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An American National Standard



Structural Welding Code— Steel



American Welding Society



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Clause C-6.11.1—New commentary added on tubular connection requirements.

Clause C-6, Figures—New figures added illustrating discontinuity acceptance criteria.

Clause C-Annex I—Section designations removed for clarification.

AWS B4.0, *Standard Methods for Mechanical Testing of Welds*, provides additional details of test specimen preparation and details of test fixture construction.

Commentary. The Commentary is nonmandatory and is intended only to provide insightful information into provision rationale.

Normative Annexes. These annexes address specific subjects in the code and their requirements are mandatory requirements that supplement the code provisions.

Informative Annexes. These annexes are not code requirements but are provided to clarify code provisions by showing examples, providing information, or suggesting alternative good practices.

Index. As in previous codes, the entries in the Index are referred to by subclause number rather than by page number. This should enable the user of the Index to locate a particular item of interest in minimum time.

Errata. It is the Structural Welding Committee's Policy that all errata should be made available to users of the code. Therefore, any significant errata will be published in the Society News Section of the *Welding Journal* and posted on the AWS web site at: <http://www.aws.org/technical/d1/>.

Suggestions. Your comments for improving AWS D1.1/D1.1M:2008, *Structural Welding Code—Steel* are welcome. Submit comments to the Managing Director, Technical Services Division, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; telephone (305) 443-9353; fax (305) 443-5951; e-mail info@aws.org; or via the AWS web site <<http://www.aws.org>>.

Errata

The following Errata have been identified and incorporated into the current reprint of this document.

Page 67—Table 3.1, Filler Metal Requirements—Remove dash from “E9018-M” under Electrode Classification column from Group IV so it reads E9018M.

Page 105—Figure 3.4, Joint Designation C-U2a-GF—Under “Notes” column, Note 1 should read Note a.

Pages 136–153—Header—Change from “Clause 4. Prequalification” to “Clause 4. Qualification” on all the designated pages.

Page 146—Table 4.9, Filler Metal Requirements—Remove dash from “E11018-M” in the Electrode Classification column under “Matching Strength Filler Metal” so it reads E11018M.

Page 150—Table 4.11, Welder and Welding Operator Qualification—Number and Type of Specimens and Range of Thickness and Diameter Qualified (Dimensions in Millimeters)—For Production Fillet Welds (T-joint and Skewed), under “Number of Specimens” column for side bend tests, Note 3 should read Note c.

Table 3.1 (Continued)
Prequalified Base Metal—Filler Metal Combinations for Matching Strength (see 3.3)

Group	Steel Specification Requirements						Filler Metal Requirements						
	Steel Specification	Minimum Yield Point/Strength		Tensile Range		Process	AWS Electrode Specification	Electrode Classification					
		ksi	MPa	ksi	MPa								
III	API 2W	Grade 60	60–90	414–621	75 min.	517 min.	SMAW	A5.5 ^c	E8015-X, E8016-X, E8018-X				
	API 2Y	Grade 60	60–90	414–621	75 min.	517 min.							
	ASTM A 572	Grade 60	60	415	75 min.	515 min.							
		Grade 65	65	450	80 min.	550 min.							
	ASTM A 537	Class 2 ^b	46–60	315–415	80–100	550–690				SAW	A5.23 ^c	F8XX-EXXX-XX, F8XX-ECXXX-XX	
	ASTM A 633	Grade E ^b	55–60	380–415	75–100	515–690							
	ASTM A 710	Grade A, Class 2 ≤ 2 in [50 mm]	60–65	415–450	72 min.	495 min.				GMAW	A5.28 ^c	ER80S-XXX, E80C-XXX	
	ASTM A 710	Grade A, Class 3 > 2 in [50 mm]	60–65	415–450	70 min.	485 min.							
	ASTM A 913 ^a	Grade 60	60	415	75 min.	520 min.							
		Grade 65	65	450	80 min.	550 min.							
		ASTM A 1018 HSLAS	Grade 60 Class 2	60	415	70 min.				480 min.	FCAW	A5.29 ^c	E8XTX-X, <u>E8XTX-XC</u> , E8XTX-XM
			Grade 70 Class 2	70	480	80 min.				550 min.			
	ASTM A 1018 HSLAS-F	Grade 60 Class 2	60	415	70 min.	480 min.							
		Grade 70 Class 2	70	480	80 min.	550 min.	SMAW	A5.5 ^c	E9015-X, E9016-X, E9018-X, E9018M				
IV	ASTM A 709	Grade HPS70W	70	485	90–110	620–760							
	ASTM A 852		70	485	90–110	620–760							
										SAW	A5.23 ^c	F9XX-EXXX-XX, F9XX-ECXXX-XX	
							GMAW	A5.28 ^c	ER90S-XXX, E90C-XXX				
							FCAW	A5.29 ^c	E9XTX-X, <u>E9XTX-XC</u> , E9XTX-XM				

^a The heat input limitations of 5.7 shall not apply to ASTM A 913 Grade 60 or 65.
^b Special welding materials and WPS (e.g., E80XX-X low-alloy electrodes) may be required to match the notch toughness of base metal (for applications involving impact loading or low temperature), or for atmospheric corrosion and weathering characteristics (see 3.7.3).
^c Filler metals of alloy group B3, B3L, B4, B4L, B5, B5L, B6, B6L, B7, B7L, B8, B8L, B9, E9015-C5L, E9015-D1, E9018-D1, E9018-D3, or any BXH grade in AWS A5.5, A5.23, A5.28, or A5.29 are not prequalified for use in the as-welded condition.

- Notes:
- In joints involving base metals of different groups, either of the following filler metals may be used: (1) that which matches the higher strength base metal, or (2) that which matches the lower strength base metal and produces a low-hydrogen deposit. Preheating shall be in conformance with the requirements applicable to the higher strength group.
 - Match API standard 2B (fabricated tubes) according to steel used.
 - When welds are to be stress-relieved, the deposited weld metal shall not exceed 0.05% vanadium.
 - See Tables 2.3 and 2.6 for allowable stress requirements for matching filler metal.
 - Filler metal properties have been moved to nonmandatory Annex V.
 - AWS A5M (SI Units) electrodes of the same classification may be used in lieu of the AWS A5 (U.S. Customary Units) electrode classification.
 - Any of the electrode classifications for a particular Group (located on the right) may be used to weld any of the base metals in that Group (located on the left).

See Notes on Page 75

Welding Process		Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation		Allowed Welding Positions	Gas Shielding for FCAW	Notes
			T ₁	T ₂	Root Opening	Groove Angle			
SMAW	C-U2a	U	U	R = 6	$\alpha = 45^\circ$	All	—	e, j	
				R = 10	$\alpha = 30^\circ$	F, V, OH	—	e, j	
				R = 12	$\alpha = 20^\circ$	F, V, OH	—	e, j	
GMAW FCAW	C-U2a-GF	U	U	R = 5	$\alpha = 30^\circ$	F, V, OH	Required	a	
				R = 10	$\alpha = 30^\circ$	F, V, OH	Not req.	a, j	
				R = 6	$\alpha = 45^\circ$	F, V, OH	Not req.	a, j	
SAW	C-L2a-S	50 max.	U	R = 6	$\alpha = 30^\circ$	F	—	j	
SAW	C-U2-S	U	U	R = 16	$\alpha = 20^\circ$	F	—	j	

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Root Opening	Root Face Groove Angle	Tolerances		Allowed Welding Positions	Gas Shielding for FCAW	Notes
		T ₁	T ₂			As Detailed (see 3.13.1)	As Fit-Up (see 3.13.1)			
		SMAW	B-U2			U	—			
GMAW FCAW	B-U2-GF	U	—	R = 0 to 3 f = 0 to 3 $\alpha = 60^\circ$	+2, -0 +2, -0 +10°, -0°	+2, -3 Not limited +10°, -5°	All	Not required	a, d, j	
SAW	B-L2c-S	Over 12 to 25	—	R = 0 f = 6 max. $\alpha = 60^\circ$	R = ±0 f = +0, -f $\alpha = +10^\circ, -0^\circ$	+2, -0 ±2 +10°, -5°	F	—	d, j	
		Over 25 to 38	—	R = 0 f = 12 max. $\alpha = 60^\circ$						
		Over 38 to 50	—	R = 0 f = 16 max. $\alpha = 60^\circ$						

