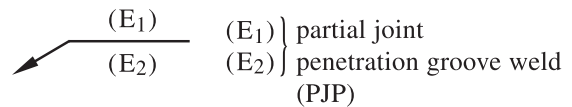


2. Design of Welded Connections

Part A General Requirements



where

(E₁) = effective weld size, other side

(E₂) = effective weld size, arrow side

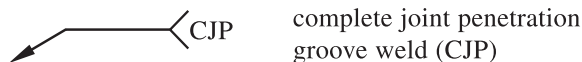
2.1 Drawings

2.1.1 Full and complete information regarding location, type, size, and extent of all welds shall be clearly shown on the drawings. The drawings shall clearly distinguish between shop and field welds. Unless specifically indicated in the design, all groove welds, both shop and field, shall be complete joint penetration (CJP) groove welds.

2.1.2 Those joints or groups of joints for which it is especially important that the welding sequence and technique be carefully controlled to minimize shrinkage stresses and distortion shall be so noted on shop and working drawings.

2.1.3 Contract design drawings shall specify the effective weld length and, for partial joint penetration (PJP) groove welds, the required weld size, as defined in 2.3. Shop or working drawings shall specify the groove angles (α and β) and depths (S) applicable for the weld size (E) required for the welding processes and position of welding to be used.

2.1.3.1 It is recommended that contract design drawings show CJP or PJP groove weld requirements. The welding symbol without dimensions designates a CJP weld, as follows:



The welding symbol with dimensions above or below the arrow designates a PJP weld, as follows:

2.1.3.2 Special groove details shall be specified where required.

2.1.4 Detail drawings shall clearly indicate by welding symbols or sketches the details of groove welded joints and the preparation of material required to make them. Both width and thickness of steel backing shall be detailed.

2.1.5 Any special inspection requirements shall be noted on the drawings or in the specifications.

2.1.6 Use of Undermatched Filler Metals. Undermatching filler metal may be used:

(1) For all fillet and PJP groove welds, when consistent with design requirements.

(2) For all CJP groove welds where the stress in the weld is tension or compression parallel to the weld axis, providing shear on the effective weld area meets AASHTO design requirements for all applications.

For CJP groove welds in compression, undermatching up to 70 MPa [10 ksi] may be used. Weld sizes shall be based on the strength of filler metal that is required to be used, or the strength of filler metal that may be used. Weld sizes and weld metal strength levels shall be in conformance with AASHTO Design Specifications. Design drawings shall show the weld size and, where required or allowed, the undermatching filler metal strength classification shall be shown. Shop drawings shall show the weld size and filler metal strength classification when undermatching filler metal is to be used. When no filler metal strength is shown, matching filler metal shall be used.

2.2 Basic Unit Stresses

Basic unit stresses for base metals and for effective areas of weld metal for application to AASHTO highway

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bridges shall be as shown in the AASHTO *Standard Specifications for Highway Bridges* or the AASHTO *LRFD Bridge Design Specification*.

2.3 Effective Weld Areas, Lengths, Throats, and Sizes

2.3.1 Groove Welds. The effective area shall be the effective weld length multiplied by the effective groove weld size.

2.3.1.1 The effective weld length for any groove weld, square or skewed, shall be the width of the part joined, perpendicular to the direction of stress.

2.3.1.2 The effective weld size of a CJP groove weld shall be the thickness of the thinner part joined. No increase is allowed for weld reinforcement.

2.3.1.3 The effective weld size of a PJP groove weld shall be the depth of bevel less 3 mm [1/8 in.] for grooves having a groove angle less than 60° but not less than 45° at the root of the groove, when made by SMAW or SAW, when made in the vertical or overhead welding positions by GMAW or FCAW.

The effective weld size of a PJP groove weld shall be the depth of bevel, without reduction, for grooves

(1) having a groove angle of 60° or greater at the root of the groove when made by any of the following welding processes: SMAW, SAW, GMAW, FCAW, EGW, or ESW, or

(2) having a groove angle not less than 45° at the root of the groove when made in flat or horizontal positions by GMAW or FCAW.

2.3.1.4 Flare groove joints shall not be used to join structural steel in bridges.

2.3.1.5 The minimum effective weld size of a PJP groove weld shall be as described in Table 2.2.

2.3.2 Fillet Welds. The effective area shall be the effective weld length multiplied by the effective throat. Stress in a fillet weld shall be considered as applied to this effective area, for any direction of applied load.

2.3.2.1 The effective length of a fillet weld shall be the overall length of the full-size fillet, including boxing. No reduction in effective length shall be made for either the start or crater of the weld if the weld is full size throughout its length.

2.3.2.2 The effective length of a curved fillet weld shall be measured along the centerline of the effective throat. If the weld area of a fillet weld in a hole or slot computed from this length is greater than the area found from 2.3.3, then this latter area shall be used as the effective area of the fillet weld.

2.3.2.3 The minimum effective length of a fillet weld shall be at least four times the nominal size, or 40 mm [1-1/2 in.], whichever is greater.

2.3.2.4 The effective throat shall be the shortest distance from the joint root to the weld face of the diagrammatic weld (see Annex I). *Note: See Annex II for method of calculating effective throats for fillet welds in skewed T-joints.* A convenient tabulation of relative leg sizes (W) for joints with zero root opening (R=0) that will have the same strength as a 90° fillet weld has been provided for dihedral angles between 60° and 135° (see Annex II, Table II.1).

2.3.3 Plug and Slot Welds. The effective area of a plug or slot weld shall be the nominal area of the hole or slot in the plane of the faying surface.

2.3.4 The effective weld size of a combination PJP groove weld and a fillet weld shall be the shortest distance from the joint root to the weld face of the diagrammatic weld minus 3 mm [1/8 in.], for any groove detail requiring such deduction (see Annex I).

Part B Structural Details

2.4 General

In general, stress concentrations should be avoided. This may be accomplished by sizing parts and organizing components to minimize constraint against ductile behavior, and avoiding unnecessary concentrations of welds, particularly where there are short unwelded portions of base metal between welds. Welds should not be larger than necessary. Welds should be sized to carry required loads at appropriate design stresses. Excess weld metal increases residual stress, and, when carried to extreme, may result in unacceptable distortion, cracks or lamellar tears. The organization of parts in welded assemblies and details of welded joints shall afford ample access for the deposition of all required weld passes.

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2.5 Welded Filler Plates

2.5.1 Welded filler plates (see Figures 2.1 and 2.2) are designated Category E fatigue details and shall be avoided when joining tension and reversal of stress members. When the design allows the use of filler plates, they may be used in the following:

- (1) Splicing parts of different thicknesses
- (2) Connections that, due to existing geometric alignment, shall accommodate offsets to allow simple framing

2.5.2 A filler plate less than 6 mm [1/4 in.] thick shall not be used to transfer stress but shall be kept flush with the welded edges of the stress-carrying part. The sizes of welds along such edges shall be increased over the required sizes by an amount equal to the thickness of the filler plate (see Figure 2.1).

2.5.3 Any filler plate 6 mm [1/4 in.] or more in thickness shall extend beyond the edges of the splice plate or connection material. It shall be welded to the part on which it is fitted, and the joint shall be of sufficient strength to transmit the splice plate or connection material stress applied at the surface of the filler plate as an eccentric load. The welds joining the splice plate or connection material to the filler plate shall be sufficient to transmit the splice plate or connection material stress and shall be long enough to avoid overstressing the filler plate along the toe of the weld (see Figure 2.2).

2.6 PJP Groove Welds

PJP groove welds shall not be used where the applied tensile stress is normal to the effective throat of the weld. Joints containing PJP groove welds, made from one side only, shall be restrained to prevent rotation.

Part C *Details of Welded Joints*

2.7 Joint Qualification

Details of welded joints that may be used in a prequalified WPS are described in 2.8 through 2.13.

2.7.1 Joint details may depart from the details described in 2.9 and 2.10 only if the Contractor submits the proposed WPSs to the Engineer for approval, and at the Contractor's expense, demonstrates their adequacy in conformance with the requirements of 5.13 of this code

and their conformance with applicable provisions of Sections 3, 4, and 5.

2.8 Details of Fillet Welds

2.8.1 The details of fillet welds made by SMAW, SAW, GMAW, or FCAW to be used without WPS qualification under 5.13 are described in 2.8.1.1 through 2.8.1.5 and detailed in Figure 2.3.

2.8.1.1 The minimum fillet weld size, except for fillet welds used to reinforce groove welds, shall be as shown in Table 2.1, or as calculated using procedures established to prevent cracking in conformance with 4.2.2. In both cases, the minimum size shall apply if it is sufficient to satisfy design requirements.

2.8.1.2 The maximum fillet weld size detailed along edges of material shall be the following:

(1) The thickness of the base metal, for metal less than 6 mm [1/4 in.] thick (see Figure 2.3, Detail A).

(2) 2 mm [1/16 in.] less than the thickness of base metal, for metal 6 mm [1/4 in.] or more in thickness (see Figure 2.3, Detail B), unless the weld is designated on the drawing to be built out to obtain full throat thickness. In the as-welded condition, the distance between the edge of the base metal and the toe of the weld may be more or less than 2 mm [1/16 in.], provided the weld size shall be clearly verifiable.

2.8.1.3 Fillet welds in holes or slots in lap joints may be used to transfer shear or to prevent buckling or separation of lapped parts. These fillet welds may overlap, subject to the provisions of 2.3.2.2. Fillet welds in holes or slots are not to be considered as plug or slot welds.

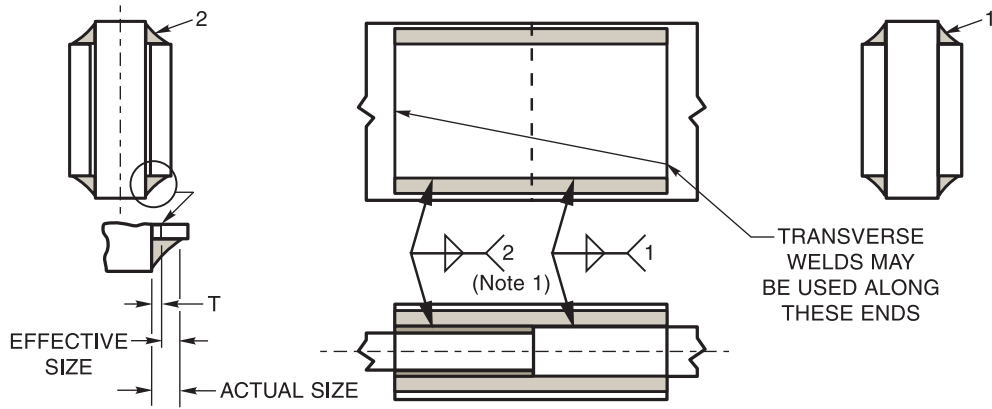
2.8.1.4 Fillet welds may be used in skewed T-joints having a dihedral angle (Ψ) of not less than 60° nor more than 135° (see Figure 2.3, Details C and D). Detail D shall be used when R_n would exceed 5 mm [3/16 in.] using Detail C.

2.8.1.5 When the design allows intermittent fillet welds, the minimum length of an intermittent fillet weld shall be as described in 2.3.2.3.

2.8.1.6 Minimum spacing and dimensions of holes or slots when fillet welding is used shall conform to the requirements of 2.9.

2.8.1.7 Fillet welds which support a tensile force that is not parallel to the axis of the weld shall not terminate at the corners of parts or members, but shall be returned continuously, full size, around the corner for a length equal to twice the weld size where such return can be

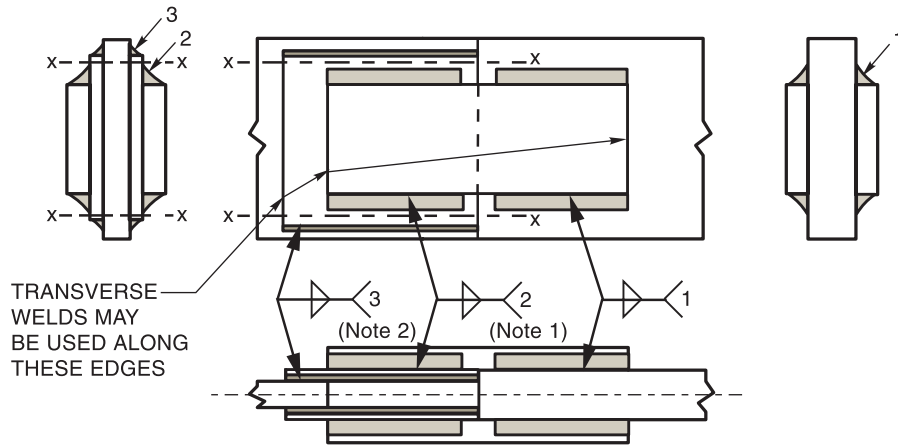
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Note:

1. The effective area of weld 2 shall equal that of weld 1, but its size shall be its effective size plus the thickness of the filler T .

