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U.S. CUSTOMARY BOS

CERTIFIED WELDING INSPECTOR (CWI) PART B PRACTICAL

BOOK OF SPECIFICATIONS (BOS)

2017

DO NOT WRITE ON THIS BOOK

FOREWORD

This *Part B Book of Specifications* is intended to be used as a reference book for taking the hands-on practical examination that is part of the CWI certification examinations. This practical examination simulates actual hands-on inspection and document reviews performed by the Certified Welding Inspector (CWI). You are expected to evaluate the acceptability of test specimens and documents for both procedure and welder qualifications and production welding by using standard measurement tools, visual inspection, and documents found in the Book of Exhibits. Acceptability is based upon the information contained in this *Book of Specifications*. The practical examination will test your ability to carry out these functions.

Although this *Book of Specifications* is formatted to look like a real codebook, it is not a real codebook and it should not be used as one. While some clauses in this *Book of Specifications* appear to be similar to codebooks that you are familiar with, read this *Book of Specifications* very carefully and do not rely on your memory to make decisions with regards to answers on this examination.

Review the organization of this *Part B Book of Specifications*. There are specific clauses that relate to workmanship and visual inspection criteria in three applications: Structural, Pipeline, and Pressure Piping. There are general clauses for inspection, procedure, and performance qualification that apply to all three applications. As this *Book of Specifications* applies to three applications, terms and definitions are not limited to AWS A3.0, *Standard Welding Terms and Definitions*.

In addition to the main body of the specification, there are annexes, tables, and figures that are important in your examination decisions. They are numbered uniquely so as to avoid confusion. Make sure that you have located all the necessary annexes, tables, and figures before you answer any question.

A Book of Exhibits is used in the exam and contains examples of various documents and photos including but not limited to WPS's, PQR's WQTR's, heat treat charts, and NDE methods. Neither the test specimens nor the Book of Exhibits are available for review prior to the examination.

For some questions, narratives will give you information upon which you will be asked specific questions. The question may make reference to locations on certain specimens included in your test kit or refer to documents within the Book of Exhibits. In addition to the Book of Exhibits, all test kits have standard measuring tools necessary to complete the examination.

IMPORTANT

1. Read each question carefully and completely, including every choice provided. There will only be one correct answer. Be careful to transfer your choice of answer to the correct location on the answer sheet.

2. The weld replicas in the assigned test kit are made of plastic to assure that every test candidate receives the exact same specimens. As a consequence of the replication process, there may be color variations from actual weld metal and visible seams from the plastic assembly process. Ignore any pinholes, seams, glue squeezed out, or color variations in your determination of a correct answer.

3. You are expected to know how to use and apply each measuring and inspection instrument in the examination kit including knowing how to properly zero the instrument where relevant.

4. Use the margins or blank pages in your examination booklet to perform any required calculations. Do not write in this booklet.

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1.0 General Requirements

1.1 Scope

1.1.1 This specification applies to the American Welding Society Certified Welding Inspector (CWI) examination and shall not be used for any other purpose. The CWI Practical Exam relies on the use of molded plastic replicas of actual weld specimens and as there are some visual characteristics of metal that do not reproduce in plastic with sufficient fidelity, the exclusion of acceptance criteria for these characteristics should not be construed as an endorsement for the exclusion of these criteria for any actual fabrication.

1.1.2 This specification includes representative requirements for Structural Steel, Pipeline, and Pressure Piping applications. They are intended to be applied to inspector examination weld replicas and not to actual industrial facilities, equipment, or structures.

1.1.3 Unless otherwise noted, requirements contained in this *Book of Specifications*, in Clauses 1.0, 5.0, and 6.0, are to be considered general requirements applicable to all three applications.

1.1.4 Normative Annexes in this specification are provided for requirements and Informative Annexes are provided for information. Both are considered as part of this specification. No inference should be drawn from the assignment of Normative versus Informative as to the use of the Annex on the examination.

1.1.5 Calculations, formulae, definitions, and material properties used on the CWI examination will be based on data published in the Annexes to this specification. As this *Book of Specifications* applies to three applications, terms and definitions are not limited to AWS A3.0, *Standard Welding Terms and Definitions*.

1.1.6 Use of the terms “shall,” “should,” and “may” in this specification have the following significance:

1.1.6.1 Shall. Specification provisions that use “shall” are mandatory.

1.1.6.2 Should. Specification provisions that use “should” are non-mandatory practices that are considered beneficial.

1.1.6.3 May. Specification provisions that use “may” mandate the choice of optional procedures or practices that can be used as an alternative or supplement to specification requirements.

1.2 Visual Inspection

1.2.1 Visual inspection for cracks in welds and base metal and other discontinuities may be aided by a flashlight, magnifier, and mirror as may be found helpful or necessary.

1.2.2 Weld sizes, length, and locations of welds shall conform to the requirements of this specification.

1.2.3 Joint preparations, assembly, and welding techniques shall be verified.

1.2.4 Suitable measuring tools and gages shall be used where necessary.

1.3 Dimensional Tolerances

Unless otherwise specified, the following standard dimensional tolerances shall apply when using this specification. They do not apply to the dimensions in test specimens, Annex IV, or to discontinuity acceptance limits.

1.3.1 Decimal tolerances are determined by the number of decimal places (precision) used in the dimension as follows:

X.X	± 0.1	(e.g., 1.0 inch could be 0.9 to 1.1 inches)
X.XX	± 0.01	(e.g., 1.00 inch could be 0.99 to 1.01 inches)
X.XXX	± 0.005	(e.g., 1.000 inch could be 0.995 to 1.005 inches)

1.3.2 Fractional Tolerances are determined by the overall dimensional length plus the fraction size (precision) used in the dimension as follows:

Whole numbers > 6 inches	± 1/8 inch
Whole numbers from 1 to 6 inches inclusive	± 1/16 inch
Fractional numbers from 1/16 to <1 inch	± 1/32 inch
Fractional numbers from 1/32 to <1/16 inch	± 1/64 inch
Fractional numbers less than 1/32 inch	± 1/128 inch

2.0 Workmanship Requirements and Visual Acceptance Criteria – Structural Steel

2.1 Base Metal Preparation

2.1.1 Mill-Induced Discontinuities. The length of these discontinuities is the visible long dimension on the cut surface of material and the depth is the distance that the discontinuity extends into the material from the cut surface. The limits of acceptability and the repair of visually observed cut surface discontinuities shall be as follows:

(a) Any discontinuity 1 inch in length or less need not be repaired and the depth need not be explored.

(b) Any discontinuity over 1 inch in length with maximum depth of 1/8 inch need not be repaired, but the depth should be explored.

(c) Any discontinuity over 1 inch in length with depth over 1/8 inch but not greater than 1/4 inch shall be completely removed and repair welded.

(d) Any discontinuity over 1 inch in length with depth over 1/4 inch shall be referred to the Engineer for disposition.

2.2 Workmanship Requirements

2.2.1 Roughness Requirements. Weld edge prep and other edge surfaces shall be evaluated with the surface roughness guide AWS C4.1-77. Acceptance criteria shall be as follows:

2.2.1.1 Weld edge prep surfaces for manual and semiautomatic welding processes shall not be rougher than Sample 3 and shall have no gouges deeper than 1/16 inch.

2.2.1.2 Weld edge prep surfaces for mechanized and automatic welding processes (except SAW) shall not be rougher than Sample 4 and shall have no gouges.

2.2.1.3 Weld edge prep surfaces for SAW shall not be rougher than Sample 3 and shall have no gouges.

2.2.1.4 Edges of members not subject to calculated stresses shall not be rougher than Sample 2 and shall have no gouges deeper than 1/8 inch.

2.2.1.5 All other edges shall not be rougher than Sample 3 and shall have no gouges deeper than 1/16 inch.

2.2.2 Arc Strikes. Base metal shall be free of arc strikes.

2.2.3 Cleaning of Completed Welds. Slag shall be removed from all completed welds. Spatter is acceptable unless NDT other than visual inspection is to be performed or otherwise specified.

2.2.4 Fillet Weld Terminations and Starts. Fillet welds shall not be terminated on corners of lap joints. Terminations and starts shall be as follows:

2.2.4.1 Statically Loaded Connections. Terminations and starts shall be made by either holding the weld back from the corner for a distance not less than the specified fillet weld size or by wrapping the weld around the corner not less than two times nor more than four times the specified fillet weld size.

2.2.4.2 Cyclically Loaded Connections. Terminations and starts shall be made by wrapping the weld around the corner for a distance not less than two times nor more than four times the specified fillet weld size.

2.2.5 Repairs. The removal of weld metal or portions of the base metal may be done by machining, grinding, chipping, or gouging. It shall be done in such a manner that the adjacent weld metal or base metal is not nicked or gouged. Unacceptable portions of the weld shall be removed without substantial removal of the base metal. The surfaces shall be cleaned thoroughly before welding. Weld metal shall be deposited to compensate for any deficiency in size in the weld metal.

2.3 Visual Inspection Acceptance Criteria. All welds shall be visually inspected and meet the acceptance criteria of Table 1.

2.3.1 Weld Profiles. Weld profiles shall be in accordance with Table 1, Table 2, and Table 3, Figure A, Figure B, except as otherwise allowed in 2.3.1.1, 2.3.1.2 and 2.3.1.3.

2.3.1.1 Fillet Welds. Unless otherwise specified, the faces of fillet welds may be slightly convex, flat, or slightly concave as shown in Figure B.

2.3.1.2 Exception for Intermittent Fillet Welds. Except for undercut, as allowed by this specification, the profile requirements of Figure B shall not apply to the ends of intermittent fillet welds outside their effective length.

2.3.1.3 Groove Welds. Groove weld reinforcement shall comply with Table 2 and Table 3. Welds shall have a gradual transition to the plane of the base-metal surfaces.

2.3.1.4 Overlap. All welds shall be free of overlap.

2.4 Fillet Weld Dimensional Tolerances

2.4.1 Weld length and spacing. Unless otherwise specified, the weld length indicated is the minimum weld length and there is no maximum. The length of a fillet weld is the overall length of the full size fillet, including end returns (boxing) as measured along the center line of the effective throat and excluding the undersize portions of starts and stops. The tolerances of subclause 1.3.2 shall be applied to determine if the minimum length is acceptable, e.g., a 2-15/16 inch weld length satisfies the requirement for a 3 inch weld.

Unless otherwise specified, the weld spacing (pitch) is the maximum spacing between the centers of adjacent welds and there is no minimum. The tolerances of subclause 1.3.2 shall be applied to determine if the actual measured maximum spacing is acceptable, e.g., a 3-1/16 inch spacing satisfies the requirement for a 3 inch spacing.

2.4.2 Fillet Weld Size. Unless otherwise specified in the visual inspection acceptance criteria, the fillet weld size is the minimum weld size and there is no maximum. The tolerances of subclause 1.3.2 do not apply.

Table 1
Visual Inspection Acceptance Criteria – Structural Steel

Discontinuity Category and Inspection Criteria	Statically Loaded Nontubular Connections	Cyclically Loaded Nontubular Connections	Tubular Connections (All Loads)
1) Crack Prohibition Any crack shall be unacceptable, regardless of size or location.	X	X	X
(2) Weld/Base-Metal Fusion Thorough fusion shall exist between adjacent layers of weld metal and between weld metal and base metal.	X	X	X
(3) Crater Cross Section All craters shall be filled to provide the specified weld size, except for the ends of intermittent fillet welds outside of their effective length.	X	X	X
(4) Weld Profiles Weld profiles shall be in conformance with 2.3.1.	X	X	X
(5) Time of Inspection Visual inspection of welds in all steels may begin immediately after the completed welds have cooled to ambient temperature. Acceptance criteria for ASTM A 514, A 517, and A 709 Grade 100 and 100 W steels shall be based on visual inspection performed not less than 48 hours after completion of the weld.	X	X	X
(6) Undersized Welds The size of a fillet weld in any continuous weld may be less than the specified nominal size (L) without correction by the following amounts (U): L, specified nominal weld size, inch / U, allowable decrease from L, inch ≤ 3/16 / ≤ 1/16 1/4 / ≤ 3/32 ≥ 5/16 / ≤ 1/8	X	X	X
(7) Undercut (A) For material less than 1 inch thick, undercut shall not exceed 1/32 inch. For material equal to or greater than 1 inch thick, undercut shall not exceed 1/16 inch for any length of weld.	X		
(B) In primary members, undercut shall be no more than 0.01 inch deep when the weld is transverse to tensile stress under any design loading condition. Undercut shall be no more than 1/32 inch deep for all other cases.		X	X
(8) Porosity (A) CJP groove welds in butt joints transverse to the direction of computed tensile stress shall have no visible porosity. For all other groove welds and for fillet welds, the sum of the visible porosity 1/32 inch or greater in diameter shall not exceed 3/8 inch in any linear inch of weld.	X		
(B) The frequency of porosity in fillet welds shall not exceed one in each 4 in of weld length and the maximum diameter shall not exceed 3/32 inch. Exception: for fillet welds connecting stiffeners to web, the sum of the diameters of porosity shall not exceed 3/8 inch in any linear inch of weld.		X	X
(C) CJP groove welds in butt joints transverse to the direction of computed tensile stress shall have no porosity. For all other groove welds, the frequency of porosity shall not exceed one in 4 inches of length and the maximum diameter shall not exceed 3/32 inch.		X	X

Note: An "X" indicates applicability for the connection type; a shaded area indicates non-applicability.

