

AWS D1.6/D1.6M:2017-AMD1
An American National Standard

Structural Welding Code— Stainless Steel



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Structural Welding Code— Stainless Steel

3rd Edition

Supersedes AWS D1.6/D1.6M:2007

Prepared by the
American Welding Society (AWS) D1 Committee on Structural Welding

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This code covers the requirements for welding stainless steel structural assemblies.



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Foreword

This foreword is not part of this standard but is included for informational purposes only.

This is the third edition of the AWS D1.6, *Structural Welding Code—Stainless Steel*; the first edition was published in 1999. This code is the product of a pool of experts arriving at a consensus position, in keeping with the American National Standard Institute's requirements.

This code covers the requirements for welding stainless steel components other than pressure vessels or pressure piping. For many years, fabrications involving structural stainless steel welding used AWS D1.1/D1.1M, *Structural Welding Code—Steel*, to provide the requirements for quality construction. However, as the AWS D1.1 document is written for the carbon and low-alloy steels commonly encountered in structural fabrication, it does not explicitly address the unique requirements of stainless steels. The AWS Structural Welding Committee thus recognized the industry need for an AWS D1.1 analogue designed for the welding of stainless steel wrought and cast shapes and plates.

Changes in Code Requirements. Underlined text in the clauses, subclauses, tables, figures, or forms indicates a change from the 2007 edition. A vertical line in the margin of a table or figure also indicates a change from the 2007 edition.

The following is a list of the most significant revisions in the 2017 edition:

Summary of Changes	
Clause/Table/Figure/Annex	Modification
Clause 1	Restructured to identify a summary of the code clauses, new safety and health information, and code limitations.
Clause 2	This is a new clause listing normative references. It replaces subclause 1.9 and Annex G from the previous edition.
Clause 3	This is a new clause that provides terms and definitions specific to this standard. It replaces subclause 1.3 and Annex G from the previous edition.
Clause 4	Clause 4 was presented as Clause 2 in the previous edition. Reorganized and updated to better parallel AWS D1.1/D1.1M, <i>Structural Welding Code—Steel</i> , where appropriate, and now also references AISC/SCI <i>Design Guide 27: Structural Stainless Steel</i> .
Clauses 5 and 7	Clause 5 was presented as Clause 3 in the previous edition. Clause 7 was presented as Clause 5 in the previous edition. Both clauses had many misplaced subclauses and requirements (some fabrication requirements were in the prequalification clause and vice versa); content has been placed in the appropriate clause. Flare-V and flare-bevel-groove welded prequalified joint details have been included to address a need for these and some interpretations, and to parallel AWS D1.1/D1.1M, <i>Structural Welding Code—Steel</i> . These clauses are now restructured to follow the standard D1 code format and provide a more logical flow.
Clause 6	Clause 6 was presented as Clause 4 in the previous edition. This clause has been rewritten and now allows qualification directly to AWS B2.1/B2.1M, <i>Specification for Welding Procedure and Performance Qualification</i> , without approval from the Engineer, all while retaining D1.6 code qualification requirements if the Contractor decides to utilize these.
Clause 8	Clause 8 was presented as Clause 6 in the previous edition. Revisions include placing all visual Inspector and NDE personnel qualification requirements together for ease of use. Visual inspection acceptance criteria were removed from the text and placed in a new Table 8.1, similar to AWS D1.1/D1.1M, <i>Structural Welding Code—Steel</i> . Several errata items were incorporated and new commentary words were inserted that were taken directly from D1.1.

(Continued)

Summary of Changes (Continued)

Clause/Table/Figure/Annex	Modification
	Annex E from the previous edition was deleted as most of its content was moved to Clause 8. Some content from Annexes H and O of the previous edition was moved into Clause 8.
Clause 9	Clause 9 was presented as Clause 7 in the previous edition. Revised to identify numerous improvements already addressed by AWS D1.1/D1.1M, <i>Structural Welding Code—Steel</i> and AASHTO/AWS D1.5M/D1.5, <i>Bridge Welding Code</i> . The manufacturers' stud base qualification testing in Annex D from the previous edition was moved into Clause 9, similar to D1.1.
Annexes A and B	Revised to parallel AWS D1.1/D1.1M, <i>Structural Welding Code—Steel</i> , and to correct terms of fillet weld size to align with the correct usage in AWS A3.0M/A3.0, <i>Standard Terms and Definitions</i> , and A2.4, <i>Standard Symbols for Welding, Brazing, and Nondestructive Examination</i> .
Annex E	This is a new annex listing informative references.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS D1 Committee on Structural Welding, American Welding Society, 8669 NW 36 St, #130, Doral, FL 33166.

Amendments

The following amendments have been identified and are incorporated in this reprint.

AWS Standard: D1.6/D1.6M:2017-AMD1
Amendment Number: 1
Subject: Subclause 5.7.1(4)
Revision: Delete subclause 5.7.1(4)

5.7.1 In addition to the requirements of Tables 5.1 and 5.4, the following requirements shall also apply to all PWPSs:

(1) The classification and size of electrode, voltage, amperage, travel speed, and gas flow rate shall be suited to the thickness of the material, type of groove, and welding position.

(2) The progression for all passes in vertical position welding shall be upward, except that GTAW, GMAW-S, and FCAW-G are prequalified vertical down for base metal of 3/16 in [5 mm] maximum thickness. Undercut may be repaired vertically downwards on the joint faces only, by any prequalified welding process listed in 5.2.1, without base metal thickness limitation, within the limits of Table 8.1.

(3) Neither the depth nor the maximum width in the cross section of weld metal deposited in each weld pass shall exceed the width at the surface of that weld pass (see Figure 5.6). The Engineer may waive this requirement if test welds are made using PWPS variables to demonstrate that crack-free welds can be produced. Production welding shall be performed using these PWPS variables, including the same filler metal and flux trade designation.

~~(4) Prequalified GMAW in the spray transfer mode is limited to welds in the flat position and fillet welds in the horizontal position.~~

(5) Weld tabs shall be of any base metal group in Table 5.2.

(6) Steel for backing shall be of the same base metal group per Table 5.2 as the base metal, unless otherwise approved by the Engineer.

AWS Standard: D1.6/D1.6M:2017-AMD1

Amendment Number: 1

Subject: Table 6.3

Revision: In the Base Metal Thickness Qualified column, change “1/16 [2]” to “1/16 [1.5].”

Table 6.3
PQR Type, Number of Test Specimens, and Range of Thickness Qualified for Procedure Qualification (see 6.4.1, 6.6.1, 6.7.1, 6.7.2, and 6.8.1)

(A) Groove Welds								
Test Weldment Thickness (T), in [mm] ^{d,f,g}	Base Metal Thickness Qualified ^{c,d,e}		Deposited Weld Metal Thickness Qualified (t) ^d	Type and Number of Tests Required				
	Min. in [mm]	Max. in [mm]		Macroetch for Weld Size [S] ^a	Tension	Side Bend	Face Bend	Root Bend
1/16 to 3/8 [1.5 to 10]	1/16 [1.5]	2T	2t	3	2	(Note b)	2 ^b	2 ^b
Over 3/8 [10], but less than 3/4 [19]	3/16 [5]	2T	2t	3	2	4	—	—
3/4 [19] to less than 1-1/2 [38]	3/16 [5]	2T	2t when t < 3/4 [19] 2T when t ≥ 3/4 [19]	3	2	4		
1-1/2 [38] to less than 6 [152]	3/16 [5]	8 [203]	2t when t < 3/4 [19] 8 [203] when t ≥ 3/4 [19]	3	2	4		
6 [152] and over	1 [25]	1.33T	2t when t < 3/4 [19] 8 [203] when 3/4 [19] ≤ t < 6 [152] 1.33t when t ≥ 6 [152]	3	2	4		

^a Partial joint penetration groove welds only.^b For 3/8 in [10 mm] plate or wall thickness, a side bend test may be substituted for each of the required face- and root-bend tests.^c All pipe/tube diameters qualified, all fillet sizes qualified on all base metal thicknesses and all diameters.^d For GMAW-S, the maximum thickness of base metal qualified is 1.1 times the thickness of the test weldment until the test weldment thickness is 1/2 in [13 mm], beyond which Table 6.3 applies. The maximum weld metal thickness qualified is 1.1 times the GMAW-S weld metal thickness deposited in the weldment. In addition, for thickness 3/8 in [10 mm] thick and greater, side bend tests shall be used to qualify GMAW-S short circuit WPSs.^e For fracture toughness applications less than 5/8 in [16 mm] thick, the base metal thickness of the test weldment is the minimum base metal thickness qualified.^f If any single pass in the test weldment is greater in thickness than 1/2 in [13 mm], the qualified base metal thickness is 1.1 times the test weldment thickness.^g For test weldments in austenitic, ferritic, or martensitic stainless steel base metals using austenitic stainless steel filler metal, the maximum qualified thicknesses are per Table 6.3 for postweld heat treatment (PWHT) below 1000°F [538°C]. For test weldment in these same base metals welded with other than austenitic stainless steel filler metal, the maximum qualified base metal and deposited weld metal thicknesses are 1.1 times the thicknesses of the test coupon for PWHT of 1000°F [538°C] or higher.

