbon Steel Backing

Welding Process: Flux Cored Arc Type: Semi Automatic Mode:

Prepared by: Date: Approved by: Date:

JOINT DESIGN

Type: 45 degree Single V Groove BU-GF
Single or Double Weld: Single Backing: Yes
Backing Material: Carbon Steel
Root Opening-R: 1/2”
Land-L: 0-1/8” Radius (J-U): N/A

BASE METALS

Metal Specification: A36
Type or Grade: Grade A
Group 1 Plate Thickness: 1”
Thickness Groove: 1” Fillet: All
Diameter (Pipe) 24” and up Wall 1/8” and up

FILLER METALS

Classification: E71T-8
Specification No. AWS 5.20

SHIELDING

Gas: N/A Composition: N/A
Flow Rate: N/A
Gas Cup Size: N/A
Electrode-Flux (Class): N/A
Flux: N/A

POSITION

Position of Groove or Fillet: 1G, 2G, 3G, 4G, 1F, 2F, 3F, 4F
Vertical Progression: Up

POSTWELD HEAT TREATMENT

Temperature Range: None
Time:

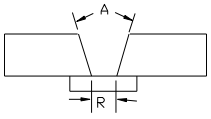
PREHEAT

Preheat Temp. Min. 200°
Interpass Temp. Min: 200° F Max: 400°F

TECHNIQUE/ OTHER

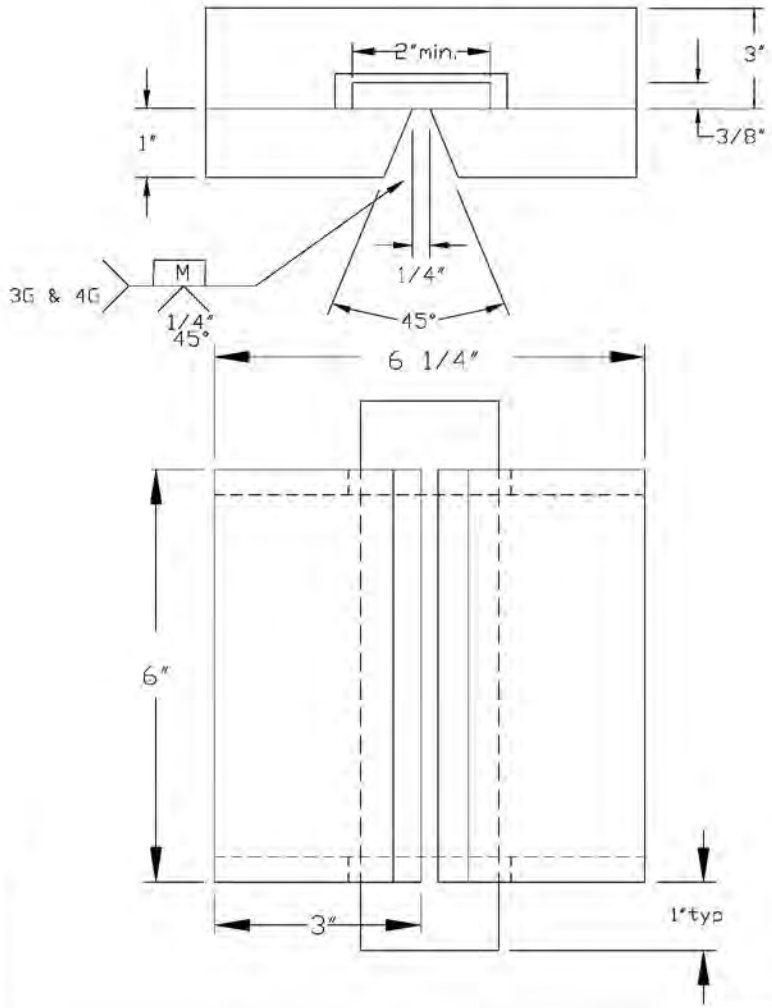
X Stringer X Weave Beads
X Multipass ☐ Single pass per side
☐ Single ☐ Multiple Electrodes