Table 2
Weld Profiles (see 2.3.1)

Weld Type	Joint Type			
	Butt	T-Joint	Lap	Corner-Inside
Groove (CJP or PJP)	Figure A	N/A	N/A	N/A
	Schedule A	N/A	N/A	N/A
Fillet	N/A	Figure B	Figure B	Figure B
	N/A	Schedule B	Schedule B	Schedule B

Table 3
Weld Profile Schedules (see 2.3.1)

Schedule A (t = thickness of thicker plate joined for CJP; t = throat size for PJP)

t	R min.	R max.
≤ 1 inch	0	1/16 inch
> 1 inch ≤ 2 inch	0	1/8 inch
> 2 inch	0	3/16 inch

Schedule B (W = width of weld face or individual surface bead; C = allowable convexity)

W	C min.	C max.
≤ 5/16 inch	0	1/16 inch
> 5/16 inch < 1 inch	0	1/8 inch
≥ 1 inch	0	3/16 inch

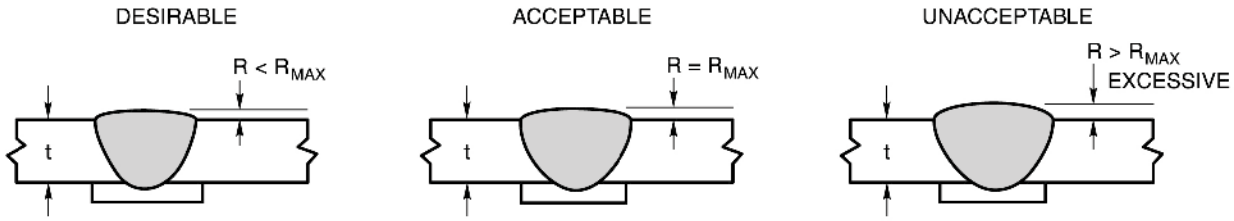

FIGURE A – WELD PROFILES FOR BUTT JOINT REQUIREMENTS (see Tables 2 and 3)

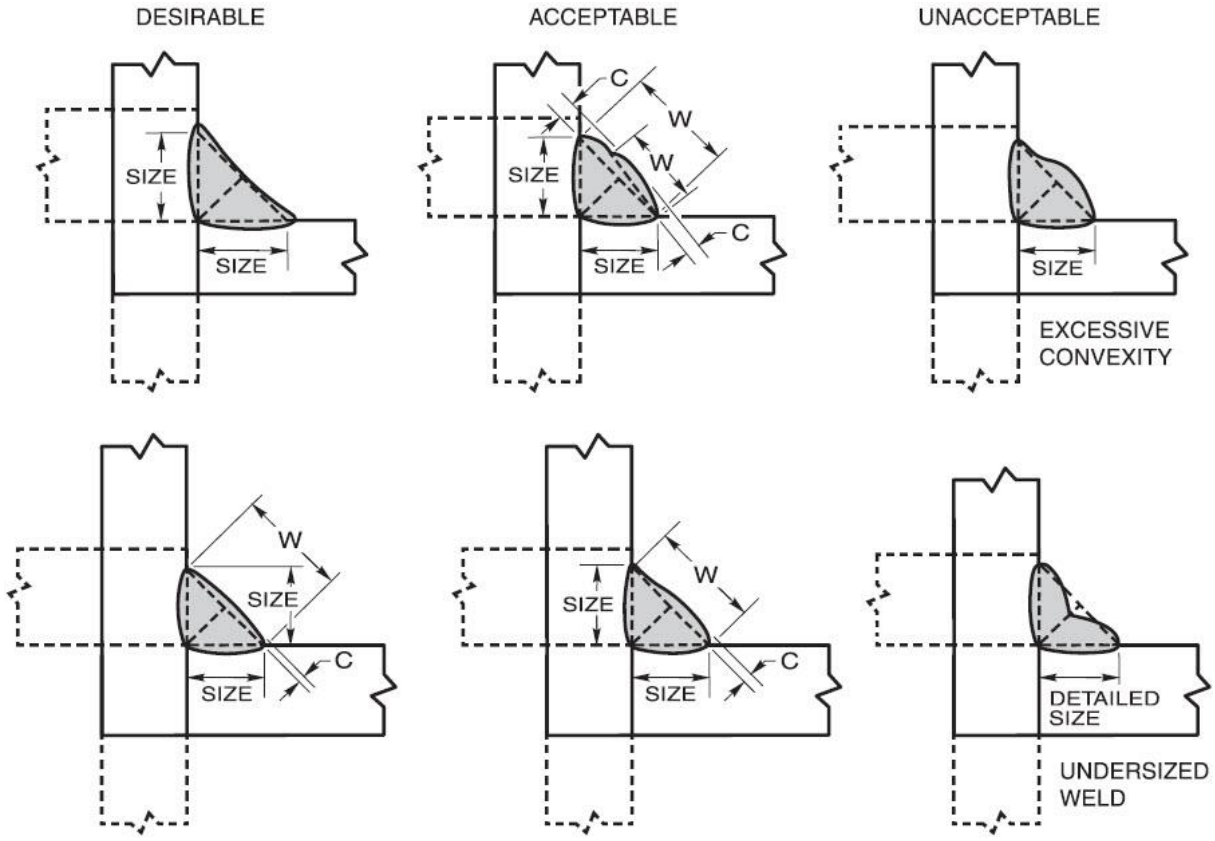

FIGURE B – FILLET WELD PROFILE REQUIREMENTS FOR INSIDE CORNER JOINTS, LAP JOINTS, AND T-JOINTS (see Tables 2 and 3)

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3.0 Workmanship Requirements and Visual Inspection Acceptance Criteria – Pipeline

3.1 Workmanship Requirements

3.1.1 Edge preparation details and fit-up dimensions shall be as specified in the WPS.

3.1.2 The beveled ends shall be smooth and uniform.

3.1.3 The alignment of abutting ends shall minimize the offset between surfaces. For pipe ends of the same nominal thickness, the offset shall not exceed 1/8 inch.

3.1.4 The number of filler and finish beads shall allow the completed weld a substantially uniform cross section around the circumference of the pipe. At no point shall the crown surface fall below the outside surface of the pipe, nor shall it be raised above the parent metal by more than 1/16 inch.

3.1.5 Adjacent beads shall neither be started nor terminated at the same location.

3.1.6 The face of the completed weld shall be no more than 1/8 inch wider than the width of the original groove.

3.1.7 The completed weld (including parent metal) shall be thoroughly brushed and cleaned. All spatter shall be removed.

3.1.8 Arc burns on the parent metal surface are unacceptable.

3.1.9 Repair and Removal of Defects

3.1.9.1 Authorization. Company authorization is required for crack repairs, back weld repairs and double repairs. Company authorization is not required for any repairs that do not involve the application of heat or weld metal, such as grinding, filing, etc. Rework is not a repair and does not require Company authorization.

3.1.9.2 Crack Repairs. Cracked welds shall be cut out unless the repair is authorized by the Company. When a crack repair is authorized:

(1) a cracked weld may be repaired by complete or partial removal of the weld provided the length of a single crack or aggregate length of more than one crack in a single repair area is less than 8% of the weld length using a qualified repair procedure;

(2) a weld that contains multiple repair areas with cracks shall not be repaired unless the total accumulated repair length is less than 8% of the weld length and a qualified repair procedure is used;

(3) a double repair of a crack is not permitted. Additional cracking in any weld after repair shall require a cut out;

(4) shallow crater cracks or star cracks found and contained completely in internal or external weld reinforcement may be repaired by grinding (i.e., abrasive methods) without a qualified repair procedure. If the grinding exceeds the internal or external reinforcement, the reinforcement shall be replaced using a qualified weld procedure.

3.1.9.3 Repairs of Defects Other Than Cracks. Defects other than cracks in the root, filler, and finish beads may be repaired with prior Company authorization. A qualified repair procedure shall be required whenever a repair is made by welding when:

(1) using a welding process, combination of welding processes, or method of application or filler metals different from that used to make the original weld; or

(2) repairs are made in a previously welded repair area; or

(3) required by the Company.

3.1.9.4 Grinding Repairs. Grinding repairs may be used to remove defects in the reinforcement of root beads and cover passes provided:

(1) there is a smooth transition free of undercutting and other imperfections between the ground area and the original weld, and

(2) pipe surface contour and the minimum wall and weld thickness requirements are not violated.

If the minimum wall/weld thickness is not known, the grinding depth is limited to the excess root bead penetration or external reinforcement. The grinding repair length and number of grinding repair areas is not limited. Grinding repairs do not require the use of a qualified repair procedure.

3.1.9.5 Back Weld Repairs. When back weld repairs are permitted by the Company, a repair procedure shall be qualified.

3.1.9.6 Welded Double Repairs. A double repair requires prior Company authorization. Subsequent repair of a double repair weld is not permitted.

3.1.9.7 Weld Repair and Inspection Procedure. Defects may be removed by grinding, chipping, or gouging or a combination of these methods followed by a weld repair. Prior to welding, the repair groove shall be examined visually and by either PT or MT to verify complete removal of the defect. Preheat and interpass heat treatment shall be the same as required for the original weld. The completed repair shall be visually examined and the entire weld shall be radiographed.

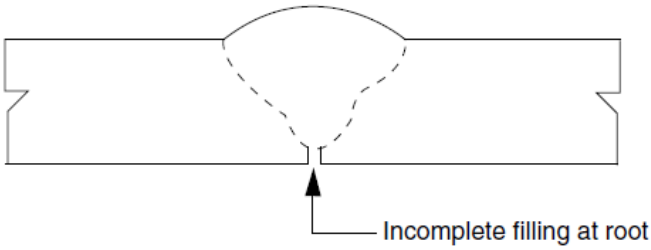
3.2 Visual Inspection Acceptance Criteria

3.2.1 Inadequate Penetration Without High-low (IP). Inadequate penetration without high-low is defined as the incomplete filling of the weld root. This condition is shown schematically in Figure C. IP shall be considered a defect should any of the following conditions exist:

3.2.1.1 The length of an individual indication of IP exceeds 1 inch.

3.2.1.2 The aggregate length of indications of IP in any continuous 12 inches length of weld exceeds 1 inch.

3.2.1.3 The aggregate length of indications of IP exceeds 8% of the weld length in any weld less than 12 inches in length.



Note: One or both root faces may be inadequately filled at the inside surface.

FIGURE C – Inadequate Penetration Without High-Low (IP)

3.2.2. Inadequate Penetration Due to High-low (IPD). Inadequate penetration due to high-low is defined as the condition that exists when one edge of the root is exposed (or unbonded) because adjacent pipe or fitting joints are misaligned. This condition is shown schematically in Figure D. IPD shall be considered a defect should any of the following conditions exist:

3.2.2.1 The length of an individual indication of IPD exceeds 2 inches.

3.2.2.2 The aggregate length of indications of IPD in any continuous 12 inch length of weld exceeds 3 inches.

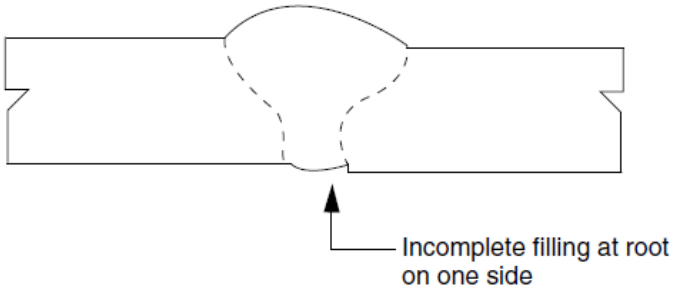


FIGURE D – Inadequate Penetration Due to High-Low (IPD)

3.2.3 Incomplete Fusion (IF). Incomplete fusion is defined as a surface imperfection between the weld metal and the base material that is open to the surface. This condition is shown schematically in Figure E. It shall be considered a defect should any of the following conditions exist:

3.2.3.1 The length of an individual indication of IF exceeds 1 inch.

3.2.3.2 The aggregate length of indications of IF in any continuous 12 inch length of weld exceeds 1 inch.

3.2.3.3 The aggregate length of indications of IF exceeds 8% of the weld length in any weld less than 12 inches in length.