Figure 2.1-Filler Plates Less Than 6 mm [1/4 in.] Thick (see 2.5.1)

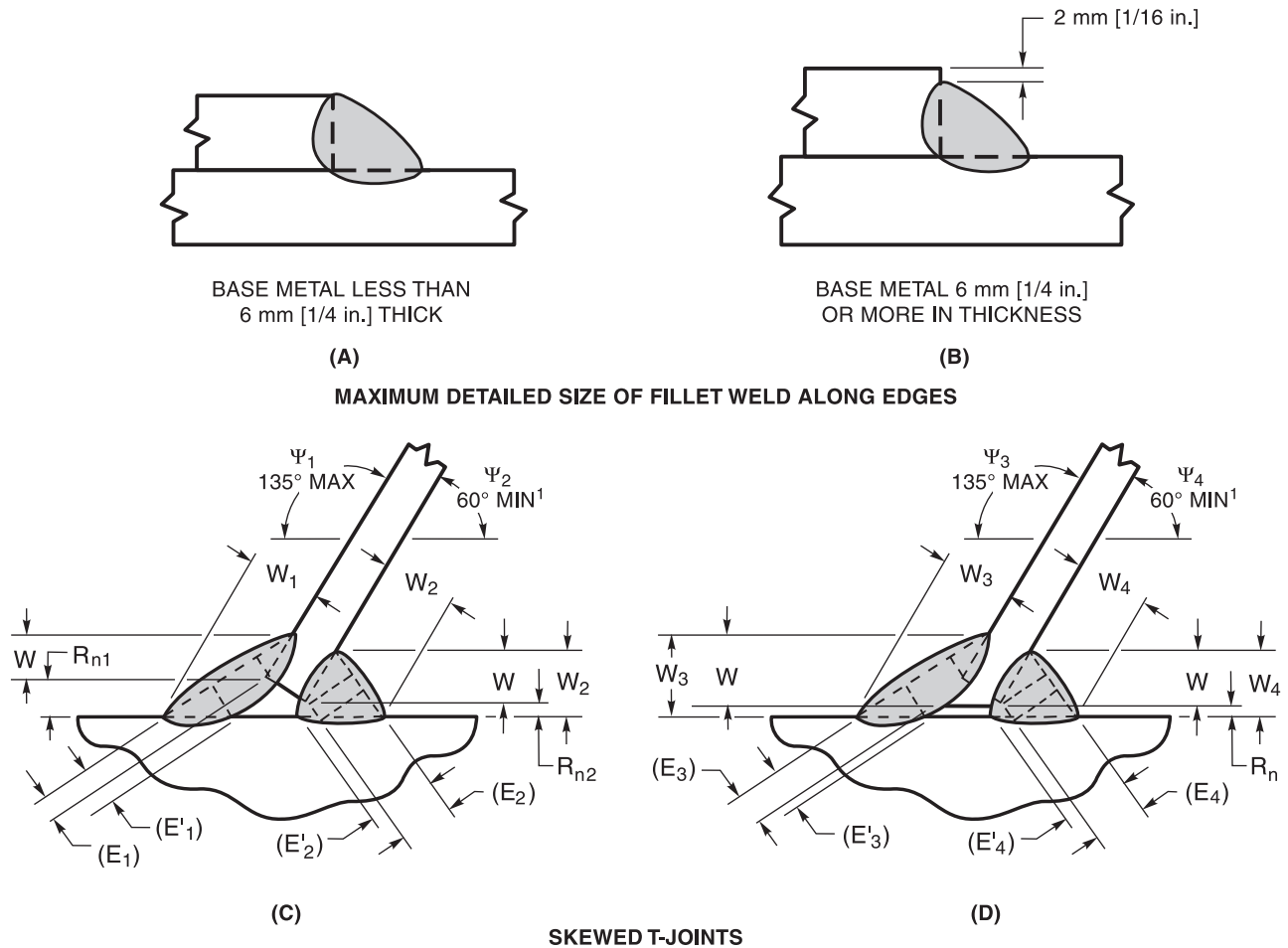


Notes:

1. The effective area of weld shall equal that of weld 1. The length of weld 2 shall be sufficient to avoid overstressing the filler plate in shear along planes $x-x$.
2. The effective area of weld 3 shall at least equal that of weld 1 and there shall be no overstress of the ends of weld 3 resulting from the eccentricity of the forces acting on the filler plate.

Figure 2.2-Filler Plates 6 mm [1/4 in.] or Thicker (see 2.5.3)

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General Note: (E)(n), (E')(n) = effective throats dependent on magnitude of root opening (R_n) (see 3.3.1). Subscript (n) represents 1, 2, 3, or 4.

Note:

- Angles smaller than 60° are allowed; however, in such cases, the weld is considered to be a PJP groove weld.

Figure 2.3—Details for Fillet Welds (see 2.8.1)

Table 2.1
Minimum Fillet Weld Size^{1,2} (see 2.8)

Base Metal Thickness of Thicker Part Joined (T)	Minimum Size of Fillet Weld	
T ≤ 20 mm [3/4 in.]	6 mm [1/4 in.]	Single-pass welds shall be used
T > 20 mm [3/4 in.]	8 mm [5/16 in.]	

Notes:

- Smaller fillet welds may be approved by the Engineer based upon applied stress and the use of appropriate preheat.
- Except that the weld size need not exceed the thickness of the thinner part joined. For this exception, particular care should be taken to provide sufficient preheat to ensure weld soundness.

made in the same plane. Boxing shall be indicated on design and detail drawings.

2.8.1.8 Fillet welds deposited on the opposite sides of a common plane of contact between two parts shall be interrupted at a corner common to both welds (see Figure 2.6).

2.9 Details of Plug and Slot Welds

2.9.1 The details of plug and slot welds made by the SMAW, GMAW, or FCAW processes are described in 2.9.2 through 2.9.7 and 3.3.1.

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2.9.1.1 Plug and slot welds may be used without performing the WPS qualification described in 5.13, provided the technique provisions of 4.21, 4.22, and 4.23, as applicable, are met.

2.9.2 The minimum diameter of the hole for a plug weld shall be no less than the thickness of the part containing it plus 8 mm [5/16 in.]. The maximum diameter shall equal the minimum diameter plus 3 mm [1/8 in.] or 2-1/4 times the thickness of the member, whichever is greater.

2.9.3 The minimum center-to-center spacing of plug welds shall be four times the diameter of the hole.

2.9.4 The length of the slot for a slot weld shall not exceed ten times the thickness of the part containing it. The width of the slot shall be no less than the thickness of the part containing it plus 8 mm [5/16 in.]. The maximum width shall equal the minimum width plus 3 mm [1/8 in.] or 2-1/4 times the thickness of the member, whichever is greater.

2.9.5 The ends of the slot shall be semicircular or shall have the corners rounded to a radius not less than the thickness of the part containing it, except those ends which extend to the edge of the part.

2.9.6 The minimum spacing of lines of slot welds in a direction transverse to their length shall be four times the width of the slot. The minimum center-to-center spacing in a longitudinal direction on any line shall be two times the length of the slot.

2.9.7 The depth of filling of plug or slot welds in metal 16 mm [5/8 in.] thick or less shall be equal to the thickness of the material. In metal over 16 mm [5/8 in.] thick, it shall be at least one-half the thickness of the material, but no less than 16 mm [5/8 in.].

2.10 Lap Joints

2.10.1 The minimum overlap of parts in stress-carrying lap joints shall be five times the thickness of the thinner part. Unless lateral deflection of the parts is prevented, they shall be connected by at least two transverse lines of fillet, plug, or slot welds or by two or more longitudinal fillet or slot welds.

2.10.2 If longitudinal fillet welds are used alone in lap joints of end connections, the length of each fillet weld shall be no less than the perpendicular distance between the welds (shown as dotted line in Figure 2.6). The transverse spacing of the welds shall not exceed 16 times the thickness of the connected thinner part unless suitable provision is made (as by intermediate plug or slot welds) to prevent buckling or separation of the parts. The longi-

tudinal fillet weld may be either at the edges of the member or in slots.

2.10.3 When fillet welds in holes or slots are used, the clear distance from the edge of the hole or slot to the adjacent edge of the part containing it, measured perpendicular to the direction of stress, shall be no less than five times the thickness of the part nor less than two times the width of the hole or slot. The strength of the part shall be determined from the critical net section of the base metal.

2.10.4 Lap joints are Category E details and should be avoided, when possible, in members subject to tension or reversal of stresses.

2.11 Corner and T-Joints

2.11.1 Corner and T-joints that are to be subjected to bending about an axis parallel to the joint shall have their welds arranged to avoid concentration of tensile stress at the root of any weld.

2.11.2 Corner and T-joints parallel to the direction of computed stress between components of built-up members designed for axial stress need not be CJP groove welds. Fillet welds or a combination of PJP welds and reinforcing fillet welds may be used.

2.12 CJP Groove Welds

2.12.1 Dimensional Tolerances. Dimensions of groove welds specified on design or detailed drawings may vary as shown in Figure 2.4.

2.12.2 Corner Joints. For corner joints using single-bevel groove welds, either plate may be bevelled, provided the basic groove configuration is not changed and adequate edge distance is maintained to support the welding operations without excessive melting. Joint preparation that bevels the plate that will be stressed in the short transverse direction will help to reduce lamellar tearing.

2.13 PJP Groove Welds (see Figure 2.5)

2.13.1 Definition. Except as provided in Figure 2.5, groove welds without steel backing, welded from one side, and groove welds welded from both sides but without backgouging, are considered PJP groove welds.

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Legend for Figures 2.4 and 2.5

Symbols for joint types

- B — butt joint
- C — corner joint
- T — T-joint
- BC — butt or corner joint
- TC — T- or corner joint
- BTC — butt, T-, or corner joint

Symbols for base-metal thickness and penetration

- L — limited thickness–CJP
- U — unlimited thickness–CJP
- P — PJP

Symbol for weld types

- 1 — square-groove
- 2 — single-V-groove
- 3 — double-V-groove
- 4 — single-bevel-groove
- 5 — double-bevel-groove
- 6 — single-U-groove
- 7 — double-U-groove
- 8 — single-J-groove
- 9 — double-J-groove

Symbols for welding processes if not SMAW

- S — SAW
- G — GMAW
- F — FCAW

Welding processes

- SMAW — shielded metal arc welding
- GMAW — gas metal arc welding
- FCAW — flux cored metal arc welding
- SAW — submerged arc welding

Welding positions

- F — flat
- H — horizontal
- V — vertical
- OH — overhead

Dimensions

- R = Root Opening
- α, β = Groove Angles
- f = Root Face
- r = J- or U-groove Radius
- S, S₁, S₂ = PJP Groove Weld Depth of Groove
- E, E₁, E₂ = PJP Groove Weld Sizes corresponding to S, S₁, S₂, respectively

Joint Designation

The lower case letters, e.g., a, b, c, etc., are used to differentiate between joints that would otherwise have the same joint designation.

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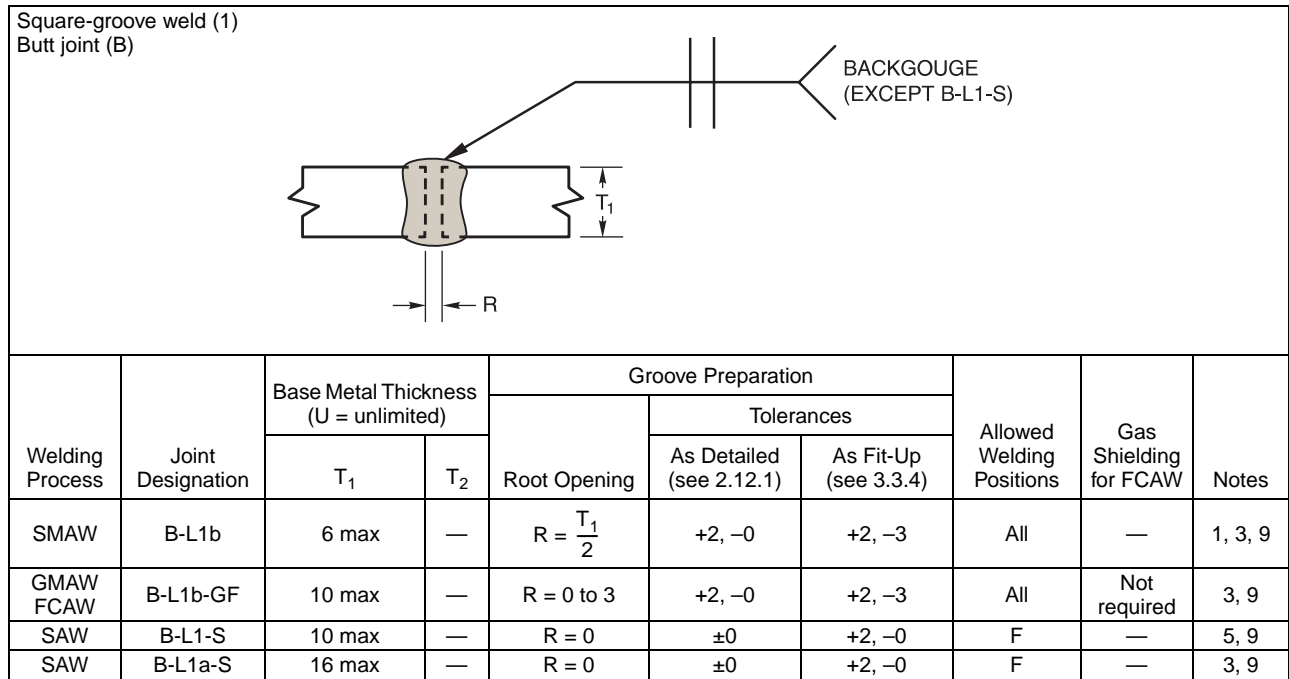
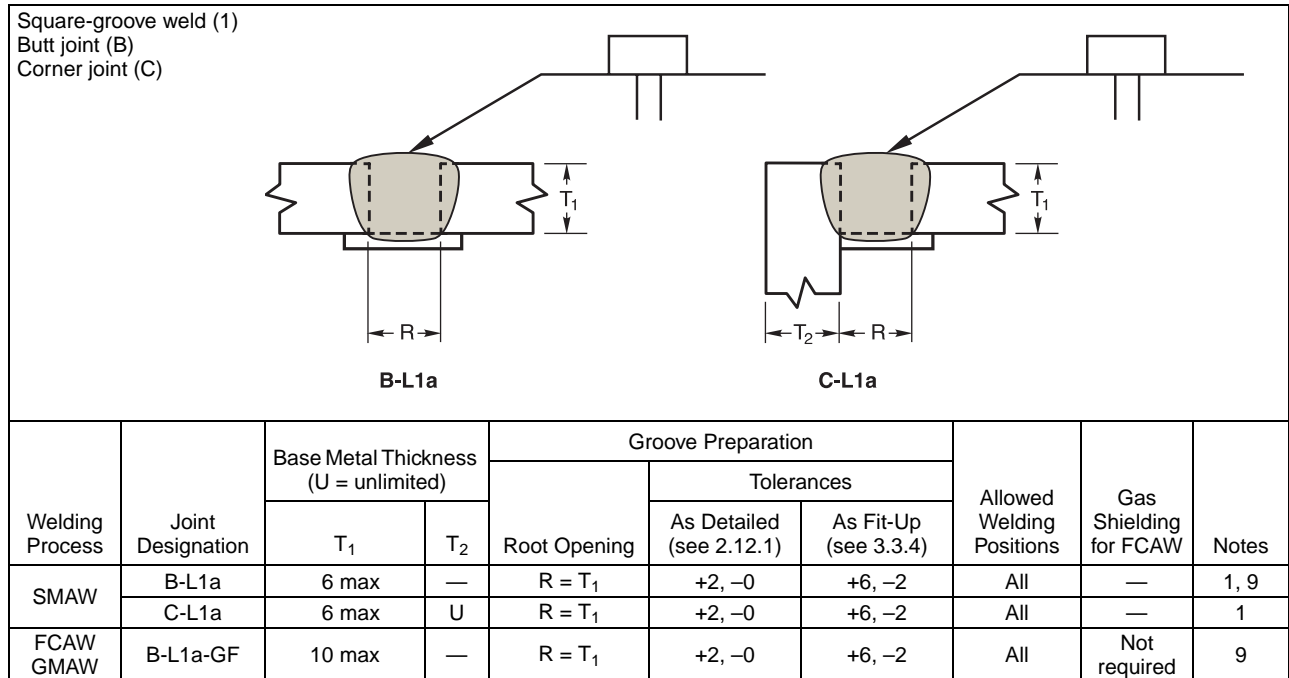


