

Specification for the Design of Welded Joints in Machinery and Equipment



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An American National Standard

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American National Standards Institute
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Specification for the Design of Welded Joints in Machinery and Equipment

5th Edition

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Prepared by the
American Welding Society (AWS) D14 Committee on Machinery and Equipment

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification establishes common acceptance criteria for classifying and applying carbon and low-alloy steel welded joints used in the manufacture of machines and equipment. It also covers weld joint design, workmanship, quality control requirements and procedures, weld joint inspection, nondestructive testing, repair of weld defects, and postweld treatment.



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This standard is subject to revision at any time by the AWS D14 Committee on Machinery and Equipment. It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are requested and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the AWS D14 Committee on Machinery and Equipment and the author of the comments will be informed of the Committee's response to the comments. Guests are invited to attend all meetings of the AWS D14 Committee on Machinery and Equipment to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

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Foreword

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

In 1967, the Technical Activities Committee of AWS established a technical committee to provide standards and recommended practices for the welding and fabrication of industrial equipment and machinery. The scope of that technical committee, identified as D14 committee, was to collect, review, and promulgate minimum requirements considered necessary for the control of welding in the fabrication of industrial machinery and equipment. This included weld design data, welding process selection, materials control, fabrication practices, quality standards, inspection and testing. The committee determined that a single universal standard and guide covering all machinery and equipment was impractical due to differences in utilization and operational requirements. Therefore, it became the policy of the D14 committee to establish subcommittees as may be required to consider specific types of machinery and equipment within the scope of the main committee. A listing of the subcommittees for D14 at the time of approval of this document is as follows:

- D14B – Subcommittee on General Design and Practices
- D14C – Subcommittee on Earthmoving and Construction Equipment
- D14E – Subcommittee on Welding Cranes and Presses
- D14G – Subcommittee on Welding Rotating Equipment
- D14H – Subcommittee on the Surfacing of Industrial Rolls and Equipment
- D14I – Subcommittee on Hydraulic Cylinders

The first edition of this Standard was published in 1977 to provide a standard for the classification of welded joints for machinery and equipment. It included weld joint design, welding fabrication practices, quality control, and inspection indices to meet general machinery performance requirements. Over time, other standards for specific areas in the machinery and equipment field were developed by the D14 committee (see list on back page of this document) and this standard then served as a supplement to these standards and continued to provide a basis for other areas in the machinery and equipment field not served by a specific standard. This standard was revised in 1997, 2005, and 2012. Today, this standard is still intended to be referenced by all D14 standards as applicable.

Thus, as the purpose of this document has undergone a subtle change, the committee has changed the title of this document to *Specification for the Design of Welded Joints in Machinery and Equipment* from its former titles of *Specification for Welded Joints in Machinery and Equipment* and *Classification and Application of Welded Joints for Machinery and Equipment*.

The purpose of this Specification is not to restrict the use of other proven methods and procedures for welding machinery and equipment. Where such methods and procedures exist, this Specification should be referenced as a supplement.

This fifth edition has been expanded to include terminology and references to numerous ISO, EN and IIW documents to better establish global relevancy and usage of this Specification throughout all International markets. To aid in communication, when appropriate, international terms shall be included in brackets “[]”, as stated in clause 1.5.

Underlined text or a vertical line in the margin indicates a change from the previous edition.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS D14 Committee on Machinery and Equipment, American Welding Society, 8669 NW 36th St #130, Miami, FL 33166.

This document will be reviewed periodically to assure its success in serving all parties concerned with its provisions. Revisions will be issued when warranted.

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Specification for the Design of Welded Joints in Machinery and Equipment

1. General Requirements

1.1 Scope. This specification establishes design, quality, and inspection requirements for carbon and low-alloy steel welded connections in machinery and equipment. It addresses topics including weld joint design, workmanship, quality acceptance criteria, non-destructive inspection methods (visual, radiographic, ultrasonic, magnetic particle, and liquid penetrant), repair of weld defects, and heat treatment.

1.2 Limitations. This specification does not dictate load determination, design assumptions, safety factors, or calculation methods. It is not the intent of this specification to restrict the use of other proven welding methods and procedures that are not mentioned herein, which achieve acceptable results as determined by the Engineer. In the case where this specification is used between the Owner and Manufacturer, the use of other proven welding methods and procedures that are not mentioned herein shall be agreed to in writing by the Owner and Manufacturer.