Figure 3.4 (Continued)—Prequalified CJP Groove Welded Joint Details (see 3.13) (Dimensions in Millimeters)

**Table 4.1
WPS Qualification—Production Welding Positions Qualified by Plate, Pipe, and Box Tube Tests (see 4.3)**

Qualification Test		Production Plate Welding Qualified				Production Pipe Welding Qualified					Production Box Tube Welding Qualified				
Weld Type	Positions	Groove CJP	Groove PJP	Fillet ⁱ	Butt Joint		T-, Y-, K-Connections		Fillet ⁱ	Butt Joint		T-, Y-, K-Connections		Fillet ⁱ	
					CJP	PJP	CJP	PJP		CJP	PJP	CJP	PJP		
P L A T E	CJP Groove ^a	1G	F	F	F	F ^b	F ^b			F	F	F		F	
		2G	F, H	F, H	F, H	(F, H) ^b	(F, H) ^b			F, H	F, H	F, H		F, H	
		3G	V	V	V	V ^b	V ^b			V	V	V		V	
		4G	OH	OH	OH	OH ^b	OH ^b			OH	OH	OH		OH	
	Fillet ^a	1F			F					F				F	
		2F			F, H					F, H				F, H	
		3F			V					V				V	
		4F			OH					OH				OH	
	Plug/ Slot	Qualifies Plug/Slot Welding for Only the Positions Tested													
	T U B E	CJP Groove	1G Rotated	F	F	F	F ^c	F		F	F	F ^c	F		F
2G			F, H	F, H	F, H	(F, H) ^c	F, H		F, H	F, H	(F, H) ^c	F, H		F, H	F, H
5G			F, V, OH	F, V, OH	F, V, OH	(F, V, OH) ^c	F, V, OH		F, V, OH	F, V, OH	(F, V, OH) ^c	F, V, OH		F, V, OH	F, V, OH
(2G + 5G)			All	All	All	All ^c	All	All ^e	All ^g	All	All ^c	All	All ^f	All ^{g, h}	All
6G			All	All	All	All ^c	All		All ^g	All	All ^c	All		All ^{g, h}	All
6GR			All ^d	All	All	All ^d	All	All ^e	All	All	All ^d	All	All ^f	All	All
Fillet		1F Rotated			F					F				F	
		2F			F, H					F, H				F, H	
		2F Rotated			F, H					F, H				F, H	
		4F			F, H, OH					F, H, OH				F, H, OH	
5F			All					All				All			

CJP—Complete Joint Penetration

PJP—Partial Joint Penetration

^a Qualifies for a welding axis with an essentially straight line, including welding along a line parallel to the axis of circular pipe.

^b Qualifies for circumferential welds in pipes equal to or greater than 24 in [600 mm] nominal outer diameter.

^c Production butt joint details without backing or backgouging require qualification testing of the joint detail shown in Figure 4.25(A).

^d Limited to prequalified joint details (see 3.12 or 3.13).

^e For production joints of CJP T-, Y-, and K-connections that conform to either Figure 3.8, 3.9, or 3.10 and Table 3.6, use Figure 4.27 detail for testing. For other production joints, see 4.12.4.1.

^f For production joints of CJP T-, Y-, and K-connections that conform to Figure 3.6, and Table 3.6, use Figures 4.27 and 4.29 detail for testing, or, alternatively, test the Figure 4.27 joint and cut macroetch specimens from the corner locations shown in Figure 4.29. For other production joints, see 4.12.4.1.

^g For production joints of PJP T-, Y-, and K-connections that conform to Figure 3.5, use either the Figure 4.25(A) or Figure 4.25(B) detail for testing.

^h For matched box connections with corner radii less than twice the chord member thickness, see 3.12.4.1.

ⁱ Fillet welds in production T-, Y-, or K-connections shall conform to Figure 3.2. WPS qualification shall conform to 4.11.

Table 4.2
WPS Qualification—CJP Groove Welds: Number and Type of Test Specimens and
Range of Thickness and Diameter Qualified (see 4.4) (Dimensions in Inches)

1. Tests on Plate ^{a, b}									
Nominal Plate Thickness (T) Tested, in	Number of Specimens				Nominal Plate, Pipe or Tube Thickness ^{c, d} Qualified, in				
	Reduced Section Tension (see Fig. 4.14)	Root Bend (see Fig. 4.12)	Face Bend (see Fig. 4.12)	Side Bend (see Fig. 4.13)	Min.	Max.			
$1/8 \leq T \leq 3/8$	2	2	2	(Note i)	1/8	2T			
$3/8 < T < 1$	2	—	—	4	1/8	2T			
1 and over	2	—	—	4	1/8	Unlimited			

2. Tests on Pipe or Tubing ^{a, g}									
Nominal Pipe Size or Diam., in	Nominal Wall Thickness, T, in	Number of Specimens				Nominal Diameter ^e of Pipe or Tube Size Qualified, in	Nominal Plate, Pipe or Tube Wall Thickness ^{c, d} Qualified, in		
		Reduced Section Tension (see Fig. 4.14)	Root Bend (see Fig. 4.12)	Face Bend (see Fig. 4.12)	Side Bend (see Fig. 4.13)		Min.	Max.	
< 24	$1/8 \leq T \leq 3/8$	2	2	2	(Note i)	Test diam. and over	1/8	2T	
	$3/8 < T < 3/4$	2	—	—	4	Test diam. and over	T/2	2T	
	$T \geq 3/4$	2	—	—	4	Test diam. and over	3/8	Unlimited	
≥ 24	$1/8 \leq T \leq 3/8$	2	2	2	(Note i)	Test diam. and over	1/8	2T	
	$3/8 < T < 3/4$	2	—	—	4	24 and over	T/2	2T	
	$T \geq 3/4$	2	—	—	4	24 and over	3/8	Unlimited	
Standard Test Pipes	2 in Sch. 80 or 3 in Sch. 40	2	2	2	—	3/4 through 4	1/8	3/4	
	6 in Sch. 120 or 8 in Sch. 80	2	—	—	4	4 and over	3/16	Unlimited	

3. Tests on ESW and EGW ^{a, h}									
Nominal Plate Thickness Tested	Number of Specimens				Nominal Plate Thickness Qualified				
	Reduced Section Tension (see Fig. 4.14)	All-Weld-Metal Tension (see Fig. 4.18)	Side Bend (see Fig. 4.13)	CVN Tests	Min.	Max.			
T	2	1	4	(Note f)	0.5T	1.1T			

^a All test plate, pipe or tube welds shall be visually inspected (see 4.8.1) and subject to NDT (see 4.8.2). One test plate, pipe or tube shall be required for each qualified position.

^b See Figures 4.10 and 4.11 for test plate requirements.

^c For square groove welds that are qualified without backgouging, the maximum thickness qualified shall be limited to the test plate thickness.

^d CJP groove weld qualification on any thickness or diameter shall qualify any size of fillet or PJP groove weld for any thickness or diameter (see 4.10.3).

^e Qualification with any pipe diameter shall qualify all box section widths and depths.

^f When specified, CVN tests shall conform to Clause 4, Part D.

^g See Table 4.1 for the groove details required for qualification of tubular butt and T-, Y-, K-connection joints.

^h See Figure 4.9 for plate requirements.

ⁱ For 3/8 in plate or wall thickness, a side-bend test may be substituted for each of the required face- and root-bend tests.