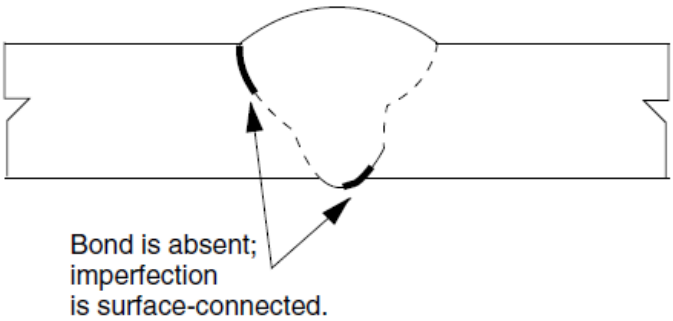


FIGURE E – Incomplete Fusion at Root of Bead or Top of Joint (IF)

3.2.4 Burn-through (BT). A burn-through is defined as a portion of the root bead where excessive penetration has caused the weld puddle to be blown into the pipe resulting in a hole or depression in the root bead of a single groove weld. BT shall be considered a defect should any of the following conditions exist:

3.2.4.1 The maximum dimension exceeds 1/4 inch.

3.2.4.2 The sum of the dimensions of separate BTs exceeds 1/2 inch in any continuous 12 inch length of weld or the total weld length, whichever is less.

3.2.5 Porosity (P). Porosity is defined as gas trapped by solidifying weld metal before the gas has a chance to rise to the surface of the molten puddle and escape. Porosity is generally spherical but may be elongated or irregular in shape, such as piping (wormhole) porosity. Porosity shall be considered a defect should any of the following conditions exist:

3.2.5.1 The size of an individual pore exceeds 1/8 inch.

3.2.5.2 The size of an individual pore exceeds 25% of the thinner of the nominal wall thicknesses joined.

3.2.5.3 Cluster porosity (CP) that occurs in the finish pass shall be considered a defect should any of the following conditions exist:

3.2.5.3.1 The diameter of the cluster exceeds 1/2 inch.

3.2.5.3.2 The aggregate length of CP in any continuous 12 inch length of weld exceeds 1/2 inch.

3.2.6 Cracks (C). Cracks shall be considered a defect.

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3.2.7 External Undercutting (EU) or Internal Undercutting (IU). Undercutting is defined as a groove melted or any reduction of the parent material adjacent to the toe or root of the weld and left unfilled by weld metal. Undercutting adjacent to the cover pass (EU) or root pass (IU) shall be considered a defect should the maximum dimensions of Table 4 be exceeded.

Table 4 – Maximum Dimensions of Undercutting (EU or IU)

Depth	Length
> 1/32 inch or > 12.5% of pipe wall thickness, whichever is smaller	Not acceptable
> 1/64 inch but ≤ 1/32 inch or > 6% but ≤ 12.5% of pipe wall thickness, whichever is smaller	2 inches in a continuous 12 inch weld length or one-sixth the weld length, whichever is smaller
≤ 1/64 inch or ≤ 6% of pipe wall thickness, whichever is smaller	Acceptable, regardless of length

3.2.8 Accumulation of Imperfections (AI). Excluding IPD, EU, and IU, any accumulation of otherwise acceptable imperfections such as P, CP, IF, IP, and BT, shall be considered a defect should any of the following conditions exist:

3.2.8.1 The aggregate length of AI in any continuous 12 inch length of weld exceeds 2 inches.

3.2.8.2 The aggregate length of AI exceeds 8% of the weld length.

4.0 Workmanship Requirements and Visual Inspection
Acceptance Criteria – Pressure Piping

4.1 Workmanship Requirements

4.1.1 The internal misalignment of the ends to be joined shall not be greater than 1/16 inch. When the internal misalignment exceeds the allowable, it is preferred that the component with the wall extending internally be internally trimmed. However, trimming shall result in a piping component thickness not less than the minimum allowable thickness, and the change in contour shall not exceed 30 degrees.

4.1.2 Edge preparation details and the root opening of the joint shall be as specified in the WPS.

4.1.3 Surfaces for welding shall be clean and free from paint, oil, rust, scale, or other material that is detrimental to welding.

4.1.4 The stopping and starting ends of tack welds shall be prepared by grinding or other mechanical means so that they can be satisfactorily incorporated into the final weld. Tack welds that have cracked are unacceptable and shall be removed and rewelded.

4.1.5 After welding commences, the minimum preheat temperature should be maintained until the joint is completed. However, welding may be interrupted and the joint allowed to cool slowly provided a minimum 3/8 inch thickness of weld is deposited or 25% of the groove is filled, whichever is less.

4.1.6 Arc strikes outside the area of the intended weld are unacceptable.

4.1.7 As-welded surfaces, including tie-ins, shall be smooth, uniform, and free from overlap.

4.1.8 Base metal surfaces shall be free of spatter.

4.1.9 Repair Welding. Any discontinuities in excess of the maximum permitted in 4.2 shall be removed and may be repaired by welding after the area has been magnetic particle or dye penetrant inspected to assure complete removal of discontinuities.

4.1.9.1 Defect Removal. All defects in welds or base materials requiring repair shall be removed by flame or arc gouging, grinding, chipping, or machining. Preheating may be required for flame or arc gouging on certain alloy materials of the air hardening type in order to prevent surface checking or cracking adjacent to the flame or arc gouged surface. When a defect is removed but welding repair is unnecessary, the surface shall be contoured to eliminate any sharp notches or corners. The contoured surface shall be reinspected by the same means originally used for locating the defect.

4.1.9.2 Repair Welds. Repair welds shall be made in accordance with a WPS using qualified welders, recognizing that the cavity to be repair welded may differ in contour and dimension from a normal joint preparation and may present different restraint conditions. All repair welds shall meet the visual acceptance criteria of 4.2.

4.1.9.3 Inspection. All weld repairs of depth exceeding 1 inch or 20% of the section thickness, whichever is the lesser (as measured from the pipe surface), shall be inspected by radiography and by magnetic particle or dye penetrant inspection of the finished weld surface. All weld repairs of depth less than 20% of the section thickness, or 1 inch, whichever is the lesser shall be examined by magnetic particle or dye penetrant inspection of the first layer of each 1/4 inch thickness of deposited weld metal, and of the finished weld surface. Magnetic particle or dye penetrant testing of the finished weld surface shall be done after postweld heat treatment.

4.2 Visual Inspection Acceptance Criteria. Any of the following indications are unacceptable:

4.2.1 Cracks

4.2.2 Undercut that is greater than 1⁄32 inch deep. This also includes any other reduction of base metal at the weld toes.

4.2.3 Weld reinforcement greater than specified in Table 5

Table 5

	Maximum Thickness of Reinforcement for Design Temperature		
	>750°F	350°F - 750°F	<350°F
Thickness of Base Metal (inches)	inch	inch	inch
Up to 1/8, incl.	1/16	3/32	3/16
Over 1/8 to 3/16, incl.	1/16	1/8	3/16
Over 3/16 to 1/2, incl.	1/16	5/32	3/16
Over 1/2 to 1, incl.	3/32	3/16	3/16
Over 1 to 2, incl.	1/8	1/4	1/4
Over 2	5/32	note (a)	note (a)

(a) The greater of 1/4 inch or 1/8 times the width of the weld.

NOTES:

1. For double welded butt joints, this limitation on reinforcement given above shall apply separately to both inside and outside surfaces of the joint.
2. For single welded butt joints, the reinforcement limits given above shall apply to the outside surface of the joint only.
3. The thickness of weld reinforcement shall be based on the thickness of the thinner of the materials being joined.
4. The weld reinforcement thicknesses shall be determined from the higher of the abutting surfaces involved.
5. Weld reinforcement may be removed if so desired.

4.2.4 Lack of fusion

4.2.5 Incomplete penetration

4.2.6 Any other linear indications greater than 3⁄16 inch long

4.2.7 Surface porosity with rounded indications having dimensions greater than 3⁄16 inch or four or more rounded indications separated by 1⁄16 inch or less edge to edge in any direction. Rounded indications are indications that are circular or elliptical with their length less than three times their width.

5.0 Procedure Qualification Requirements

5.1 Welding Procedure Specification Data.

Table 6 indicates the welding data to be included in a WPS for each welding process. A WPS may be presented in any format, written or tabular, provided the data required in Table 6 are included. A suggested WPS format appears in Annex VII. The WPS may list variables recorded on the PQR within the full range permitted for qualification variables and for practical limits determined by the welding organization for other welding data.

Table 6
WPS Data Matrix

	FCAW	GMAW	GTAW	SMAW
5.1.1 Joint Design				
(1) Joint type and dimensions.	X	X	X	X
(2) Treatment of backside, method of gouging/preparation.	X	X	X	X
(3) Backing material, if used.	X	X	X	X
5.1.2 Base Metal				
(1) M-Number and Group Number.	X	X	X	X
(2) Thickness range qualified.	X	X	X	X
(3) Diameter (tubular only).	X	X	X	X
(4) The coating description or type, if present.	X	X	X	X
5.1.3 Filler Metals				
(1) Specification, classification, F- and A-Number, or if not classified the nominal composition.	X	X	X	X
(2) Weld metal thickness by process and filler metal classification.	X	X	X	X
(3) Filler metal size or diameter.	X	X	X	X
(4) Penetration enhancing flux.			X	
(5) Supplemental filler metal.	X	X	X	
(6) Consumable insert and type.			X	
(7) Energized filler metal “hot.”			X	
5.1.4 Position				
(1) Welding position(s).	X	X	X	X
(2) Progression for vertical welding.	X	X	X	X

Table 6
WPS Data Matrix (Cont'd)

	FCAW	GMAW	GTAW	SMAW
5.1.5 Preheat and Interpass				
(1) Preheat minimum.	X	X	X	X
(2) Interpass temperature maximum (if applicable).	X	X	X	X
(3) Preheat maintenance.	X	X	X	X
5.1.6 Heat Treatment				
(1) PWHT temperature and time.	X	X	X	X
5.1.7 Shielding Gas				
(1) Torch shielding gas and flow rate range.	X	X	X	
(2) Root shielding gas and flow rate range.			X	
5.1.8 Electrical				
(1) Current (or wire feed speed), current type, and polarity.	X	X	X	X
(2) Voltage range (except for manual welding).	X	X	X	
(3) Specification, classification, and diameter of tungsten electrode.			X	
(4) Transfer mode.	X	X		
(5) A change to or from pulsed current.	X	X	X	X
5.1.9 Variables				
(1) Welding process and whether manual, semiautomatic, mechanized, or automatic.	X	X	X	X
(2) For mechanized or automatic, single or multiple electrode and spacing.	X	X	X	
(3) Single or multipass.	X	X	X	X
(4) Contact tube to work distance.	X	X		
(5) Cleaning.	X	X	X	X
(6) Peening.	X	X	X	X
(7) Stringer or weave bead.	X	X	X	X
(8) Travel-speed range for mechanized or automatic welding and manual applications requiring heat input calculations.	X	X	X	

5.2 Procedure Qualification Variables. A change in a WPS beyond that allowed in this clause shall require requalification of the procedure and preparation of a new or revised WPS. Changes not addressed in this clause shall not require requalification, provided such changes are documented in a new or revised WPS.

5.2.1 Test Weldments. The welding organization shall prepare a sufficient number of qualification test weldments to cover the anticipated processes, materials, thicknesses, etc. as described herein. Each groove test weldment shall be large enough to provide the necessary test specimens required in 5.3.

5.2.1.1 For the welding of base metals with different M-Numbers, a procedure qualification test shall be made for each combination of M-Numbers to be joined. However, a procedure qualification test with one M-Number shall also qualify for that metal welded to itself and to each of the lower M-Number metals for:

(1) Base metals M-1, M-3, M-4, and M-5A; and

(2) Welding processes SMAW, GTAW, GMAW, and FCAW.

(*Example:* M-5A to M-5A would qualify for M-5A to M-5A, as well as M-5A to M-4, M-5A to M-3, and M-5A to M-1. Refer to Annexes III-A and III-B for listings of base metal M-Numbers)

5.2.1.2 If fracture toughness testing is required, then procedure qualification shall be made for each combination M-Number and Group Number to be joined. A procedure qualification shall be made for each M-Number and Group Number combination of base metals, even though procedure qualification tests have been made for each of the two base metals welded to itself.

(1) If the Welding Procedure Specification (WPS) for welding the combination of base metals specifies the same qualification variables, including electrode or filler metal, as both WPSs for welding each base metal to itself, such as that the base metal is the only change, then the WPS for welding the combination of base metals is also qualified.

(2) When base metals of two different M-Numbers and Group Numbers are qualified using a single test weldment, that test weldment qualifies the welding of those two M-Numbers and Group Numbers to themselves as well as to each other using the variables qualified.

5.2.2 Qualification Thickness Limitations

5.2.2.1 Limitations on the thickness ranges qualified by procedure qualification tests are given in Table 7.

5.2.2.2 The limitations in Table 7 are based upon the base metal and weld metal thickness for groove welds.

5.2.2.3 Complete penetration groove welds shall also qualify partial penetration groove welds, fillet welds, and weld buildups within the qualification limits given in Table 7.

5.2.2.4 In addition to the welding data required to be included in the WPS by 5.1, when multiple process or multiple filler metal classifications are used in a single test weldment, the thickness ranges permitted for use in the WPS shall apply separately to each welding process and filler metal classification. The weld deposit thickness for each welding process and each filler metal classification used in the qualification test shall be recorded on the PQR.