1.3 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.

1.4 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.

1.5 International Usage. This specification includes terms and symbols that are more commonly used outside of the North American market. These terms are shown in brackets [] when used in the specification.

1.6 Engineer Responsibility.

1.6.1 The 'Engineer' in this document shall have specific technical expertise in welding engineering or design engineering; the expertise is not limited to these two areas of engineering. Unless otherwise specified in the contract

documents, the Manufacturer shall determine the responsible technical authority when the term Engineer is used (i.e. Welding Engineer or Design Engineer).

1.6.1.1 Welding Engineer. The technical authority typically responsible for developing Welding Procedure Specifications (WPS), Procedure Qualification Records (PQR) and Performance Qualification Test Records (PQTR). The Welding Engineer might also have expertise in weld process selection; welding metallurgy and weld filler metal selection; weld joint design and weld sizing; weld fixture design and weld robot programing; welding inspection and weld defect/failure root cause analysis. Qualifications for a welding engineer shall meet one of the following criteria:

- (1) An AWS Certified Welding Engineer in conformance with the provisions of AWS B5.16 *Specification for the Qualification of Welding Engineers* or,
- (2) IIW International Welding Engineer (IWE),
- (3) Professional Engineer – Welding,
- (4) An individual who by degree, training, or experience is qualified in welding engineering disciplines.

1.6.1.2 Design Engineer. The technical authority typically responsible for developing equipment configuration; analyzing stress levels, finite element analysis, and strain gage data to mitigate stress hot spots; choosing steel material type and thickness; determining weld joint type and weld size; and evaluating cyclic loading and fatigue life. The Design Engineer might also provide judgments on weld defect criticality and welding inspection requirements. Qualification for a design engineer shall meet one of the following criteria:

- (1) Professional or Chartered Engineer – Mechanical, Civil, Structural, Agricultural, or
- (2) An individual who by degree, training, or experience is qualified in design of structures.

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.

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

AWS B4.0, *Standard Methods for Mechanical Testing of Welds* (U. S. Customary units only)

AWS B4.0M, *Standard Methods for Mechanical Testing of Welds* (SI units only)

AWS B5.17, Specification for the Qualification of Welding Fabricators

AWS C4.6M (ISO 9013), Thermal Cutting – Classification of Thermal Cuts – Geometric Product Specification and Quality Tolerances

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

AWS QC7, *Standard for Certified Welders*

AWS QC15, Specification for the Certification of Radiographic Interpreters

American Institute of Steel Construction (AISC) standard:

AISC 360–05, Specification for Structural Steel Buildings

American Society of Mechanical Engineers (ASME) standards:

ASME Section VIII-Div 1, *ASME Boiler and Pressure Vessel Code, Section VIII, Division 1: Design and Fabrication of Pressure Vessels*

ASME Section VIII-Div 2, *ASME Boiler and Pressure Vessel Code, Section VIII, Division 2: Alternative Rules*

ASME Section IX, *ASME Boiler and Pressure Vessel Code – Section IX: Welding and Brazing Qualifications*

American Society of Testing and Materials (ASTM) standards:

ASTM A6/A6M, *Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling*

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

ASTM A435/435M, *Standard Specification for Straight-Beam Ultrasonic Examination of Steel Plates*

ASTM E94, *Standard Guide for Radiographic Examination*

ASTM E164, *Standard Practice for Contact Ultrasonic Testing of Weldments*

ASTM E165, *Standard Test Method for Liquid Penetrant Examination*

ASTM E390, *Standard Reference Radiographs for Steel Fusion Welds*

ASTM E587, *Standard Practice for Ultrasonic Angle Beam Contact Testing*

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*

ASTM E1417, *Standard Practice for Liquid Penetrant Testing*

American Society for Nondestructive Testing (ASNT) standards:

ANSI/ASNT CP-189, *ASNT Standard for Qualification and Certification of Nondestructive Testing Personnel*

SNT-TC-1A, *Personnel Qualification and Certification in Nondestructive Testing*

Canadian Standards Association (CSA) standard:

CSA W178.2, *Certification of Welding Inspectors*

International Institute of Welding (IIW) standard:

IIW-2259-15, *Recommendations for Fatigue Design of Welded Joints and Components*

International Organization for Standardization (ISO) standards:

EN ISO 473, *Qualification and certification of NDT personnel – General principles*

EN ISO 15614-1, *Specification and qualification of welding procedures for metallic materials – Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys*

ISO 2553, *Welded, Brazed and Soldered Joints – Symbolic Representations on Drawings*

ISO 3452-1, *Non-destructive testing – Penetrant testing – Part 1: General principles*

ISO 3834, *Quality requirements for fusion welding of metallic materials*

ISO 4063, *Welding and allied processes – Nomenclature of processes and reference numbers*

ISO 6947, *Welding and allied processes – Welding positions*

ISO 9606–1, *Qualification testing of welders – Fusion welding – Part 1: Steels*

ISO 9692–1, *Welding and allied processes – Types of joint preparation – Part 1: Manual metal-arc welding, gas-shielded metal arc welding, gas welding, TIG welding and beam welding of steels*

ISO 9692–2, *Welding and allied processes – Joint preparation – Part 2: Submerged arc welding of steels*

ISO 9712, *Non-destructive testing – Qualification and certification of personnel*

ISO 15607 *Specification and qualification of welding procedures for metallic materials – General rules*

ISO 15609–1 *Specification and qualification of welding procedures for metallic materials – Welding procedure specification – Part 1: Arc welding*

ISO 17636, *Non-destructive testing of welds- Radiographic testing of fusion welded joints*

ISO 17637, *Non-destructive testing of welds – Visual testing of fusion-welded joints*

ISO 17640, *Non-destructive testing of welds – Ultrasonic testing – Techniques, testing levels, and assessments*

ISO 19232–5, *Non-destructive testing- Image quality of radiographs- Part 5: Image quality indicators (duplex wire type) – Determination of image unsharpness value*

3. Terms and Definitions

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*, provides the basis for terms and definitions used herein. However, the following terms and definitions are included below to accommodate usage specific to this document.

attachment. A component connected to a principal structural weldment, by welding or mechanical means, not required to carry the main working loads during normal operations.

Engineer. The responsible technical authority.

Manufacturer. The organization responsible for the performance of the work covered by this specification.

Owner. The person, company, or agency exercising legal ownership of the machinery or equipment produced in accordance with this standard.

primary weld. Any weld on a principal structural weldment directly transferring the main working load(s).

principal structural weldments. Any weldments that carry the main working loads during normal operations.

secondary member. Any component not carrying the main working loads during normal operations.

secondary weld. Any weld that does not directly transfer the main working loads through components that make up the principal structural weldment. All welds on secondary weldments are secondary welds. Welds that join attachments to principal structural weldments are secondary welds. A secondary weld can fail through the throat and not affect the normal operation of the equipment.

secondary weldment. A welded secondary member.

stress range. The algebraic difference between the maximum stress and minimum stress in a fatigue loading cycle.

tensile strength of the weld metal. The minimum tensile strength of a filler metal classification as specified in the applicable filler metal specification.

toe reentrant angle. The angle between lines tangent to the adjacent base metal surface and weld face at the weld toe or root surface at the weld root. (see Figure 3.1)