(B) Fillet Welds (see 6.8.1)

Test Specimen ^h	Fillet Weld Size	Macroetch Test Specimens Required ^k (6.9.3.4)	Sizes Qualified	
			Plate/Pipe Thickness ⁱ	Fillet Weld Size
Plate T-test (Figure 6.4)	Single pass, max size to be used in construction	3 faces	Unlimited	Max. tested single pass and smaller
	Multiple pass, min size to be used in construction	3 faces	Unlimited	Min. tested multiple pass and larger
Pipe T-test ^j (Figure 6.4)	Single pass, max size to be used in construction	3 faces (except for 4F and 5F, 4 faces required)	Unlimited	Max. tested single pass and smaller
	Multiple pass, min size to be used in construction	3 faces (except for 4F and 5F, 4 faces required)	Unlimited	Min. tested multiple pass and larger

^h All welded test pipes and plates shall be visually examined per 6.9.3.1.ⁱ The minimum thickness qualified is 1/16 in [2 mm].^j All pipe/tube diameters are qualified.^k See 6.8.1.2 and 6.10.3 for alternate fillet weld bend-break test.

Errata

The following errata have been identified and are incorporated into this reprint.

Page 39, Figure 5.3 (inches), Joint Designation BC-P2: Replace “GMAW” with “GTAW”

Page 40, Figure 5.3 (inches), Joint Designation BTC-P4: Replace “GMAW” with “GTAW”

Page 43, Figure 5.3 (inches), Joint Designation BTC-P9: Replace “ $r = T/2^a$ ” with “ $r = T/2^b$ ”

Page 43, Figure 5.3 (inches), Joint Designation BTC-P9-GF: Replace “BTC-P9-GF^a” with “BTC-P9-GF^b”

Page 47, Figure 5.3 (millimeters), Joint Designation BC-P2: Replace “GMAW” with “GTAW”

Page 48, Figure 5.3 (millimeters), Joint Designation BTC-P4: Replace “GMAW” with “GTAW”

Page 55, Figure 5.4 (inches), Joint Designations B-U2 and B-L2, move the horizontal line for the Joint Designation and Base Metal Thickness columns slightly up to fall in between the two lines on the right:

B-U2	U	—
B-L2	2 max.	—

Page 55, Figure 5.4 (inches), Insert table footnote: “^a Limited by a minimum groove depth.”

Page 61, Figure 5.4 (inches), Joint Designation B-L6, Tolerances column, As Detailed column: replace “ $R = +T/2 \leq 1/8, -0$ ” with “ $r = +T/2 \leq 1/8, -0$ ”

Page 61, Figure 5.4 (inches), Joint Designation B-U6, Tolerances column, As Detailed column: replace “ $r = +T/4 \leq 1/16, -0$ ” with “ $R = +T/4 \leq 1/16, -0$ ”

Page 62, Figure 5.4 (inches), Joint Designation B-U7, Tolerances column, As Detailed column: replace “ $R = +T/2 \leq 1/4, -0$ ” with “ $r = +T/2 \leq 1/4, -0$ ”

Page 66, Figure 5.4 (millimeters), Insert table footnote: “^a Limited by a minimum groove depth.”

Page 72, Figure 5.4 (millimeters), Joint Designation B-L6, Tolerances column, As Detailed column: replace “ $R = T/2 \leq 3, -0$ ” with “ $r = T/2 \leq 3, -0$ ”

Page 72, Figure 5.4 (millimeters), Joint Designation B-U6, Tolerances column, As Detailed column: replace “ $r = T/4 \leq 2, -0$ ” with “ $R = T/4 \leq 2, -0$ ”

Page 73, Figure 5.4 (millimeters), Joint Designation B-U7, Tolerances column, As Detailed column: replace “ $R = +T/2 \leq 6, -0$ ” with “ $r = +T/2 \leq 6, -0$ ”

Page 233, Table D.1 – the suggested filler metal for 202 and 304 should be 308, not 3080.

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List of Prequalified Partial Joint Penetration (PJP) Groove Weld Joint Details—Nontubular for Figure 5.3

<u>Joint Detail Designation</u>	<u>Page No. (Dimensions in inches)</u>	<u>Page No. (Dimensions in millimeters)</u>
B-P1a	38	46
B-P1b	38	46
B-P1c	38	46
BC-P2	39	47
BC-P2-GS	39	47
BC-P2-GF	39	47
B-P3	39	47
B-P3-GF	39	47
B-P3-GS	39	47
BTC-P4	40	48
BTC-P4-GF	40	48
TC-P4-GS	40	48
BTC-P5	40	48
BTC-P5-G	40	48
BTC-P5-F	40	48
TC-P5-GS	40	48
BC-P6	41	49
BC-P6-F	41	49
BC-P6-GS	41	49
B-P7	41	49
B-P7-F	41	49
B-P7-GS	41	49
TC-P8	42	50
BC-P8	42	50
TC-P8-F	42	50
BC-P8-F	42	50
TC-P8-GS	42	50
C-P8-GS	42	50
BTC-P9	43	51
BTC-P9-GF	43	51
BTC-P9a-GF	43	51
C-P9-S	43	51
C-P9-GFS	43	51
T-P9-S	43	51
BTC-P10	44	52
BTC-P10-GF	44	52
B-P10-S	44	52
B-P11	45	53
B-P11-GF	45	53
B-P11-S	45	53

List of Prequalified Complete Joint Penetration (CJP) Groove Weld Joint Details—Nontubular for Figure 5.4

<u>Joint Detail Designation</u>	<u>Page No. (Dimensions in inches)</u>	<u>Page No. (Dimensions in millimeters)</u>
B-L1a	54	65
C-L1a	54	65
B-L1a-F	54	65
B-L1-S	54	65
B-L1b	54	65
B-L1b-F	54	65
B-L1b-G	54	65
B-L1-S	54	65
B-L1a-S	54	65
TC-L1b	55	66
TC-L1-GF	55	66
TC-L1-S	55	66
B-U2	55	66
B-L2	55	66
B-U2-GF	55	66
B-L2c-S	55	66
B-U2a	56	67
B-L2a	56	67
B-U2a-GF	56	67
B-L2a-S	56	67
B-U2-S	56	67
B-L2b	56	67
C-U2a	57	68
C-L2a	57	68
C-U2a-GF	57	68
C-L2a-S	57	68
C-U2-S	57	68
B-U3b	57	68
B-L3b	57	68
B-U3-GF	57	68
B-U3c-S	57	68
B-U4a	58	69
B-L4a	58	69
B-U4a-GF	58	69
B-U4a-S	58	69
TC-U4a	58	69
TC-L4a	58	69
TC-U4a-GF	58	69
TC-U4a-S	58	69
B-U4b	59	70
B-L4b	59	70
B-U4b-GF	59	70
B-U4b-S	59	70
TC-U4b	59	70
TC-L4b	59	70

List of Prequalified Complete Joint Penetration (CJP) Groove Weld Joint Details—Nontubular for Figure 5.4

<u>Joint Detail Designation</u>	<u>Page No. (Dimensions in inches)</u>	<u>Page No. (Dimensions in millimeters)</u>
TC-U4b-GF	59	70
TC-U4b-S	59	70
B-U5a	60	71
B-L5a	60	71
B-U5-F	60	71
TC-U5b	60	71
TC-L5b	60	71
TC-U5-F	60	71
TC-U5-S	60	71
B-L6	61	72
B-U6	61	72
C-U6	61	72
B-U6-GF	61	72
C-U6-GF	61	72
BC-U6-S	61	72
B-U7	62	73
B-U7-GF	62	73
BC-U7-S	62	73
B-U8	62	73
B-L8	62	73
B-U8-GF	62	73
B-U8-S	62	73
TC-U8a	63	74
TC-L8a	63	74
TC-U8a-GF	63	74
TC-U8a-S	63	74
B-U9	63	74
B-L9	63	74
B-U9-GF	63	74
TC-U9a	64	75
TC-L9a	64	75
TC-U9a-GF	64	75

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Structural Welding Code—Stainless Steel

1. General Requirements

1.1 Scope

This code contains welding requirements for the fabrication, assembly, and erection of welded structures and weldments subject to design stress where at least one of the materials being joined is stainless steel. The code is intended to be used for base metals with a minimum thickness of 1/16 in [1.5 mm] or 16 gage. It shall be used in conjunction with any complementary code or specification for the design or construction of stainless steel structures and weldments. When this code is stipulated in contract documents, conformance with all provisions of the code shall be required, except for those provisions that the Engineer (see 1.5.1) or contract documents specifically modify or exempt.

The following is a summary of the code clauses:

- (1) **General Requirements.** This clause contains basic information on the scope and limitations of the code, key definitions, and the major responsibilities of the parties involved with stainless steel fabrication.
- (2) **Normative References.** This clause contains a list of reference documents that assist the user in implementation of this code or are required for implementation.
- (3) **Terms and Definitions.** This clause contains terms and definitions as they relate to this code.
- (4) **Design of Welded Connections.** This clause contains requirements for the design of welded connections.
- (5) **Prequalification.** This clause contains the requirements for exempting a Welding Procedure Specification (WPS) from qualification by testing.
- (6) **Qualification.** This clause contains the requirements for qualification of WPSs and welding personnel (welders and welding operators) by testing, including the tests required and the ranges qualified.
- (7) **Fabrication.** This clause contains welding requirements for fabrication, assembly, and erection of welded stainless steel structures governed by this code, including the requirements for base metals, welding consumables, welding technique, weld details, material preparation and assembly, workmanship, weld repair, and other requirements.
- (8) **Inspection.** This clause contains the requirements for the Inspector's qualifications and responsibilities, acceptance criteria for discontinuities, and procedures for nondestructive testing (NDT).
- (9) **Stud Welding.** This clause contains the requirements for welding of studs to structures where at least one of the materials being joined is stainless steel.