Contact Tube to Work Distance: 3/4”
Peening: None on root/ cover
Initial Cleaning:
All areas to be welded shall be cleaned for oil, grease, paint, etc., for at least two (2) inches from the toes of the weld
Interpass Cleaning:
Remove all oxides and slag with a clean wire brush and/or chipping hammer
Notes:
1. A stringer or slight weave may be used as required to provide proper bead shape and side wall wetting.
2. Initial and interpass cleaning shall be accomplished by wire brushing, chipping, and no grinding.
3. Welder shall accomplish a visual inspection of previously deposited weld metal, prior to depositing the next bead.
4. Welding electrode shall be stored in dry area and located in close proximity to the work area.
5. Preheating shall be accomplished using oxy-fuel torches.
6. Weld shall be allowed to cool slowly, keeping air drafts to a minimum.

Pass or Weld Layer(s)	Process	Filler Metals		Current		Volts	Travel Speed (IPM)	Joint Details
		Class	Dia.	Type and Polarity	Amps or wire feed speed			
All	FCAW	E71T-8	1/16”	DCEN	180–280A	19-23	4-6	

All the pieces needed to assemble a Single V Groove Weld with Strong Backs.

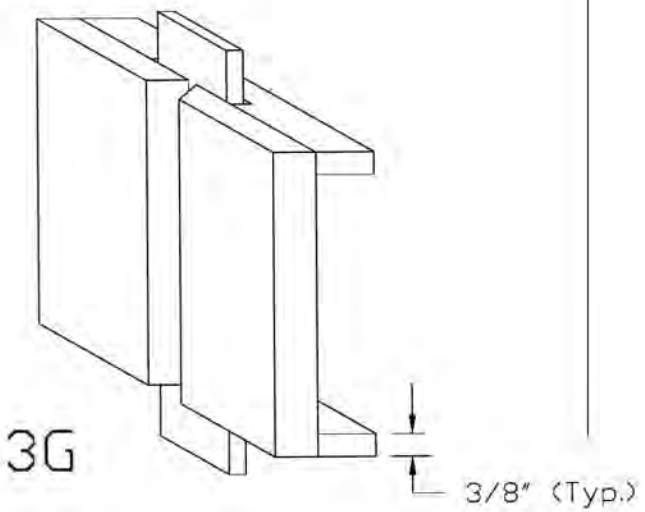
WLD 153
Single "V" Groove 3G



Welding Procedure for
Single "V" Groove 3G

1. Electrode
2. Diameter
3. Polarity
4. Amperage
5. Arc Length
6. Welding Position — Vertical and Overhead
7. Travel Angle
8. Work Angle
9. Technique

* Bend Test required Per AWS D1.1 for both 3G and 4G plates.



Inch	MM
1/16"	1.6
1/8"	3.2
1/4"	6.4
1/2"	12.7
1"	25.4

Part	No. Required	Size (TxWxL)	S.I. Conversion

Portland Community College
Welding Technology

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

Drawn By: John Deering

Chk By: Date: 7/23/05

WLD

Size: | Qc No. | Rev.