Figure 2.4—Details of Welded Joints for CJP Groove Welds (see 2.12.1) (Dimensions in Millimeters)

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Single-V-groove weld (2)
Corner joint (C)

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 Root Face Groove Angle	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
SMAW	C-U2	U	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	—	1, 3, 6, 12
GMAW FCAW	C-U2-GF	U	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	3, 6, 12
SAW	C-U2b-S	25 min	U	R = 0 f = 6 max $\alpha = 60^\circ$	± 0 +6, -0 +10°, -0°	+2, -0 ± 2 +10°, -5°	F	—	3, 6, 12

Double-V-groove weld (3)
Butt joint (B)

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 Root Face Groove Angle	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
SMAW	B-U3b	U	—	R = 0 to 3 f = 0 to 3 $\alpha = \beta = 60^\circ$	+2, -0 +2, -0 +10°, -0°	+2, -3 Not limited +10°, -5°	All	—	1, 3, 7, 9
GMAW FCAW	B-U3-GF								
SAW	B-U3c-S	U	—	R = 0 f = 6 min $\alpha = \beta = 60^\circ$	+2, -0 +6, -0 +10°, -0°	+2, -0 +6, -0 +10°, -5°	F	—	3, 7, 9
To find S ₁ see table above: S ₂ = T ₁ - (S ₁ + f)									

For B-U3c-S only		
T ₁		S ₁
Over	to	
50	60	35
60	80	45
80	90	55
90	100	60
100	120	70
120	140	80
140	160	95

Figure 2.4 (Continued) (Millimeters)

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Welding Process		Joint Designation		Base Metal Thickness (U = unlimited)		Groove Preparation		Tolerances		Notes
								As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)	
								R = +2, -0	+6, -2	
								a = +10°, -0°	+10°, -5°	

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	α = 45°	All	—	1, 12
				R = 10	α = 30°	F, V, OH	—	1, 12
				R = 12	α = 20°	F, V, OH	—	1, 12
GMAW FCAW	C-U2a-GF	U	U	R = 5	α = 30°	F, V, OH	Required	12
				R = 10	α = 30°	F, V, OH	Not req.	12
				R = 6	α = 45°	F, V, OH	Not req.	12
SAW	C-L2a-S	50 max	U	R = 6	α = 30°	F	—	12
SAW	C-U2-S	U	U	R = 16	α = 20°	F	—	12

Welding Process		Joint Designation		Base Metal Thickness (U = unlimited)		Groove Preparation		Allowed Welding Positions	Gas Shielding for FCAW	Notes
						Root Opening	Tolerances			
						Root Face	As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)		
						Groove Angle	As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)		
SMAW	B-U2	U	—	R = 0 to 3 f = 0 to 3 α = 60°	+2, -0 +2, -0 +10°, -0°	+2, -3 Not limited +10°, -5°	All	—	1, 3, 9	
GMAW FCAW	B-U2-GF	U	—	R = 0 to 3 f = 0 to 3 α = 60°	+2, -0 +2, -0 +10°, -0°	+2, -3 Not limited +10°, -5°	All	Not required	3, 9	
SAW	B-L2c-S	Over 12 to 25	—	R = 0 f = 6 min α = 60°	R = ±0 f = +6, -0 α = +10°, -0°	+2, -0 Not limited +10°, -5°	F	—	3, 9	
		Over 25 to 38	—	R = 0 f = 10 min α = 60°						
		Over 38 to 50	—	R = 0 f = 12 min α = 60°						

Figure 2.4 (Continued) (Millimeters)

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Square-groove weld (1)
T-joint (T)
Corner joint (C)

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	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 2.12.1)			
SMAW	TC-L1b	6 max	U	$R = \frac{T_1}{2}$	+2, -0	+2, -3	All	—	1, 3, <u>6</u>
GMAW FCAW	TC-L1-GF	10 max	U	R = 0 to 3	+2, -0	+2, -3	All	Not required	3, <u>6</u>
SAW	TC-L1-S	10 max	U	R = 0	±0	+2, -0	F	—	3, <u>6</u>

Single-V-groove weld (2)
Butt joint (B)

Tolerances	
As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)
R = +2, -0	+6, -2
α = +10°, -0°	+10°, -5°

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	B-U2a	U	—	R = 6	α = 45°	All	—	1, 9
				R = 10	α = 30°	F, V, OH	—	1, 9
				R = 12	α = 20°	F, V, OH	—	1, 9
GMAW FCAW	B-U2a-GF	U	—	R = 5	α = 30°	F, V, OH	Required	9
				R = 10	α = 30°	F, V, OH	Not req.	9
				R = 6	α = 45°	F, V, OH	Not req.	9
SAW	B-L2a-S	50 max	—	R = 6	α = 30°	F	—	9
SAW	B-U2-S	U	—	R = 16	α = 20°	F	—	9

Figure 2.4 (Continued) (Millimeters)

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See Notes on Page 43

Single-bevel-groove weld (4) Butt joint (B)				Tolerances				
				As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
				R = +2, -0	+6, -2			
				a = +10°, -0°	+10°, -5°			
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	B-U4a	U	—	R = 6	α = 45°	F, H	—	1, 9, 13
				R = 10	α = 30°	F, H	—	1, 9, 13
GMAW FCAW	B-U4a-GF	U	—	R = 5	α = 30°	H	Required	9
				R = 6	α = 45°	H	Not req.	9
				R = 10	α = 30°	H	Not req.	9

Single-bevel-groove weld (4) T-joint (T) Corner joint (C)				Tolerances				
				As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
				R = +2, -0	+6, -2			
				α = +10°, -0°	+10°, -5°			
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	TC-U4c	U	U	R = 6	α = 45°	All	—	1, 12
				R = 10	α = 30°	F, OH, H	—	1, 12
GMAW FCAW	TC-U4c-GF	U	U	R = 5	α = 30°	All	Required	12
				R = 10	α = 30°	F	Not req.	12
				R = 6	α = 45°	All	Not req.	12
SAW	TC-U4a-S	U	U	R = 10	α = 30°	F	—	12
				R = 6	α = 45°			

Figure 2.4 (Continued) (Millimeters)

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See Notes on Page 43

Single-bevel-groove weld (4)
Butt joint (B)

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	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
SMAW	B-U4b	U	—	R = 0 to 3 f = 0 to 3 α = 45°	+2, -0 +2, -0 +10°, -0°	+2, -3 Not limited 10°, -5°	F, H	—	1, 3, 9, 13
GMAW FCAW	B-U4b-GF	U	—				H	Not required	3, 9

Single-bevel-groove weld (4)
T-joint (T)
Corner joint (C)

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 Root Face Groove Angle	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
SMAW	TC-U4b	U	U	R = 0 to 3 f = 0 to 3 α = 45°	+2, -0 +2, -0 +10°, -0°	+2, -3 Not limited 10°, -5°	All	—	1, 3, 6, 12
GMAW FCAW	TC-U4b-GF	U	U				All	Not required	3, 6, 12
SAW	TC-U4b-S	U	U	R = 0 f = 3 max α = 60°	±0 +0, -3 +10°, -0°	+6, -0 ±2 10°, -5°	F	—	3, 6, 12

Figure 2.4 (Continued) (Millimeters)

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See Notes on Page 43

Double-bevel-groove weld (5)
Butt joint (B)

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 Root Face Groove Angle	Tolerances				
					As Detailed (see 2.12.1)				As Fit-Up (see 3.3.4)
SMAW	B-U5a	U	—	R = 0 to 3 f = 0 to 3 $\alpha = 45^\circ$ $\beta = 0^\circ$ to 15°	+2, -0 +2, -0 $\alpha + \beta +10^\circ$ -0°	+2, -3 Not limited $\alpha + \beta +10^\circ$ -5°	F, H	—	1, 3, 7, 9, 13
GMAW FCAW	B-U5-GF	U	—	R = 0 to 3 f = 0 to 3 $\alpha = 45^\circ$ $\beta = 0^\circ$ to 15°	+2, -0 +2, -0 $\alpha + \beta =$ +10°, -0°	+2, -3 Not limited $\alpha + \beta =$ +10°, -5°	H	Not required	3, 7, 9

Double-bevel-groove weld (5)
T-joint (T)
Corner joint (C)

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 Root Face Groove Angle	Tolerances				
					As Detailed (see 2.12.1)				As Fit-Up (see 3.3.4)
SMAW	TC-U5b	U	U	R = 0 to 3 f = 0 to 3 $\alpha = 45^\circ$	+2, -0 +2, -0 +10°, -0°	+2, -3 Not limited +10°, -5°	All	—	1, 3, 6, 7, 12
GMAW FCAW	TC-U5-GF	U	U	R = 0 to 3 f = 0 to 3 $\alpha = 45^\circ$	+2, -0 +2, -0 +10°, -0°	+2, -3 Not limited +10°, -5°	All	Not required	3, 6, 7, 12
SAW	TC-U5-S	U	U	R = 0 f = 5 max $\alpha = 60^\circ$	± 0 +0, -5 +10°, -0°	+2, -0 ± 2 +10°, -5°	F	—	3, 6, 7, 12

Figure 2.4 (Continued) (Millimeters)

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Single-U-groove weld (6) Butt joint (B) Corner joint (C)		Tolerances	
		As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)
		$R = +2, -0$	$+2, -3$
		$\alpha = +10^\circ, -0^\circ$	$+10^\circ, -5^\circ$
		$f = \pm 2$	Not Limited
		$r = +3, -0$	$+3, -0$

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	Root Face	Groove Radius			
SMAW	B-U6	U	U	R = 0 to 3	$\alpha = 45^\circ$	f = 3	r = 6	All	—	1, 3, 9
				R = 0 to 3	$\alpha = 20^\circ$	f = 3	r = 6	F, OH	—	1, 3, 9
	C-U6	U	U	R = 0 to 3	$\alpha = 45^\circ$	f = 3	r = 6	All	—	1, 3, 12
				R = 0 to 3	$\alpha = 20^\circ$	f = 3	r = 6	F, OH	—	1, 3, 12
GMAW FCAW	B-U6-GF	U	U	R = 0 to 3	$\alpha = 20^\circ$	f = 3	r = 6	All	Not req.	3, 9
	C-U6-GF	U	U	R = 0 to 3	$\alpha = 20^\circ$	f = 3	r = 6	All	Not req.	3, 12
SAW	B-U6-S	16 min	16 min	R = 0	$\alpha = 20^\circ$	f = 6 min	r = 6	F	—	3, 9
	C-U6-S	16 min	16 min	R = 0	$\alpha = 20^\circ$	f = 6 min	r = 6	F	—	3, 12

Double-U-groove weld (7) Butt joint (B)		Tolerances	
		As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)
		For B-U7 and B-U7-GF	
		$R = +2, -0$	$+2, -3$
		$\alpha = +10^\circ, -0^\circ$	$+10^\circ, -5^\circ$
		$f = \pm 2, -0$	Not Limited
		$r = +6, -0$	± 2
		For B-U7-S	
	$R = \pm 0$	$+2, -0$	
	$f = +0, -6$	± 2	

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	Root Face	Groove Radius			
SMAW	B-U7	U	—	R = 0 to 3	$\alpha = 45^\circ$	f = 3	r = 6	All	—	1, 3, 7, 9
				R = 0 to 3	$\alpha = 20^\circ$	f = 3	r = 6	F, OH	—	1, 3, 7, 9
GMAW FCAW	B-U7-GF	U	—	R = 0 to 3	$\alpha = 20^\circ$	f = 3	r = 6	All	Not required	3, 7, 9
SAW	B-U7-S	U	—	R = 0	$\alpha = 20^\circ$	f = 6 max	r = 6	F	—	3, 7, 9

Figure 2.4 (Continued) (Millimeters)

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See NOTES on Page 43

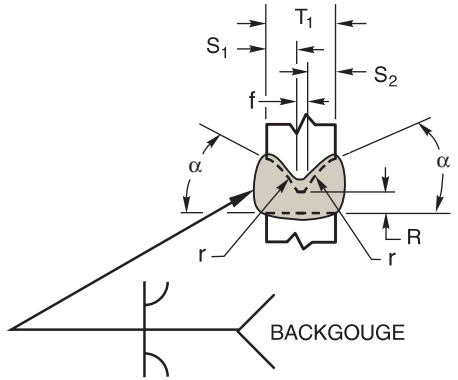
Single-J-groove weld (8) Butt joint (B)								<table border="1"> <tr><th colspan="2">Tolerances</th></tr> <tr><td>As Detailed (see 2.12.1)</td><td>As Fit-Up (see 3.3.4)</td></tr> <tr><td>R = +2, -0</td><td>+2, -3</td></tr> <tr><td>$\alpha = +10^\circ, -0^\circ$</td><td>+10°, -5°</td></tr> <tr><td>f = +2, -0</td><td>Not Limited</td></tr> <tr><td>r = +6, -0</td><td>±2</td></tr> </table>		Tolerances		As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)	R = +2, -0	+2, -3	$\alpha = +10^\circ, -0^\circ$	+10°, -5°	f = +2, -0	Not Limited	r = +6, -0	±2
Tolerances																					
As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)																				
R = +2, -0	+2, -3																				
$\alpha = +10^\circ, -0^\circ$	+10°, -5°																				
f = +2, -0	Not Limited																				
r = +6, -0	±2																				
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	Root Face	Groove Radius														
SMAW	B-U8	U	—	R = 0 to 3	$\alpha = 45^\circ$	f = 3	r = 10	F, H	—	1, 3, 9, 13											
GMAW FCAW	B-U8-GF	U	—	R = 0 to 3	$\alpha = 30^\circ$	f = 3	r = 10	H	Not required	3, 9											