1.2 Units of Measurement

This standard makes use of both U.S. Customary Units and the International System of Units (SI). The latter are shown within brackets ([]) or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system must be used independently.

1.3 Safety

Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein.

Safety and health information is available from the following sources:

American Welding Society

- (1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*
- (2) AWS Safety and Health Fact Sheets
- (3) Other safety and health information on the AWS Website

Material or Equipment Manufacturers:

- (1) Safety Data Sheets supplied by materials manufacturers
- (2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies.

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

1.4 Limitations

This code does not apply to:

- (1) Stainless steel structures that utilize base metals thinner than 1/16 in [1.5 mm] or 16 gage
- (2) Pressure vessels
- (3) Pressure piping

The suitability of this code for applications beyond the scope described herein is subject to approval of the Engineer. The Engineer shall incorporate into the contract documents any necessary changes determined by evaluation of the suitability of the code for the application.

The Structural Welding Committee encourages the Engineer to consider the applicability of other AWS D1 codes for applications involving carbon and low-alloy steels (AWS D1.1), aluminum (AWS D1.2), sheet steel equal to or less than 3/16 in [5 mm] thick (AWS D1.3), and reinforcing steel (AWS D1.4). The AASHTO/AWS D1.5, *Bridge Welding Code*, was specifically developed for welding highway bridge components and is recommended for those applications.

1.4.1 The base metals to be welded under this code shall be stainless steels with the following chemical composition limits:

- (1) Chromium (Cr) content equal to or greater than 10.5%
- (2) Carbon (C) content equal to or less than 0.5%
- (3) Iron (Fe) content exceeding the content of any other single element

Free machining steels and steels with intentional additions of sulfur (S), selenium (Se), or lead (Pb) shall not be welded.

This code also governs the welding of structural assemblies whose members include any combination of the stainless steels in 1.4.2 or any of these stainless steels welded to weldable carbon or low-alloy steels.

1.4.2 Stainless steel base metals may include alloys from any of the following categories:

- (1) Austenitic
- (2) Ferritic

- (3) Martensitic
- (4) Precipitation Hardening (austenitic, semi-austenitic, and martensitic)
- (5) Duplex

1.4.3 The stainless steel base metals may be in any of the following product forms:

- (1) Sheet—cold rolled
- (2) Sheet, plate—hot rolled
- (3) Shapes
- (4) Tubular products
- (5) Clad materials
- (6) Castings
- (7) Forgings

1.4.4 Stainless steels are generally identified by American Iron and Steel Institute (AISI) identifications, Unified Numbering System (UNS) numbers, or by ASTM International specifications. Newer proprietary steels may not be covered by standards and shall be identified by chemical composition or other suitable means which clearly define the steel.

1.4.5 Specified Base Metal. The contract documents shall designate the base metal to be used.

1.4.6 Service Temperature Limits. The contract documents shall specify service temperature limits for the weldment or structure.

1.4.7 Base Metal Prequalification. Austenitic stainless steels that are welded with filler metals that normally produce a small amount of ferrite (see Table 5.2 for prequalified base materials) shall be considered prequalified, provided they are welded with filler metals in accordance with Table 5.3, and the WPSs used conform to all the applicable requirements of Clause 5. WPSs for all other base metals and filler metals (except as permitted in 1.4.8.1), and WPSs that are not prequalified, shall be qualified in conformance to Clause 6. Suggested filler metals for welding many stainless steels to themselves, or to other stainless steels, carbon steels, or low-alloy steels are shown in Annex D.

1.4.8 Use of Unlisted Base Metals. When a stainless steel other than one of those listed in Table 5.2 is proposed for welded construction under this code, WPSs shall be qualified in accordance with the requirements of Clause 6, except as permitted in 1.4.8.1. The Contractor shall have the responsibility for establishing the WPS by qualification.

1.4.8.1 An unlisted base metal that has similar chemical composition and specified minimum ultimate tensile strength as a listed steel may be welded with a prequalified or qualified WPS for the listed steel, with the approval of the Engineer.

1.4.8.2 Weldability Tests. The Engineer may prescribe additional weldability testing of the unlisted steel. The responsibility for determining weldability is assigned to the party who either specifies a material not listed in Table 5.2, except as permitted by 1.4.8.1, or who proposes the use of a substitute material not listed in Table 5.2.

1.5 Responsibilities

1.5.1 Engineer's Responsibilities. The Engineer (see Clause 3) shall be responsible for the development of the contract documents that govern products or structural assemblies produced under this code. The Engineer may add to, delete from, or otherwise modify the requirements of this code to meet the particular requirements of a specific structure. If alternate requirements are proposed by other parties such as the Contractor, the Engineer may approve them based on provided documentation. Alternate requirements shall be based upon evaluation of suitability for service using past experience, experimental evidence or engineering analysis considering material type, service load effects, and environmental factors. All requirements that modify this code shall be incorporated into contract documents. The Engineer shall determine the suitability of all joint details to be used in a welded assembly.

The Engineer shall specify in contract documents, as necessary and as applicable, the following:

- (1) Optional requirements that are applicable only when specified by the Engineer.
- (2) All additional NDT that is not specifically addressed in the code.
- (3) Verification inspection, when required by the Engineer.
- (4) Weld acceptance criteria other than that specified in Clause 8 (including criteria for other types/grades of stainless steels in 8.7).
- (5) CVN toughness criteria for weld metal, base metal, and/or HAZ.
- (6) All serviceability testing, including but not limited to tests for corrosion resistance, carbide sensitization, and creep. Standards for test methods and acceptance criteria shall be specified in the contract documents.
- (7) Whether the structure is statically or cyclically loaded.
- (8) All additional requirements that are not specifically addressed in the code.
- (9) For OEM applications, the responsibilities of the parties involved.
- (10) Service Temperature Limits (see 1.4.6).
- (11) Weldability Tests (see 1.4.8.2).

1.5.2 Contractor's Responsibilities. The Contractor (see Clause 3) shall be responsible for WPSs, qualification of welding personnel, the Contractor's inspection, and performing work in conformance with the requirements of this code and contract documents. The Contractor may submit to the Engineer requests to modify the requirements of this code to suit particular conditions related to feasibility and quality of a specific structure.

1.5.3 Inspector's Responsibilities

1.5.3.1 Contractor's Inspection. Contractor's inspection (see Clause 3) shall be supplied by the Contractor and shall be performed as necessary to ensure that materials and workmanship meet the requirements of the contract documents.

1.5.3.2 Verification Inspection. The Engineer shall determine if Verification Inspection (see Clause 3) shall be performed. Responsibilities for Verification Inspection shall be established between the Engineer and the Verification Inspector.

1.6 Approval

All references to the need for approval shall be interpreted to mean approval by the Authority Having Jurisdiction or the Engineer.

1.7 Welding Symbols

Welding symbols shall be those shown in AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*. Special conditions shall be fully explained by added notes or details.

2. Normative References

The documents listed below are referenced within this publication and are mandatory to the extent specified herein. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. A list of informative documents referenced in this code is included in Annex E.

American Welding Society (AWS) standards:

AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*

AWS A4.2M (ISO 8249:2000 MOD), *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*

AWS A5.1/A5.1M, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*

AWS A5.4/A5.4M, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*

AWS A5.5/A5.5M, *Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*

AWS A5.9/A5.9M, *Specification for Bare Stainless Steel Welding Electrodes and Rods*

AWS A5.11/A5.11M, *Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding*

AWS A5.12M/A5.12 (ISO 6848:2004 MOD), *Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting*

AWS A5.14/A5.14M, *Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods*

AWS A5.18/A5.18M, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*

AWS A5.22/A5.22M, *Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods*

AWS A5.28/A5.28M, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*

AWS A5.30/A5.30M, *Specification for Consumable Inserts*

AWS A5.32M/A5.32 (ISO 14175:2008 MOD), *Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*

AWS A5.34/A5.34M, *Specification for Nickel-Alloy Electrodes for Flux Cored Arc Welding*

AWS A5.36/A5.36M, *Specification for Carbon and Low-Alloy Steel Flux Cored Electrodes for Flux Cored Arc Welding and Metal Cored Electrodes for Gas Metal Arc Welding*

AWS B2.1/B2.1M, *Specification for Welding Procedure and Performance Qualification*

AWS B2.1-X-XXX, *Series on Standard Welding Procedure Specifications*

AWS B4.0, *Standard Methods for Mechanical Testing of Welds*

AWS D1.1/D1.1M, *Structural Welding Code—Steel*

AWS QC1, *Standard for AWS Certification of Welding Inspectors*

ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

American Institute of Steel Construction (AISC) standard:

AISC Design Guide 27: *Structural Stainless Steel*, AISC

American Society for Nondestructive Testing (ASNT) standard:

ASNT, *Recommended Practice No. SNT-TC-1A: Personnel Qualification and Certification in Nondestructive Testing*

ASTM International standards:

Specific ASTM base metal specifications are listed in Table 5.2 (or Clause 9 for stud materials).