5.2.2.5 In addition to the procedure qualification variables required to be recorded on the PQR by 5.2.3, the weld deposit thickness for each welding process and each filler metal classification used in the qualification test shall be recorded on the PQR for all applications.

Table 7
Thickness Limitation of Plate and Pipe for Groove Welds for Procedure Qualification

Test Weldment Thickness (T), inch[a]	Base Metal Thickness Qualified [b,c,d,e,f]		Deposit Weld Metals Thickness Qualified (t) [b, g]
	Minimum, inch	Maximum, inch	Maximum, inch
Less than 1/16	1/2T	2T	2t
1/16 to 3/8	1/16	2T	2t
Over 3/8, but less than 3/4	3/16	2T	2t
3/4 to less than 1-1/2	3/16	2T	2t when t < 3/4 2T when t ≥ 3/4
1-1/2 to less than 6	3/16	8	2t when t < 3/4 8 when t ≥ 3/4
6 and over	1	1.33T	2t when t < 3/4 8 when 3/4 ≤ t < 6 1.33t when t ≥ 6

(a) When the groove is filled using a combination of welding processes:

(1) The test weldment thickness "T" is applicable for the base metal and shall be determined from the Base Metal Thickness Qualified column.

(2) The thickness "t" of the weld metal for each welding process shall be determined from the Deposited Weld Metal thickness column.

(3) Each welding process qualified in this combination manner may be used separately only within the same qualification variables and the thickness limits.

(b) For GMAW-S, the maximum thickness of base metal qualified is 1.1 times the thickness of the test weldment until the test weldment thickness is 1/2 inch, beyond which Table 7 applies. The maximum weld metal thickness qualified is 1.1 times the GMAW-S weld metal thickness deposited in the weldment. In addition, for thickness 3/8 inch thick and greater, side bend tests shall be used to qualify GMAW-S WPSs.

(c) For fracture toughness applications, minimum base metal thickness qualified is T or 5/8 inch, whichever is less.

(d) If any single pass in the test weldment base metal is greater in thickness than 1/2 inch, the qualified base metal thickness is 1.1 times the test weldment thickness.

(e) If a test weldment receives a postweld heat treatment exceeding the lower transformation temperature, the maximum base metal thickness qualified is 1.1 times the base metal thickness of the test weldment, and the maximum weld thickness qualified is 1.1 times the weld metal of the test weldment.

(f) For base metals equal to or less than 3/8 inch, fillet welds have the same base metal thickness qualifications as groove welds. For base metals thickness greater than 3/8 inch, the maximum base metal thickness qualified for fillet welds is unlimited.

(g) Deposited weld metal thickness limitations do not apply to fillet welds or weld buildups.

NOTES:
T = The thickness of the Test Weldment Base Metal.
t = The thickness of the Weld Deposit, excluding reinforcement.

5.2.3 Table 8 lists the procedure qualification variables to be recorded on the PQR for each welding process. A change in a procedure qualification variable beyond the limits shown in Table 8 shall require a new or revised WPS and a new PQR. The PQR shall list the actual values of the variables used. The key to the entries in the body of the table is as follows:

Q—Qualification variable for all applications

T— Qualification variable for all fracture toughness applications

Table 8
PQR Data Matrix

	FCAW	GMAW	GTAW	SMAW
5.2.3.1 Joint Design				
(1) A change from a fillet to a groove weld.	Q	Q	Q	Q
(2) A change in the M-Number of backing.	Q	Q	Q	Q
5.2.3.2 Base Metal				
(1) A change in base metal thickness beyond the range permitted in 5.2.2.	Q	Q	Q	Q
(2) A change from one M-Number base metal to another M-Number base metal or to a combination of M-Number base metals, except as permitted in 5.2.1.1.	Q	Q	Q	Q
(3) A change from one M-Number Group Number to any other M-Number Group Number, except as permitted in 5.2.1.2.	T	T	T	T
(4) A change from one M-5 group (A, B, etc.) to any other. A change from M-9A to M-9B, but not vice versa. A change from one M-10 or M-11 group (A, B, etc.) to any other group.	Q	Q	Q	Q
5.2.3.3 Filler Metals				
(1) A change from one F-Number to any other F-Number or to any filler metal not listed in Annex II.	Q	Q	Q	Q
(2) For ferrous materials, a change from one A-Number to any other A-Number.	Q	Q	Q	Q

Table 8
PQR Data Matrix (Cont'd)

	FCAW	GMAW	GTAW	SMAW
5.2.3.3 Filler Metals (Cont'd)				
(3) A change in filler metal tensile strength exceeding 10 000 psi, or a change in filler metal classified to a strength lower than the specified minimum tensile strength designator of the base metal.	Q	Q	Q	Q
(4) The addition or deletion of filler material.			Q	
(5) A change in the weld metal thickness beyond that permitted in 5.2.2.	Q	Q	Q	Q
5.2.3.4 Preheat and Interpass Temperature				
(1) A decrease in preheat of more than 100°F from that qualified.	Q	Q	Q	Q
(2) An increase of more than 100°F in the maximum interpass temperature from that recorded on the PQR.	T	T	T	T
5.2.3.5 Postweld Heat Treatment				
(1) For the following M-Numbers 1, 3, 4, 5, 6, 7, 9, 10, and 11 a change from any one condition to any other requires requalification: (a) No PWHT. (b) PWHT below the lower transformation temperature. (c) PWHT within the transformation temperature range. (d) PWHT above the upper transformation temperature. (e) PWHT above the upper transformation temperature, followed by treatment below the lower transformation temperature.	Q	Q	Q	Q
(2) For all materials not covered above, a separate PQR is required for no PWHT and PWHT.	Q	Q	Q	Q

Table 8
PQR Data Matrix (Cont'd)

	FCAW	GMAW	GTAW	SMAW
5.2.3.6 Shielding Gas				
(1) Addition or deletion of torch shielding gas.	Q	Q	Q	
(2) A change in the specified nominal composition of shielding gas.	Q	Q	Q	
5.2.3.7 Electrical Characteristics				
(1) An increase in heat input or volume of weld metal deposited per unit length of weld, over that qualified, except when a grain refining austenitizing heat treatment is applied after welding. The increase may be measured by either of the following: (a) Heat Input (J/inch) $= \frac{\text{volts x amps x 60}}{\text{travel speed (inch/min)}}$ (b) Weld Metal Volume–An increase in bead size, (width x thickness) or a decrease in the length of weld bead per unit length of electrode.	T	T	T	T
(2) A change in the mode of metal transfer from short circuiting to globular, spray, or pulsed and vice versa.	Q	Q		
5.2.3.8 Other Variables				
(1) A change in welding process.	Q	Q	Q	Q
(2) A change exceeding $\pm$ 20% in the oscillation variables for mechanized or automatic welding.	T	T	T	
(3) A change from multipass per side to single pass per side.	T	T	T	T
(4) A change from a stringer bead to a weave bead in vertical uphill welding.	T	T	T	T

5.3 Procedure Qualification Test Requirements

5.3.1 Evaluation of Groove Test Weldments. Test weldments shall be subjected to the following:

(1) Visual Examination

(2) Guided Bend Test

(a) 4 side bend specimens, or

(b) 2 face bend and 2 root bend specimens

Side bend specimens may be substituted for face and root bend specimens for metal thicknesses from 3/8 to 3/4 inch inclusive. For metal over 3/4 inch thick, side bend specimens are required. For base metals 3/8 inch thick and greater, side bends are required for GMAW-S.

(3) Tension Test

(a) 2 transverse specimens

(4) CVN Fracture Toughness (if required)

(a) 3 specimens from weld metal

(b) 3 specimens from HAZ

5.4 Procedure Qualification Acceptance Criteria

5.4.1 Visual Examination Acceptance Criteria. Prior to removing specimen blanks from the completed test weldment, the weld shall be visually examined on all accessible surfaces and shall meet the following criteria:

5.4.1.1 There shall be no evidence of cracks, incomplete fusion, or incomplete joint penetration.

5.4.1.2 The depth of undercut shall not exceed the lesser of 10% of the base metal thickness or 1/32 inch.

5.4.1.3 Porosity shall not exceed the limitations of clause 2.0, 3.0, or 4.0, as applicable.

5.4.2 Bend Criteria. Transverse bend specimens shall be prepared as specified in Annex IV. The specimen edge radius shall not exceed 1/8 inch. It is recommended, but not a requirement, that the specimen grinding direction be parallel to the direction of bending. For face bend specimens, the weld face side shall be on the convex side of the bend specimen. For root bend specimens, the weld root side shall be on the convex side of the bend specimen. Side bend specimens may be bent in either direction. For all transverse bend specimens, the weld metal and heat-affected zone shall be completely within the bent portion of the specimen after bending.

Unless otherwise specified, specimens containing a rejectable discontinuity shall be considered as failed, regardless of their conformance to preparation or bending requirements. Specimens not meeting preparation or bending requirements that do not contain a rejectable discontinuity shall be disregarded and a replacement specimen prepared from the original weldment shall be tested.

The convex surface of the bend test specimen (beginning at the edge of the specimen and including the specimen edge radius) shall be visually examined and meet the requirements of 5.4.2.1, 5.4.2.2 or 5.4.2.3, as applicable.

5.4.2.1 Structural Steel Applications. For acceptance, the surface shall contain no discontinuities in the weld or heat-affected zone per the following:

(1) >1/8 inch measured in any direction on the surface, or

(2) >3/8 inch —the sum of the greatest dimensions of all discontinuities exceeding 1/32 inch, but less than or equal to 1/8 inch, or

(3) 1/4 inch —the maximum corner crack, except when that corner crack results from visible slag inclusion or other fusion type discontinuity, then the 1/8 inch maximum shall apply.

Specimens with corner cracks exceeding 1/4 inch with no evidence of slag inclusions or other fusion type discontinuity shall be disregarded, and a replacement test specimen from the original weldment shall be tested.

5.4.2.2 Pipeline Applications. The bend test shall be considered acceptable if no crack or other imperfection exceeding 1/8 inch or one-half the specified wall thickness, whichever is smaller, in any direction is present in the weld or between the weld and the fusion zone after bending. Cracks that originate on the outer radius of the bend along the edges of the specimen during testing and that are less than 1/4 inch, measured in any direction, shall not be considered unless obvious imperfections are observed.

5.4.2.3 Pressure Piping Applications. For acceptance, the surface shall contain no discontinuities in the weld or heat-affected zone per the following:

(1) >1/8 inch measured in any direction on the surface.

(2) Open discontinuities occurring on the corners of the specimen during testing shall not be considered and a replacement test specimen from the original weldment shall be tested unless there is definite evidence that the open discontinuities result from lack of fusion, slag inclusions, or other internal discontinuities.

5.4.3 Tension Test Criteria. The procedures and method for tension testing shall conform to AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. (Note: B4.0 is referenced, but not needed when taking this examination.) Each tensile test specimen shall have a tensile strength not less than the following:

5.4.3.1 The minimum tensile strength of the base metal as specified in Annex III-B, or of the weaker of the two base metals if metals of different minimum tensile strength are used; or

5.4.3.2 The specified minimum tensile strength of the electrode or filler metal classification when undermatching filler metal is used; or

5.4.3.3 If the specimen breaks in the base metal outside of the weld or weld interface, the test shall be accepted, provided the strength is not more than 5% below the specified minimum tensile strength of the base metal; or

5.4.3.4 If the base metal has no specified minimum tensile strength then failure in the base metal shall be acceptable.

5.4.4 CVN Fracture Toughness Criteria. For fracture toughness testing, the type of test, number of specimens, and acceptance criteria shall be as specified. The procedures and apparatus shall conform to the requirements of AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. (Note: B4.0 is referenced, but not needed when taking this examination.)

5.5 Procedure Qualification Documentation. Welding variables used to produce an acceptable test weldment and the results of tests conducted on that weldment to qualify a WPS shall be recorded on a Welding Procedure Qualification

Record (PQR). The PQR may be presented in any format, written or tabular. A suggested format for the PQR is included in Annex VIII. The WPS shall reference all PQR's which support the qualification of that WPS.

6.0 Performance Qualification Requirements

6.1 General

6.1.1 This specification addresses the requirements for welder performance qualifications. It does not contain requirements for welding operators or tack welders. Tack welds shall be made by welders qualified in accordance with this specification.

6.1.2 Welder qualification on one WPS will also qualify for welding with any other WPS within the performance qualification variables specified in 6.2.

6.1.3 Completion of an acceptable procedure or performance qualification test shall qualify the welder who welded the test weldment within the limits of performance qualification variables specified in 6.2.

6.1.4 Qualification on a complete joint penetration groove weld also qualifies the welder for partial joint penetration groove welds and fillet welds. Qualification on a partial joint penetration groove weld qualifies only for partial joint penetration groove welds and fillet welds.

6.2 Performance Qualification Variables

A change in any variable listed below from that which was used in a welder's qualification test will require requalification of that welder:

(1) A change in welding process except that welders qualified with GMAW spray, pulsed spray, or globular transfer are also qualified to weld with gas shielded FCAW and vice versa.

(2) The deletion of backing.

(3) A change in filler metal F-Number except as allowed in 6.3.2.2.