Approve | Date | Sheet

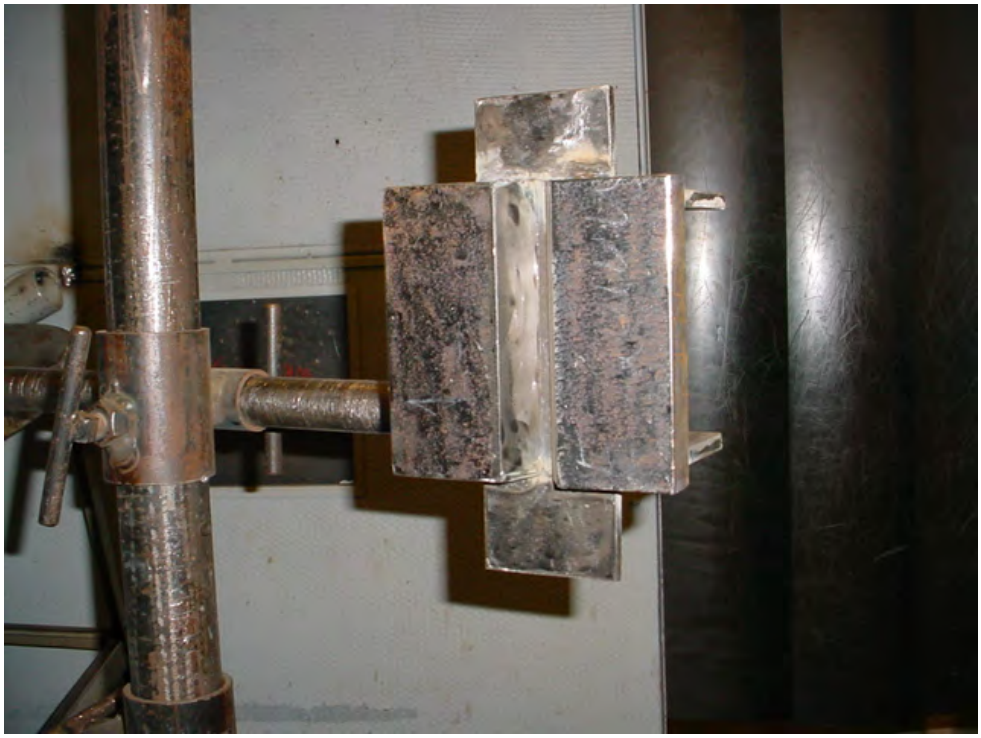
E71T-8 Butt Joint- Single V Groove Weld (3G)

Welding Sequence

E71T-8-- Root Pass Single pass technique with slight weave to ensure the weld metal is fusing into all three pieces of metal.

E71T-8—Fill Use the multi-pas technique with stringer beads ensuring even fill.

E71T-8—Finish Beads Use stringer bead technique keeping the electrode in the puddle at all times.



Successful completion of this project will require the student to complete ***THREE weldments*** that meet both visual testing requirements and bend test requirements set forth in AWS D1.1 Structural Steel Welding Code.

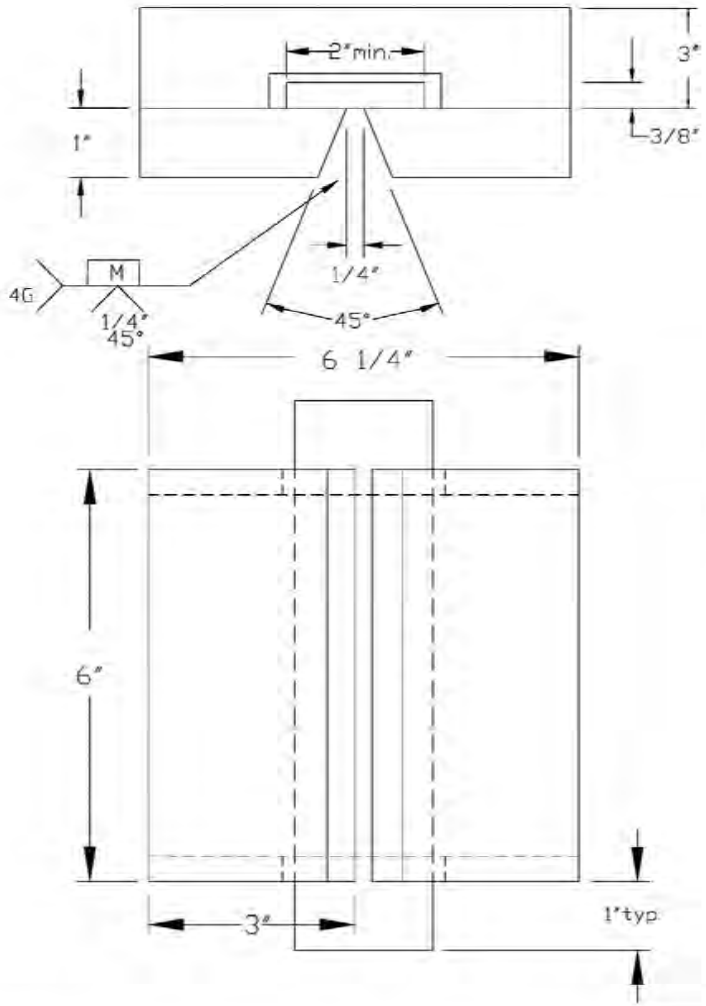
VT Criteria	Project #1	Project #2	Project #3
Reinforcement	ROOT	ROOT	ROOT
Undercut			
Bead Contour			
Cracks	COVER	COVER	COVER
Arc Strikes			
Fusion			
Porosity	BENDS	BENDS	BENDS
Bend Test			
	Grade Date	**Grade Date**	**Grade Date**