Table 4.2
WPS Qualification—CJP Groove Welds: Number and Type of Test Specimens and Range of Thickness and Diameter Qualified (see 4.4) (Dimensions in Millimeters)

1. Tests on Plate^{a, b}

Nominal Plate Thickness (T) Tested, mm	Number of Specimens				Nominal Plate, Pipe or Tube Thickness ^{c, d} Qualified, mm	
	Reduced Section Tension (see Fig. 4.14)	Root Bend (see Fig. 4.12)	Face Bend (see Fig. 4.12)	Side Bend (see Fig. 4.13)	Min.	Max.
3 ≤ T ≤ 10	2	2	2	(Note i)	3	2T
10 < T < 25	2	—	—	4	3	2T
25 and over	2	—	—	4	3	Unlimited

2. Tests on Pipe or Tubing^{a, g}

Nominal Pipe Size or Diam., mm	Nominal Wall Thickness, T, mm	Number of Specimens				Nominal Diameter ^e of Pipe or Tube Size Qualified, mm	Nominal Plate, Pipe or Tube Wall Thickness ^{c, d} Qualified, mm	
		Reduced Section Tension (see Fig. 4.14)	Root Bend (see Fig. 4.12)	Face Bend (see Fig. 4.12)	Side Bend (see Fig. 4.13)		Min.	Max.
Job Size Test Pipes < 600	3 ≤ T ≤ 10	2	2	2	(Note i)	Test diam. and over	3	2T
	10 < T < 20	2	—	—	4	Test diam. and over	T/2	2T
	T ≥ 20	2	—	—	4	Test diam. and over	10	Unlimited
≥ 600	3 ≤ T ≤ 10	2	2	2	(Note i)	Test diam. and over	3	2T
	10 < T < 20	2	—	—	4	600 and over	T/2	2T
	T ≥ 20	2	—	—	4	600 and over	10	Unlimited
Standard Test Pipes	50 mm OD × 6 mm WT or 75 mm OD × 6 mm WT	2	2	2	—	20 through 100	3	20
	150 mm OD × 14 mm WT or 200 mm OD × 12 mm WT	2	—	—	4	100 and over	5	Unlimited

3. Tests on ESW and EGW^{a, h}

Nominal Plate Thickness Tested	Number of Specimens				Nominal Plate Thickness Qualified	
	Reduced Section Tension (see Fig. 4.14)	All-Weld-Metal Tension (see Fig. 4.18)	Side Bend (see Fig. 4.13)	CVN Tests	Min.	Max.
T	2	1	4	(Note f)	0.5T	1.1T

^a All test plate, pipe or tube welds shall be visually inspected (see 4.8.1) and subject to NDT (see 4.8.2). One test plate, pipe or tube shall be required for each qualified position.

^b See Figures 4.10 and 4.11 for test plate requirements.

^c For square groove welds that are qualified without backgouging, the maximum thickness qualified shall be limited to the test plate thickness.

^d CJP groove weld qualification on any thickness or diameter shall qualify any size of fillet or PJP groove weld for any thickness or diameter (see 4.10.3).

^e Qualification with any pipe diameter shall qualify all box section widths and depths.

^f When specified, CVN tests shall conform to Clause 4, Part D.

^g See Table 4.1 for the groove details required for qualification of tubular butt and T-, Y-, K-connection joints.

^h See Figure 4.9 for plate requirements.

ⁱ For 10 mm plate or wall thickness, a side-bend test may be substituted for each of the required face- and root-bend tests.

Table 4.3
Number and Type of Test Specimens and Range of Thickness Qualified—
WPS Qualification; PJP Groove Welds (see 4.10)

Test Groove Depth, T in [mm]	Number of Specimens ^{a,b}					Qualification Ranges ^{c,d}		
	Macroetch for Weld Size (E)	Reduced- Section Tension	Root Bend	Face Bend	Side Bend	Groove Depth	Nominal Plate, Pipe or Tubing Plate Thickness, in [mm]	
	4.10.2 4.10.3 4.10.4	(see Fig. 4.14)	(see Fig. 4.12)	(see Fig. 4.12)	(see Fig. 4.13)		Min.	Max.
1/8 ≤ T ≤ 3/8 [3 ≤ T ≤ 10]	3	2	2	2	—	T	1/8 [3]	2T
3/8 < T ≤ 1 [10 < T ≤ 25]	3	2	—	—	4	T	1/8 [3]	Unlimited

BASIC REQUIREMENTS

^a One test plate, pipe, or tubing per position shall be required (see Figure 4.10 or 4.11 for test plate). Use the production PJP groove detail for qualification. All plates, pipes, or tubing shall be visually inspected (see 4.8.1).

^b If a PJP bevel- or J-groove weld is to be used for T-joints or double-bevel- or double-J-groove weld is to be used for corner joints, the butt joint shall have a temporary restrictive plate in the plane of the square face to simulate a T-joint configuration.

^c See the pipe diameter qualification requirements of Table 4.2.

^d Any PJP qualification shall also qualify any fillet weld size on any thickness.

Table 4.4
Number and Type of Test Specimens and Range of Thickness Qualified—
WPS Qualification; Fillet Welds (see 4.11.1)

Test Specimen	Fillet Size	Number of Welds per WPS	Test Specimens Required ^b			Sizes Qualified	
			Macroetch 4.11.1 4.8.4	All-Weld-Metal Tension (see Figure 4.18)	Side Bend (see Figure 4.13)	Plate/Pipe Thickness ^a	Fillet Size
Plate T-test (Figure 4.19)	Single pass, max. size to be used in construction	1 in each position to be used	3 faces	—	—	Unlimited	Max. tested single pass and smaller
	Multiple pass, min. size to be used in construction	1 in each position to be used	3 faces	—	—	Unlimited	Min. tested multiple pass and larger
Pipe T-test ^c (Figure 4.20)	Single pass, max. size to be used in construction	1 in each position to be used (see Table 4.1)	3 faces (except for 4F & 5F, 4 faces req'd)	—	—	Unlimited	Max. tested single pass and smaller
	Multiple pass, min. size to be used in construction	1 in each position to be used (see Table 4.1)	3 faces (except for 4F & 5F, 4 faces req'd)	—	—	Unlimited	Min. tested multiple pass and larger
Groove test ^d (Figure 4.23)	—	1 in 1G position	—	1	2	Qualifies welding consumables to be used in T-test above	

^a The minimum thickness qualified shall be 1/8 in [3 mm].

^b All welded test pipes and plates shall be visually inspected per 4.8.1.

^c See Table 4.2(2) for pipe diameter qualification.

^d When the welding consumables used do not conform to the prequalified provisions of Clause 3, and a WPS using the proposed welding consumables has not been established by the Contractor in conformance with either 4.9 or 4.10.1, a CJP groove weld test plate shall be welded in conformance with 4.9.