(4) A change in base metal except as permitted in 6.3.2.1.

(5) For GTAW, a change from alternating to direct current or vice versa, or a change in polarity.

(6) A change in position from that qualified, except as permitted in 6.3.2.3.

(7) A change in vertical weld progression from uphill to downhill, or vice versa for any pass except root passes that are completely removed by back gouging or final passes used to dress the final weld surface.

(8) For GMAW, a change from spray transfer, globular transfer, or pulsed spray welding to short-circuiting transfer; or vice versa.

(9) For GMAW or GTAW, omission or addition of consumable inserts, or deletion of root shielding gas except for double welded butt joints, partial penetration groove, and fillet welds.

(10) A change in thickness or diameter from that tested except as permitted in Tables 9 and 10.

Table 9
Limitations for Performance Qualification on Groove Welds in Pipe and Tube

Test Weldment, inch		Qualifies for Pipe and Plate			
		Minimum Outside Diameter, inch		Maximum Deposit Thickness	
Outside Diameter	Deposit Thickness (t)	Grooves	Fillets	Grooves	Fillets
Less than 1		Size welded	All		
1 through 2-7/8		1	All		
Over 2-7/8		2-7/8	All		
	Less than 3/4			2t	All
	3/4 and over			Unlimited	All

t = The thickness of the Weld Deposit, excluding reinforcement.
Note:
For GMAW-S, the maximum weld metal thickness qualified shall not exceed 1.1 times the thickness of weld metal deposited by the GMAW-S process in the qualification test. For base metals 3/8 inch thick and greater, side bends are required for GMAW-S.

Table 10
Limitations for Performance Qualification in Plate Groove Welds

Test Weldment Thickness (T), inch	Qualifies for Plate[a]	
	Deposit Thickness (t), Maximum[b]	Fillet Weld Size
< 3/4	2t	Unlimited
≥ 3/4	Unlimited	Unlimited

[a] Qualification on plate will also qualify for groove welds in pipe over 24 inches in diameter.
[b] For GMAW-S, the maximum weld metal thickness qualified shall not exceed 1.1 times the thickness of weld metal deposited by the GMAW-S process in the qualification test. For base metals 3/8 inch thick and greater, side bends are required for GMAW-S.

NOTES:
T = The thickness of the Test Weldment Base Metal.
t = The thickness of the Weld Deposit, excluding reinforcement.

6.3 Performance Qualification Test Requirements

6.3.1 Qualification by Standard Test. Qualification requires completion of a standard test weldment in accordance with a qualified WPS, evaluation of the test weldment by the methods listed in Table 11, and acceptance of the weldment in accordance with the criteria of 6.4, Examination Acceptance Criteria. The number of bend tests required for each position and product form is shown in Table 12.

Table 11
Examination Requirements for Performance Qualification

	Tube or Sheet Less than 1/16 inch	Pipe or Plate Equal to or Greater than 1/16 inch
Type of Test	Groove	Groove
Visual Examination	Yes	Yes
Radiography	No	Yes[a] (in lieu of bends)
Bend Test	No	Yes[a, b]

[a] Radiography may be substituted for bend testing for the SMAW, GTAW, GMAW (except short-circuiting), and FCAW processes, as applicable, for qualifications.
[b] See Table 12.

Table 12
Number of Bend Tests for Performance Qualification

	Product Form			
	Plate	Pipe	Tube	Sheet
1G	*2*	2	2	2
2G	*2*	2	2	2
3G	*2*	—	—	2
4G	*2*	—	—	2
5G	—	4	4	—
6G	—	4	4	—

6.3.2 Test Weldments

6.3.2.1 Qualification is valid only for metals having the same M-Numbers, except as otherwise permitted in Table 13.

6.3.2.2 Tests shall be performed using a filler metal which has an assigned F-Number listed in Annex II. Table 14 provides a matrix showing filler metals which, if used in qualification testing, will qualify that welder to use other filler metals without further testing. A test using a filler metal not assigned an F-Number in Annex II shall qualify only for that filler metal.

6.3.2.3 Test coupons welded in the specific test positions qualify the welder to weld plate or pipe as permitted in Table 15.

6.3.2.4 One or more welding process may be qualified on a single test weldment. Multiple welders may be qualified for specific portions of one test. Failure of any portion of such test weldments constitutes failure for all processes and welders used in that test weldment.

Table 13
Allowable Base Metals for Performance Qualification

Test Weldment Material[a]	Qualifies for Production Welding Materials
M-1 through M-11	M-1 through M-11

[a] If materials not listed in Annex III are used for qualification tests, the welder shall be qualified to weld only on the material used in the test weldment.

Table 14
Allowable Filler Metals for Performance Qualification

Filler Metal Used In Qualification Test	Qualifies a Welder to Use the Filler Metals Listed Below
F-Number 1 through 5	The F-Number used in the test and any lower F-Number
F-Number 6[a]	All F-Number 6 filler metals

[a] Deposited solid bare wire, which is not covered by an AWS specification but which conforms to an A-Number analysis in Annex I may be considered classified as F-Number 6.

Table 15
Position Limitation for Performance Tests

Test Positions[d]		Qualified Position[c]		
		Groove		Fillet
Weld	Position	Plate and Pipe Over 24 inches O.D.	Pipe ≤ 24 inches O.D.	Plate and Pipe
Plate Groove	1G	F		F, H
	2G	F, H		F, H
	3G	F, V		F, H, V
	4G	F, O		F, H, O
	3G and 4G	F, V, O		All
	2G, 3G, and 4G	All		All
Plate Fillet	1F	—	—	F
	2F	—	—	F, H
	3F	—	—	F, H, V
	4F	—	—	F, H, O
	3F and 4F	—	—	All
Pipe Groove[a,b]	1G	F	F	F, H
	2G	F, H	F, H	F, H
	5G	F, V, O	F, V, O	All
	6G	All	All	All
	2G and 5G	All	All	All
Pipe Fillet	1F	—	—	F
	2F	—	—	F, H
	2FR	—	—	F, H
	4F	—	—	F, H, O
	5F	—	—	All

[a] Welders qualified on tubular product forms may weld on both tubular and plate in accordance with any restrictions on diameter contained in other portions of this document.
[b] See Table 9.
[c] F = Flat, H = Horizontal, V = Vertical, O = Overhead.
[d] Welding test position definitions are as defined in AWS A3.0, "Standard Welding Terms and Definitions".

6.4 Performance Qualification Acceptance Criteria

6.4.1 Visual. Examination procedures and acceptance criteria shall be as specified in the following paragraphs.

6.4.1.1 Visual Examination Procedure. The test weld may be examined visually at any time, and the test terminated at any stage if the necessary skills are not exhibited. The completed test weld shall be visually examined.

6.4.1.2 Visual Examination Acceptance Criteria. Acceptance criteria for visual examination of standard test plate and pipe weldments shall be as follows:

(1) No cracks or incomplete fusion.

(2) No incomplete joint penetration in groove welds, except where partial joint penetration groove welds are specified.

(3) Undercut depth shall not exceed the lesser of 10% of the base metal thickness or 1/32 inch.

(4) Face reinforcement or root reinforcement shall not exceed 1/8 inch.

(5) No single pore shall exceed 3/32 inch diameter.

6.4.2 Bend Tests. Bend testing requirements and acceptance criteria are as specified in 5.3.1(2) and 5.4.2.

6.5 Performance Qualification Documentation

The qualification test for each welder shall be documented for both acceptable and unacceptable tests. There is no required format for Welder Performance Qualification Test Records (WQTR). Any WQTR form may be used. See Annex IX for a suggested format. The documentation shall:

(1) Identify the WPS used;

(2) Address each of the qualification variables in 6.2;

(3) Identify test and examination methods used and results; and

(4) Identify the limits of qualification for the welder.

Annex I (Normative) – A Number Table

Classification of Ferrous Weld Metal for Procedure Qualification

A-No.	Type of Weld Metal	Chemical Composition, wt %					
		C	Cr	Mo	Ni	Mn	Si
1	Low-carbon	0.20	0.20	0.30	0.50	1.60	1.00
2	Carbon-Molybdenum	0.15	0.50	0.40–0.65	0.50	1.60	1.00
3	Chromium-Molybdenum	0.15	0.40–2.00	0.40–0.65	0.50	1.60	1.00
4	Chromium-Molybdenum	0.15	2.00–4.00	0.40–1.50	0.50	1.60	2.00
5	Chromium-Molybdenum	0.15	4.00–10.5	0.40–1.50	0.80	1.20	2.00
6	Chromium, martensitic	0.15	11.00–15.0	0.70	0.80	2.00	1.00
7	Chromium, ferritic	0.15	11.00–30.0	1.00	0.80	1.00	3.00
8	Chromium-Nickel	0.15	14.50–30.0	4.00	7.50–15.00	2.50	1.00
9	Chromium-Nickel	0.30	19.0–30.0	6.00	15.0–37.00	2.50	1.00
10	Nickel	0.15	0.50	0.55	0.80–4.00	1.70	1.00
11	Manganese-Molybdenum	0.17	0.50	0.25–0.75	0.85	1.25–2.25	1.00
12	Nickel-Chromium-Molybdenum	0.15	1.50	0.25–0.80	1.25–2.80	0.75–2.25	1.00

Note:
Single values in this table are maximum values.

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Annex II (Normative) – F Number Table

Grouping of Welding Electrodes and Rods for Qualification

F-No.	AWS Specification	AWS Classification
		Steel
1	A5.1	EXX20, EXX22, EXX24, EXX27, EXX28
1	A5.4	EXXX(X)-26
1	A5.5	EXX20-XX, EXX27-XX
2	A5.1	EXX12, EXX13, EXX14, EXX19
2	A5.5	E(X)XX13-XX
3	A5.1	EXX10, EXX11
3	A5.5	E(X)XX10-XX, E(X)XX11-XX
4	A5.1	EXX15, EXX16, EXX18, EXX18M, EXX48
4	A5.4 other than austenitic and duplex	EXXX(X)-15, EXXX(X)-16, EXXX(X)-17
4	A5.5	E(X)XX15-XX, E(X)XX16-XX, E(X)XX18-XX, E(X)XX18M, E(X)XX18M1, E(X)XX45-P2
5	A5.4 austenitic and duplex	EXXX(X)-15, EXXX(X)-16, EXXX(X)-17
6	A5.9	All Classifications
6	A5.18	All Classifications
6	A5.20	All Classifications
6	A5.22	All Classifications
6	A5.28	All Classifications
6	A5.29	All Classifications
6	A5.30	INMs-X, IN5XX, IN3XX(X)

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Annex III-A (Normative)

List of Base Metal Specifications—Ferrous Alloys

Standard	Base Metal Specification	Material Number	Group Number	Type, Grade, or Alloy Designation	UNS Number	Product Form
Steel and Steel Alloys						
ASTM	A 36	1	1	A 36	K02599	Plate & Bars
ASTM	A 36	1	1	A 36	K02598	Plate & Bars
ASTM	A 36	1	1	A 36	K02597	Plate & Bars
ASTM	A 36	1	1	A 36	K02596	Plate & Bars
ASTM	A 106	1	1	Grade B	K03006	Seamless Pipe
ASTM	A 106	1	2	Grade C	K03501	Seamless Pipe
ASTM	A 202	4	1	Grade A	K11742	Plate
ASTM	A 202	4	1	Grade B	K12542	Plate
ASTM	A 203	9A	1	Grade A	K21703	Plate
ASTM	A 203	9A	1	Grade B	K22103	Plate
ASTM	A 203	9B	1	Grade D	K31718	Plate
ASTM	A 203	9B	1	Grade E	K32018	Plate
ASTM	A 204	3	1	Grade A	K11820	Plate
ASTM	A 204	3	2	Grade B	K12020	Plate
ASTM	A 204	3	2	Grade C	K12320	Plate
ASTM	A 225	10A	1	Grade C	K12524	Plate
ASTM	A 225	10A	1	Grade D	—	Plate
ASTM	A 240	6	1	Type 410	S41000	Plate
ASTM	A 240	6	2	Type 429	S42900	Plate
ASTM	A 240	6	4	Grade S41500	S41500	Plate
ASTM	A 240	7	1	Type 405	S40500	Plate
ASTM	A 240	7	1	Type 409	S40900	Plate
ASTM	A 240	7	1	Type 410S	S41008	Plate
ASTM	A 240	7	2	Type 18-2	S44400	Plate
ASTM	A 240	7	2	Type 430	S43000	Plate
ASTM	A 240	8	2	S30815	S30815	Plate, Sheet & Strip
ASTM	A 312	8	1	TP304	S30400	Seamless & Welded Pipe
ASTM	A 312	8	1	TP304L	S30403	Seamless & Welded Pipe
ASTM	A 312	8	1	TP316	S31600	Seamless & Welded Pipe
ASTM	A 312	8	1	TP316L	S31603	Seamless & Welded Pipe
ASTM	A 312	8	3	TPXM-19	S20910	Seamless & Welded Pipe
ASTM	A 312	8	3	TP-11	S21904	Seamless & Welded Pipe
ASTM	A 312	8	4	317LM	S31725	Seamless & Welded Pipe
ASTM	A 312	8	4	S31254	S31254	Seamless & Welded Pipe
ASTM	A 333	4	2	Grade 4	K11267	Pipe
ASTM	A 333	9A	1	Grade 7	K21903	Pipe
ASTM	A 333	9A	1	Grade 9	K22035	Pipe
ASTM	A 333	9B	1	Grade 3	K31918	Pipe
ASTM	A 335	4	1	Grade P11	K11597	Pipe
ASTM	A 335	4	1	Grade P12	K11562	Pipe
ASTM	A 335	5B	2	Grade P91	K91560	Seamless Pipe
ASTM	A 353	11A	1		K81340	Plate
ASTM	A 369	3	1	Grade FP1	K11522	Forged Pipe
ASTM	A 387	3	2	Grade 2, Class 2	K12143	Plate
ASTM	A 387	5A	1	Grade 21, Class 1	K31545	Plate