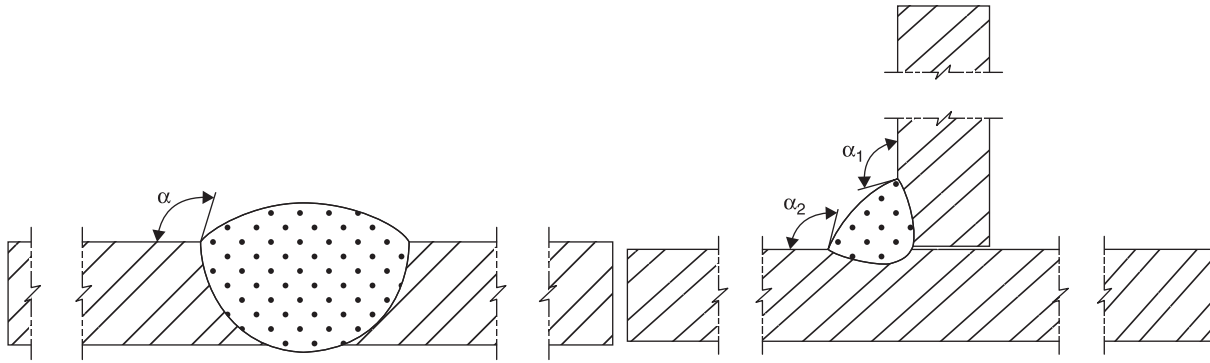


Figure 3.1—Toe Reentrant Angle, Groove and Fillet Welds

4. General Design Requirements

4.1 Weldment Classifications.

4.1.1 Principal Structural Weldments. The Design Engineer shall determine which weldment(s) carry the main working load(s) during normal operations, and are therefore principal structural weldment(s). Weldments that do not carry main working load(s) during normal operations may be considered secondary weldments.

4.1.1.1 Roll Over Protective Structure/Falling Object Protective Structure (ROPS/FOPS). All weldments that are part of the ROPS or FOPS shall be considered as principal structural weldments.

4.1.1.2 Transportation Weldments. Weldments through which normal transportation loads are carried shall be considered as principal structural weldments. Transportation loads associated with the initial shipping of the product are not considered normal transportation loads.

4.1.2 Welded Attachments. Attachments to principal structural weldments that are connected with welds that are 4 inches [100 mm] or longer in length in the direction of principal stress shall be considered to be part of the principal structural weldment. Attachments that are welded to principal structural weldments that are connected with welds that are less than 4 inches [100 mm] in length in the direction of principal stress may be considered secondary weldments.

4.1.3 Mechanically Fastened Attachments. Attachments that are mechanically fastened to principal structural weldments may be considered secondary members.

4.1.4 Secondary Weldments Identification. Drawings of all secondary weldments shall identify the weldment as secondary. Weldments that are not identified on drawings as secondary weldments shall be considered principal structural weldments.

4.2 Weld Classifications.

4.2.1 Primary Welds. The Design Engineer shall determine which welds are primary welds. Primary welds shall include all welds on principal structural weldments that directly transfer main working loads through the weldment. Primary welds shall be subject to the restrictions of clauses 5.12 and 5.13.

4.2.2 Secondary Welds. The Design Engineer shall determine which welds are secondary welds. Welds that are less than 4 inches [100 mm] in length that connect attachments to principal structural weldments are not primary welds. All secondary welds on principal structural weldments shall be identified on drawings.

4.2.3 Unidentified Welds. Welds on principal structural weldments that are not identified as secondary welds shall be considered as primary welds.

4.3 Loading Classification.

4.3.1 Static Versus Cyclic Loading. The Design Engineer shall determine which principal structural weldments are subject to cyclic loading under normal operating conditions. Weldments subject to fewer than 20,000 cycles of live load during the normal service life shall be considered to be statically loaded.

4.3.2 Statically loaded principal structural weldments shall be subject to the requirements of 5.10.

4.3.3 Cyclically loaded principal structural weldments shall be subject to the requirements of 5.11.

4.4 Combined Unit Stresses. In the case of axial stress combined with bending, the allowable unit stress of each kind shall be governed by the requirements of 5.10 and 5.11, and the maximum combined unit stresses calculated shall be limited in accordance with the requirements of the contract.

4.5 Fracture Toughness Requirements. Design criteria of welded joints in machinery and equipment could specify a minimum level of fracture toughness. Design criteria requiring fracture toughness may be specified by, but not limited to, the following:

- (1) The Owner specifies requirements for fracture toughness in the contract documents.
- (2) Required by the Engineer.
- (3) Low temperature service conditions are stated in the design specification.
- (4) Regulatory requirements such as Roll-Over Protective Structure/Falling-Object Protective Structure (ROPS/FOPS) specifications require fracture toughness.

When fracture toughness is required, the Engineer shall specify the materials and portions of the structure requiring testing, the method of fracture toughness testing, testing temperatures, frequency of testing, acceptance criteria, when heat-affected zone testing is required, and other circumstances associated with the required testing. When minimum fracture toughness for welded joints is required, the welding procedure specification(s) for the applicable joints shall be qualified by test; qualification by prototype testing or prequalified welding procedures is not permitted. Welding procedure qualification testing shall include fracture toughness testing of the weld metal and, if required, the heat-affected zone.