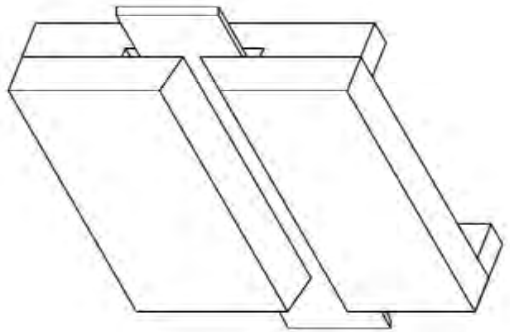
WLD 153

Welding Procedure for Single "V" Groove 4G

1. Electrode
2. Diameter
3. Polarity
4. Amperage
5. Arc Length
6. Welding Position — Vertical and Overhead
7. Travel Angle
8. Work Angle
9. Technique

* Bend Test required Per AWS D1.1 for both 3G and 4G plates.





4G

Inch	MM
1/16"	1.6
1/8"	3.2
1/4"	6.4
1/2"	12.7
1"	25.4

Part	No. Required	Size (TxWxL)	S.I. Conversion

Portland Community College
Welding Technology

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

Drawn By: John Deering — Size — Qc No. — Rev.

Chk By: — Date: 7/23/05 — Approve — Date — Sheet

E71T-8 Butt Joint- Single V Groove Weld (4G) Project #4,5,6

Welding Sequence

E71T-8-- Root Pass Single pass technique with slight weave to ensure the weld metal is fusing into all three pieces of metal.

E71T-8—Fill Use the multi-pass technique with stringer beads ensuring even fill.

E71T-8—Finish Beads Use stringer bead technique keeping the electrode in the puddle at all times.

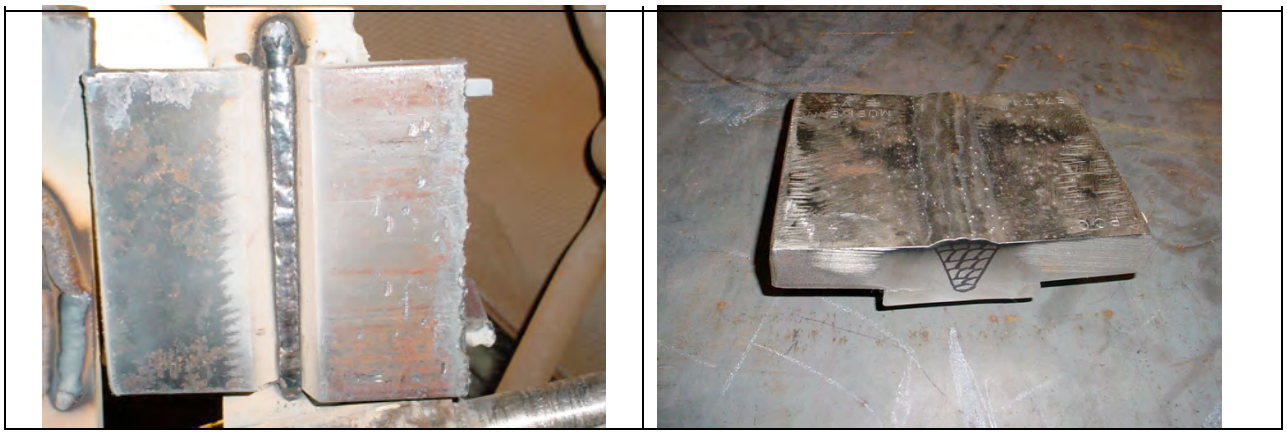
Successful completion of this project will require the student to complete ***THREE*** weldments that meet both visual testing requirements and bend test requirements set forth in AWS D1.1 Structural Steel Welding Code.