List of Base Metal Specifications—Ferrous Alloys

Standard	Base Metal Specification	Material Number	Group Number	Type, Grade, or Alloy Designation	UNS Number	Product Form
			Steel and Steel Alloys			
ASTM	A 387	5A	1	Grade 21, Class 2	K31545	Plate
ASTM	A 387	5B	1	Grade 5, Class 1	K41545	Plate
ASTM	A 387	5B	1	Grade 5, Class 2	K41545	Plate
ASTM	A 387	5B	2	Grade 91, Class 2	S50460	Plate
ASTM	A 420	11A	1	Grade WPL8	K81340	Pipe
ASTM	A 514	11B	1	Grade A	K11856	Plate
ASTM	A 514	11B	2	Grade E	K11856	Plate
ASTM	A 516	1	1	Grade 55	K01800	Plate
ASTM	A 516	1	1	Grade 65	K02403	Plate
ASTM	A 516	1	2	Grade 70	K02700	Plate
ASTM	A 517	11B	1	Grade A	K11856	Plate
ASTM	A 517	11B	2	Grade E	K21604	Plate
ASTM	A 533	3	3	Type A, Class 1	K12521	Plate
ASTM	A 533	3	3	Type A, Class 2	K12521	Plate
ASTM	A 533	3	3	Type B, Class 1	K12539	Plate
ASTM	A 533	3	3	Type B, Class 2	K12539	Plate
ASTM	A 533	11A	4	Grade A, Class 3	K12521	Plate
ASTM	A 533	11A	4	Grade B, Class 3	K12539	Plate
ASTM	A 543	11A	5	Type B, Class 1	K42339	Plate
ASTM	A 543	11A	5	Type B, Class 3	K42339	Plate
ASTM	A 542	5C	3	Type A, Class 3	K21590	Plate
ASTM	A 542	5C	4	Type A, Class 1	K21590	Plate
ASTM	A 542	5C	5	Type A, Class 2	K21590	Plate
ASTM	A 612	10C	1	—	K02900	Plate
ASTM	A 645	11A	2	—	K41583	Plate
ASTM	A 709	11B	1	Grade 100, Type A	K11856	Plate & Shapes
ASTM	A 709	11B	1	Grade 100W, Type A	K11856	Plate & Shapes
ASTM	A 709	11B	2	Grade 100, Type E	K21604	Plate & Shapes
ASTM	A 709	11B	2	Grade 100W, Type E	K21604	Plate & Shapes
ASTM	A 832	5C	1	Grade 21V	K31830	
ASTM	A 871	3	2	Grade 60	—	Plate
ASTM	A 945	3	2	Grade 65	—	Plate
API	5L	1	1	Grade X42	—	Pipe
API	5L	1	2	Grade X52	—	Pipe
API	5L	1	2	Grade X60	—	Pipe
API	5L	1	4	Grade X80	—	Pipe

M-Number Listing of Base Metals—Ferrous Alloys

Material Number	Group Number	Standard	Base Metal Specification	Type, Grade, or Alloy Designation	UNS Number	Thickness Limitations	Minimum Tensile/Yield Strength, ksi	Product Form	Nominal Composition
Steel and Steel Alloys									
1	1	ASTM	A 36	A 36	K02599	≤0.75	58/36	Plate & Bars	C-Mn-Si
1	1	ASTM	A 36	A 36	K02598	>0.75≤1.5	58/36	Plate & Bars	C-Mn-Si
1	1	ASTM	A 36	A 36	K02597	>1.5≤2.5	58/36	Plate & Bars	C-Mn-Si
1	1	ASTM	A 36	A 36	K02596	>2.5≤4.0	58/36	Plate & Bars	C-Mn-Si
1	1	ASTM	A106	Grade B	K03006	—	60/35	Seamless Pipe	C-Mn-Si
1	1	ASTM	A 516	Grade 55	K01800	—	55/30	Plate	C-Mn-Si
1	1	ASTM	A 516	Grade 65	K02403	—	65/35	Plate	C-Mn-Si
1	1	API	5L	Grade X42	—	—	60/42	Pipe	C-Mn
1	2	ASTM	A 106	Grade C	K03501	—	70/40	Seamless Pipe	C-Mn-Si
1	2	ASTM	A 516	Grade 70	K02700	—	70/38	Plate	C-Mn-Si
1	2	API	5L	Grade X52	—	—	66/52	Pip	C-Mn
1	2	API	5L	Grade X60	—	—	5/60	Pipe	C-Mn-Cb-V-Ti
1	4	API	5L	Grade X80	—	—	90/80	Pipe	C-Mn
3	1	ASTM	A 204	Grade A	K11820	—	65/37	Plate	C-0.5Mo
3	1	ASTM	A 369	Grade FP1	K11522	—	55/30	Pipe	C-0.5Mo
3	2	ASTM	A 204	Grade B	K12020	—	70/40	Plate	C-0.5Mo
3	2	ASTM	A 204	Grade C	K12320	—	75/43	Plate	C-0.5Mo
3	2	ASTM	A 387	Grade 2, Class 2	K12143	—	70/45	Plate	0.5Cr-0.5Mo
3	2	ASTM	A 871	Grade 60	—	—	75/60	Plate	C-Mn-Ni-Cu-Cr-V
3	2	ASTM	A 945	Grade 65	—	—	78/65	Plate	LowC-Mn
3	3	ASTM	A 533	Type A, Class 1	K12521	—	80/50	Plate	Mn-0.5Mo
3	3	ASTM	A 533	Type A, Class 2	K12521	—	90/70	Plate	Mn-0.5Mo
3	3	ASTM	A 533	Type B, Class 1	K12539	—	80/50	Plate	Mn-0.5Mo-0.5Ni
3	3	ASTM	A 533	Type B, Class 2	K12539	—	90/70	Plate	Mn-0.5Mo-0.5Ni

4	1	ASTM	A 202	Grade A	K11742	—	75/45	Plate	0.5Cr-1.25Mn-Si
4	1	ASTM	A 202	Grade B	K12542	—	85/47	Plate	0.5Cr-1.25Mn-Si
4	1	ASTM	A 335	Grade P11	K11597	—	60/30	Pipe	1.25Cr-0.5Mo-Si
4	1	ASTM	A 335	Grade P12	K11562	—	60/32	Pipe	1Cr-0.5Mo
4	2	ASTM	A 333	Grade 4	K11267	—	60/35	Pipe	0.75Cr-0.75Ni-Cu-Al
5A	1	ASTM	A 387	Grade 21, Class 1	K31545	—	60/30	Plate	3Cr-1Mo
5A	1	ASTM	A 387	Grade 21, Class 2	K31545	—	75/45	Plate	3Cr-1Mo
5B	1	ASTM	A 387	Grade 5, Class 1	K41545	—	60/30	Plate	5Cr-0.5Mo
5B	1	ASTM	A 387	Grade 5, Class 2	K41545	—	75/45	Plate	5Cr-0.5Mo
5B	2	ASTM	A 335	Grade P91	K91560	—	85/60	Seamless Pipe	9Cr-1Mo-V
5B	2	ASTM	A 387	Grade 91, Class 2	S50460	—	85/60	Plate	9Cr-1Mo-V
5C	1	ASTM	A 832	Grade 21V	K31830	—	85/60	Plate	3Cr-1Mo-0.25V
5C	3	ASTM	A 542	Type A, Class 3	K21590	—	95/75	Plate	2.25Cr-1Mo
5C	4	ASTM	A 542	Type A, Class 1	K21590	—	105/85	Plate	2.25Cr-1Mo
5C	5	ASTM	A 542	Type A, Class 2	K21590	—	115/100	Plate	2.25Cr-1Mo
6	1	ASTM	A 240	Type 410	S41000	—	65/30	Plate	13Cr
6	2	ASTM	A 240	Type 429	S42900	—	65/30	Plate	15Cr
6	4	ASTM	A 240	S41500	S41500	—	115/90	Plate	13Cr-4.5Ni-Mo
7	1	ASTM	A 240	Type 405	S40500	—	60/25	Plate	12Cr-1Al
7	1	ASTM	A 240	Type 409	S40900	—	55/25	Plate	11Cr-Ti
7	1	ASTM	A 240	Type 410S	S41008	—	60/30	Plate	13Cr
7	2	ASTM	A 240	Type 18-2	S44400	—	60/40	Plate	18Cr-2Mo
7	2	ASTM	A 240	Type 430	S43000	—	65/30	Plate	17Cr
8	1	ASTM	A 312	TP304	S30400	—	75/30	Seamless & Welded Pipe	18Cr-8Ni
8	1	ASTM	A 312	TP304L	S30403	—	75/25	Seamless & Welded Pipe	18Cr-8Ni
8	1	ASTM	A 312	TP316	S31600	—	75/30	Seamless & Welded Pipe	16Cr-12Ni-2Mo
8	1	ASTM	A 312	TP316L	S31603	—	70/25	Seamless & Welded Pipe	16Cr-12Ni-2Mo
8	2	ASTM	A 240	S30815	S30815	<3/16	87/45	Plate, Sheet & Strip	21Cr-11Ni-N
8	3	ASTM	A 312	TP-11	S21904	—	90/50	Seamless & Welded Pipe	21Cr-6Ni-9Mn
8	3	ASTM	A 312	TPXM-19	S20910	—	100/55	Seamless & Welded Pipe	22Cr-13Ni-5Mn
8	4	ASTM	A 312	S31254	S31254	—	94/44	Seamless & Welded Pipe	20Cr-18Ni-6Mo
8	4	ASTM	A 312	317LM	S31725	—	75/30	Seamless & Welded Pipe	19Cr-15Ni-4Mo

9A	1	ASTM	A 203	Grade A	K21703	—	65/37	Plate	2.5Ni
9A	1	ASTM	A 203	Grade B	K22103	—	70/40	Plate	2.5Ni
9A	1	ASTM	A 333	Grade 7	K21903	—	65/35	Pipe	2.5Ni
9A	1	ASTM	A 333	Grade 9	K22035	—	63/46	Pipe	2Ni-1Cu
9B	1	ASTM	A 203	Grade D	K31718	—	65/37	Plate	3.5Ni
9B	1	ASTM	A 203	Grade E	K32018	—	70/40	Plate	3.5Ni
9B	1	ASTM	A 333	Grade 3	K31918	—	65/35	Pipe	3.5Ni
10A	1	ASTM	A 225	Grade C	K12524	—	105/70	Plate	Mn-0.5Ni-V
10A	1	ASTM	A 225	Grade D	—	≤3.0	80/60	Plate	Mn-0.5Ni-V
10A	1	ASTM	A 225	Grade D	—	>3.0≤6.0	75/55	Plate	Mn-0.5Ni-V
10C	1	ASTM	A 612	—	K02900	≤0.5	83/50	Plate	C-Mn-Si
10C	1	ASTM	A 612	—	K02900	>0.5	81/50	Plate	C-Mn-Si
11A	1	ASTM	A 353	—	K81340	—	100/75	Plate	9Ni
11A	1	ASTM	A 420	Grade WPL8	K81340	—	100/75	Pipe	9Ni
11A	2	ASTM	A 645	—	K41583	—	95/65	Plate	0.5Ni-0.25Mo
11A	4	ASTM	A 533	Grade A, Class 3	K12521	—	100/83	Plate	Mn-0.5Mo
11A	4	ASTM	A 533	Grade B, Class 3	K12539	—	100/83	Plate	Mn-0.5Mo-0.5Ni
11A	5	ASTM	A 543	Type B, Class 1	K42339	—	105/85	Plate	3Ni-1.75Cr-0.5Mo
11A	5	ASTM	A 543	Type B, Class 3	K42339	—	90/70	Plate	3Ni-1.75Cr-0.5Mo
11B	1	ASTM	A 514	Grade A	K11856	≤2.5	110/100	Plate	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 514	Grade A	K11856	>2.5≤6.0	110/90	Plate	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 514	Grade A	K11856	≤2.5	115/100	Plate	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 514	Grade A	K11856	>2.5≤6.0	105/90	Plate	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 709	Grade 100, Type A	K11856	≤2.5	110/100	Plate & Shapes	0.5Cr-0.25Mo-Si
11B	1	ASTM	A 709	Grade 100W, Type A	K11856	≤2.5	110/100	Plate & Shapes	0.5Cr-0.25Mo-Si
11B	2	ASTM	A 514	Grade E	K21604	≤2.5	110/100	Plate	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 514	Grade E	K21604	>2.5≤6.0	110/90	Plate	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 517	Grade E	K21604	≤2.5	115/100	Plate	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 517	Grade E	K21604	>2.5≤6.0	105/90	Plate	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 709	Grade 100, Type E	K21604	≤2.5	110/100	Plate & Shapes	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 709	Grade 100, Type E	K21604	>2.5≤4.0	100/90	Plate & Shapes	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 709	Grade 100W, Type E	K21604	≤2.5	110/100	Plate & Shapes	1.75Cr-0.5Mo-Cu
11B	2	ASTM	A 709	Grade 100W, Type E	K21604	>2.5≤4.0	100/90	Plate & Shapes	1.75Cr-0.5Mo-Cu