ASTM A370, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

ASTM A1022/A1022M, *Standard Specification for Deformed and Plain Stainless Steel Wire and Welded Wire for Concrete Reinforcement*

ASTM E23, *Standard Test Methods for Notched Bar Impact Testing of Metallic Materials*

ASTM E94, *Standard Guide for Radiographic Examination*

ASTM E165, *Standard Practice for Liquid Penetrant Examination for General Industry*

ASTM E709, *Standard Guide for Magnetic Particle Testing*

ASTM E747, *Standard Practice for Design, Manufacture, and Material Grouping Classification of Wire Image Quality Indicators (IQI) Used for Radiology*

ASTM E1025, *Standard Practice for Design, Manufacture, and Material Grouping Classification of Hole-Type Image Quality Indicators (IQI) Used for Radiology*

ASTM E1032, *Standard Test Method for Radiographic Examination of Weldments*

ASME International (ASME) standard:

ASME Boiler & Pressure Vessel Code. Section V, *Nondestructive Examination*

CSA Group (CSA) standard:

W178.2, *Certification of Welding Inspectors*

3. Terms and Definitions

The welding terms used in this code shall be interpreted in conformance with the definitions given in AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*. The terms and definitions in this clause are defined by the AWS Structural Welding Committee as they relate to this code. Terms and definitions that apply only to ultrasonic testing or radiographic testing are designated by *ultrasonic testing* or *radiographic testing* following the term. For the purposes of this document, the following terms and definitions apply:

attenuation, *ultrasonic testing*. Loss of sound intensity as the sound travels through the material.

Authority Having Jurisdiction. The organization, political subdivision, office, or individual charged with the administration and enforcement of this standard.

Contractor. Any company, or that individual representing a company, responsible for the fabrication, erection, assembly, manufacturing, or welding, in conformance with the provisions of this code.

decibel (dB), *ultrasonic testing*. The logarithmic expression of a ratio of two amplitudes or intensities of acoustic energy.

$$dB = 10 \log_{10}(P_1/P_2)$$
, where P_1 and P_2 are two considered levels of energy.

drawings. Design and detail drawings, and assembly or erection plans.

Engineer. The designated individual who acts for, and in behalf of, the Owner on all matters within the scope of the code.

fatigue. The damage that may result in fracture after a sufficient number of stress fluctuations. Stress range is defined as the peak-to-trough magnitude of these fluctuations. In the case of stress reversal, stress range shall be computed as the numerical sum (algebraic difference) of maximum repeated tensile and compressive stresses, or the sum of shearing stresses of opposite direction at a given point, resulting from changing conditions of load.

fusion-type discontinuity. Signifies slag inclusion, incomplete fusion, incomplete joint penetration, and similar discontinuities associated with fusion.

geometric unsharpness, *radiographic testing*. The fuzziness or lack of definition in a radiographic image resulting from the source size, object-to-film distance, and source-to-object distance. Geometric unsharpness may be expressed mathematically as:

$$U_g = F(L_i - L_o) / L_o$$

Where U_g is the geometric unsharpness, F is the size of the focal spot or gamma radiation, L_i is the source-to-film distance, and L_o is the source-to-object distance.

image quality indicator (IQI), *radiographic testing*. A device whose image in a radiograph is used to determine radiographic quality level.

indication, *ultrasonic testing*. The signal displayed on the instrument signifying the presence of a sound wave reflector in the part being tested.

indication level, *ultrasonic testing*. The calibrated gain or attenuation control reading obtained for a reference distance amplitude correction (DAC) line height indication from a discontinuity.

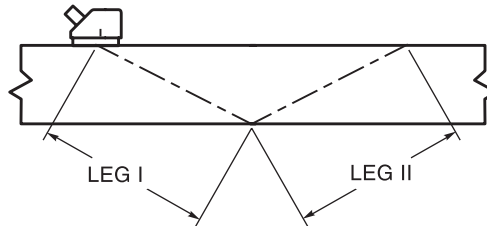
Inspector

- (1) **Contractor's Inspector**. The designated person who acts for, and on behalf of, the Contractor on all inspection and quality matters within the scope of the code and of the contract documents.
- (2) **Verification Inspector**. The designated person who acts for, and on behalf of, the Owner or Engineer on all inspection and quality matters specified by the Engineer.

(3) Inspector(s). When the term “Inspector” is used without further qualification as to the specific Inspector category described above, it applies equally to the Contractor’s Inspector and the Verification Inspector within the limits of responsibility described in 8.1.3.

leg, *ultrasonic testing*. The path the shear wave travels in a straight line before being reflected by the surface of material being tested. See sketch for leg identification.

NOTE: Leg I plus leg II equals one V-path.



node, *ultrasonic testing*. See leg.

nondestructive testing (NDT). The process of determining acceptability of a material or a component in accordance with established criteria without impairing its future usefulness.

Original Equipment Manufacturer (OEM). The single Contractor that assumes some or all of the responsibilities assigned by this code to the Engineer.

Owner. The individual or company that exercises legal ownership of the product or structural assembly produced under this code.

pipe. Tubular-shaped product of circular cross section. See tubular.

postweld heat treatment. Any heat treatment after welding.

reference level, *ultrasonic testing*. The decibel reading obtained for a horizontal reference-line height indication from a reference reflector.

reference reflector, *ultrasonic testing*. The reflector of known geometry contained in the IIW reference block or other approved blocks.

resolution, *ultrasonic testing*. The ability of ultrasonic equipment to give separate indications from closely spaced reflectors.

code terms “Shall,” “Should,” and “May”

shall. Code provisions that use “shall” are mandatory unless specifically modified in contract documents by the Engineer.

should. The word “should” is used to recommend practices that are considered beneficial, but are not requirements.

may. The word “may” in a provision allows the use of optional procedures or practices that can be used as an alternative or supplement to code requirements. Those optional procedures that require the Engineer’s approval shall either be specified in the contract documents or require the Engineer’s approval. The Contractor may use any option without the Engineer’s approval when the code does not specify that the Engineer’s approval shall be required.

sound path distance, *ultrasonic testing*. The distance between the search unit test material interface and the reflector as measured along the centerline of the sound beam.

stud base. The stud tip at the welding end, including flux and container, and 1/8 in [3 mm] of the body of the stud adjacent to the tip.

tubular. A generic term that refers to sections including pipe products (see pipe) and the family of square, rectangular, and round hollow-section products produced or manufactured in accordance with a tubular product specification. Also referred to as hollow structural section (HSS).

tubular connection. A connection in the portion of a structure that contains two or more intersecting members, at least one of which is a tubular member.

4. Design of Welded Connections

Part A *General Requirements*

4.0 General

Stainless steel welded connections shall be designed to meet the loading requirements. The Engineer shall also consider other factors that might affect the suitability for service of the stainless steel structure, including, but not limited to, corrosion resistance, carbide sensitization, and creep. The provisions of AISC Design Guide 27: *Structural Stainless Steel* and of SEI/ASCE 8-02, *Specification for the Design of Cold-Formed Stainless Steel Structural Members*, may be applied in addition to the provisions of this code:

- (1) *Corrosion.* Necessary design adjustments shall be made, such as appropriate selection of base and filler metals and application of seal welds.
- (2) *Elevated Temperature.* For elevated service temperatures, a decrease in short-term and creep strengths of base and filler metals shall be considered.
- (3) *Heat Treatment.* Where necessary, heat treatment shall be prescribed.
- (4) *Dissimilar Connections.* The Engineer shall not design welded connections of an austenitic stainless steel member to a ferritic stainless steel, martensitic stainless steel or a carbon/low-alloy steel member without due consideration of a judicious choice of filler metal based on metallurgical criteria.
- (5) Other factors not mentioned herein, that could adversely affect the welded connection, shall be taken into account.

4.1 Contract Plans and Specifications

4.1.1 Plan and Drawing Information. Complete information regarding base metal specification designation, location, type, size, and extent of all welds shall be clearly shown on the contract plans and specifications, hereinafter referred to as the contract documents. If the Engineer requires specific welds to be performed in the field, they shall be designated in the contract documents. The fabrication and erection drawings, hereinafter referred to as the shop drawings, shall clearly distinguish between shop and field welds.

4.1.2 Notch Toughness Requirements. If notch toughness of welded joints is required, the Engineer shall specify the minimum absorbed energy with the corresponding test temperature for the filler metal classification to be used, or the Engineer shall specify that the WPSs be qualified with CVN tests. If WPSs with CVN tests are required, the Engineer shall specify the minimum absorbed energy, the test temperature, and whether the required CVN test performance is to be in the weld metal, or both in the weld metal and the HAZ.

4.1.3 Specific Welding Requirements. The Engineer, in the contract documents, and the Contractor, in the shop drawings, shall indicate those joints or groups of joints for which the Engineer or Contractor require a specific assembly order, welding sequence, welding technique, or other special precautions.