Single-J-groove weld (8) T-joint (T) Corner joint (C)								<table border="1"> <tr><th colspan="2">Tolerances</th></tr> <tr><td>As Detailed (see 2.12.1)</td><td>As Fit-Up (see 3.3.4)</td></tr> <tr><td>R = +2, -0</td><td>+2, -3</td></tr> <tr><td>$\alpha = +10^\circ, -0^\circ$</td><td>+10°, -5°</td></tr> <tr><td>f = +2, -0</td><td>Not Limited</td></tr> <tr><td>r = +6, -0</td><td>±2</td></tr> </table>		Tolerances		As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)	R = +2, -0	+2, -3	$\alpha = +10^\circ, -0^\circ$	+10°, -5°	f = +2, -0	Not Limited	r = +6, -0	±2
Tolerances																					
As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)																				
R = +2, -0	+2, -3																				
$\alpha = +10^\circ, -0^\circ$	+10°, -5°																				
f = +2, -0	Not Limited																				
r = +6, -0	±2																				
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	Root Face	Groove Radius														
SMAW	TC-U8a	U	U	R = 0 to 3	$\alpha = 45^\circ$	f = 3	r = 10	All	—	1, 3, 6, 9											
				R = 0 to 3	$\alpha = 30^\circ$	f = 3	r = 10	F, OH	—	1, 3, 6, 9											
GMAW FCAW	TC-U8a-GF	U	U	R = 0 to 3	$\alpha = 30^\circ$	f = 3	r = 10	All	Not required	3, 6, 9											
SAW	TC-U8a-S	16 min	16 min	R = 0	$\alpha = 30^\circ$	f = 6 min	r = 10	F	—	3, 6, 9											

Figure 2.4 (Continued) (Millimeters)

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Double-J-groove weld (9) Butt joint (B)								Tolerances		
								As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)	
				R = +2, -0	+2, -3					
				$\alpha = +10^\circ, -0^\circ$	+10°, -5°					
				f = +2, -0	Not Limited					
				r = +3, -0	±2					
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	Root Face	Groove Radius			
SMAW	B-U9	U	—	R = 0 to 3	$\alpha = 45^\circ$	f = 3	r = 10	F, H	—	1, 3, 7, 9, 13
GMAW FCAW	B-U9-GF	U	—	R = 0 to 3	$\alpha = 30^\circ$	f = 3	r = 10	H	Not required	3, 7, 9

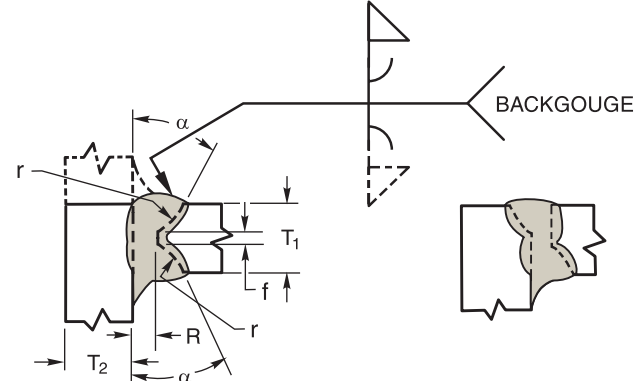
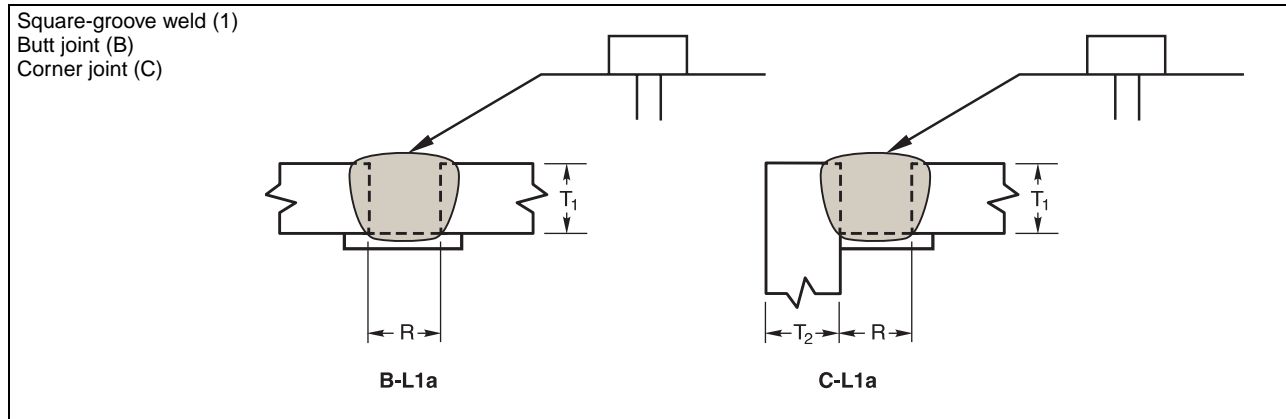
Double-J-groove weld (9) T-joint (T) Corner joint (C)								Tolerances		
								As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)	
				R = +2, -0	+2, -3					
				$\alpha = +10^\circ, -0^\circ$	+10°, -5°					
				f = +2, -0	Not Limited					
				r = +3, -0	±2					
Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation				Allowed Welding Positions	Gas Shielding for FCAW	Notes
		T ₁	T ₂	Root Opening	Groove Angle	Root Face	Groove Radius			
SMAW	TC-U9a	U	U	R = 0 to 3	$\alpha = 45^\circ$	f = 3	r = 10	All	—	1, 3, 6, 7, 12
				R = 0 to 3	$\alpha = 30^\circ$	f = 3	r = 10	F, OH	—	3, 6, 7, 12
GMAW FCAW	TC-U9a-GF	U	U	R = 0 to 3	$\alpha = 30^\circ$	f = 3	r = 10	All	Not required	3, 6, 7, 12
SAW	TC-U9a-S	10 min	10 min	R = 0	$\alpha = 30^\circ$	f = 6	r = 10	F	—	3, 6, 7, 12

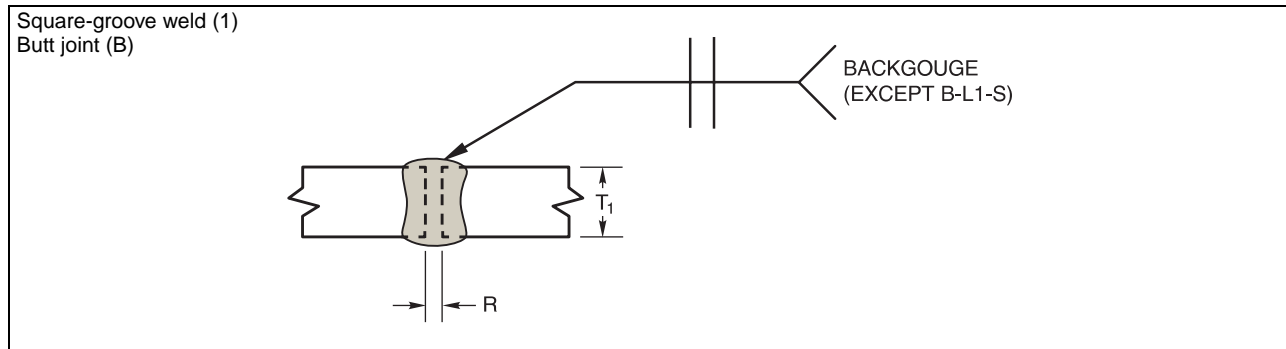
Figure 2.4 (Continued) (Millimeters)

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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	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
SMAW	B-L1a	1/4 max	—	R = T ₁	+1/16, -0	+1/4, -1/16	All	—	1, 9
	C-L1a	1/4 max	U	R = T ₁	+1/16, -0	+1/4, -1/16	All	—	1
FCAW GMAW	B-L1a-GF	3/8 max	—	R = T ₁	+1/16, -0	+1/4, -1/16	All	Not required	9



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	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
SMAW	B-L1b	1/4 max	—	$R = \frac{T_1}{2}$	+1/16, -0	+1/16, -1/8	All	—	1, 3, 9
GMAW FCAW	B-L1b-GF	3/8 max	—	R = 0 to 1/8	+1/16, -0	+1/16, -1/8	All	Not required	3, 9
SAW	B-L1-S	3/8 max	—	R = 0	±0	+1/16, -0	F	—	5, 9
SAW	B-L1a-S	5/8 max	—	R = 0	±0	+1/16, -0	F	—	3, 9

Figure 2.4 (Continued) (Inches)

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Single-V-groove weld (2)
Corner joint (C)

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 Root Face Groove Angle	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
SMAW	C-U2	U	U	R = 0 to 1/8 f = 0 to 1/8 α = 60°	+1/16, -0 +1/16, -0 +10°, -0°	+1/16, -1/8 Not limited +10°, -5°	All	—	1, 3, 6, 12
GMAW FCAW	C-U2-GF	U	U	R = 0 to 1/8 f = 0 to 1/8 α = 60°	+1/16, -0 +1/16, -0 +10°, -0°	+1/16, -1/8 Not limited +10°, -5°	All	Not required	3, 6, 12
SAW	C-U2b-S	1 min	U	R = 0 f = 1/4 max α = 60°	±0 +1/4, -0 +10°, -0°	+1/16, -0 ±1/16 +10°, -5°	F	—	3, 6, 12

Double-V-groove weld (3)
Butt joint (B)

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 Root Face Groove Angle	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
SMAW	B-U3b	U	—	R = 0 to 1/8 f = 0 to 1/8 α = β = 60°	+1/16, -0 +1/16, -0 +10°, -0°	+1/16, -1/8 Not limited +10°, -5°	All	—	1, 3, 7, 9
GMAW FCAW	B-U3-GF								
SAW	B-U3c-S	U	—	R = 0 f = 1/4 min α = β = 60°	+1/16, -0 +1/4, -0 +10°, -0°	+1/16, -0 +1/4, -0 +10°, -5°	F	—	3, 7, 9
To find S ₁ see table above: S ₂ = T ₁ - (S ₁ + f)									

For B-U3c-S only		
T ₁		S ₁
Over	to	
2	2-1/2	1-3/8
2-1/2	3	1-3/4
3	3-5/8	2-1/8
3-5/8	4	2-1/2
4	4-3/4	2-3/4
4-3/4	5-1/2	3
5-1/2	6-1/4	3-3/4
For T ₁ > 6-1/4 or T ₁ ≤ 2 S ₁ = 2/3 (T ₁ - 1/4)		

Figure 2.4 (Continued) (Inches)

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Welding Process		Joint Designation		Base Metal Thickness (U = unlimited)		Groove Preparation		Allowed Welding Positions	Gas Shielding for FCAW	Notes
						Root Opening	Groove Angle			
SMAW	C-U2a	U	U	R = 1/4	$\alpha = 45^\circ$	All	—	1, 12		
				R = 3/8	$\alpha = 30^\circ$	F, V, OH	—	1, 12		
				R = 1/2	$\alpha = 20^\circ$	F, V, OH	—	1, 12		
GMAW FCAW	C-U2a-GF	U	U	R = 3/16	$\alpha = 30^\circ$	F, V, OH	Required	12		
				R = 3/8	$\alpha = 30^\circ$	F, V, OH	Not req.	12		
				R = 1/4	$\alpha = 45^\circ$	F, V, OH	Not req.	12		
SAW	C-L2a-S	2 max	U	R = 1/4	$\alpha = 30^\circ$	F	—	12		
SAW	C-U2-S	U	U	R = 5/8	$\alpha = 20^\circ$	F	—	12		

Welding Process		Joint Designation		Base Metal Thickness (U = unlimited)		Groove Preparation		Allowed Welding Positions	Gas Shielding for FCAW	Notes
						Root Opening	Tolerances			
SMAW	B-U2	U	—	R = 0 to 1/8 f = 0 to 1/8 $\alpha = 60^\circ$	As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)	All	—	1, 3, 9	
					+1/16, -0 +1/16, -0 +10°, -0°	+1/16, -1/8 Not limited +10°, -5°				
GMAW FCAW	B-U2-GF	U	—	R = 0 to 1/8 f = 0 to 1/8 $\alpha = 60^\circ$	As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)	All	Not required	3, 9	
					+1/16, -0 +1/16, -0 +10°, -0°	+1/16, -1/8 Not limited +10°, -5°				
SAW	B-L2c-S	Over 1/2 to 1	—	R = 0 f = 1/4 min $\alpha = 60^\circ$	R = ±0 f = +1/4, -0 $\alpha = +10^\circ, -0^\circ$	+1/16, -0 Not limited +10°, -5°	F	—	3, 9	
		Over 1 to 1-1/2	—	R = 0 f = 3/8 min $\alpha = 60^\circ$						
		Over 1-1/2 to 2	—	R = 0 f = 1/2 min $\alpha = 60^\circ$						

Figure 2.4 (Continued) (Inches)

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Square-groove weld (1)
T-joint (T)
Corner joint (C)

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	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 2.12.1)			
SMAW	TC-L1b	1/4 max	U	$R = \frac{T_1}{2}$	+1/16, -0	+1/16, -1/8	All	—	1, 3, <u>6</u>
GMAW FCAW	TC-L1-GF	3/8 max	U	R = 0 to 1/8	+1/16, -0	+1/16, -1/8	All	Not required	3, <u>6</u>
SAW	TC-L1-S	3/8 max	U	R = 0	±0	+1/16, -0	F	—	3, <u>6</u>

Single-V-groove weld (2)
Butt joint (B)

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	B-U2a	U	—	R = 1/4	α = 45°	All	—	1, 9
				R = 3/8	α = 30°	F, V, OH	—	1, 9
				R = 1/2	α = 20°	F, V, OH	—	1, 9
GMAW FCAW	B-U2a-GF	U	—	R = 3/16	α = 30°	F, V, OH	Required	9
				R = 3/8	α = 30°	F, V, OH	Not req.	9
				R = 1/4	α = 45°	F, V, OH	Not req.	9
SAW	B-L2a-S	2 max	—	R = 1/4	α = 30°	F	—	9
SAW	B-U2-S	U	—	R = 5/8	α = 20°	F	—	9