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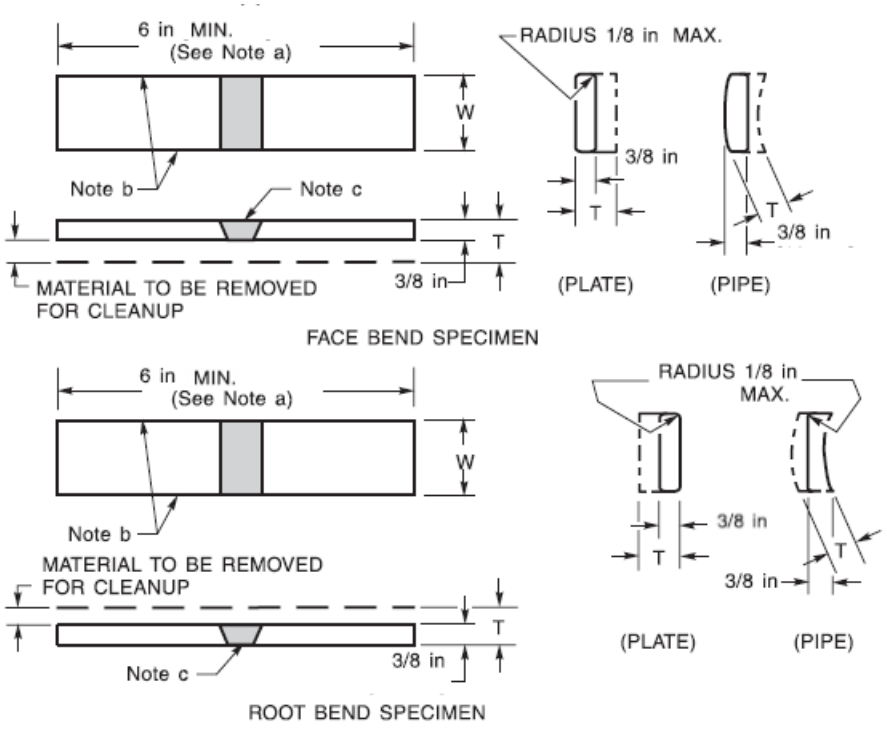
Annex IV (Normative)
Transverse Face and Root Bend Specimen Preparation Requirements



TRANSVERSE BEND SPECIMEN	
Dimensions	
Test Weldment	Test Specimen Width, W
Plate	1-1/2 inches
Test pipe or tube	
≤ 4 inches diameter NPS	Note d
> 4 inches diameter NPS	1-1/2 inches

(a) A longer specimen length may be necessary when using a wraparound type bending fixture or when testing steel with a yield strength of 90 ksi or more.

(b) Except on M-1 materials, thermal cut edges shall be dressed by grinding.

(c) The weld reinforcement and backing, if any, shall be removed flush with the surface of the specimen. If a recessed backing is used, this surface may be machined to a depth not exceeding the depth of the recess to remove the backing; in such a case, the thickness of the finished specimen shall be that specified above. Cut surfaces shall be smooth and parallel.

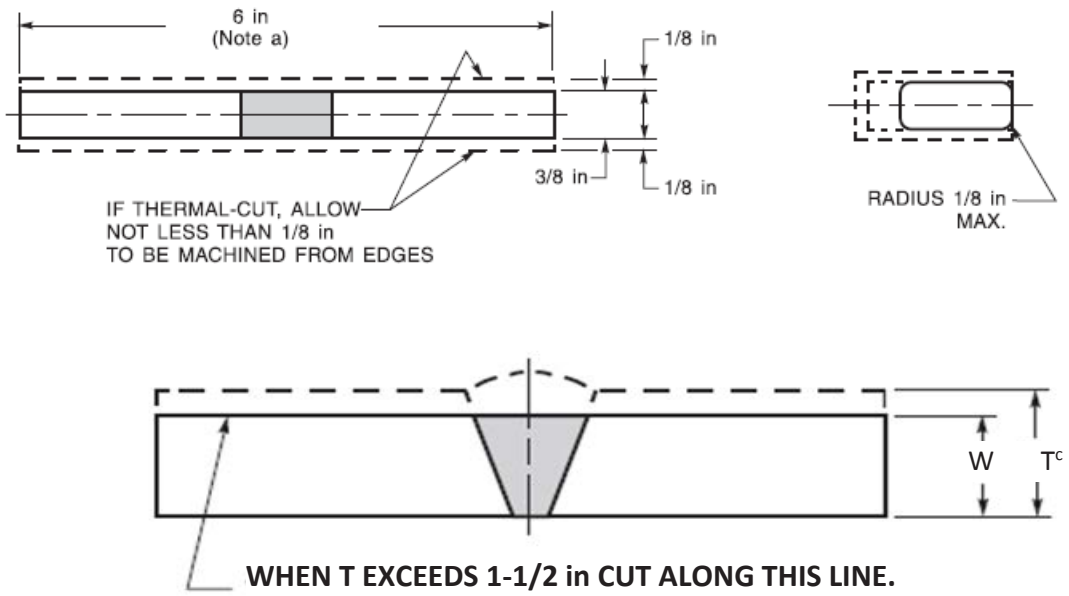
(d) For pipe diameters of 2 inches through 4 inches NPS, the width of the bend specimen shall not be less than 3/4 inch. For pipe diameters of 3/8 inch to 2 inches NPS, the bend specimen width shall not be less than be 3/8 inch with an alternative (permitted for pipe 1 inch NPS and less) of cutting the pipe into quarter sections, in which case the weld reinforcement may be removed and no other preparation of the specimens is required.

Notes:

1. T = plate or pipe thickness.
2. When the thickness of the test plate is less than 3/8 inch, the nominal thickness shall be used for face and root bends.
3. The specimen grinding direction should be parallel to the direction of bending.

Transverse Face and Root Bend Specimens

Annex IV (Normative)
Side Bend Specimen Preparation Requirements



T	W
3/8 to 1-1/2 inches	T (inches)
> 1-1/2 inches	(Note b)

(a) A longer specimen length may be necessary when using a wraparound-type bending fixture or when testing steel with a yield strength of 90 ksi or more.

(b) For plates over 1-1/2 inches thick, the specimen shall be cut into approximately equal strips with W between 3/4 inch and 1-1/2 inches and each strip shall be tested.

(c) T = nominal plate or pipe thickness.

Note:

1. The specimen grinding direction should be parallel to the direction of bending.
2. Except on M-1 materials, thermal cut edges shall be dressed by grinding.

Side Bend Specimens

Annex V (Informative)
Useful Formulas, Conversions, Abbreviations and Information

The purpose of this annex is to provide some direction to test takers regarding abbreviations, concepts, and terms used within this Book of Specifications solely for the purpose of taking an AWS examination. The scope of this Book of Specifications covers multiple industries which use different terms for the same concepts. This annex explains how these differences are addressed in this AWS exam.

Abbreviation	Description
AI	accumulation of imperfections
BT	burn-through
C	cracks
CJP	complete joint penetration
CP	cluster porosity
CFH	cubic feet per hour
CSA	cross sectional area
CVN	Charpy V-notch testing
EU	undercut adjacent to the cover pass
ET	electromagnetic testing
ID	inside diameter
IF	incomplete fusion
INCL	inclusive
IP	inadequate penetration without high-low
IPD	inadequate penetration due to high-low
IPM	inches per minute
IU	undercut adjacent to the root pass
J	Joule
J/in	Joules per inch
LT	leak testing
MT	magnetic particle testing
NDE	nondestructive examination
NDT	nondestructive testing
NPS	nominal pipe size
OD	outside diameter
P	porosity
PJP	partial joint penetration
PQR	procedure qualification record
PT	penetrant testing
PWHT	post weld heat treatment
RT	radiographic testing
TYP	typical
UNS	unified numbering system
UT	ultrasonic testing
UTS	ultimate tensile strength
VT	visual testing
W	width of bend specimen
WPS	welding procedure specification
WQTR	welder qualification test record

Concept	Description
AWS C4.1-77	refers to both the written standard and physical gauge for comparative measurement of oxyfuel cut surfaces
Sample 1	first roughness sample on the AWS C4.1-77 gauge; roughest cut
Sample 2	second roughness sample on the AWS C4.1-77 gauge
Sample 3	third roughness sample on the AWS C4.1-77 gauge
Sample 4	fourth roughness sample on the AWS C4.1-77 gauge; smoothest cu

The International System of Units (SI) is used in many applications. Shown in the tables below are the conversion factors used to convert U. S. Customary units to SI units, and the metric (SI) prefixes for the multiplication factors of units.

Table 16 – SI Conversion Factors

Property	To Convert from U. S. Customary Units	To SI Units	Multiply by
Force	pound-force (lbf)	Newton (N)	4.45
	kip (1000 lbf)	Newton (N)	4450
Linear Dimension	inch (in)	millimeter (mm)	25.4
Tensile Strength	pounds per square inch (psi)	Pascal (Pa)	6890
	pounds per square inch (psi)	kiloPascal (kPa)	6.89
	pounds per square inch (psi)	megaPascal (MPa)	0.00689
Mass	pound mass	kilogram (kg)	0.454
Angle, plane	degree	Radian	0.0175
Flow Rate	cubic feet per hour (cfh)	liter per minute (l/min)	0.472
Heat Input	Joules per inch (J/in)	Joules per meter (J/m)	39.4
Travel Speed, wire	inches per minute (in/min)	millimeters per second (mm/s)	0.423
Temperature	degrees Fahrenheit (°F)	degrees Celsius (°C)	use the formula: °C = (°F – 32)/1.8

Table 17 – SI Prefixes

Exponential Expression	Multiplication Factor	Prefix	Symbol
10^9	1 000 000 000	giga	G
10^6	1 000 000	mega	M
10^3	1 000	kilo	k
10^{-3}	0.001	milli	m
10^{-6}	0.000 001	micro	**μ**
10^{-9}	0.000 000 001	nano	n

Table 18 – Fraction/Decimal Equivalencies

8ths	1/8 .125	1/4 .250	3/8 .375	1/2 .500	5/8 .625	3/4 .750	7/8 .875									
16ths	1/16 .062	3/16 .187	5/16 .312	7/16 .437	9/16 .562	11/16 .687	13/16 .812	15/16 .937								
32nds	1/32 .031	3/32 .093	5/32 .156	7/32 .218	9/32 .281	11/32 .343	13/32 .406	15/32 .468	17/32 .531	19/32 .593	21/32 .656	23/32 .718	25/32 .781	27/32 .843	29/32 .906	31/32 .968
64ths	1/64 .015	3/64 .046	5/64 .078	7/64 .109	9/64 .140	11/64 .171	13/64 .203	15/64 .234	17/64 .265	19/64 .296	21/64 .328	23/64 .359	25/64 .390	27/64 .421	29/64 .453	31/64 .484
	33/64 .515	35/64 .546	37/64 .578	39/64 .609	41/64 .640	43/64 .671	45/64 .703	47/64 .734	49/64 .765	51/64 .796	53/64 .828	55/64 .859	57/64 .890	59/64 .921	61/64 .953	63/64 .984

Cross Sectional Area (CSA) for rectangular tensile bars:

CSA = w x t

Where w = width and t = thickness

Cross Sectional Area (CSA) for round tensile bars:

CSA = $\pi d^2/4$

Where π = mathematical constant 3.1416 and
d = original diameter of the bar

Ultimate Tensile Strength (UTS) [psi]:

UTS (in psi) = Maximum Load in pounds / original cross sectional area (sq. in)

Formula to convert pounds per square inch (psi) to kilo-pounds per square inch (ksi) and vice versa:

psi = ksi x 1000

ksi = psi / 1000

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Annex VI (Informative)
Pipe Schedules