Table 4.5
PQR Essential Variable Changes Requiring WPS Requalification for
SMAW, SAW, GMAW, FCAW, and GTAW (see 4.7.1)

Essential Variable Changes to PQR Requiring Requalification	Process				
	SMAW	SAW	GMAW	FCAW	GTAW
Filler Metal					
1) Increase in filler metal classification strength	X		X	X	
2) Change from low-hydrogen to nonlow-hydrogen SMAW electrode	X				
3) Change from one electrode or flux-electrode classification to any other electrode or flux-electrode classification ^a		X		X	X
4) Change to an electrode or flux-electrode classification ^c not covered in:	AWS A5.1 or A5.5	AWS A5.17 or A5.23	AWS A5.18 or A5.28	AWS A5.20 or A5.29	AWS A5.18 or A5.28
5) Addition or deletion of filler metal					X
6) Change from cold wire feed to hot wire feed or vice versa					X
7) Addition or deletion of supplemental powdered or granular filler metal or cut wire		X			
8) Increase in the amount of supplemental powdered or granular filler metal or wire		X			
9) If the alloy content of the weld metal is largely dependent on supplemental powdered filler metal, any WPS change that results in a weld deposit with the important alloying elements not meeting the WPS chemical composition requirements		X			
10) Change in nominal filler metal diameter by:	> 1/32 in [0.8 mm] increase	Any increase ^b	Any increase or decrease	Any increase	> 1/16 in [1.6 mm] increase or decrease
11) Change in number of electrodes		X	X	X	<u>X</u>
Process Parameters					
12) A change in the amperage for each diameter used by:	To a value not recommended by manufacturer	> 10% increase or decrease	> 10% increase or decrease	> 10% increase or decrease	> 25% increase or decrease
13) A change in type of current (ac or dc) or polarity (electrode positive or negative for dc current)	X	X	X	X	X
14) A change in the mode of transfer			X		
15) A change from CV to CC output			X	X	
16) A change in the voltage for each diameter used by:		> 7% increase or decrease	> 7% increase or decrease	> 7% increase or decrease	
17) An increase or decrease in the wire feed speed for each electrode diameter (if not amperage controlled) by:		> 10%	> 10%	> 10%	

(Continued)

Table 4.5 (Continued)
PQR Essential Variable Changes Requiring WPS Requalification for
SMAW, SAW, GMAW, FCAW, and GTAW (see 4.7.1)

Essential Variable Changes to PQR Requiring Requalification	Process				
	SMAW	SAW	GMAW	FCAW	GTAW
Process Parameters (Cont'd)					
18) A change in the travel speed ^c by:		> 15% increase or decrease	> 25% increase or decrease	> 25% increase or decrease	> 50% increase or decrease
Shielding Gas					
19) A change in shielding gas from a single gas to any other single gas or mixture of gas, or in the specified nominal percentage composition of a gas mixture, or to no gas			X	X	X
20) A change in total gas flow rate by:			Increase > 50% Decrease > 20%	Increase > 50% Decrease > 20%	Increase > 50% Decrease > 20%
21) A change to a shielding gas not covered in:			AWS A5.18 or A5.28	AWS A5.20 or A5.29	
SAW Parameters					
22) A change of > 10%, or 1/8 in [3 mm], whichever is greater, in the longitudinal spacing of the arcs		X			
23) A change of > 10%, or 1/8 in [3 mm], whichever is greater, in the lateral spacing of the arcs		X			
24) An increase or decrease of more than 10° in the angular orientation of any parallel electrode		X			
25) For machine or automatic SAW; an increase or decrease of more than 3° in the angle of the electrode		X			
26) For machine or automatic SAW, an increase or decrease of more than 5° normal to the direction of travel		X			
General					
27) A change in position not qualified by Table 4.1	X	X	X	X	X
28) A change in diameter, or thickness, or both, not qualified by Table 4.2	X	X	X	X	X
29) A change in base metal or combination of base metals not listed on the PQR or qualified by Table 4.8	X	X	X	X	X
30) Vertical Welding: For any pass from uphill to downhill or vice versa	X		X	X	X

(Continued)

Table 4.5 (Continued)

Essential Variable Changes to PQR Requiring Requalification	Process				
	SMAW	SAW	GMAW	FCAW	GTAW
General (Cont'd)					
31) A change in groove type (e.g., single-V to double-V), except qualification of any CJP groove weld qualifies for any groove detail conforming with the requirements of 3.12 or 3.13	X	X	X	X	X
32) A change in the type of groove to a square groove and vice versa	X	X	X	X	X
33) A change exceeding the tolerances of 3.12, 3.13, 3.13.4, 5.22.4.1, or 5.22.4.2 involving: a) A decrease in the groove angle b) A decrease in the root opening c) An increase in the root face	X	X	X	X	X
34) The omission, but not inclusion, of backing or backgouging	X	X	X	X	X
35) Decrease from preheat temperature ^d by:	> 25°F [15°C]	> 25°F [15°C]	> 25°F [15°C]	> 25°F [15°C]	> 100°F [55°C]
36) Decrease from interpass temperature ^d by:	> 25°F [15°C]	> 25°F [15°C]	> 25°F [15°C]	> 25°F [15°C]	> 100°F [55°C]
37) Addition or deletion of PWHT	X	X	X	X	X

^a The filler metal strength may be decreased without WPS requalification.

^b For WPSs using alloy flux, any increase or decrease in the electrode diameter shall require WPS requalification.

^c Travel speed ranges for all sizes of fillet welds may be determined by the largest single pass fillet weld and the smallest multiple-pass fillet weld qualification tests.

^d The production welding preheat or interpass temperature may be less than the PQR preheat or interpass temperature provided that the provisions of 5.6 are met, and the base metal temperature shall not be less than the WPS temperature at the time of subsequent welding.

^e AWS A5M (SI Units) electrodes of the same classification may be used in lieu of the AWS A5 (U.S. Customary Units) electrode classification.

Note: An “x” indicates applicability for the process; a shaded block indicates nonapplicability.

Table 4.6
PQR Supplementary Essential Variable Changes for CVN Testing Applications
Requiring WPS Requalification for SMAW, SAW, GMAW, FCAW, and GTAW

Variable	SMAW	SAW	GMAW	FCAW	GTAW
Base Metal					
1) A change in Group Number	X	X	X	X	X
2) Minimum thickness qualified is T or 5/8 in [16 mm] whichever is less, except if T is less than 1/4 in [6 mm], then the minimum thickness qualified is 1/8 in [3 mm]	X	X	X	X	X
Filler Metal					
3) A change in the AWS A5.X Classification, or to a weld metal or filler metal classification not covered by A5.X specifications	X	X	X	X	X
4) A change in the Flux/Wire classification, or a change in either the electrode or flux trade name when not classified by an AWS specification, or to a crushed slag		X			
5) A change in the manufacturer or the manufacturer's brand name or type of electrode				X	
Position					
6) A change in position to vertical up. A 3G vertical up test qualifies for all positions and vertical down	X		X	X	X
Preheat/Interpass Temperature					
7) An increase of more than 100°F [56°C] in the maximum <u>preheat</u> or interpass temperature qualified	X	X	X	X	X
Post Weld Heat Treatment					
8) A change in the PWHT temperature and/or time ranges. The PQR test shall be subject to 80% of the aggregate times at temperature(s). The PWHT total time(s) at temperature(s) may be applied in one heating cycle	X	X	X	X	X
Electrical Characteristics					
9) 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/in) = $\frac{\text{Volts} \times \text{Amps} \times 60}{\text{Travel Speed (in/min)}}$ b) Weld Metal Volume—An increase in bead size, or a decrease in the length of weld bead per unit length of electrode	X	X	X	X	X
Other Variables					
10) In the vertical position, a change from stringer to weave	X	X	X	X	X
11) A change from multipass per side to single pass per side	X	X	X	X	X
12) A change exceeding ±20% in the oscillation variables for mechanized or automatic welding		X	X	X	X