Figure 2.4 (Continued) (Inches)

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See Notes on Page 43

Single-bevel-groove weld (4) Butt joint (B)				Tolerances					
				As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)				
				$R = +1/16, -0$	$+1/4, -1/16$				
				$a = +10^\circ, -0^\circ$	$+10^\circ, -5^\circ$				
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	B-U4a	U	—	R = 1/4	$\alpha = 45^\circ$	F, H	—	1, 9, 13	
				R = 3/8	$\alpha = 30^\circ$	F, H	—	1, 9, 13	
GMAW FCAW	B-U4a-GF	U	—	R = 3/16	$\alpha = 30^\circ$	H	Required	9	
				R = 1/4	$\alpha = 45^\circ$	H	Not req.	9	
				R = 3/8	$\alpha = 30^\circ$	H	Not req.	9	

Single-bevel-groove weld (4) T-joint (T) Corner joint (C)				Tolerances					
				As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)				
				$R = +1/16, -0$	$+1/4, -1/16$				
				$\alpha = +10^\circ, -0^\circ$	$+10^\circ, -5^\circ$				
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	TC-U4c	U	U	R = 1/4	$\alpha = 45^\circ$	All	—	1, 12	
				R = 3/8	$\alpha = 30^\circ$	F, OH, H	—	1, 12	
GMAW FCAW	TC-U4c-GF	U	U	R = 3/16	$\alpha = 30^\circ$	All	Required	12	
				R = 3/8	$\alpha = 30^\circ$	F	Not req.	12	
				R = 1/4	$\alpha = 45^\circ$	All	Not req.	12	
SAW	TC-U4a-S	U	U	R = 3/8	$\alpha = 30^\circ$	F	—	12	
				R = 1/4	$\alpha = 45^\circ$				

Figure 2.4 (Continued) (Inches)

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See Notes on Page 43

Single-bevel-groove weld (4)
Butt joint (B)

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	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
SMAW	B-U4b	U	—	R = 0 to 1/8 f = 0 to 1/8 α = 45°	+1/16, -0 +1/16, -0 +10°, -0°	+1/16, -1/8 Not limited 10°, -5°	F, H	—	1, 3, 9, 13
GMAW FCAW	B-U4b-GF	U	—				H	Not required	3, 9

Single-bevel-groove weld (4)
T-joint (T)
Corner joint (C)

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 Root Face Groove Angle	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
SMAW	TC-U4b	U	U	R = 0 to 1/8 f = 0 to 1/8 α = 45°	+1/16, -0 +1/16, -0 +10°, -0°	+1/16, -1/8 Not limited 10°, -5°	All	—	1, 3, 6, 12
GMAW FCAW	TC-U4b-GF	U	U				All	Not required	3, 6, 12
SAW	TC-U4b-S	U	U	R = 0 f = 1/8 max α = 60°	±0 +0, -1/8 +10°, -0°	+1/4, -0 ±1/16 10°, -5°	F	—	3, 6, 12

Figure 2.4 (Continued) (Inches)

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Double-bevel-groove weld (5)
Butt joint (B)

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 Root Face Groove Angle	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
SMAW	B-U5a	U	—	R = 0 to 1/8 f = 0 to 1/8 α = 45° β = 0° to 15°	+1/16, -0 +1/16, -0 α + β +10° -0°	+1/16, -1/8 Not limited α + β +10° -5°	F, H	—	1, 3, 7, 9, 13
GMAW FCAW	B-U5-GF	U	—	R = 0 to 1/8 f = 0 to 1/8 α = 45° β = 0° to 15°	+1/16, -0 +1/16, -0 α + β = +10°, -0°	+1/16, -1/8 Not limited α + β = +10°, -5°	H	Not required	3, 7, 9

Double-bevel-groove weld (5)
T-joint (T)
Corner joint (C)

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 Root Face Groove Angle	Tolerances				
					As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)			
SMAW	TC-U5b	U	U	R = 0 to 1/8 f = 0 to 1/8 α = 45°	+1/16, -0 +1/16, -0 +10°, -0°	+1/16, -1/8 Not limited +10°, -5°	All	—	1, 3, 6, 7, 12
GMAW FCAW	TC-U5-GF	U	U	R = 0 to 1/8 f = 0 to 1/8 α = 45°	+1/16, -0 +1/16, -0 +10°, -0°	+1/16, -1/8 Not limited +10°, -5°	All	Not required	3, 6, 7, 12
SAW	TC-U5-S	U	U	R = 0 f = 3/16 max α = 60°	±0 +0, -3/16 +10°, -0°	+1/16, -0 ±1/16 +10°, -5°	F	—	3, 6, 7, 12

Figure 2.4 (Continued) (Inches)

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See NOTES on Page 43

		Base Metal Thickness (U = unlimited)		Groove Preparation				Tolerances		Notes
								As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)	
Single-U-groove weld (6) Butt joint (B) Corner joint (C)								R = +1/16, -0	+1/16, -1/8	
								$\alpha = +10^\circ, -0^\circ$	+10°, -5°	
								f = ±1/16	Not Limited	
								r = +1/8, -0	+1/8, -0	

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	Root Face	Groove Radius			
SMAW	B-U6	U	U	R = 0 to 1/8	$\alpha = 45^\circ$	f = 1/8	r = 1/4	All	—	1, 3, 9
	C-U6	U	U	R = 0 to 1/8	$\alpha = 20^\circ$	f = 1/8	r = 1/4	F, OH	—	1, 3, 9
GMAW FCAW	B-U6-GF	U	U	R = 0 to 1/8	$\alpha = 45^\circ$	f = 1/8	r = 1/4	All	—	1, 3, 12
	C-U6-GF	U	U	R = 0 to 1/8	$\alpha = 20^\circ$	f = 1/8	r = 1/4	F, OH	—	1, 3, 12
SAW	B-U6-S	5/8 min	5/8 min	R = 0	$\alpha = 20^\circ$	f = 1/4 min	r = 1/4	All	Not req.	3, 9
	C-U6-S	5/8 min	5/8 min	R = 0	$\alpha = 20^\circ$	f = 1/4 min	r = 1/4	F	—	3, 12

		Base Metal Thickness (U = unlimited)		Groove Preparation				Tolerances		Notes
								As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)	
Double-U-groove weld (7) Butt joint (B)								R = +1/16, -0	+1/16, -1/8	
								$\alpha = +10^\circ, -0^\circ$	+10°, -5°	
								f = ±1/16, -0	Not Limited	
								r = +1/4, -0	±1/16	
								For B-U7-S		
								R = ±0	+1/16, -0	
								f = +0, -1/4	±1/16	

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	Root Face	Groove Radius			
SMAW	B-U7	U	—	R = 0 to 1/8	$\alpha = 45^\circ$	f = 1/8	r = 1/4	All	—	1, 3, 7, 9
				R = 0 to 1/8	$\alpha = 20^\circ$	f = 1/8	r = 1/4	F, OH	—	1, 3, 7, 9
GMAW FCAW	B-U7-GF	U	—	R = 0 to 1/8	$\alpha = 20^\circ$	f = 1/8	r = 1/4	All	Not required	3, 7, 9
SAW	B-U7-S	U	—	R = 0	$\alpha = 20^\circ$	f = 1/4 max	r = 1/4	F	—	3, 7, 9

Figure 2.4 (Continued) (Inches)

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See NOTES on Page 43

Single-J-groove weld (8) Butt joint (B)								<table border="1"> <tr><th colspan="2">Tolerances</th></tr> <tr><td>As Detailed (see 2.12.1)</td><td>As Fit-Up (see 3.3.4)</td></tr> <tr><td>R = +1/16, -0</td><td>+1/16, -1/8</td></tr> <tr><td>α = +10°, -0°</td><td>+10°, -5°</td></tr> <tr><td>f = +1/16, -0</td><td>Not Limited</td></tr> <tr><td>r = +1/4, -0</td><td>±1/16</td></tr> </table>		Tolerances		As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)	R = +1/16, -0	+1/16, -1/8	α = +10°, -0°	+10°, -5°	f = +1/16, -0	Not Limited	r = +1/4, -0	±1/16
Tolerances																					
As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)																				
R = +1/16, -0	+1/16, -1/8																				
α = +10°, -0°	+10°, -5°																				
f = +1/16, -0	Not Limited																				
r = +1/4, -0	±1/16																				
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	Root Face	Groove Radius														
SMAW	B-U8	U	—	R = 0 to 1/8	α = 45°	f = 1/8	r = 3/8	F, H	—	1, 3, 9, 13											
GMAW FCAW	B-U8-GF	U	—	R = 0 to 1/8	α = 30°	f = 1/8	r = 3/8	H	Not required	3, 9											

Single-J-groove weld (8) T-joint (T) Corner joint (C)								<table border="1"> <tr><th colspan="2">Tolerances</th></tr> <tr><td>As Detailed (see 2.12.1)</td><td>As Fit-Up (see 3.3.4)</td></tr> <tr><td>R = +1/16, -0</td><td>+1/16, -1/8</td></tr> <tr><td>α = +10°, -0°</td><td>+10°, -5°</td></tr> <tr><td>f = +1/16, -0</td><td>Not Limited</td></tr> <tr><td>r = +1/4, -0</td><td>±1/16</td></tr> </table>		Tolerances		As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)	R = +1/16, -0	+1/16, -1/8	α = +10°, -0°	+10°, -5°	f = +1/16, -0	Not Limited	r = +1/4, -0	±1/16
Tolerances																					
As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)																				
R = +1/16, -0	+1/16, -1/8																				
α = +10°, -0°	+10°, -5°																				
f = +1/16, -0	Not Limited																				
r = +1/4, -0	±1/16																				
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	Root Face	Groove Radius														
SMAW	TC-U8a	U	U	R = 0 to 1/8	α = 45°	f = 1/8	r = 3/8	All	—	1, 3, 6, 9											
				R = 0 to 1/8	α = 30°	f = 1/8	r = 3/8	F, OH	—	1, 3, 6, 9											
GMAW FCAW	TC-U8a-GF	U	U	R = 0 to 1/8	α = 30°	f = 1/8	r = 3/8	All	Not required	3, 6, 9											
SAW	TC-U8a-S	5/8 min	5/8 min	R = 0	α = 30°	f = 1/4 min	r = 3/8	F	—	3, 6, 9											

Figure 2.4 (Continued) (Inches)

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See Notes on Page 43

Double-J-groove weld (9) Butt joint (B)								Tolerances		
								As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)	
				$R = +1/16, -0$	$+1/16, -1/8$					
				$\alpha = +10^\circ, -0^\circ$	$+10^\circ, -5^\circ$					
				$f = +1/16, -0$	Not Limited					
				$r = +1/8, -0$	$\pm 1/16$					
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	Root Face	Groove Radius			
SMAW	B-U9	U	—	R = 0 to 1/8	$\alpha = 45^\circ$	f = 1/8	r = 3/8	F, H	—	1, 3, 7, 9, 13
GMAW FCAW	B-U9-GF	U	—	R = 0 to 1/8	$\alpha = 30^\circ$	f = 1/8	r = 3/8	H	Not required	3, 7, 9

Double-J-groove weld (9) T-joint (T) Corner joint (C)								Tolerances		
								As Detailed (see 2.12.1)	As Fit-Up (see 3.3.4)	
				$R = +1/16, -0$	$+1/16, -1/8$					
				$\alpha = +10^\circ, -0^\circ$	$+10^\circ, -5^\circ$					
				$f = +1/16, -0$	Not Limited					
				$r = +1/8, -0$	$\pm 1/16$					
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	Root Face	Groove Radius			
SMAW	TC-U9a	U	U	R = 0 to 1/8	$\alpha = 45^\circ$	f = 1/8	r = 3/8	All	—	1, 3, 6, 7, 12
				R = 0 to 1/8	$\alpha = 30^\circ$	f = 1/8	r = 3/8	F, OH	—	3, 6, 7, 12
GMAW FCAW	TC-U9a-GF	U	U	R = 0 to 1/8	$\alpha = 30^\circ$	f = 1/8	r = 3/8	All	Not required	3, 6, 7, 12
SAW	TC-U9a-S	3/8 min	3/8 min	R = 0	$\alpha = 30^\circ$	f = 1/4	r = 3/8	F	—	3, 6, 7, 12

Figure 2.4 (Continued) (Inches)

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See Notes on Page 43

Square-groove weld (1)
Butt joint (B)

FOR BUTT JOINT RESTRICTIONS, SEE 2.14

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	B-P1a	3 max	—	R = 0 to 2	+2, -0	±2	All	T ₁ - 1	1, 2
	B-P1c	6 max	—	R = $\frac{T_1}{2}$ min	+2, -0	±2	All	$\frac{T_1}{2}$	1, 2

Square-groove weld (1)
Butt joint (B)

E₁ + E₂ MUST NOT EXCEED $\frac{3T_1}{4}$

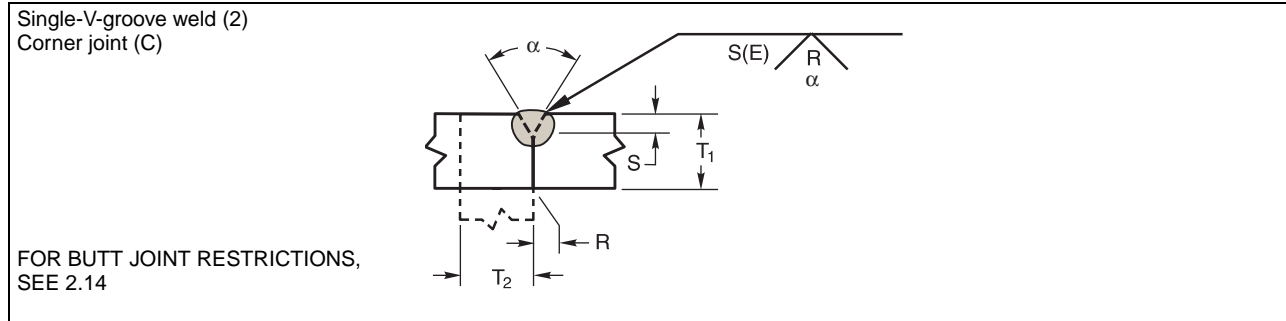
FOR BUTT JOINT RESTRICTIONS, SEE 2.14

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Total Weld Size (E ₁ + E ₂)	Notes
		T ₁	T ₂	Root Opening	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	B-P1b	6 max	—	R = $\frac{T_1}{2}$	+2, -0	±2	All	$\frac{3T_1}{4}$	1