4.1.4 Weld Size and Length. Contract design drawings shall specify the effective weld length and, for PJP groove welds, the required weld size “(S).” For fillet welds and skewed T-joints, the following shall be provided on the contract documents:

- (1) For fillet welds between parts with surfaces meeting at an angle between 80° and 100°, contract documents shall specify the fillet weld size.

(2) For welds between parts with the surfaces meeting at an angle less than 80° or greater than 100° , the contract documents shall specify the effective throat. End returns and hold-backs for fillet welds, if required by design, shall be indicated on the contract documents.

4.1.5 Shop Drawing Requirements. Shop drawings shall clearly indicate by welding symbols or sketches the details of groove welded joints and the preparation of base metal required to make them. Both width and thickness of steel backing shall be detailed.

4.1.5.1 PJP Groove Welds. Shop drawings shall indicate the weld groove depths “D” needed to attain the weld size “(S)” required for the welding process and position of welding to be used.

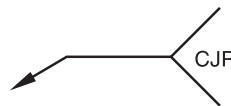
4.1.5.2 Fillet Welds and Welds in Skewed T-Joints. The following shall be provided on the shop drawings:

(1) For fillet welds between parts with surfaces meeting at an angle between 80° and 100° , shop drawings shall show the fillet weld size,

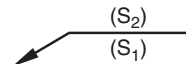
(2) For welds between parts with surfaces meeting at an angle less than 80° or greater than 100° , the shop drawings shall show the detailed arrangement of welds and required size to account for effects of joint geometry and, where appropriate, the Z-loss reduction for the process to be used and the angle,

(3) Shop drawings shall show end returns and hold backs.

4.1.5.3 Symbols. The contract documents shall show complete joint penetration (CJP) or partial joint penetration (PJP) groove weld requirements. Contract documents do not need to show the groove type or groove dimensions. The welding symbol without dimensions and with “CJP” in the tail designates a CJP weld as follows:



The welding symbol without dimension and without CJP in the tail designates a weld that will develop the adjacent base metal strength in tension and shear. A welding symbol for a PJP groove weld shall show dimensions enclosed in parentheses below “(S₁)” and/or above “(S₂)” the reference line to indicate the groove weld sizes on the arrow and other sides of the weld joint, respectively, as shown below:



4.1.5.4 Prequalified Detail Dimensions. The joint details described in Clause 5 have repeatedly demonstrated their adequacy in providing the conditions and clearances necessary for depositing and fusing sound weld metal to base metal. However, the use of these details shall not be interpreted as implying consideration of the effects of welding process on base metal beyond the fusion boundary nor suitability of the joint detail for a given application.

4.1.5.5 Special Details. When special groove details are required, they shall be detailed in the contract documents.

4.1.5.6 Specific Inspection Requirements. Any specific inspection requirements shall be noted on the contract documents.

4.2 Eccentricity of Connections

4.2.1 Intersecting Parts. Eccentricity between intersecting parts and members shall be avoided insofar as practicable.

4.2.2 Bending Stresses. Adequate provisions shall be made for bending stresses due to eccentricity resulting from the location and types of welds. 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.

4.2.3 Symmetry. 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 asymmetrical distribution of stresses.

4.2.4 Center of Gravity. For axially stressed angles, the center of gravity of the connecting welds shall 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 permitted by the contract specification.

4.3 Allowable Stresses

4.3.1 Allowable Base Metal Stresses. The allowable stresses for the base metals shall be as specified in the applicable contract specification.

4.3.2 Allowable Stresses in Welds. For allowable stresses in welds, see Table 4.1.

4.3.2.1 Fillet Welds and Welds in Skewed T-Joints. Stress on the effective area of fillet welds and of welds in skewed joints shall be considered as shear stress, regardless of the direction of application.

4.3.2.2 Intermittent Fillet Welds. Intermittent fillet welds may be used to carry calculated static stress.

4.3.2.3 Plug and Slot Welds. When used, plug and slot welds shall only transfer shear, prevent buckling, or prevent separation of lapped parts.

4.3.2.4 Bending Stresses. Fiber stresses due to bending shall not exceed the values prescribed for tension and compression.

4.3.2.5 Increased Allowable Stresses. Where permitted in the applicable design specification, the allowable stresses, as defined in 4.3, may be increased.

4.3.2.6 Allowable Stresses Established by Testing. Mechanical properties of joints and allowable stresses may be established by testing. These tests shall be agreed upon between the Engineer and Contractor (see Notes in Table 4.1 and Annex G, G2.2).

4.3.3 Fatigue Provisions. Fatigue stress provisions for structures subject to cyclic loading shall be determined by the Engineer and be included in the contract specification.

Contractual fatigue provisions shall be established by the Engineer based on, as applicable:

- (1) Data or considerations in AISC Design Guide 27.
- (2) Stainless steel fatigue provisions that are approved by the Engineer.
- (3) The environmental conditions such as fluids, temperatures, and atmospheres to which the structure will be subjected.
- (4) Conditions specific to thin-walled structures, such as load-induced distortion and local stress concentration. The hot spot stress approach may be considered to accommodate these conditions.
- (5) Consideration of the stress intensification effects of the weld details.
- (6) Fatigue performance of the applicable type and grade of stainless steels.

Part B

Weld Lengths and Areas

4.4 Effective Areas

4.4.1 Groove Welds

4.4.1.1 Effective Area. The effective area of groove welds shall be the effective length multiplied by the effective weld size.

4.4.1.2 Effective Weld Size

(1) For CJP groove welds, the effective weld size shall be the thickness of the thinner part joined. No weld size increase for weld reinforcement shall be allowed.

(2) For PJP groove welds, the effective weld size shall be as determined in 5.10 and 5.13 for joints with beveled edges and as determined in 4.4.1.2(4) for flare-groove welds. In order to establish larger weld sizes, qualification testing per 6.7.2.2 is required. No weld size increase for penetration into the joint root or for weld reinforcement shall be allowed (see Annex A).

(3) For PJP groove welds with reinforcing fillet welds, see 4.4.2.2(2) and 4.4.2.2(3).

(4) For flare-groove welds filled flush, the weld size shall be as shown in Table 4.2 (see Annex A).

4.4.1.3 Effective Length. The maximum effective length of any groove weld, regardless of orientation, shall be the width of the part joined perpendicular to the direction of tensile or compressive stress. For groove welds transmitting shear, the effective length is the length specified.

4.4.2 Fillet Welds, PJP Welds with Reinforcing Fillet Welds, and Welds in Skewed Joints

4.4.2.1 Effective Area. The effective area shall be the effective weld length multiplied by the effective throat [see also 4.4.2.3(2)].

4.4.2.2 Effective Throat

(1) For fillet welds, the effective throat shall be the shortest distance from the joint root to the weld face of the diagrammatic weld (see Annex A).

(2) For PJP groove welds with reinforcing fillet welds, the effective throat shall be the shortest distance from the joint root to the weld face of the diagrammatic weld minus 1/8 in [3 mm] for any groove detail requiring such deduction (see 5.10 and 5.13, Figure 5.3, and Annex A).

(3) For flare-bevel-groove welds with reinforcing fillet welds, the effective throat shall be the shortest distance from the joint root to the weld face of the diagrammatic weld minus the deduction for incomplete joint penetration (see Table 4.2 and Annex A).

(4) For skewed joints having angles between parts of 60° or more, the weld effective throat shall be the shortest distance from the joint root to the face of the diagrammatic weld as determined in Annex B. For angles less than 60°, the provisions of 4.16 shall apply.

4.4.2.3 Effective Lengths of Fillet Welds

(1) *Straight Welds.* The effective length of a fillet weld shall be the overall length of the weld, including end returns. No reduction in effective specified length shall be made for either the start or stop crater of the weld.

(2) *Curved Welds.* The effective length of a curved fillet weld shall be measured along the centerline of the effective throat. If the effective area of a fillet weld in a hole or slot calculated from this length is greater than the area calculated from 4.5.5, then this latter area shall be used as the effective area of the fillet weld.

(3) *Minimum Length.* The minimum effective length of a fillet weld shall be at least four times the nominal size, or the effective size of the weld shall be considered not to exceed 25% of its effective length.

The minimum length of an intermittent fillet weld segment shall be 1–1/2 in [40 mm] unless otherwise shown on approved design drawings.

4.4.2.4 Maximum Specified Fillet Weld Size in Lap Joints. The maximum fillet weld size detailed along the edges of base metal in lap joints (see Figure 4.1) shall be the following:

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

(2) 1/16 in [2 mm] less than the thickness of base metal, for metal 1/4 in [6 mm] or more in thickness, 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 less than 1/16 in [2 mm], provided the weld size is clearly verifiable.

4.4.3 Length and Spacing of Longitudinal Fillet Welds. If longitudinal fillet welds are used alone in lap joint end connections, the length of each fillet weld shall be no less than the perpendicular distance between the welds. The transverse spacing of longitudinal fillet welds used in end connections shall not exceed 8 in [200 mm], unless end transverse welds or intermediate plug or slot welds are used. The longitudinal fillet weld may be either at the edges of the member or in the slots.

4.4.4 Fillet Weld Terminations

4.4.4.1 Unless otherwise specified in this code or other contract documents, fillet welds connecting attachments need not start nor terminate less than the weld size from the end of the joint.