**Table 4.7
PQR Essential Variable Changes Requiring WPS Requalification for ESW or EGW (see 4.7.2)**

Essential Variable Changes to PQR Requiring Requalification	Requalification by WPS Test	Requalification by RT or UT ^a
Filler Metal		
1) A “significant” change in filler metal or consumable guide metal composition	X	
Molding Shoes (fixed or movable)		
2) A change from metallic to nonmetallic or vice versa		X
3) A change from fusing to nonfusing or vice versa		X
4) A reduction in any cross-sectional dimension or area of a solid nonfusing shoe > 25%		X
5) A change in design from nonfusing solid to water cooled or vice versa	X	
Filler Metal Oscillation		
6) A change in oscillation traverse speed > 10 ipm (4 mm/s)		X
7) A change in oscillation traverse dwell time > 2 seconds (except as necessary to compensate for joint opening variations)		X
8) A change in oscillation traverse length which affects by more than 1/8 in [3 mm], the proximity of filler metal to the molding shoes		X
Filler Metal Supplements		
9) A change in consumable guide metal core cross-sectional area > 30%	X	
10) A change in the flux system, i.e., cored, magnetic electrode, external, etc.	X	
11) A change in flux composition including consumable guide coating	X	
12) A change in flux burden > 30%		X
Electrode/Filler Metal Diameter		
13) Increase or decrease in electrode diameter > 1/32 in [1 mm]		X
14) A change in the number of electrodes used	X	
Electrode Amperage		
15) An increase or decrease in the amperage > 20%	X	
16) A change in type of current (ac or dc) or polarity		X
Electrode Arc Voltage		
17) An increase or decrease in the voltage > 10%		X
Process Characteristics		
18) A change to a combination with any other welding process	X	
19) A change from single pass to multi-pass and vice versa	X	
20) A change from constant current to constant voltage and vice versa		X
Wire Feed Speed		
21) An increase or decrease in the wire feed speed > 40%	X	
Travel Speed		
22) An increase or decrease in the travel speed (if not an automatic function of arc length or deposition rate) > 20% (except as necessary to compensate for variation in joint opening)		X

(Continued)

Table 4.7 (Continued)
PQR Essential Variable Changes Requiring WPS Requalification for ESW or EGW (see 4.7.2)

Essential Variable Changes to PQR Requiring Requalification	Requalification by WPS Test	Requalification by RT or UT ^a
Electrode Shielding (EGW only)		
23) A change in shielding gas composition of any one constituent > 5% of total flow	X	
24) An increase or decrease in the total shielding flow rate > 25%		X
Welding Position		
25) A change in vertical position by > 10°		X
Groove Type		
26) An increase in cross-sectional area (for nonsquare grooves)	X	
27) A decrease in cross-sectional area (for nonsquare grooves)		X
28) A change in PQR joint thickness, T outside limits of 0.5T–1.1T	X	
29) An increase or decrease > 1/4 in [6 mm] in square groove root opening		X
Postweld Heat Treatment		
30) A change in PWHT	X	

^a Testing shall be performed in conformance with Clause 6, Parts E or F, as applicable.

Note: An “x” indicates applicability for the requalification method; a shaded block indicates nonapplicability.

Table 4.8
Table 3.1, Table 4.9, and Unlisted Steels Qualified by PQR (see 4.7.3)

PQR Base Metal	WPS Base Metal Group Combinations Allowed by PQR
Any Group I Steel to Any Group I Steel	Any Group I Steel to Any Group I Steel
Any Group II Steel to Any Group II Steel	Any Group I Steel to Any Group I Steel Any Group II Steel to Any Group I Steel Any Group II Steel to Any Group II Steel
Any Specific Group III or Table 4.9 Steel to Any Group I Steel	The Specific PQR Group III or Table 4.9 Steel Tested to Any Group I Steel
Any Specific Group III or Table 4.9 Steel to Any Group II Steel	The Specific PQR Group III or Table 4.9 Steel Tested to Any Group I or Group II Steel
Any Group III Steel to the Same or Any Other Group III Steel or Any Group IV Steel to the Same or Any Other Group IV Steel or Any Table 4.9 Steel to the Same or Any Other Table 4.9 Steel	Steels shall be of the same material specification, grade/type and minimum yield strength as the Steels listed in the PQR
Any Combination of Group III, IV, and Table 4.9 Steels	Only the Specific Combination of Steels listed in the PQR
Any Unlisted Steel to Any Unlisted Steel or Any Steel Listed in Table 3.1 or Table 4.9	Only the Specific Combination of Steels listed in the PQR

Notes:

- Groups I through IV are found in Table 3.1.
- When allowed by the steel specification, the yield strength may be reduced with increased metal thickness.

**Table 4.9
Code-Approved Base Metals and Filler Metals Requiring Qualification per Clause 4**

Base Metal					Matching Strength Filler Metal			Base Metal Thickness, T		Minimum Preheat and Interpass Temperature	
Specification	Minimum Yield Point/Strength		Tensile Range		Process	AWS Electrode Specification	Electrode Classification				
	ksi	MPa	ksi	MPa							
ASTM A 871 Grades 60, 65	60	415	70 min.	520 min.	SMAW	A5.5	E8015-X, E8016-X, E8018-X				
	65	450	80 min.	550 min.	SAW	A5.23	F8XX-EXXX-XX, F8XX-ECXXX-XX				
					GMAW	A5.28	ER80S-XXX, E80C-XXX				
					FCAW	A5.29	E8XTX-X, E8XTX-XC, E8XTX-XM				
ASTM A 514 (Over 2-1/2 in [65 mm])	90	620	100–130	690–895	SMAW	A5.5	E10015-X, E10016-X, E10018-X, E10018M	Up to 3/4	Up to 20	50	10
ASTM A 709 Grades 100, 100W (Over 2-1/2 in to 4 in [65 to 100 mm])	90	620	100–130	690–895	SAW	A5.23	F10XX-EXXX-XX, F10XX-ECXXX-XX	Over 3/4 thru 1-1/2	Over 20 thru 38	125	50
ASTM A 710 Grade A. Class 1 ≤ 3/4 in [20 mm]	80	550	90 min.	620 min.	GMAW	A5.28	ER100S-XXX, E100C-XXX	Over 1-1/2 thru 2-1/2	Over 38 thru 65	175	80
ASTM A 710 Grade A. Class 3 ≤ 2 in [50 mm]	75	515	85 min.	585 min.	FCAW	A5.29	E10XTX-XC, E10XTX-XM	Over 2-1/2	Over 65	225	110
ASTM A 514 (2-1/2 in [65 mm] and under)	100	690	110–130	760–895	SMAW	A5.5	E11015-X, E11016-X, E11018-X, E11018M				
ASTM A 517	90–100	620–690	105–135	725–930	SAW	A5.23	F11XX-EXXX-XX, F11XX-ECXXX-XX				
ASTM A 709 Grades 100, 100W (2-1/2 in [65 mm] and under)	100	690	110–130	760–895	GMAW	A5.28	ER110S-XXX, E110C-XXX				
					FCAW	A5.29	E11XTX-XC, E11XTX-XM				

Notes:

- When welds are to be stress relieved, the deposited weld metal shall not exceed 0.05% vanadium (see 5.8).
- When required by contract or job specifications, deposited weld metal shall have a minimum CVN energy of 20 ft-lbs. [27.1 J] at 0°F [20°C] as determined using CVN testing in conformance with Clause 4, Part D.
- For ASTM A 514, A 517, and A 709, Grades 100 and 100W, the maximum preheat and interpass temperature shall not exceed 400°F [200°C] for thicknesses up to 1-1/2 [38 mm] inclusive, and 450°F [230°C] for greater thickness.
- Filler metal properties have been moved to informative Annex V.
- AWS A5M (SI Units) electrodes of the same classification may be used in lieu of the AWS A5 (U.S. Customary Units) electrode classification.