Figure 2.5—Details of Welded Joints for PJP Groove Welds (see 2.13.1) (Dimensions in Millimeters)

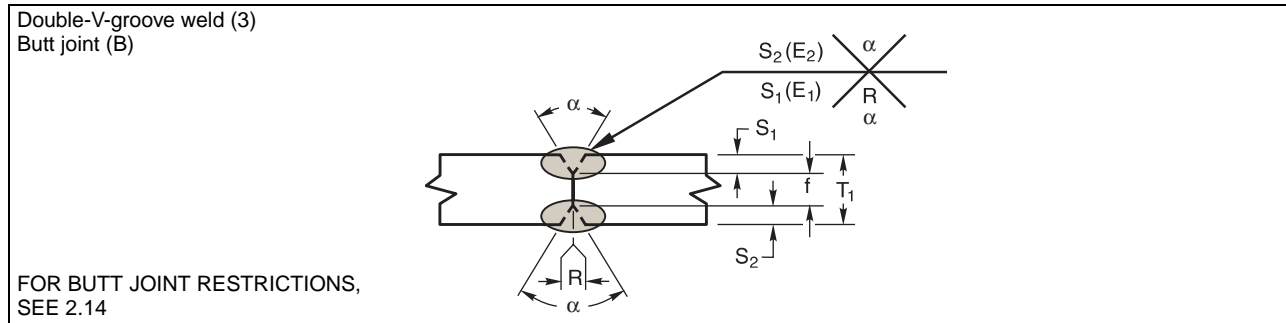
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See Notes on Page 43



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	C-P2	6 min	U	R = 0 f = 1 min α = 60°	+2, -0 Unlimited +10°, -0°	+3, -2 ±2 +10°, -5°	All	S	1, 2, 4, 11
GMAW FCAW	C-P2-GF	6 min	U	R = 0 f = 3 min α = 60°	+2, -0 Unlimited +10°, -0°	+3, -2 ±2 +10°, -5°	All	S	2, 4, 11
SAW	C-P2-S	11 min	U	R = 0 f = 6 min α = 60°	±0 Unlimited +10°, -0°	+2, -0 [‡] ±2 +10°, -5°	F	S	2, 4, 11

[‡]Fit-up tolerance, see 3.3.2, for rolled shapes R may be 8 mm in thick plates if backing is provided.



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Total Weld Size (E ₁ + E ₂)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	B-P3	12 min	—	R = 0 f = 3 min α = 60°	+2, -0 Unlimited +10°, -0°	+3, -2 ±2 +10°, -5°	All	S ₁ + S ₂	1, 4, 8, 11
GMAW FCAW	B-P3-GF	12 min	—	R = 0 f = 3 min α = 60°	+2, -0 Unlimited +10°, -0°	+3, -2 ±2 +10°, -5°	All	S ₁ + S ₂	4, 8, 11
SAW	B-P3-S	20 min	—	R = 0 f = 6 min α = 60°	±0 Unlimited +10°, -0°	+2, -0 ±2 +10°, -5°	F	S ₁ + S ₂	4, 8, 11

Figure 2.5 (Continued) (Millimeters)

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See Notes on Page 43

Single-bevel-groove (4)
T-joint (T)
Corner joint (C)

FOR CORNER AND T-JOINT RESTRICTIONS, SEE 2.11

FOR BUTT JOINT RESTRICTIONS, SEE 2.14

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	TC-P4	U	U	R = 0 f = 3 min $\alpha = 45^\circ$	+2, -0 Unlimited +10°, -0°	+3, -2 ± 2 +10°, -5°	All	S-3	1, 2, 4, 6, 11
GMAW FCAW	TC-P4-GF	6 min	U	R = 0 f = 3 min $\alpha = 45^\circ$	+2, -0 Unlimited +10°, -0°	+3, -2 ± 2 +10°, -5°	All	S-3	2, 4, 6, 11
SAW	TC-P4-S	11 min	U	R = 0 f = 6 min $\alpha = 60^\circ$	± 0 Unlimited +10°, -0°	+2, -0 [†] ± 2 +10°, -5°	F	S	2, 4, 6, 11

[†]Fit-up tolerance, see 3.3.2, for rolled shapes R may be 8 mm in thick plates if backing is provided.

Double-bevel-groove weld (5)
T-joint (T)
Corner joint (C)

FOR CORNER AND T-JOINT RESTRICTIONS, SEE 2.11

FOR BUTT JOINT RESTRICTIONS, SEE 2.14

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Total Weld Size (E ₁ + E ₂)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	TC-P5	8 min	U	R = 0 f = 3 min $\alpha = 45^\circ$	+2, -0 Unlimited +10°, -0°	+3, -2 ± 2 +10°, -5°	All	(S ₁ + S ₂) -6	1, 4, 6, 8, 11
GMAW FCAW	TC-P5-GF	12 min	U	R = 0 f = 3 min $\alpha = 45^\circ$	+2, -0 Unlimited +10°, -0°	+3, -2 ± 2 +10°, -5°	All	(S ₁ + S ₂) -6	4, 6, 8, 11
SAW	TC-P5-S	20 min	U	R = 0 f = 6 min $\alpha = 60^\circ$	± 0 Unlimited +10°, -0°	+2, -0 ± 2 +10°, -5°	F	S ₁ + S ₂	4, 6, 8, 11

[†]Fit-up tolerance, see 3.3.2, for rolled shapes R may be 8 mm in thick plates if backing is provided.

Figure 2.5 (Continued) (Millimeters)

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See Notes on Page 43

Single-U-groove weld (6)
Corner joint (C)

FOR CORNER AND T-JOINT RESTRICTIONS, SEE 2.11

FOR BUTT JOINT RESTRICTIONS, SEE 2.14

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Radius Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	C-P6	6 min	U	R = 0 f = 1 min r = 6 α = 45°	+2, -0 +U, -0 +6, -0 +10°, -0°	+3, -2 ±2 ±2 +10°, -5°	All	S	1, 2, 4, 11
GMAW FCAW	C-P6-GF	6 min	U	R = 0 f = 3 min r = 6 α = 20°	+2, -0 +U, -0 +6, -0 +10°, -0°	+3, -2 ±2 ±2 +10°, -5°	All	S	2, 4, 11
SAW	C-P6-S	11 min	U	R = 0 f = 6 min r = 6 α = 20°	±0 +U, -0 +6, -0 +10°, -0°	+2, -0 [‡] ±2 ±2 +10°, -5°	F	S	2, 4, 11

[‡]Fit-up tolerance, see 3.3.2, for rolled shapes R may be 8 mm in thick plates if backing is provided.

Figure 2.5 (Continued) (Millimeters)

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See Notes on Page 43

Single-J-groove weld (8)
T-joint (T)
Corner joint (C)

FOR CORNER AND T-JOINT RESTRICTIONS, SEE 2.11

FOR BUTT JOINT RESTRICTIONS, SEE 2.14

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Radius Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	TC-P8	6 min	U	R = 0 f = 3 min r = 10 α = 45°	+2, -0 Not limited +6, -0 +10°, -0°	+3, -2 ±2 ±2 +10°, -5°	All	S	1, 4, 6, 11
SMAW	C-P8*	6 min	U	R = 0 f = 3 min r = 10 α = 30°	+2, -0 Not limited +6, -0 +10°, -0°	+3, -2 ±2 ±2 +10°, -5°	All	S	1, 4, 6, 11
GMAW FCAW	TC-P8-GF	6 min	U	R = 0 f = 3 min r = 10 α = 45°	+2, -0 Not limited +6, -0 +10°, -0°	+3, -2 ±2 ±2 +10°, -5°	All	S	4, 6, 11
GMAW FCAW	C-P8-GF*	6 min	U	R = 0 f = 3 min r = 10 α = 30°	+2, -0 Not limited +6, -0 +10°, -0°	+3, -2 ±2 ±2 +10°, -5°	All	S	4, 6, 11
SAW	TC-P8-S	11 min	U	R = 0 f = 6 min r = 12 α = 45°	±0 Not limited +6, -0 +10°, -0°	+2, -0 [‡] ±2 ±2 +10°, -5°	F	S	4, 6, 11
SAW	C-P8-S*	11 min	U	R = 0 f = 6 min r = 12 α = 30°	±0 Not limited +6, -0 +10°, -0°	+2, -0 [‡] ±2 ±2 +10°, -5°	F	S	4, 6, 11

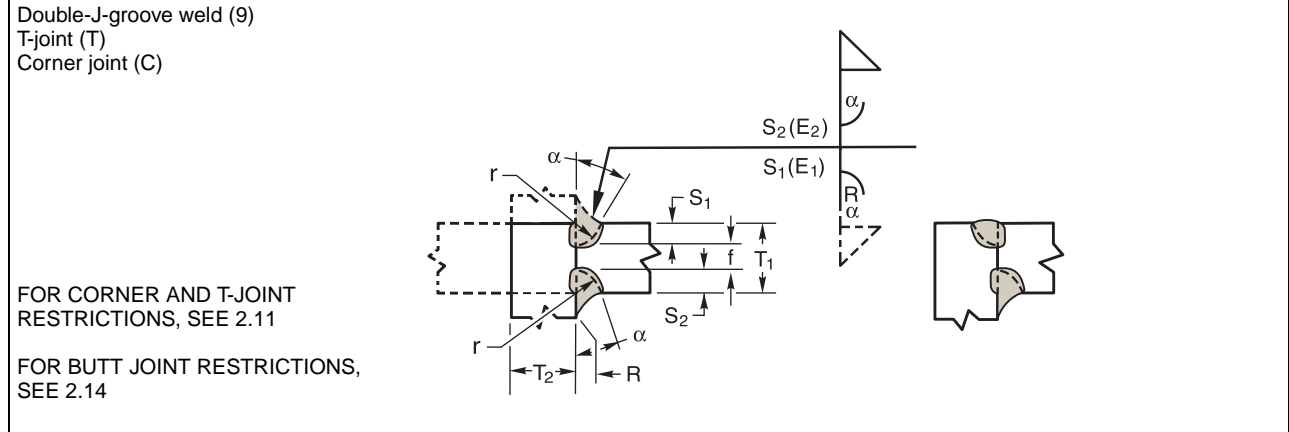
[‡]Fit-up tolerance, see 3.3.2, for rolled shapes R may be 8 mm in thick plates if backing is provided.

*Applies to outside corner joints.

Figure 2.5 (Continued) (Millimeters)

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Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Total Weld Size (E ₁ + E ₂)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Radius Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	TC-P9	12 min	U	R = 0 f = 3 min r = 10 α = 45°	+2, -0 -0 +6, -0 +10°, -0°	+3, -2 ±2 ±2 +10°, -5°	All	S ₁ + S ₂	1, 4, 6, 8, 11
GMAW FCAW	TC-P9-GF*	12 min	U	R = 0 f = 3 min r = 10 α = 30°	+2, -0 Not limited +6, -0 +10°, -0°	+3, -2 ±2 ±2 +10°, -5°	All	S ₁ + S ₂	4, 6, 8, 11
SAW	C-P9-S	20 min	U	R = 0 f = 6 min r = 12 α = 45°	±0 Not limited +6, -0 +10°, -0°	+2, -0 ±2 ±2 +10°, -5°	F	S ₁ + S ₂	4, 6, 8, 11
SAW	C-P9-S*	20 min	U	R = 0 f = 6 min r = 12 α = 20°	±0 Not limited +6, -0 +10°, -0°	+2, -0 [‡] ±2 ±2 +10°, -5°	F	S ₁ + S ₂	4, 6, 8, 11
SAW	T-P9-S	20 min	U	R = 0 f = 6 min r = 12 α = 45°	±0 Not limited +6, -0 +10°, -0°	+2, -0 [‡] ±2 ±2 +10°, -5°	F	S ₁ + S ₂	4, 6, 8, 11

[‡]Fit-up tolerance, see 3.3.2, for rolled shapes R may be 8 mm in thick plates if backing is provided.
*Applies to outside corner joints.

Figure 2.5 (Continued) (Millimeters)

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Square-groove weld (1)
Butt joint (B)

FOR BUTT JOINT RESTRICTIONS, SEE 2.14

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	B-P1a	1/8 max	—	R = 0 to 1/16	+1/16, -0	±1/16	All	T ₁ - 1/32	1, 2
	B-P1c	1/4 max	—	R = $\frac{T_1}{2}$ min	+1/16, -0	±1/16	All	$\frac{T_1}{2}$	1, 2

Square-groove weld (1)
Butt joint (B)

E₁ + E₂ MUST NOT EXCEED $\frac{3T_1}{4}$

FOR BUTT JOINT RESTRICTIONS, SEE 2.14

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Total Weld Size (E ₁ + E ₂)	Notes
		T ₁	T ₂	Root Opening	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	B-P1b	1/4 max	—	R = $\frac{T_1}{2}$	+1/16, -0	±1/16	All	$\frac{3T_1}{4}$	1

Figure 2.5 (Continued) (Inches)

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See NOTES on Page 43

Single-V-groove weld (2)
Corner joint (C)

FOR BUTT JOINT RESTRICTIONS, SEE 2.14

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	C-P2	1/4 min	U	R = 0 f = 1/32 min α = 60°	+1/16, -0 Unlimited +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S	1, 2, 4, 11
GMAW FCAW	C-P2-GF	1/4 min	U	R = 0 f = 1/8 min α = 60°	+1/16, -0 Unlimited +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S	2, 4, 11
SAW	C-P2-S	7/16 min	U	R = 0 f = 1/4 min α = 60°	±0 Unlimited +10°, -0°	+1/16, -0 [‡] ±1/16 +10°, -5°	F	S	2, 4, 11

[‡]Fit-up tolerance, see 3.3.2, for rolled shapes R may be 5/16 in. in thick plates if backing is provided.