4.4.4.2 Boxing. Fillet welds stressed by forces not parallel to the faying surface shall not terminate at corners of parts or members, except as required in 4.4.4.3, but shall be returned continuously, full size, around the corner for a length equal to twice the weld size where such return can be made in the same plane. Boxing shall be indicated on design and detail drawings where required.

4.4.4.3 Opposite Sides of a Common Plane. For cyclically loaded structures, fillet welds deposited on the opposite sides of a common plane may be, at the discretion of the Engineer, continuous around the common corner or interrupted (see Figure 4.2). The selected option shall be specified in the contract documents and in shop drawings. For the continuous weld option, consideration shall be given to ensure that excessive undercut is avoided and that the full weld size is maintained throughout the corner.

4.4.5 Fillet Welds in Holes or Slots

4.4.5.1 Fillet welds in holes or slots in lap joints may be used to transfer shear or to prevent buckling or separation of lapped parts. Fillet welds in holes or slots are not to be considered as plug or slot welds.

4.4.5.2 Sizes of holes and slots in which fillet welds are to be deposited shall be large enough to ensure that the fillet welds do not overlap, and base metal is visible between the weld toes.

Should the fillet welds in holes or slots overlap, the welds shall be considered as partially filled plug or slot welds (see 4.5).

4.4.5.3 Slot Ends. Except for those ends extending to the edge of the part, the ends of the slots in which fillet welds are to be deposited shall be semicircular or shall have the corners rounded to a radius not less than the thickness of the part in which it is made.

4.5 Plug and Slot Welds

4.5.1 Plug Weld Spacing. The minimum center-to-center spacing of plug welds shall be four times the diameter of the hole.

4.5.2 Slot Weld Spacing. 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.

4.5.3 Plug Weld Sizes. The minimum diameter of the hole in which a plug weld is to be deposited shall be the thickness of the part in which it is made plus 5/16 in [8 mm]. The maximum diameter of the hole shall be the minimum diameter plus 1/8 in [3 mm] or 2–1/4 times the thickness of the part, whichever is greater.

4.5.4 Slot Weld Sizes and Shape. The minimum width of slot in which a slot weld is to be deposited shall be the thickness of the part in which it is made plus 5/16 in [8 mm] or 2–1/2 times the thickness of the member, whichever is smaller. The maximum width of the slot shall be the minimum width plus 1/8 in [3 mm] or 2–1/4 times the thickness of the part, whichever is greater. The ends of the slot shall be semicircular.

4.5.5 Plug and Slot Weld Effective Areas. The effective area shall be the nominal area of the hole or slot in the plane of the faying surface.

4.5.6 Depth of Filling of Plug and Slot Welds. The depth of filling of plug or slot welds in metal 5/8 in [16 mm] thick or less shall be equal to the thickness of the material. In metal over 5/8 in [16 mm] thick, it shall be at least one-half the thickness of the material, but no less than 5/8 in [16 mm]. The Engineer may specify an alternative limit of depth of filling. In no case is the depth of filling required to be greater than the thickness of the thinner part being joined.

Part C

Miscellaneous Structural Details

4.6 General

These provisions define requirements, limitations, and prohibitions for typical welded structural details, such as filler plates, lap joints, transitions, connections or splices, stiffeners, built-up members/shapes for statically loaded structures, plug and slot dimensions, specific requirements for cyclically loaded structures, and weld combinations. Details shall promote ductile behavior, minimize restraint, avoid undue concentration of welding, and afford ample access for depositing the weld metal.

4.7 Filler Plates

4.7.1 Filler Plate Usage. Filler plates may be used in:

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

4.7.2 Filler Plates Less Than 1/4 in [6 mm]. Any filler plate less than 1/4 in [6 mm] 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.

4.7.3 Filler Plates 1/4 in [6 mm] and Larger. Any filler plate 1/4 in [6 mm] or more in thickness shall be capable of transferring the stress and 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.

4.7.4 Filler Plates Used for Dissimilar Thickness Connections. For assemblies, in which the thickness is less than 1/4 in [6 mm], the Engineer may specify a limit of filler plate thickness less than 1/4 in [6 mm] as determined in 4.7.2 and 4.7.3. In no case, however, shall the thickness of filler plate used as per 4.7.3 be less than the thickness of the thinner of the connected parts.

4.8 Lap Joints

4.8.1 Minimum Overlap. The minimum overlap of parts in stress-carrying lap joints shall be five times the thickness of the thinner part joined but not less than 1 in [25 mm] (see Figures 4.3 and 4.4).

4.8.2 Double Fillet Welded Lap Joints. Lap joints in parts carrying axial stress shall be double-fillet welded (see Figure 4.4), except where deflection of the joint is sufficiently restrained to prevent it from opening under load.

4.8.3 Double Plug or Slot Welds. Unless lateral deflection of the parts is prevented, they are to be connected by at least two transverse lines of plug or slot welds, or by two or more longitudinal slot welds.

4.9 Transitions of Butt Joints in Nontubular Connections

Butt joints between axially aligned members of different thicknesses or widths, or both, and subject to fatigue loads, shall have appropriate transition in thickness as per 4.9.1 and in width as per 4.9.2. For statically loaded joints, transitions need not be provided unless required by the Engineer.

4.9.1 Transition in Thicknesses. For cyclically loaded joints, the slope in the transition in thickness shall not exceed 1 in 2-1/2 with the surface of either part (see Figure 4.5). The transition shall be accomplished by chamfering the thicker part, sloping the weld metal, or by any combination of these.

4.9.2 Transition in Width. For cyclically loaded joints, parts having different widths shall have a smooth transition between offset edges at a slope of no more than 1 in 2–1/2 with the edge of either part or shall be transitioned with a 2 ft [600 mm] minimum radius tangent to the narrower part of the center of the butt joints.

4.10 Transitions in Tubular Connections

4.10.1 Size Transition. Flared connections and tube size transitions not excepted below shall be checked for local stresses caused by the change in direction [angle (Ψ)] at the transition. Exceptions for static loads: Circular tubes having D/t less than 30, box sections having a/t less than 20, and transition slopes for circular tubes and box sections less than 1 in 4.

4.10.2 Transition in Thicknesses. Tension butt joints in cyclically loaded axially aligned primary members of different material thicknesses or size shall be made in such a manner that the slope through the transition zone does not exceed 1 in 2–1/2. The transition shall be accomplished by chamfering the thicker part, sloping the weld metal, or by any combination of these methods (see Figure 4.6). For statically loaded joints, transitions need not be provided, unless required by the Engineer.

4.11 Joint Configurations and Details

4.11.1 General Considerations. Welded connections shall be designed in conformance with the contract documents.

4.11.2 Compression Member Connections and Splices

4.11.2.1 Connections and Splices Designed to Bear Other than Connections to Base Plates. Column splices that are finished to bear shall be connected by PJP groove welds or by fillet welded details sufficient to hold the parts in place. Where compression members other than columns are finished to bear at splices or connections, welds shall be designed to hold all parts in alignment and shall be proportioned for 50% of the force in the member.

4.11.2.2 Connections and Splices Not Finished to Bear Except for Connections to Base Plates. Welds joining splices in columns and splices and connections in other compression members that are not finished to bear, shall be designed to transmit the force in the members, unless CJP welds or more restrictive requirements are specified in contract documents or governing specifications.

4.11.2.3 Connections to Base Plates. At base plates of columns and other compression members, the connection shall be adequate to hold the members securely in place.

4.12 Built-Up Members in Statically Loaded Structures

4.12.1 Minimum Required Welding. If two or more plates or rolled shapes are used to build up a member, sufficient welding (fillet, plug, or slot type) shall be provided to make the parts act in unison but not less than that which may be required to transmit the calculated stress between the parts joined.

4.12.2 Maximum Longitudinal Spacing of Intermittent Welds. In built-up tension and compression members, longitudinal spacing of intermittent welds connecting a plate component to other components shall not exceed 24 times the thickness of the thinner plate nor exceed 12 in [300 mm]. The longitudinal spacing between intermittent fillet welds connecting two or more rolled shapes shall not exceed 24 in [600 mm].

4.12.3 Intermittent or Partial Length Groove Welds. Intermittent or partial length groove welds shall be prohibited except as specified in 4.12.4.

4.12.4 Groove Welds in Elements Connected by Fillet Welds. Members built-up of elements connected by fillet welds, at points of localized load application, may have groove welds of limited length to participate in the transfer of the localized load. The groove weld shall extend at uniform size for at least the length required to transfer the load. Beyond this length, the groove shall be transitioned in depth to zero over a distance not less than four times its depth. The groove shall be filled flush before the application of the fillet weld.

4.13 Noncontinuous Beams

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

4.14 Specific Requirements for Cyclically Loaded Structures

4.14.1 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.

4.14.2 Prohibited Types of Joints and Welds

4.14.2.1 In butt joints, PJP welds subject to tension normal to their longitudinal axes are prohibited. In other joints, transversely loaded PJP welds are prohibited, unless fatigue design criteria allow for their application.

4.14.2.2 Intermittent groove welds are prohibited.

4.14.2.3 Intermittent fillet welds are prohibited.

4.14.2.4 Plug and slot welds on primary tension members are prohibited.

4.15 Combinations of Different Types of Welds

If two or more welds of different types (groove, fillet, plug, slot) are combined to share the load in a single connection, the capacity of the connection shall be calculated as the sum of the individual welds determined relative to the direction of applied load. This method of adding individual capacities of welds does not apply to fillet welds reinforcing PJP groove welds (see Annex A).