Table 4.10

Welder and Welding Operator Qualification—Production Welding Positions Qualified by Plate, Pipe, and Box Tube Tests (see 4.18.1)^j

Qualification Test		Production Plate Welding Qualified			Production Pipe Welding Qualified					Production Box Tube Welding Qualified						
Weld Type	Positions ^a	Groove CJP	Groove PJP	Fillet	Butt Joint		T-, Y-, K-Connections		Fillet	Butt Joint		T-, Y-, K-Connections		Fillet		
					CJP	PJP	CJP	PJP		CJP	PJP	CJP	PJP			
P L A T E	Groove ^b	1G	F	F	(F, H) ^h	F ^c	F ^c		F ^{c,e}	(F, H) ^h	F ^d	F		F ^c	(F, H) ^h	
		2G	F, H	F, H	(F, H) ^h	(F, H) ^c	(F, H) ^c		(F, H) ^{c,e}	(F, H) ^h	(F, H) ^d	F, H		(F, H) ^c	(F, H) ^h	
		3G	F, H, V	F, H, V	(F, H, V) ^h	(F, H, V) ^c	(F, H, V) ^c		(F, H, V) ^{c,e}	(F, H, V) ^h	(F, H, V) ^d	F, H, V		(F, H, V) ^c	(F, H, V) ^h	
F I L L E T	Fillet	4G	F, OH	F, OH	(F, H, OH) ^h	(F, OH) ^c	(F, OH) ^c		(F, OH) ^{c,e}	(F, H, OH) ^h	(F, OH) ^d	F, OH		(F, OH) ^c	(F, H, OH) ^h	
		3G + 4G	All	All	All ^h	All ^c	All ^c		All ^{c,e}	All ^h	All ^d	All		All ^c	All ^h	
		1F			F ^h					F ^h					F ^h	
		2F			(F, H) ^h					(F, H) ^h					(F, H) ^h	
P L A T E	Fillet	3F			(F, H, V)					(F, H, V) ^h				(F, H, V) ^h		
		4F			(F, H, OH) ^h					(F, H, OH) ^h				(F, H, OH) ^h		
		3F + 4F			All ^h					All ^h				All ^h		
		Plug	Qualifies Plug and Slot Welding for Only the Positions Tested													
T U B U L A R	Groove ^a (Pipe or Box)	1G Rotated ⁱ	F	F	(F, H) ^h	F ^f	F ^f		F ^{e,f}	(F, H) ^h	F	F		F ^c	(F, H) ^h	
		2G ^j	F, H	F, H	(F, H) ^h	(F, H) ^f	(F, H) ^f		(F, H) ^{e,f}	(F, H) ^h	F, H	F, H		(F, H) ^c	(F, H) ^h	
		5G ^j	F, V, OH	F, V, OH	(F, V, OH) ^h	(F, V, OH) ^f	(F, V, OH) ^f		(F, V, OH) ^{e,f}	(F, V, OH) ^h	F, V, OH	F, V, OH		(F, V, OH) ^c	(F, V, OH) ^h	
	6G ^j	All	All	All ^h	All ^f	All ^f		All ^{e,f}	All ^h	All	All		All ^c	All ^h		
P I P E	Pipe Fillet	(2G + 5G) ⁱ	All	All	All ^h	All ^f	All ^f		All ^{e,f}	All ^h	All	All		All ^c	All ^h	
		6GR (Fig. 4.27)	All	All	All ^h	All ^{d,f}	All ^f	All ^{e,f}	All ^{e,f}	All ^h	All ^d	All		All ^c	All ^h	
		6GR (Fig. 4.27 & 4.29)	All	All	All ^h	All ^{d,f}	All ^f	All ^{e,f}	All ^{e,f}	All ^h	All ^d	All	All ^{e,g}	All ^c	All ^h	
P I P E	Pipe Fillet	1F Rotated			F ^h					F ^h				F ^h		
		2F			(F, H) ^h					(F, H) ^h				(F, H) ^h		
		2F Rotated			(F, H) ^h					(F, H) ^h				(F, H) ^h		
		4F			(F, H, OH) ^h					(F, H, OH) ^h				(F, H, OH) ^h		
P I P E	Pipe Fillet	5F			All ^h					All ^h				All ^h		

CJP—Complete Joint Penetration; PJP—Partial Joint Penetration

^a See Figures 4.3, 4.4, 4.5, and 4.6.

^b Groove weld qualification shall also qualify plug and slot welds for the test positions indicated.

^c Only qualified for pipe equal to or greater than 24 in [600 mm] in diameter with backing, backgouging, or both.

^d Not qualified for joints welded from one side without backing, or welded from two sides without backgouging.

^e Not qualified for welds having groove angles less than 30° (see 4.12.4.2).

^f Qualification using box tubing (Figure 4.27) also qualifies welding pipe over 24 in [600 mm] in diameter.

^g Pipe or box tubing is required for the 6GR qualification (Figure 4.27). If box tubing is used per Figure 4.27, the macroetch test may be performed on the corners of the test specimen (similar to Figure 4.29).

^h See 4.25 and 4.28 for dihedral angle restrictions for plate joints and tubular T-, Y-, K-connections.

ⁱ Qualification for welding production joints without backing or backgouging shall require using the Figure 4.24(A) joint detail. For welding production joints with backing or backgouging, either the Figure 4.24(A) or Figure 4.24(B) joint detail may be used for qualification.

^j The qualification of welding operators for electroslag welding (ESW) or electrogas welding (EGW) shall only apply for the position tested.

Notes:

1. Not applicable for welding operator qualification (see Table 4.12).
2. Footnotes shown at the bottom of a column box apply to all entries:

**Table 4.11
Welder and Welding Operator Qualification—Number and Type of Specimens and
Range of Thickness and Diameter Qualified (Dimensions in Inches) (see 4.18.2.1)**

(1) Test on Plate			Number of Specimens ^a				Qualified Dimensions					
Production Groove or Plug Welds			Face Bend ^b (Fig. 4.12)	Root Bend ^b (Fig. 4.12)	Side Bend ^b (Fig. 4.13)	Macro-etch	Nominal Plate, Pipe or Tube Thickness Qualified, in					
Type of Test Weld (Applicable Figures)	Nominal Thickness of Test Plate (T) in	Min.					Max.	Min.	Max.			
Groove (Fig. 4.31 or 4.32)	3/8	1	1	(Note c)	—	1/8	3/4 max ^d					
Groove (Fig. 4.21, 4.22, or 4.30)	3/8 < T < 1	—	—	2	—	1/8	2T max ^d					
Groove (Fig. 4.21, 4.22, or 4.30)	1 or over	—	—	2	—	1/8	Unlimited ^d					
Plug (Fig. 4.38)	3/8	—	—	—	2	1/8	Unlimited					
Production Fillet Welds (T-joint and Skewed)		Number of Specimens ^a					Qualified Dimensions					
Type of Test Weld (Applicable Figures)	Nominal Test Plate Thickness, T, in	Fillet Weld Break	Macro-etch	Side Bend ^b	Root Bend ^b	Face Bend ^b	Nominal Plate Thickness Qualified, in		Dihedral Angles Qualified ^h			
							Min.	Max.	Min.	Max.		
Groove (Fig. 4.31 or 4.32)	3/8	—	—	(Note c)	1	1	1/8	Unlimited	30°	Unlimited		
Groove (Fig. 4.31 or 4.32)	3/8 < T < 1	—	—	2	—	—	1/8	Unlimited	30°	Unlimited		
Groove (Fig. 4.21, 4.22, or 4.30)	≥ 1	—	—	2	—	—	1/8	Unlimited	30°	Unlimited		
Fillet Option 1 (Fig. 4.37)	1/2	1	1	—	—	—	1/8	Unlimited	60°	135°		
Fillet Option 2 (Fig. 4.33)	3/8	—	—	—	2	—	1/8	Unlimited	60°	135°		
Fillet Option 3 (Fig. 4.20) [Any diam. pipe]	> 1/8	—	1	—	—	—	1/8	Unlimited	30°	Unlimited		
(2) Tests on Pipe or Tubing ^f			Number of Specimens ^a						Qualified Dimensions		Nominal Plate, Pipe or Tube Wall Thickness ^d Qualified, in	
Production CJP Groove Butt Joints			1G and 2G Positions Only			5G, 6G and 6GR Positions Only			Nominal Pipe or Tube Size Qualified, in			
Type of Test Weld	Nominal Size of Test Pipe, in	Nominal Test Thickness, in	Face Bend ^b	Root Bend ^b	Side Bend ^b	Face Bend ^b	Root Bend ^b	Side Bend ^b	Min.	Max.	Min.	Max.
Groove	≤ 4	Unlimited	1	1	(Note c)	2	2	(Note c)	3/4	4	1/8	3/4
Groove	> 4	≤ 3/8	1	1	(Note c)	2	2	(Note c)	(Note e)	Unlimited	1/8	3/4
Groove	> 4	> 3/8	—	—	2	—	—	4	(Note e)	Unlimited	3/16	Unlimited