Pipe Size *(inches)*	Outside Diameter OD *(inches)*	Identification			Nominal Wall Thickness - T - *(inches)*	Minimum Wall Thickness (inches)	Inside Diameter - ID - *(inches)*
		Steel		Stainless Steel Schedule No.			
		Iron Pipe Size	Schedule No.				
2 1/2	2.875	-	-	5S	.083	0.073	2.709
		-	-	10S	.120	0.105	2.635
		STD	40	40S	.203	0.178	2.469
		XS	80	80S	.276	0.242	2.323
		-	160	-	.375	0.328	2.125
		XXS	-	-	.552	0.483	1.771
3	3.500	-	-	5S	.083	0.073	3.334
		-	-	10S	.120	0.105	3.260
		STD	40	40S	.216	0.189	3.068
		XS	80	80S	.300	0.263	2.900
		-	160	-	.438	0.383	2.624
		XXS	-	-	.600	0.525	2.300
3 1/2	4.000	-	-	5S	.083	0.073	3.834
		-	-	10S	.120	0.105	3.760
		STD	40	40S	.226	0.198	3.548
		XS	80	80S	.318	0.278	3.364
4	4.500	-	-	5S	.083	0.073	4.334
		-	-	10S	.120	0.105	4.260
		STD	40	40S	.237	0.207	4.026
		XS	80	80S	.337	0.295	3.826
		-	120	-	.438	0.383	3.624
		-	160	-	.531	0.465	3.438
		XXS	-	-	.674	0.590	3.152
5	5.563	-	-	5S	.109	0.095	5.345
		-	-	10S	.134	0.117	5.295
		STD	40	40S	.258	0.226	5.047
		XS	80	80S	.375	0.328	4.813
		-	120	-	.500	0.438	4.563
		-	160	-	.625	0.547	4.313
		XXS	-	-	.750	0.656	4.063
6	6.625	-	-	5S	.109	0.095	6.407
		-	-	10S	.134	0.117	6.357
		STD	40	40S	.280	0.245	6.065
		XS	80	80S	.432	0.378	5.761
		-	120	-	.562	0.492	5.501
		-	160	-	.718	0.628	5.189
		XXS	-	-	.864	0.756	4.897
8	8.625	-	-	5S	.109	0.095	8.407
		-	-	10S	.148	0.130	8.329
		-	20	-	.250	0.219	8.125
		-	30	-	.277	0.242	8.071
		STD	40	40S	.322	0.282	7.981
		-	60	-	.406	0.355	7.813
		XS	80	80S	.500	0.438	7.625
		-	100	-	.594	0.520	7.437
		-	120	-	.719	0.629	7.187
		-	140	-	.812	0.711	7.001
		XXS	-	-	.875	0.766	6.875

Annex VII (Informative)
Welding Procedure Specification (WPS)

WPS Number [1]	Date [2]	Revision [3]	Page 1 of 2

SUPPORTING PQR (s) ID.

[4]

SCOPE

[5]

WELDING PROCESS(ES) & TYPE

Process(es): [6]

JOINT DESIGN

Joint Design:	[7]
Root Spacing:	[8]
Backing Material:	[9]
Treatment of backside, method of gouging/preparation:	[10]
Maximum Mismatch:	[11]
Typical Joint Details:	[12]

[13]

BASE METALS

M-No. [14] **Group No.** [15] **To M-No.** [16] **Group No.** [17]

Thickness Range Qualified: [18]
Diameter (Tubular Only): [19]
Coating Description or Type: [20]

FILLER METALS

Process:	[21]
AWS Specification No.:	[22]
AWS No. (Classification):	[23]
F-No.	[24]
Weld Metal Analysis A-No.:	[25]
Weld Metal Deposit Thickness:	[26]
Filler Metal Size:	[27]
Flux-Electrode Classification:	[28]
Supplemental Filler Metal:	[29]
Consumable Insert & Type:	[30]
Consumable Insert:	[31]
Supplemental Deoxidant:	[32]
Energized Filler Metal "Hot"	[33]

WPS Number [1]	Date [2]	Revision [3]	Page 2 of 2

POSITION

Welding Positions: [34]
Progression for Vertical Welding: [35]

PREHEAT AND INTERPASS

Preheat Minimum: [36]
Interpass Temperature Maximum: [37]
Preheat Maintenance: [38]

HEAT TREATMENT

PWHT Type: [39]
PWHT Temperature: [40]
PWHT Holding Time: [41]
Heating and Cooling Rate: [42]

SHIELDING GAS

	Type and % Composition (if applicable)	**Flow Rate Range**
Torch Shielding Gas:	[43]	[48]
Root Shielding Gas:	[44]	[49]
Environmental Shielding:	[45]	
Vacuum Pressure:	[46]	
Gas Cup Size:	[47]	

ELECTRICAL

Process:	[50]			
Filler Metal Diameter:	[51]			
Current Type and Polarity:	[52]			
Amperage Range:	[53]			
Transfer Mode:	[54]			
Wire Feed Speed (ipm)	[55]			
Voltage Range:	[56]			
Tungsten Specification No.:	[57]			
Tungsten Classification:	[58]			
Tungsten Electrode Diameter:	[59]			
Maximum Heat Input (J/in):	[60]			
Pulsed Current:	[61]			

VARIABLES

Single to Multiple Electrodes: [62]
Electrode Spacing (in.): [63]
Single or Multipass: [64]
Contact Tube to Work Distance (in.): [65]
Cleaning: [66]
Peening: [67]
Conventional or Keyhole Technique: [68]
Stringer or Weave Bead: [69]
Travel-Speed Range (ipm): [70]

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Annex VIII (Informative)
Procedure Qualification Record (PQR)

WELDING PROCESS & Type			
Process 1:	[1]		
Process 2:	[2]		
BASE METALS			
Base Material Spec.:	[3]	to	[4]
M-No.:	[5]	Group No.:	
to M-No.:		Group No.:	
Plate or Pipe:	[6]	Pipe Diameter:	[7]
Thickness:	[8]		
Coating:	[9]		

FILLER METALS		
Specification No.:	[10]	
AWS No. Classification:	[11]	
F-No.:	[12]	
Weld Metal Analysis A-No.:	[13]	
Filler Metal Size:	[14]	
Supplemental Filler:	[15]	
Weld Metal Deposit Thickness:	[16]	

POSITION	
Position of Joint:	[17]
Vertical Welding Progression:	[18]
PREHEAT	
Min. Preheat Temperature:	[19]
Max. Interpass Temperature:	[20]

ELECTRICAL		
Current & Polarity:	[21]	
Amperage Range:	[22]	
Pulsed Current:	[23]	
Wire Feed Speed (ipm)	[24]	
Voltage Range:	[25]	
Travel Speed IPM:	[26]	
Transfer Mode:	[27]	
Maximum Heat Input J/in.:	[28]	
Tungsten Type:	[29]	
Tungsten Diameter:	[30]	

JOINTS	
Weld Type:	[31]
Groove Type:	[32]
Root Spacing:	[33]
Metal Backing:	[34]
Thermal Backgouging:	[35]

[36]

Sketch of Joint

POSTWELD HEAT TREATMENT	
PWHT Type:	[37]
PWHT Temperature:	[38]
PWHT Time:	[39]
GAS	
Shielding Gas:	[40]
Composition:	[41]
Flow:	[42]
Gas Cup Size:	[43]
TECHNIQUE	
Stringer or Weave:	[44]
Method of Cleaning:	[45]
Oscillation:	[46]
Contact Tube to Work Distance:	[47]
Multipass or Single pass per side:	[48]
Number of Electrodes:	[49]
Electrode Spacing:	[50]
Peening:	[51]

VISUAL EXAMINATION: [52]

TENSILE TESTS

Specimen No.	Width in.	Thickness in.	Area in.^{2}	Ultimate Total Load (lbs)	Ultimate Unit Stress (psi)	Type of Failure & Location
[53]	[54]	[55]	[56]	[57]	[58]	[59]

GUIDED-BEND TESTS

Type	Results	Type	Results
[60]	[61]	[62]	[63]

Welder's Name [64] Stamp or Clock No. [65]

We certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of the Part B Practical CWI Exam Requirements. It is intended to be used for the CWI Part B Exam only and is not intended to be used for actual production welding or any other use without the written consent of AWS.

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Annex IX (Informative)
Welder Qualification Test Record (WQTR)

Welder's Name [1] **ID No.** [2] **Symbol** [3]

Identification of WPS followed: [4]

Specification of base metal(s) welded: [5] **Thickness:** [6]

Testing Variables and Qualification Limits

Welding Variables			Actual Values	Range Qualified
Welding Process(es)			[13]	[31]
Type (i.e.; manual, semi-automatic)			[14]	[32]
Backing (metal, weld metal)	Process 1:	[7]	[15]	[33]
	Process 2:	[8]	[16]	[34]
☐ Plate ☐ Pipe (enter diameter if pipe or tube)			[17]	[35]
Base Metal M-Number to M-Number			[18]	[36]
AWS Filler metal or Electrode Specification(s)			[19]	
Filler metal or electrode classification(s)			[20]	
Filler metal F-Numbers	Process 1:	[9]	[21]	[37]
	Process 2:	[10]	[22]	[38]
Consumable Insert for GTAW			[23]	[39]
Weld deposit thickness for each welding process:				
	Process 1:	[11]	[24]	[40]
	Process 2:	[12]	[25]	[41]
Position Qualified (2G, 6G, etc.)			[26]	[42]
Vertical progression (Uphill or Downhill)			[27]	[43]
Inert gas backing for GTAW or GMAW			[28]	[44]
Transfer Mode (spray/globular or pulse to short circuit-GMAW)			[29]	[45]
GTAW welding current type/polarity (AC, DCEP, DCEN)			[30]	[46]

Results

Visual Examination of Completed Weld : [47]

Guided Bend Test Type: ☐ **Transverse Side** ☐ **Transverse Root & Face**

Specimen No.	Results	Specimen No.	Results
[48]	[49]	[50]	[51]

Alternative radiographic examination results [52]

Fillet Weld – fracture test [53] Length and percent of defects [54] in.

Macro Examination [55] Fillet size (in.) [56] x [57] Concavity/convexity (in.) [58]

Other tests [59]

Film or specimens evaluated by [60] Company [61]

Mechanical tests conducted by [62] Laboratory test no. [63]

Welding supervised by [64]

We certify that the statements in this record are correct and that the test coupons were prepared, welded, and tested in accordance with the requirements of CWI Part B Practical Book of Specifications. It is to be used for the CWI Part B Practical Exam only and is not intended to be used for actual production welding or any other use without the written consent of AWS.

Organization [65]

By [66] Date [67]

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Annex X (Informative)
Industry-Specific Non-Standard Terms and Definitions

arc burn. Preferred term for 'arc strike' in pipeline applications.

backstep sequence. A longitudinal sequence in which weld passes are made in the direction opposite to the progress of welding.

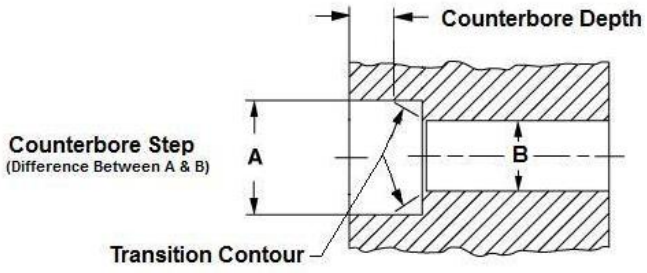
back weld repair. For pipeline applications, a repair weld made at the back side of a groove weld.

Company. For the purpose of this examination, the Company is the fictitious entity responsible for legal ownership and public safety of weldments fabricated in accordance with this specification.

counterbore. A machined feature on out-of-round pipe inside diameters to make sure inside diameters are in proper alignment for welding. See also **counterbore depth.**

counterbore step. The transition area between the machined counterbore and the unmachined pipe inside diameter. See also **counterbore** and **counterbore depth.**

counterbore depth. The distance a counterbore extends axially into a pipe. See also **counterbore** and **counterbore step.**



Counterbore

crown surface. Alternate term for Weld Face in the pipeline applications.

double repair. For Pipeline applications, second repair in a previously repaired area of a completed weld; typically referred to as a "repair of a repair" or a "re-repair."

high-low. Preferred term for 'internal misalignment' in pipeline applications.

imperfection. A departure of a quality characteristic from its intended condition.

indication. The response or evidence from the application of a nondestructive examination.

internal misalignment. Misalignment of joint members such as the inside diameter of misaligned pipes or pipes with different inside diameters. *(Also called weld joint mismatch and high-low offset.)*

nominal size. A size "in name only" used for identification purposes. The nominal size may not correspond to an actual measured size, but would represent a range of sizes falling within standardized tolerances.

parent metal surface. Preferred term for 'base metal' in pipeline applications.

primary member. A structural element which transmits the primary tensile stress and whose sole failure would be catastrophic.

repair. For Pipeline applications, any grinding or welding on a completed weld to correct an individual defect or accumulation of defects in the weld that has been rejected by visual or nondestructive testing.

rework. For Pipeline applications, during welding or after the weld has been completed, the removal of an imperfection that requires grinding and/or welding that is performed prior to visual or nondestructive testing of a completed weld. Note: rework is not a repair.

temper bead. A weld bead placed at a specific location in or at the surface of a weld for the purpose of affecting the metallurgical properties of the heat-affected zone or previously deposited weld metal.

weld crown. Alternate term in pipeline applications for weld reinforcement.

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