VT Criteria	Project #4	Project #5	Project #6
Reinforcement	ROOT	ROOT	ROOT
Undercut			
Bead Contour			
Cracks	COVER	COVER	COVER
Arc Strikes			
Fusion			
Porosity	BENDS	BENDS	BENDS
Bend Test			
	Grade Date	**Grade Date**	**Grade Date**

Final Exam

Part One
This portion of the final exam is a closed book test.

Part Two TWO TEST PLATES - 3G and 4G
This portion of the exam is a practical test where you will weld out a vertical and an overhead one-inch certification test plate in accordance with AWS D1.1 requirements using **"Innershield."** The evaluation of this portion of the exam will be based on AWS D1.1 Structural Steel Welding Code.



Example of a High Quality Weld

SUMMARY OF VISUAL INSPECTION CRITERIA

A. The test must be complete. The full length (6”) of the test plate will be visually inspected. Use your run off tabs throughout the test to insure quality results at the start and finish at both ends of the plates. All craters shall be filled to the full cross section of the weld.

B. Reinforcement layer (**cover pass**) height shall be **Flush** to **1/8” (3 mm)** above the plate.

C. A reinforcement layer higher that **1/8” (3 mm)** will not be accepted.

D. Weld width cannot exceed ¼” wider than original groove opening.

E. Weld shall merge smoothly with the base metal.

F. Weld must be free of porosity, slag inclusions, and/or cold lap.

G**.** Undercut shall not exceed **1/32 in. (1 mm).**

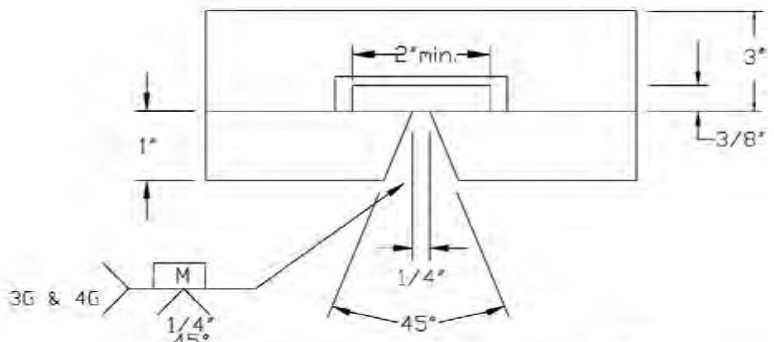
H**.** Arc strikes outside of the weld area are **NOT** acceptable.

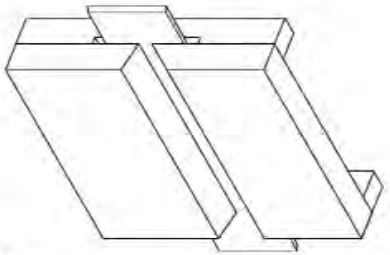
WLD 153
Final Exam

Welding Procedure for Single "V" Groove 3G and 4G

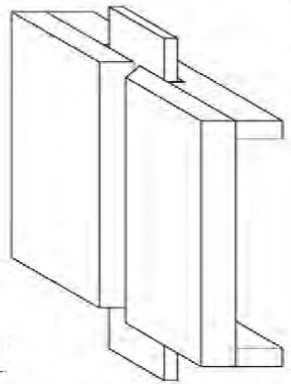
1. Electrode
2. Diameter
3. Polarity
4. Amperage
5. Arc Length
6. Welding Position — Vertical and Overhead
7. Travel Angle
8. Work Angle
9. Technique

* Bend Test required Per AWS D1.1 for both 3G and 4G plates.