Double-V-groove weld (3)
Butt joint (B)

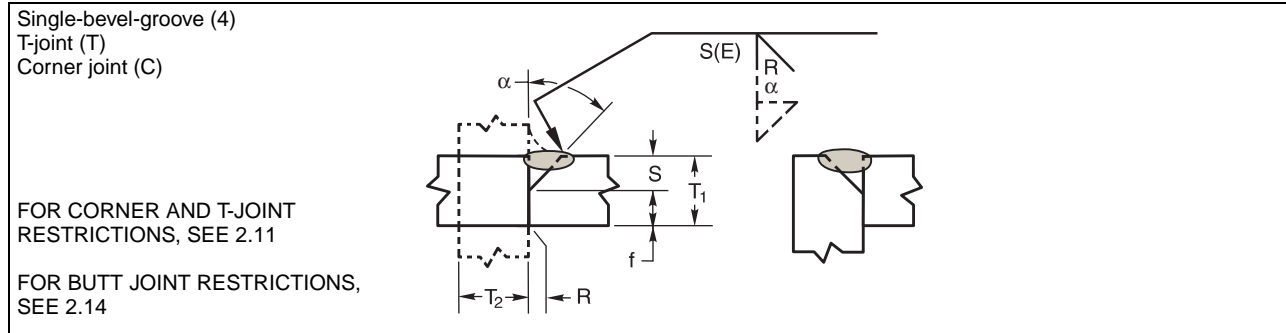
FOR BUTT JOINT RESTRICTIONS, SEE 2.14

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Total Weld Size (E ₁ + E ₂)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	B-P3	1/2 min	—	R = 0 f = 1/8 min α = 60°	+1/16, -0 Unlimited +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S ₁ + S ₂	1, 4, 8, 11
GMAW FCAW	B-P3-GF	1/2 min	—	R = 0 f = 1/8 min α = 60°	+1/16, -0 Unlimited +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S ₁ + S ₂	4, 8, 11
SAW	B-P3-S	3/4 min	—	R = 0 f = 1/4 min α = 60°	±0 Unlimited +10°, -0°	+1/16, -0 ±1/16 +10°, -5°	F	S ₁ + S ₂	4, 8, 11

Figure 2.5 (Continued) (Inches)

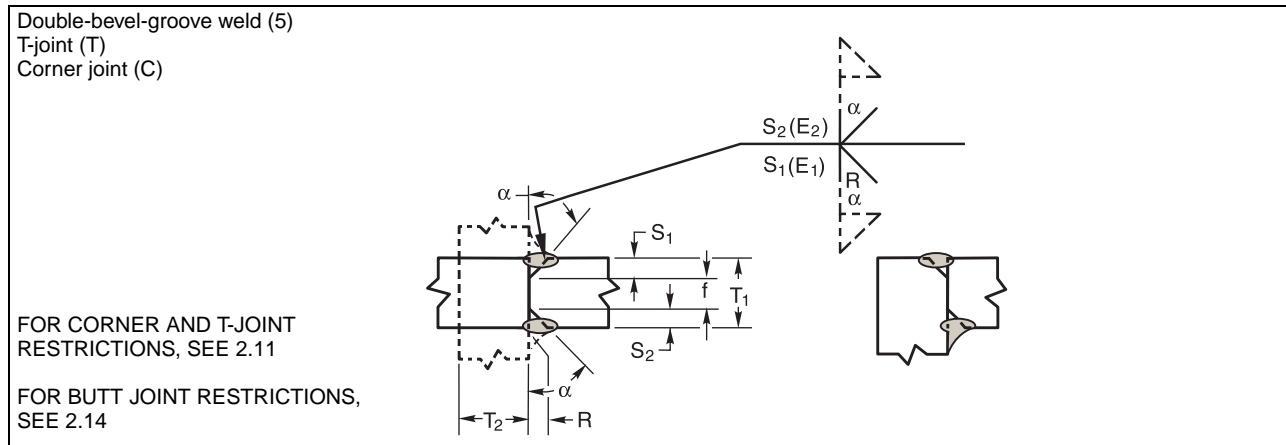
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See Notes on Page 43



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	TC-P4	U	U	R = 0 f = 1/8 min α = 45°	+1/16, -0 Unlimited +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S-1/8	1, 2, 4, 6, 11
GMAW FCAW	TC-P4-GF	1/4 min	U	R = 0 f = 1/8 min α = 45°	+1/16, -0 Unlimited +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	S-1/8	2, 4, 6, 11
SAW	TC-P4-S	7/16 min	U	R = 0 f = 1/4 min α = 60°	±0 Unlimited +10°, -0°	+1/16, -0 [‡] ±1/16 +10°, -5°	F	S	2, 4, 6, 11

[‡]Fit-up tolerance, see 3.3.2, for rolled shapes R may be 5/16 in. in thick plates if backing is provided.



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Total Weld Size (E ₁ + E ₂)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	TC-P5	5/16 min	U	R = 0 f = 1/8 min α = 45°	+1/16, -0 Unlimited +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	(S ₁ + S ₂) -1/4	1, 4, 6, 8, 11
GMAW FCAW	TC-P5-GF	1/2 min	U	R = 0 f = 1/8 min α = 45°	+1/16, -0 Unlimited +10°, -0°	+1/8, -1/16 ±1/16 +10°, -5°	All	(S ₁ + S ₂) -1/4	4, 6, 8, 11
SAW	TC-P5-S	3/4 min	U	R = 0 f = 1/4 min α = 60°	±0 Unlimited +10°, -0°	+1/16, -0 ±1/16 +10°, -5°	F	S ₁ + S ₂	4, 6, 8, 11

[‡]Fit-up tolerance, see 3.3.2, for rolled shapes R may be 5/16 in. in thick plates if backing is provided.

Figure 2.5 (Continued) (Inches)

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See Notes on Page 43

Single-U-groove weld (6)
Corner joint (C)

FOR CORNER AND T-JOINT RESTRICTIONS, SEE 2.11

FOR BUTT JOINT RESTRICTIONS, SEE 2.14

Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Radius Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	C-P6	1/4 min	U	R = 0 f = 1/32 min r = 1/4 alpha = 45°	+1/16, -0 +U, -0 +1/4, -0 +10°, -0°	+1/8, -1/16 ±1/16 ±1/16 +10°, -5°	All	S	1, 2, 4, 11
GMAW FCAW	C-P6-GF	1/4 min	U	R = 0 f = 1/8 min r = 1/4 alpha = 20°	+1/16, -0 +U, -0 +1/4, -0 +10°, -0°	+1/8, -1/16 ±1/16 ±1/16 +10°, -5°	All	S	2, 4, 11
SAW	C-P6-S	7/16 min	U	R = 0 f = 1/4 min r = 1/4 alpha = 20°	±0 +U, -0 +1/4, -0 +10°, -0°	+1/16, -0 [‡] ±1/16 ±1/16 +10°, -5°	F	S	2, 4, 11

[‡]Fit-up tolerance, see 3.3.2, for rolled shapes R may be 5/16 in. in thick plates if backing is provided.

Figure 2.5 (Continued) (Inches)

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See Notes on Page 43

Single-J-groove weld (8)
T-joint (T)
Corner joint (C)

FOR CORNER AND T-JOINT RESTRICTIONS, SEE 2.11

FOR BUTT JOINT RESTRICTIONS, SEE 2.14

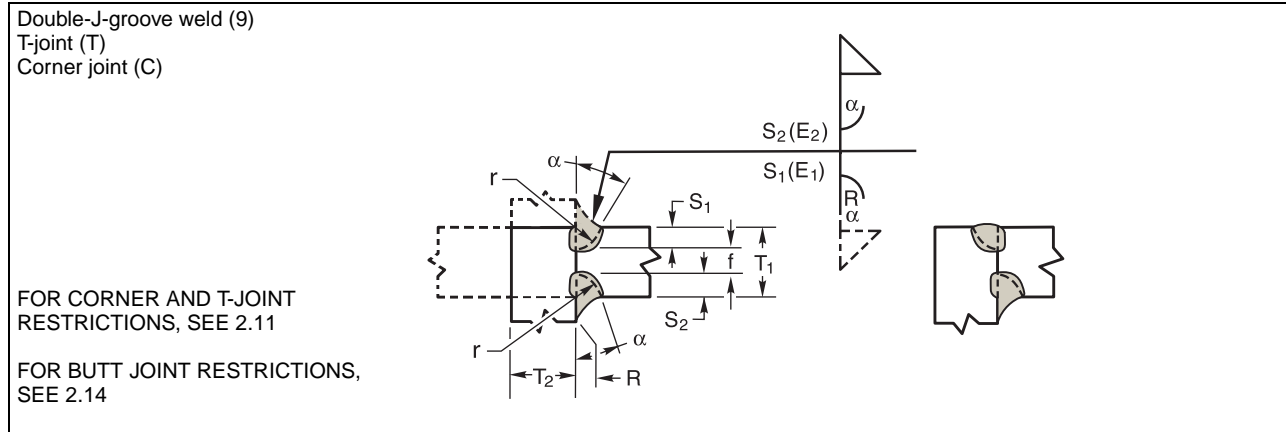
Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Weld Size (E)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Radius Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	TC-P8	1/4 min	U	R = 0 f = 1/8 min r = 3/8 α = 45°	+1/16, -0 Not limited +1/4, -0 +10°, -0°	+1/8, -1/16 ±1/16 ±1/16 +10°, -5°	All	S	1, 4, 6, 11
SMAW	C-P8*	1/4 min	U	R = 0 f = 1/8 min r = 3/8 α = 30°	+1/16, -0 Not limited +1/4, -0 +10°, -0°	+1/8, -1/16 ±1/16 ±1/16 +10°, -5°	All	S	1, 4, 6, 11
GMAW FCAW	TC-P8-GF	1/4 min	U	R = 0 f = 1/8 min r = 3/8 α = 45°	+1/16, -0 Not limited +1/4, -0 +10°, -0°	+1/8, -1/16 ±1/16 ±1/16 +10°, -5°	All	S	4, 6, 11
GMAW FCAW	C-P8-GF*	1/4 min	U	R = 0 f = 1/8 min r = 3/8 α = 30°	+1/16, -0 Not limited +1/4, -0 +10°, -0°	+1/8, -1/16 ±1/16 ±1/16 +10°, -5°	All	S	4, 6, 11
SAW	TC-P8-S	7/16 min	U	R = 0 f = 1/4 min r = 1/2 α = 45°	±0 Not limited +1/4, -0 +10°, -0°	+1/16, -0 [‡] ±1/16 ±1/16 +10°, -5°	F	S	4, 6, 11
SAW	C-P8-S*	7/16 min	U	R = 0 f = 1/4 min r = 1/2 α = 30°	±0 Not limited +1/4, -0 +10°, -0°	+1/16, -0 [‡] ±1/16 ±1/16 +10°, -5°	F	S	4, 6, 11

[‡]Fit-up tolerance, see 3.3.2, for rolled shapes R may be 5/16 in. in thick plates if backing is provided.

*Applies to outside corner joints.

Figure 2.5 (Continued) (Inches)

See Notes on Page 43



Welding Process	Joint Designation	Base Metal Thickness (U = unlimited)		Groove Preparation			Allowed Welding Positions	Total Weld Size (E ₁ + E ₂)	Notes
		T ₁	T ₂	Root Opening Root Face Groove Radius Groove Angle	Tolerances				
					As Detailed (see 2.13.1)	As Fit-Up (see 3.3.4)			
SMAW	TC-P9	1/2 min	U	R = 0 f = 1/8 min r = 3/8 α = 45°	+1/16, -0 -0 +1/4, -0 +10°, -0°	+1/8, -1/16 ±1/16 ±1/16 +10°, -5°	All	S ₁ + S ₂	1, 4, 6, 8, 11
GMAW FCAW	TC-P9-GF*	1/2 min	U	R = 0 f = 1/8 min r = 3/8 α = 30°	+1/16, -0 Not limited +1/4, -0 +10°, -0°	+1/8, -1/16 ±1/16 ±1/16 +10°, -5°	All	S ₁ + S ₂	4, 6, 8, 11
SAW	C-P9-S	3/4 min	U	R = 0 f = 1/4 min r = 1/2 α = 45°	±0 Not limited +1/4, -0 +10°, -0°	+1/16, -0 ±1/16 ±1/16 +10°, -5°	F	S ₁ + S ₂	4, 6, 8, 11
SAW	C-P9-S*	3/4 min	U	R = 0 f = 1/4 min r = 1/2 α = 20°	±0 Not limited +1/4, -0 +10°, -0°	+1/16, -0 [‡] ±1/16 ±1/16 +10°, -5°	F	S ₁ + S ₂	4, 6, 8, 11
SAW	T-P9-S	3/4 min	U	R = 0 f = 1/4 min r = 1/2 α = 45°	±0 Not limited +1/4, -0 +10°, -0°	+1/16, -0 [‡] ±1/16 ±1/16 +10°, -5°	F	S ₁ + S ₂	4, 6, 8, 11

[‡]Fit-up tolerance, see 3.3.2, for rolled shapes R may be 5/16 in. in thick plates if backing is provided.

*Applies to outside corner joints.

Figure 2.5 (Continued) (Inches)

Notes for Figures 2.4 and 2.5

Notes:

- Groove preparations detailed for SMAW joints may be used for GMAW or FCAW.
- Joint shall be welded from one side only.
- Backgouge root to sound metal before welding second side.
- Minimum weld size (E) as shown in Table 2.2; S as specified on drawings.
- Evidence of CJP shall be required (see 4.7.5).
- Groove welds in corner and T-joints shall be reinforced with fillet welds with a leg size equal to or greater than T/4, but need not exceed 10 mm [3/8 in.]. T shall be defined as the thinner of the attaching elements.
- Double-groove welds may have grooves of unequal depth, but the depth of the shallower groove shall be no less than one-fourth of the thickness of the thinner part joined.
- Double-groove welds may have grooves of unequal depth, provided they conform to the limitations of Note D. Also the weld size (E), less any reduction, applies individually to each groove.
- The orientation of the two members in the joints may vary from 135° to 180° provided that the basic joint configuration (groove angle, root face, root opening) remains the same and that the design weld size shall be maintained.
- For corner and T-joints, the member orientation may be changed provided the groove angle shall be maintained as specified.
- The member orientation may be changed provided that the groove dimensions shall be maintained as specified.
- The orientation of the two members in the joints may vary from 45° to 135° for corner joints and from 45° to 90° for T-joints, provided that the basic joint configuration (groove angle, root face, root opening) remains the same and that the design weld size shall be maintained.
- These joint details shall not be used where V-groove or U-groove details are practicable (see 2.14).