(Continued)

Table 4.11 (Continued)
Welder and Welding Operator Qualification—Number and Type of Specimens and Range of Thickness and Diameter Qualified (Dimensions in Inches) (see 4.18.2.1)

(2) Test on Pipe or Tubing ^f (Cont'd)			Qualified Dimensions							
Production T-, Y-, or K-Connection CJP Groove Welds			Number of Specimens ^a		Nominal Pipe or Tube Size Qualified, in		Nominal Wall or Plate Thickness ^c Qualified, in		Dihedral Angles Qualified ^g	
Type of Test Weld	Nominal Size of Test Pipe, in	Nominal Test Thickness, in	Side Bend ^b	Macro-etch	Min.	Max.	Min.	Max.	Min.	Max.
Pipe Groove (Fig. 4.27)	≥ 6 O.D.	≥ 1/2	4	—	4	Unlimited	3/16	Unlimited	30°	Unlimited
Pipe Groove (Fig. 4.28)	< 4 O.D.	≥ 0.203	Note i	—	3/4	< 4	1/8	Unlimited	30°	Unlimited
Box Groove (Fig. 4.29)	Unlimited	≥ 1/2	4	4	Unlimited (Box only)	Unlimited (Box only)	3/16	Unlimited	30°	Unlimited

Production T-, Y-, or K-Connection Fillet Welds			Number of Specimens ^a				Qualified Dimensions					
Type of Test Weld	Nominal Size of Test Pipe, D	Nominal Test Thickness, in	Fillet Weld Break	Macro-etch	Root Bend ^b	Face Bend ^b	Nominal Pipe or Tube Size Qualified, in		Nominal Wall or Plate Thickness Qualified		Dihedral Angles Qualified ^g	
							Min.	Max.	Min.	Max.	Min.	Max.
5G position (Groove)	Unlimited	≥ 1/8	—	—	2 (Note c)	2 (Note c)	(Note e)	Unlimited	1/8 (Note d)	Unlimited (Note d)	30°	Unlimited
Option 1— Fillet (Fig. 4.37) ^g	—	≥ 1/2	1	1	—	—	24	Unlimited	1/8	Unlimited	60°	Unlimited
Option 2— Fillet (Fig. 4.33) ^g	—	3/8	—	—	2	—	24	Unlimited	1/8	Unlimited	60°	Unlimited
Option 3— Fillet (Fig. 4.20)	Unlimited	≥ 1/8	—	1	—	—	D	Unlimited	1/8	Unlimited	30°	Unlimited

(3) Tests on Electroslag and Electrogas Welding

Production Plate Groove Welds		Number of Specimens ^a		Nominal Plate Thickness Qualified, in	
Type of Test Weld	Nominal Plate Thickness Tested, T, in	Side Bend ^b (see Fig. 4.13)		Min.	Max.
Groove (Fig. 4.36)	< 1-1/2	2		1/8	T
	1-1/2	2		1/8	Unlimited

^a All welds shall be visually inspected (see 4.30.1). One test pipe, plate or tubing shall be required for each position tested, unless otherwise noted.

^b Radiographic examination of the test plate, pipe or tubing may be made in lieu of the bend tests (see 4.19.1.1).

^c For 3/8 in plate or wall thickness, a side-bend test may be substituted for each of the required face- and root-bend tests.

^d Also qualifies for welding any fillet or PJP weld size on any thickness of plate, pipe or tubing.

^e The minimum pipe size qualified shall be 1/2 the test diameter or 4 in, whichever is greater.

^f See Table 4.10 for appropriate groove details.

^g Two plates required, each subject to the test specimen requirements described. One plate shall be welded in the 3F position and the other in the 4F position.

^h For dihedral angles < 30°, see 4.26.1.

ⁱ Two root and two face bends.

Table 4.11 (Continued)
Welder and Welding Operator Qualification—Number and Type of Specimens and Range of Thickness and Diameter Qualified (Dimensions in Millimeters) (see 4.18.2.1)

(1) Test on Plate			Number of Specimens ^a				Qualified Dimensions					
Production Groove or Plug Welds			Face Bend ^b (Fig. 4.12)	Root Bend ^b (Fig. 4.12)	Side Bend ^b (Fig. 4.13)	Macro-etch	Nominal Plate, Pipe or Tube Thickness Qualified, mm					
Type of Test Weld (Applicable Figures)	Nominal Thickness of Test Plate, T, mm	Min.					Max.					
Groove (Fig. 4.31 or 4.32)	10	1	1	(Note c)	—	3	20 max ^d					
Groove (Fig. 4.21, 4.22, or 4.30)	10 < T < 25	—	—	2	—	3	2T max ^d					
Groove (Fig. 4.21, 4.22, or 4.30)	25 or over	—	—	2	—	3	Unlimited ^d					
Plug (Fig. 4.38)	10	—	—	—	2	3	Unlimited					
Production Fillet Welds (T-joint and Skewed)			Number of Specimens ^a				Qualified Dimensions					
Type of Test Weld (Applicable Figures)	Nominal Test Plate Thickness, T, mm	Fillet Weld Break	Macro-etch	Side Bend ^b	Root Bend ^b	Face Bend ^b	Nominal Plate Thickness Qualified, mm		Dihedral Angles Qualified ^b			
							Min.	Max.	Min.	Max.		
Groove (Fig. 4.31 or 4.32)	10	—	—	(Note c)	1	1	3	Unlimited	30°	Unlimited		
Groove (Fig. 4.31 or 4.32)	10 < T < 25	—	—	2	—	—	3	Unlimited	30°	Unlimited		
Groove (Fig. 4.21, 4.22, or 4.30)	≥ 25	—	—	2	—	—	3	Unlimited	30°	Unlimited		
Fillet Option 1 (Fig. 4.37)	12	1	1	—	—	—	3	Unlimited	60°	135°		
Fillet Option 2 (Fig. 4.33)	10	—	—	—	2	—	3	Unlimited	60°	135°		
Fillet Option 3 (Fig. 4.20) [Any diam. pipe]	> 3	—	1	—	—	—	3	Unlimited	30°	Unlimited		
(2) Tests on Pipe or Tubing ^c			Number of Specimens ^a						Qualified Dimensions		Nominal Plate, Pipe or Tube Wall Thickness ^d Qualified, mm	
Production CJP Groove Butt Joints			1G and 2G Positions Only			5G, 6G and 6GR Positions Only			Nominal Pipe or Tube Size Qualified, mm			
Type of Test Weld	Nominal Size of Test Pipe, mm	Nominal Test Thickness, mm	Face Bend ^b	Root Bend ^b	Side Bend ^b	Face Bend ^b	Root Bend ^b	Side Bend ^b	Min.	Max.	Min.	Max.
Groove	≤ 100	Unlimited	1	1	(Note c)	2	2	(Note c)	20	100	3	20
Groove	> 100	≤ 10	1	1	(Note c)	2	2	(Note c)	(Note e)	Unlimited	3	20
Groove	> 100	> 10	—	—	2	—	—	4	(Note e)	Unlimited	5	Unlimited

(Continued)

Table 4.11 (Continued)
Welder and Welding Operator Qualification—Number and Type of Specimens and Range of Thickness and Diameter Qualified (Dimensions in Millimeters) (see 4.18.2.1)

(2) Test on Pipe or Tubing^f (Cont'd)