4.16 Skewed T-Joints (see Annex B, Figure B.1).

Z-loss values for skewed T-joints in stainless steels, having angles between members less than 60°, have not been determined. Therefore, these joints shall be qualified in accordance with Clause 6 to establish the effective weld size that can be consistently achieved for a given set of procedural conditions.

Table 4.1
Allowable Stresses in Welds (see 4.3.2)

Stress in Weld	Allowable Stress ^{a,b,c,d,e}
<i>CJP Groove Welds</i>	
Tension normal to the effective area	The lesser of values for base metal or filler metal
Compression normal to the effective area	The lesser of values for base metal (<u>specified minimum yield strength</u>) or for filler metal
Tension or compression parallel to the axis of the weld	Same as for base metal (<u>specified minimum yield strength</u>)
Shear on the effective area	$0.30 \times$ nominal tensile strength of filler metal, except shear stress on base metal shall not exceed $0.40 \times$ <u>specified minimum yield strength</u> of base metal
<i>PJP Groove Welds</i>	
Tension normal to the effective area	$0.30 \times$ nominal tensile strength of filler metal, except tensile stress on base metal shall not exceed $0.60 \times$ <u>specified minimum yield strength</u> of base metal
Compression normal to the effective area	<u>$0.75 \times$ lesser of tensile strength values for base metal (specified) or for filler metal</u>
	Joint not designed to bear
	Joint designed to bear
	<u>$0.90 \times$ lesser value of nominal tensile strength of filler metal or specified minimum yield strength of the connected base metal</u>
Tension or compression parallel to the axis of the weld	Same as for base metal (<u>specified minimum yield strength</u>)
Shear parallel to the axis of the weld	$0.30 \times$ nominal tensile strength of filler metal, except shear stress on base metal shall not exceed $0.40 \times$ <u>specified minimum yield strength</u> of base metal
<i>Fillet Welds</i>	
Shear on effective area of weld	$0.30 \times$ nominal tensile strength of filler metal, except that the base metal <u>net section shear area stress</u> shall not exceed $0.40 \times$ <u>specified minimum yield strength</u> of base metal
Tension or compression parallel to the axis of the weld	Same as for base metal (<u>specified minimum yield strength</u>)
<i>Plug and Slot Welds</i>	
Shear parallel to the faying surface on the effective area	$0.30 \times$ nominal tensile strength of filler metal, except shear stress on base metal shall not exceed $0.40 \times$ <u>specified minimum yield strength</u> of base metal

^a The strengths of the various types of stainless steel base metals and filler metals begin to decrease at temperatures over 200°F [95°C]. The Engineer should consult strength data that indicate the allowable stress at service temperatures greater than 200°F [95°C], e.g., ASME Section II, Part D.

^b In contrast to carbon steels, where filler metal is selected on the basis of its strength, in stainless steels the selection of filler metal is predominantly based on metallurgical criteria. This may lead to an overmatching or undermatching condition of yield and/or tensile strength, which shall be taken into account by the Engineer.

^c For cold-worked austenitic stainless steels, properties for the annealed condition shall be used. Properties higher than those for the annealed condition may be established by testing.

^d Nominal tensile strength of filler metals for stainless steels shall be determined as follows:

- (1) for covered electrodes, nominal tensile strength shall be that required in AWS A5.4/A5.4M,
- (2) for flux cored and metal cored filler metals, nominal tensile strength shall be that required in AWS A5.22/A5.22M,
- (3) for solid filler metals, nominal tensile strength shall be that required in AWS A5.4/A5.4M for covered electrodes of corresponding composition of weld metal,
- (4) for filler metals not covered in AWS A5.4/A5.4M, AWS A5.9/A5.9M, or A5.22/A5.22M, nominal tensile strength shall be assessed by the Engineer.

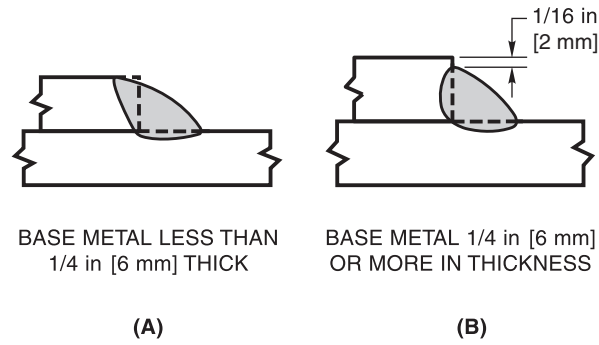
^e Yield strengths of filler metals for stainless steels is not specified in pertinent AWS A5 specifications. For design based on yield criteria, the Engineer shall assess yield stress values for filler metals selected.

Table 4.2
Effective Size of Flare-Groove
Welds Filled Flush (see 4.4.1.2 and 4.4.2.2)

Flare-Bevel-Groove Welds	Flare-V-Groove Welds
$(5/16) R$	$(1/2) R^a$

^a Use $(3/8) R$ for GMAW. Effective size shall be qualified for the GMAW short circuiting transfer process.

Note: R = radius of outside surface.



Maximum detailed size of fillet weld along edges

Figure 4.1—Maximum Fillet Weld Size Along Edges in Lap Joints (see 4.4.2.4)

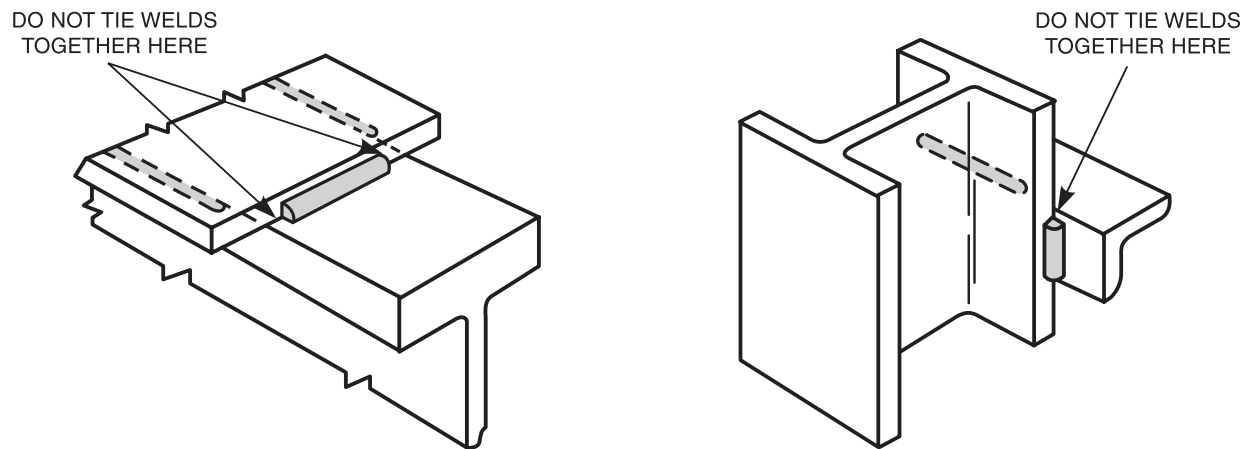


Figure 4.2—Fillet Welds on Opposite Sides of a Common Plane of Contact for Cyclically Loaded Structures (see 4.4.4.3)

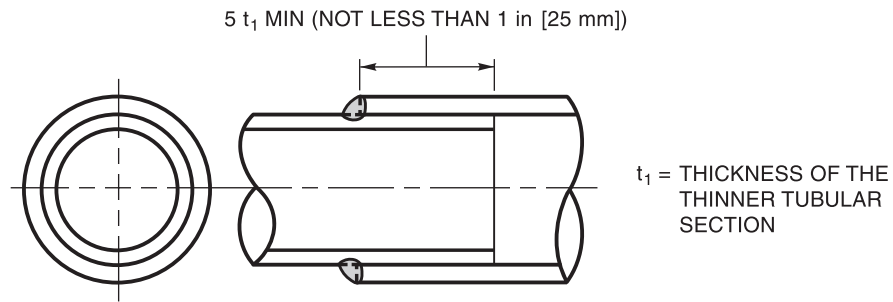
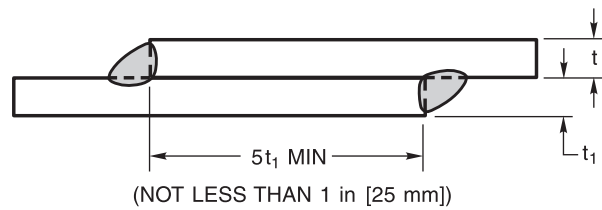
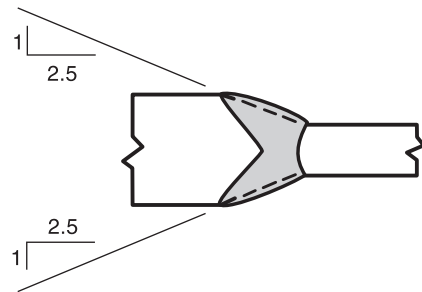


Figure 4.3—Fillet Welded Lap Joint in Tubular Connections (see 4.8.1)

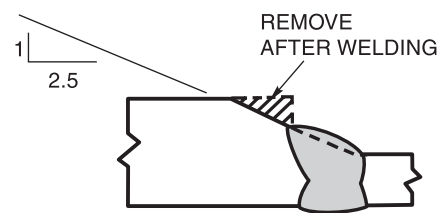
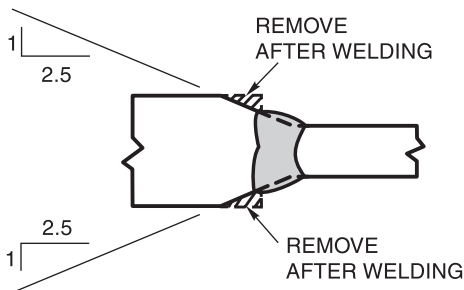
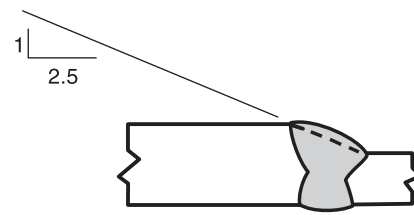


Note: t = thicker member, t_1 = thinner member.