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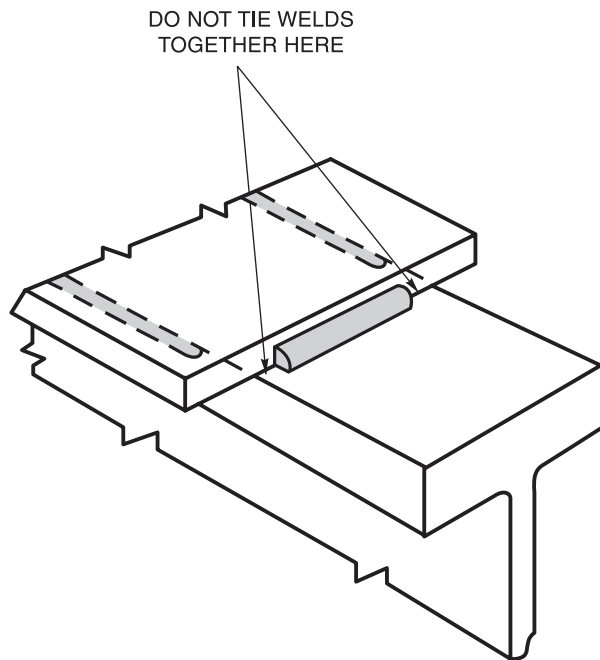


Figure 2.6—Fillet Welds on Opposite Sides of a Common Plane of Contact (see 2.8.1.8)

2.13.1.1 All PJP groove welds made by GMAW-S shall be qualified by the WPS qualification tests described in 5.13.

2.13.2 Minimum Effective Weld Size. The minimum effective weld size of PJP square-, single-, or double-V-, bevel-, J-, and U-groove welds shall be as shown in Table 2.2.

Shop or working drawings shall specify the groove depths (S) applicable for the effective weld size (E) required for the welding process and position of welding to be used.

2.13.3 Corner Joints. For corner joints using single-bevel groove welds, either plate may be beveled, provided the basic groove configuration is not changed and adequate edge distance is maintained to support the welding operations without excessive melting. Joint preparation that bevels the plate that will be stressed in the short-transverse direction will help to reduce lamellar tearing.

2.14 Prohibited Types of Joints and Welds

The joints and welds described in the following paragraphs shall be prohibited:

Table 2.2
Minimum Effective Weld Size for PJP Groove Welds^{1,2} (see 2.13.3)

Base Metal Thickness of Thicker Part Joined (T)	Minimum Effective Weld Size
$T \leq 20 \text{ mm [3/4 in.]}$	6 mm [1/4 in.]
$T > 20 \text{ mm [3/4 in.]}$	8 mm [5/16 in.]

Notes:

- Smaller welds may be approved by the Engineer based upon applied stress and the use of appropriate preheat.
- Except that the weld size need not exceed the thickness of the thinner part.

(1) All PJP groove welds in butt joints except those conforming to 2.17.3

(2) CJP groove welds, in all members carrying calculated stress or in secondary members subject to tension or the reversal of stress, made from one side only without any backing, or with backing other than steel, that has not been qualified in conformance with 5.13

(3) Intermittent groove welds

(4) Intermittent fillet welds, except as approved by the Engineer

(5) Flat position bevel-groove and J-groove welds in butt joints where V-groove and U-groove welds are practicable

(6) Plug and slot welds in members subject to tension and reversal of stress

2.15 Combinations of Welds

If two or more of the general types of welds (groove, fillet, plug, slot) are combined in a single joint, their allowable capacity shall be computed with reference to the axis of the group in order to determine the allowable capacity of the combination (see Annex I). However, such methods of adding individual capacities of welds do not apply to fillet welds reinforcing CJP groove welds.

2.16 Welds in Combination with Rivets and Bolts

In new work, rivets or bolts in combination with welds shall not be considered as sharing the stress, and the welds shall be provided to carry the entire stress for which the connection is designed. Bolts or rivets used in

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assembly may be left in place if their removal is not specified. If bolts are to be removed, the plans should indicate whether holes should be filled and in what manner.

2.17 Connection Details

2.17.1 Eccentricity of Connections

2.17.1.1 Eccentricity between intersecting parts and members shall be avoided insofar as practical.

2.17.1.2 In designing welded joints, adequate provision shall be made for bending stresses due to eccentricity, if any, in the disposition and section of base metal parts and in the location and types of welded joints.

2.17.1.3 For members having symmetrical cross sections, the connection welds shall be arranged symmetrically about the axis of the member, or proper allowance shall be made for unsymmetrical distribution of stresses.

2.17.1.4 For axially stressed angle members, the center of gravity of the connecting welds shall preferably lie between the line of the center of gravity of the angle's cross section and the centerline of the connected leg. If the center of gravity of the connecting weld lies outside of this zone, the total stresses, including those due to the eccentricity from the center of gravity of the angle, shall not exceed those allowed by this code.

2.17.2 Connections or Splices—Tension and Compression Members. Connections or splices of tension or compression members made by groove welds shall have CJP groove welds. Connections or splices made with fillet welds, except as noted in 2.17.3, shall be designed for an average of the calculated stress and the strength of the member, but not less than 75 percent of the strength of the member, or if there is repeated application of load, the maximum stress or stress range in such connection or splice shall not exceed the fatigue stress allowed by the applicable AASHTO specification.

2.17.3 Connections or Splices in Compression Members with Milled Joints. If members subject only to compression are spliced and full-milled bearing is provided, the splice material and its welding shall be arranged, unless otherwise stipulated by the applicable general specifications, to hold all parts in alignment and shall be proportioned to carry 50 percent of the computed stress in the member. Where such members are in full-milled bearing on base plates, there shall be sufficient welding to hold all parts securely in place.

2.17.4 Connections of Components of Built-Up Members. When a member is built up of two or more pieces,

the pieces shall be connected along their longitudinal joints by sufficient continuous welds to make the pieces act in unison.

2.17.5 Transition of Thicknesses or Widths at Butt Joints

2.17.5.1 Butt joints between parts having unequal thicknesses and subject to tensile stress shall have a smooth transition between the offset surfaces at a slope of no more than 1 transverse to 2.5 longitudinal with the surface of either part. The transition may be accomplished by sloping weld surfaces, by chamfering the thicker part, or by a combination of the two methods (see Figure 2.7).

2.17.5.2 In butt joints between parts of unequal thickness that are subject only to shear or compressive stress, transition of thickness shall be accomplished as described in 2.17.5.1 when offset between surfaces at either side of the joint is greater than the thickness of the thinner part connected. When the offset is equal to or less than the thickness of the thinner part connected, the face of the weld shall be sloped no more than 1 transverse to 2.5 longitudinal from the surface of the thinner part or shall be sloped to the surface of the thicker part if this requires a lesser slope with the following exception: Truss member joints and beam and girder flange joints shall be made with smooth transitions of the type described in 2.17.5.1.

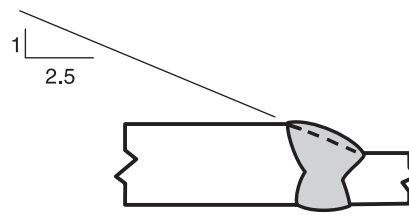
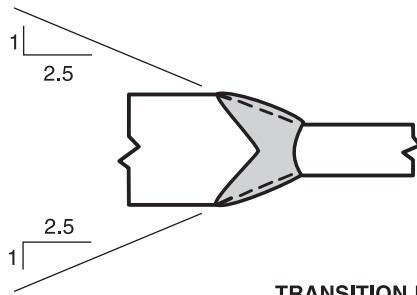
2.17.5.3 Butt joints between parts having unequal width and subject to tensile stress shall have a smooth transition between offset edges at a slope of no more than 1 transverse to 2.5 longitudinal with the edge of either part or shall be transitioned with a 600 mm [24 in.] minimum radius tangent to the narrower part at the center of the butt joint (see Figure 2.8). A radius transition is required for M270M (M270) Grades 690/690W (100/100W) (A 709M [A 709] Grades 690/690W [100/100W]) and M270M (M270) Grade 485W (70W) (A 709M [A 709] Grade 485W [70W]).

2.17.6 Girders and Beams

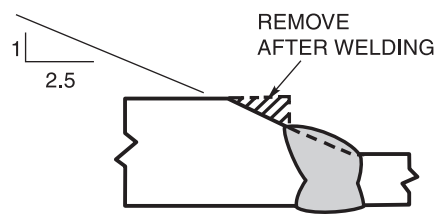
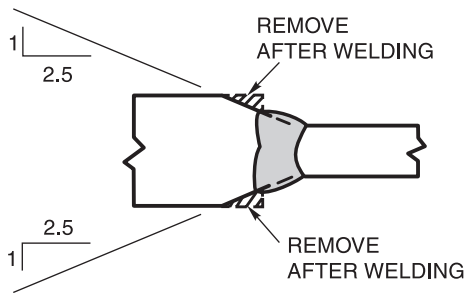
2.17.6.1 Connections or splices in beams or girders when made by groove welds shall have CJP groove welds. Connections or splices made with fillet or plug welds shall be designed for the average of the calculated stress and the strength of the member, but no less than 75 percent of the strength of member. When there is repeated application of load, the maximum stress or stress range in such connections or splices shall not exceed the fatigue stress allowed by the AASHTO specification.

2.17.6.2 Splices between sections of rolled beams or built-up girders shall preferably be made in a single

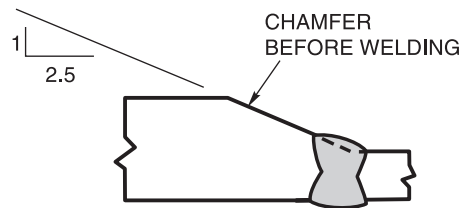
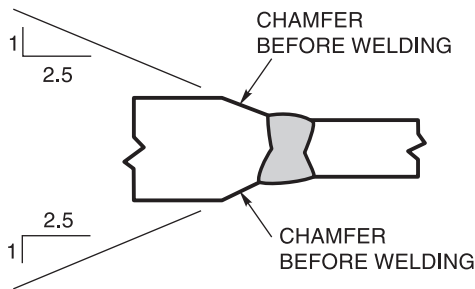
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TRANSITION BY SLOPING WELD SURFACE



TRANSITION BY SLOPING WELD SURFACE AND CHAMFERING



TRANSITION BY CHAMFERING THICKER PART

CENTERLINE ALIGNMENT
(PARTICULARLY APPLICABLE TO WEB PLATES)

OFFSET ALIGNMENT
(PARTICULARLY APPLICABLE TO FLANGE PLATES)

General Notes:

- Groove may be of any allowed or qualified type and detail.
- Transition slopes shown are the maximum allowed.

Figure 2.7—Transition of Thickness at Butt Joints of Parts Having Unequal Thickness (see 2.17.5.1)

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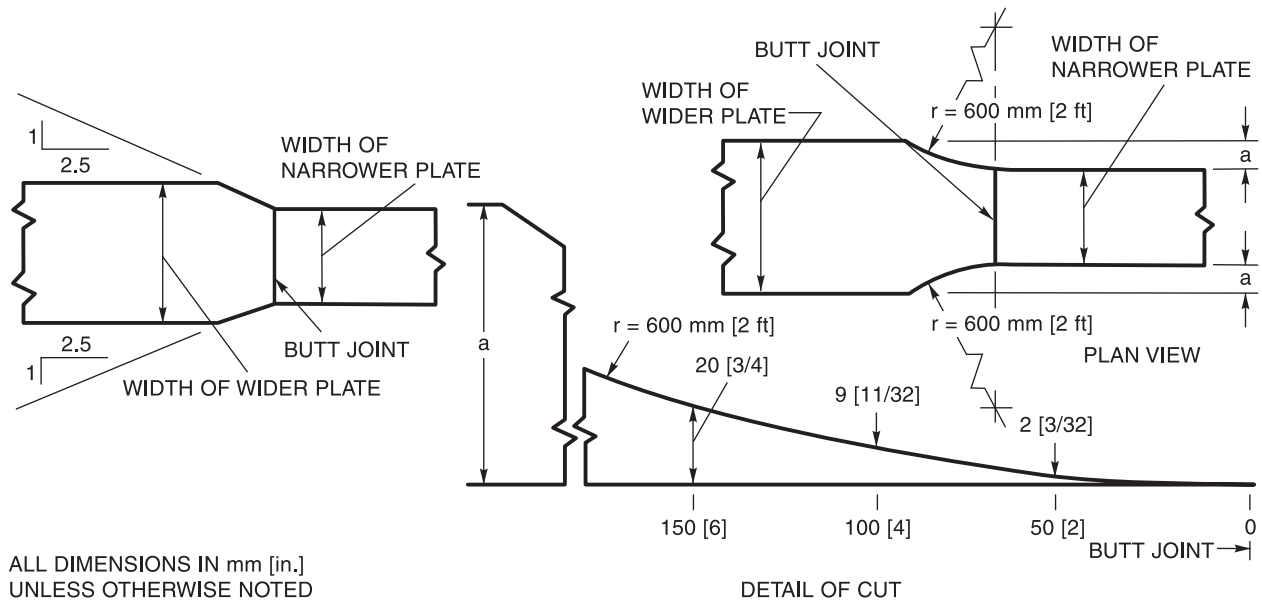


Figure 2.8—Transition of Width at Butt Joints of Parts Having Unequal Width (see 2.17.5.3)

transverse plane. Shop splices of webs and flanges in built-up girders, made before the webs and flanges are joined to each other, may be located in a single transverse plane or multiple transverse planes, but the fatigue stress provisions of the AASHTO specifications shall apply.

2.17.6.3 Noncontinuous Beams. The connections at the ends of noncontinuous beams shall be designed with flexibility so as to avoid excessive secondary stresses due to bending. Seated connections with a flexible or guiding device to prevent end twisting are recommended.