Production T-, Y-, or K-Connection CJP Groove Welds			Number of Specimens ^a		Qualified Dimensions					
					Nominal Pipe or Tube Size Qualified, mm		Nominal Wall or Plate Thickness ^d Qualified, mm		Dihedral Angles Qualified ^h	
Type of Test Weld	Nominal Size of Test Pipe, mm	Nominal Test Thickness, mm	Side Bend ^b	Macro- etch	Min.	Max.	Min.	Max.	Min.	Max.
Pipe Groove (Fig. 4.27)	≥ 150 O.D.	≥ 12	4	—	100	Unlimited	5	Unlimited	30°	Unlimited
Pipe Groove (Fig. 4.28)	< 100 O.D.	≥ 5	Note i	—	20	< 100	3	Unlimited	30°	Unlimited
Box Groove (Fig. 4.29)	Unlimited	≥ 12	4	4	Unlimited (Box only)	Unlimited (Box only)	5	Unlimited	30°	Unlimited

Production T-, Y-, or K-Connection Fillet Welds			Number of Specimens ^a				Qualified Dimensions					
Type of Test Weld	Nominal Size of Test Pipe, D	Nominal Test Thickness, mm	Fillet Weld Break	Macro- etch	Root Bend ^b	Face Bend ^b	Nominal Pipe or Tube Size Qualified, mm		Nominal Wall or Plate Thickness Qualified, mm		Dihedral Angles Qualified ^h	
							Min.	Max.	Min.	Max.	Min.	Max.
5G position (Groove)	Unlimited	≥ 3	—	—	2 (Note c)	2 (Note c)	(Note e)	Unlimited	3 (Note d)	Unlimited (Note d)	30°	Unlimited
Option 1— Fillet (Fig. 4.37) ^g	—	≥ 12	1	1	—	—	600	Unlimited	3	Unlimited	60°	Unlimited
Option 2— Fillet (Fig. 4.33) ^g	—	10	—	—	2	—	600	Unlimited	3	Unlimited	60°	Unlimited
Option 3— Fillet (Fig. 4.20)	Unlimited	≥ 3	—	1	—	—	D	Unlimited	3	Unlimited	30°	Unlimited

(3) Tests on Electroslag and Electrogas Welding

Production Plate Groove Welds		Number of Specimens ^a		Nominal Plate Thickness Qualified, mm	
Type of Test Weld	Nominal Plate Thickness Tested, T, mm	Side Bend ^b (see Fig. 4.13)	Min.	Max.	
Groove (Fig. 4.36)	< 38	2	3	T	
	38	2	3	Unlimited	

^a All welds shall be visually inspected (see 4.30.1). One test pipe, plate or tubing shall be required for each position tested, unless otherwise noted.

^b Radiographic examination of the test plate, pipe or tubing may be made in lieu of the bend tests (see 4.19.1.1).

^c For 10 mm plate or wall thickness, a side-bend test may be substituted for each of the required face- and root-bend tests.

^d Also qualifies for welding any fillet or PJP weld size on any thickness of plate, pipe or tubing.

^e The minimum pipe size qualified shall be 1/2 the test diameter or 100 mm, whichever is greater.

^f See Table 4.10 for appropriate groove details.

^g Two plates required, each subject to the test specimen requirements described. One plate shall be welded in the 3F position and the other in the 4F position.

^h For dihedral angles < 30°, see 4.26.1.

ⁱ Two root and two face bends.

Table 4.12
Welding Personnel Performance Essential Variable Changes
Requiring Requalification (see 4.22)

Essential Variable Changes to WPQR Requiring Requalification	Welding Personnel		
	Welders ^b	Welding Operators ^{b,c}	Tack Welders
(1) To a process not qualified (GMAW-S is considered a separate process)	X	X	X
(2) To an SMAW electrode with an F-number (see Table 4.13) higher than the WPQR electrode F-number	X		X
(3) To a position not qualified	X	X	X
(4) To a diameter or thickness not qualified	X	X	
(5) To a vertical welding progression not qualified (uphill or downhill)	X		
(6) The omission of backing (if used in the WPQR test)	X	X	
(7) To multiple electrodes (if a single electrode was used in the WPQR test) but not vice versa		X ^a	

^a Not for ESW or EGW.

^b Welders qualified for SAW, GMAW, FCAW or GTAW shall be considered as qualified welding operators in the same process(es) and subject to the welder essential variable limitations.

^c A groove weld qualifies a slot weld for the WPQR position and the thickness ranges as shown in Table 4.11.

Notes:

1. An “x” indicates applicability for the welding for the welding personnel; a shaded area indicates nonapplicability.

2. WPQR = Welding Performance Qualification Record.

3. See Table 4.10 for positions qualified by welder WPQR.

4. See Table 4.11 for ranges of diameters or thicknesses qualified.

Table 4.13
Electrode Classification Groups
(see Table 4.12)

Group Designation	AWS Electrode Classification
F4	EXX15, EXX16, EXX18, EXX48, EXX15-X, EXX16-X, EXX18-X
F3	EXX10, EXX11, EXX10-X, EXX11-X
F2	EXX12, EXX13, EXX14, EXX13-X
F1	EXX20, EXX24, EXX27, EXX28, EXX20-X, EXX27-X

Note: The letters “XX” used in the classification designation in this table stand for the various strength levels (60 [415], 70 [485], 80 [550], 90 [620], 100 [690], 110 [760], and 120 [830]) of electrodes.

Table 4.14
CVN Test Requirements (see 4.35)

Welding Process ^a	Test Location	Number of Specimens ^b	Test Temperature °F/°C	Specimen Size, ^d mm	Minimum Average Absorbed Energy, ^e ft-lbf [J]	Minimum Individual Absorbed Energy, ^e ft-lbf [J]	Minimum Average Percent Shear Area, %	Minimum Average Lateral Expansion, Mils/mm
SMAW	Weld Metal	3	(Note c)	10 × 10	20 [27]	15 [20]	(Note f)	(Note f)
GTAW	Fusion Line +1 mm	3	(Note c)	10 × 10	20 [27]	15 [20]	(Note f)	(Note f)
GMAW								
SAW	Fusion Line +5 mm	3	(Note c)	10 × 10	20 [27]	15 [20]	(Note f)	(Note f)
ESW								
EGW FCAW-S FCAW-G								

^a A WPS which combines FCAW-S with another welding process shall be specifically tested to assure CVN test criteria are met at the interface between the weld deposits.

^b The alternate number of specimens allowed per test location is five. The highest and lowest values shall be discarded to minimize some of the scatter normally associated with CVN testing of welds and HAZs.

^c Test temperatures shall be specified in contract documents or specifications. When sub-sized specimens are required, and the width of the specimens across the notch is less than 80% of the base metal thickness, the test temperature shall be reduced in conformance with Table 4.15.

^d Full size specimens shall be used when test material is 7/16 in [11 mm] or thicker. Sub-sized specimens shall be used when test material thickness is less than 7/16 in [11 mm], or when weldment geometry prohibits the removal of full sized samples.

^e Applicable in welds between base materials with a specified minimum yield strength (SMYS) of 50 ksi [345 MPa] or less. Acceptance criteria for welds between materials exceeding SYMS of 50 ksi [345 MPa] shall be specified in the contract documents or specifications.

^f Values for percent shear and lateral expansion shall be recorded when specified in the contract documents or specifications.

Table 4.15
CVN Test Temperature Reduction (see 4.35.5)

For sub-sized CVN test specimens where the width across the notch is less than 80% of the base metal thickness.

Specimen Size mm	Test Temperature Reduction Below the Specified Test Temperature	
	°F	°C
10 × 10	0	0
10 × 9	0	0
10 × 8	0	0
10 × 7.5	5	2.8
10 × 7	8	4.5
10 × 6.7	10	5.6
10 × 6	15	8.4
10 × 5	20	11.1
10 × 4	30	16.8
10 × 3.3	35	19.4
10 × 3	40	22.4
10 × 2.5	50	27.8

Example: If design drawings or specifications indicate that CVN tests shall be performed at 32°F [0°C] and 10 mm × 5 mm sub-sized specimens are used; the actual test temperature would be 12°F [-11°C].

Note: The reduction in the minimum acceptance energy values for sub-sized specimens shall be determined in conformance with ASTM A 370a-97, Table 9.