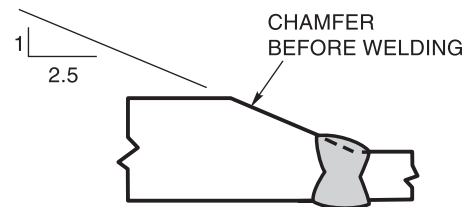
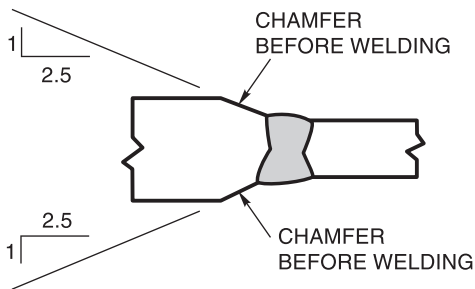
Figure 4.4—Double-Fillet Welded Lap Joint (see 4.8.1 and 4.8.2)



(A) TRANSITION BY SLOPING WELD SURFACE

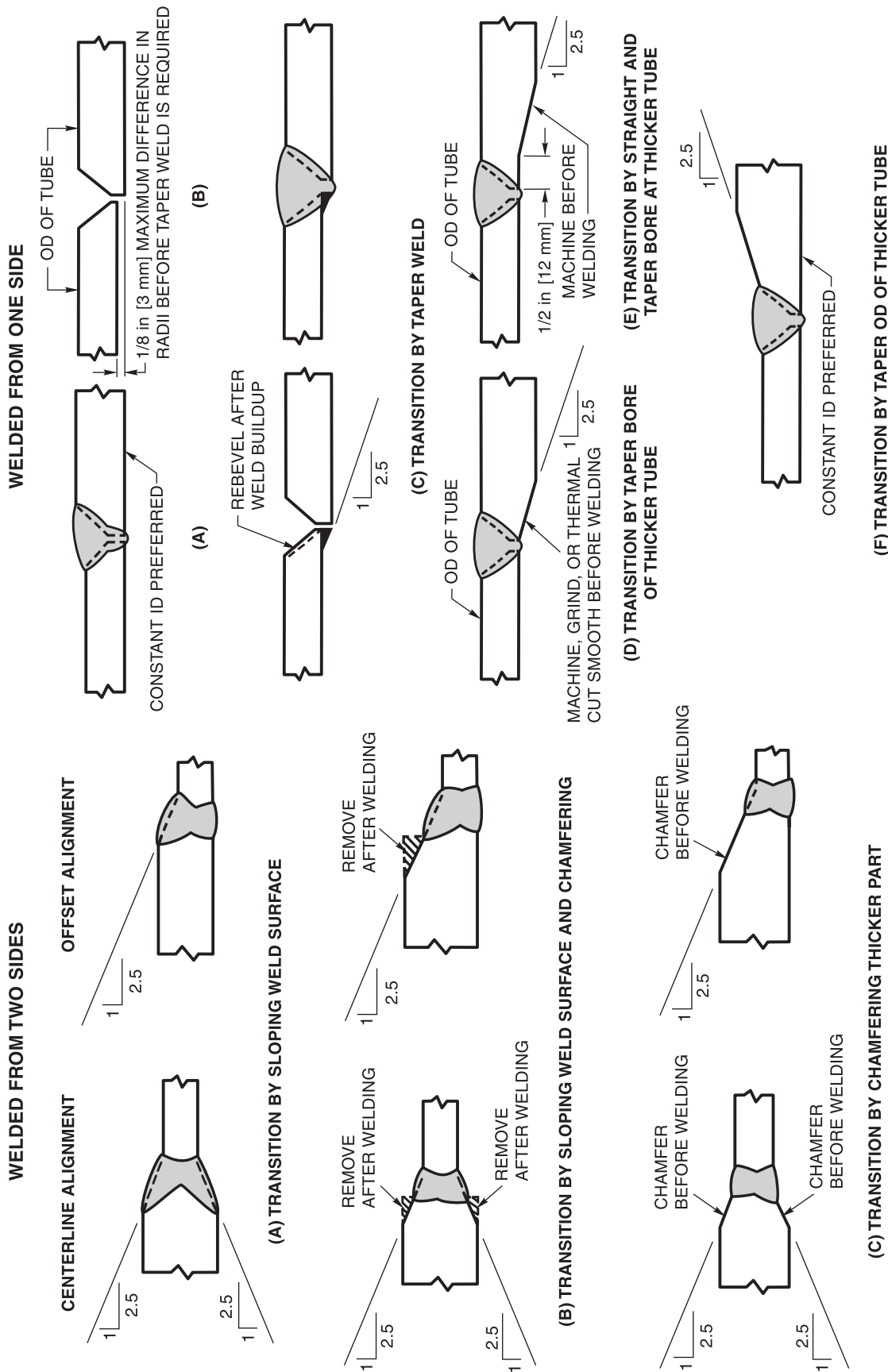


(B) TRANSITION BY SLOPING WELD SURFACE AND CHAMFERING



(C) TRANSITION BY CHAMFERING THICKER PART

Figure 4.5—Transition of Butt Joints in Nontubular Connections of Unequal Thickness
(see 4.9.1)



Notes:

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

Figure 4.6—Transition of Butt Joints in Tubular Connections of Unequal Thickness (see 4.10.2)

5. Prequalification

5.1 Scope

Included in this clause are requirements for the generation and application of Prequalified Welding Procedure Specifications (PWPSs). As such, PWPSs are exempt from qualification by testing in accordance with Clause 6, as are applicable Standard Welding Procedure Specifications (SWPSs) of the AWS B2.1-X-XXX series. PWPSs must be documented (see Annex H for a recommended format). PWPSs may be used to join members for service in the temperature range of -100°F to 800°F [-75°C to 430°C]. This clause applies only to nominally austenitic stainless steel base metals and filler metals whose as-welded weld metal normally contains delta ferrite of at least 3 Ferrite Number (FN) as determined in accordance with Figure 5.1. Filler metals used for prequalified WPSs shall have strengths that equal or exceed the corresponding minimum specified base metal strength and provide resistance to normal atmospheric corrosion.

Prequalification may still be applicable if the selected materials are listed in Tables 5.2 and 5.3 and is permitted by 1.4. All other materials shall be qualified per the requirements of Clause 6.

Welders and welding operators that use PWPSs shall be qualified in conformance with Clause 6.

NOTE: The use of prequalified joints or a prequalified WPS is not a substitute for education, experience or engineering judgment in the welding of stainless steel structures.

5.2 Welding Processes

5.2.1 Prequalified Welding Processes. WPSs that conform to the provisions of Clause 5 for shielded metal arc welding (SMAW), gas metal arc welding (GMAW), gas tungsten arc welding (GTAW) (including autogenous GTAW), and flux cored arc welding (FCAW) are prequalified and approved for use without the WPS qualification tests prescribed in Clause 6. SAW WPSs that conform to the provisions of 5.2.2 are also prequalified.

5.2.2 Submerged Arc Welding (SAW). Fluxes for SAW of stainless steels are not presently classified by AWS. Fluxes of a particular trade designation may be used with PWPSs for welding stainless steels when it can be proven that the weld metal deposit produced using the flux has a FN of at least 3.

This can be determined from either a test weld or a production weld using a base metal in Table 5.2, a matching filler metal from Table 5.3, and the flux.

The FN shall be determined from the top centerline of the weld bead using an instrument calibrated according to AWS A4.2M (ISO 8249:2000 MOD), *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*.

5.2.2.1 SAW that does not meet the requirements of 5.2.2 shall be qualified as prescribed in Clause 6.

5.2.2.2 Melted Flux (Crushed Slag). Crushed slag shall not be used as flux in prequalified SAW WPSs and its use shall be qualified as prescribed in Clause 6.

5.2.3 Code-Approved Processes. Plasma arc welding (PAW) may be used, provided the WPSs are qualified in accordance with the requirements of Clause 6.

5.2.4 Other Welding Processes. Other welding processes may be used, provided they are approved by the Engineer and the WPS using the processes are qualified in accordance with Clause 6.