4G



3G

3/8" (Typ.)

Inch	MM
1/16"	1.6
1/8"	3.2
1/4"	6.4
1/2"	12.7
1"	25.4

Part	No. Required	Size (TxWxL)	S.I. Conversion

Portland Community College
Welding Technology

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

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Size | Qc No. | Rev.
Chk By: Date: 7/23/05
Approve | Date | Sheet

WLD 153 Homework

1) The major atmospheric contaminations com from_____.

2) _____are added to the flux and form a slag.

3) _____ rapidly expand and push the surrounding air away from the molten weld pool.

4) _____helps the weld by protecting the hot metal from the effects of the atmosphere.

5) When the electrode provides all of the shielding, it is called_____.

6) How is the amperage adjusted on a FCA welding machine?

7) If the voltage and wire feed speed are not changed but a larger wire size is used, the ….

8) Which of the following is true of fluxes?

   a) Fluxes cause undercutting along the junction of the weld and the base metal.
   b) Fluxes decrease the stability of the arc.
   c) Fluxes provide oxidation
   d) Fluxes are slag formers

9) What two electrical terms have the same meaning?

   a) Impedance and amperage
   b) Potential and voltage
   c) Resistance and current
   d) Ohms and potential

10) Too light a roller pressure will…..

11) Which of the following is a benefit of FCA welding?
   a) FCA requires beveling the plate prior to welding.
   b) A much lower skill level is required
   c) The ability to make 100%-joint-penetrating welds without beveling the edges of the plates.
   d) Welding thick plates is very easy.

12) _____weld faces tend to trap slag along the toe of the weld.

13) The visual inspection of the cover pass looks to see that…..

14) What type of joints would a fillet weld be performed on?

15) A fillet weld should be built up to be _____ the thick ness of the plate.
   a) Equal to
   b) Half the thickness of
   c) Slightly thicker than much thicker than
   d) Much thicker than

16) Too large a _____ pass can trap slag under overlap along the lower edge of the weld.

17) A small molten weld pool can be achieved by using_____current settings and _____traveling speeds.
   a) lower, slower
   b) lower, faster
   c) higher, slower
   d) higher, faster

18) A major skill requirement for making consistently accurate FCA welds is_____.
   a) Knowing your skill limitations
   b) Not to drink coffee because it can cause your hand to shake too much
   c) The ability to set up the welding system
   d) to use smaller diameter electrode wire sizes

19) Which of the following is true of weld penetration into the base metal at the start of a bead?
   a) It can be obtained by using a quick start.
   b) It can be obtained by quickly reversing the weld direction
   c) It is not possible for the start of the weld to have deep penetration
   d) Excess heat prevents deep penetration.

20) What is the maximum reinforcement for the cover pass?

21) The deposition rate will _____ as the welding current is _____.

a) Decrease, maintained
b) Decrease, increase
c) Increase, decreased
d) Increase, increased

22) The _____ efficiency of a welding process refers to the percentage of the welding filler material that actually becomes part of the weld deposit.

Final Grading Rubric for practical exam
Class Name: WLD 153

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 153 FCAW E71T-8: Project Assessment Form
Student Name:_____ Date_____

Vertical V-Groove	Assessment	Instructor Signature/Date
Root		
Cover Pass		
Side Bends		

Vertical V-Groove	Assessment	Instructor Signature/Date
Root		
Cover Pass		
Side Bends		

Vertical V-groove	Assessment	Instructor Signature/Date
Root		
Cover Pass		
Side Bends		

Overhead V-Groove	Assessment	Instructor Signature/Date
Root		
Cover Pass		
Side Bends		

Overhead V-Groove	Assessment	Instructor Signature/Date
Root		
Cover Pass		
Side Bends		

Overhead V-Groove	Assessment	Instructor Signature/Date
Root		
Cover Pass		
Side Bends		