4.6 Filler Metals. All primary welds on principal structural weldments shall be made with filler metals meeting the requirements of Table 5.7.

4.7 Nondestructive Testing.

4.7.1 Standard Inspection. All welds shall be subject to the inspection requirements of 8.1.3.1. Additionally, all primary welds on the principal structural weldment shall be subject to the inspection requirements of Table 8.2, as applicable.

4.7.2 Additional NDT. When nondestructive testing beyond the requirements of Table 8.2 is to be performed, the extent of testing shall be specified in contract documents.

4.7.3 NDT requirements in Table 8.2 may be modified as determined by the Owner.

4.7.4 The Engineer may deviate from the requirements of Table 8.2. Deviations from NDT requirements should be validated by the use of any combination of finite element analysis, representative sample testing, or prototype testing determined appropriate for the product by the Engineer.

4.8 Requirements for Secondary Welds. Secondary welds are not required to conform to Clause 5, Welded Connection Design. All other clauses are required for secondary welds, as applicable.

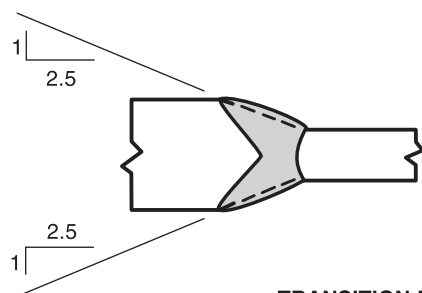
5. Welded Connection Design

5.1 Joint Details.

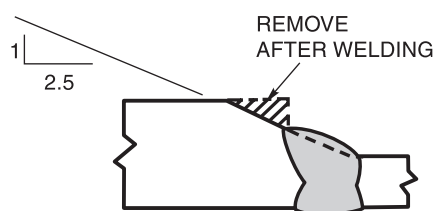
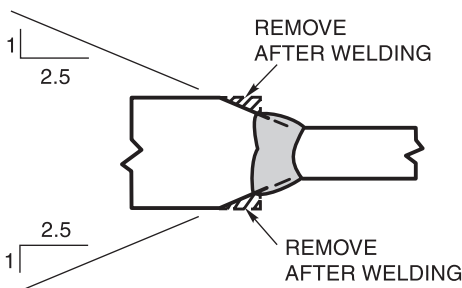
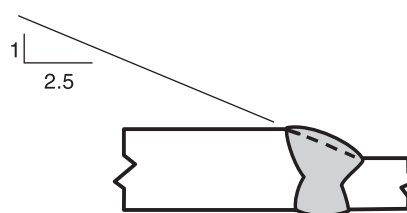
5.1.1 Typical joint details can be found in Annex B. The standard welding symbols used to describe joint details shall comply with either AWS A2.4, Standard Symbols for Welding Brazing, and Nondestructive Examination or ISO 2553, Welded, Brazed and Soldered Joints – Symbolic Representations on Drawings. The Manufacturer shall specify which standard shall be used on the drawings or in the contract documents.

5.2 Transition of Thicknesses or Widths at Butt Joints.

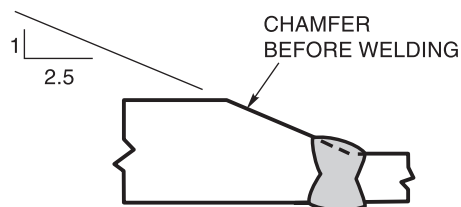
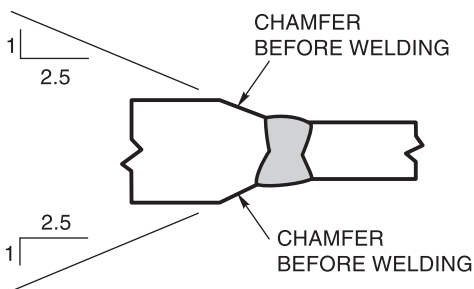
5.2.1 Butt joints in principal structural weldments between parts having unequal thicknesses and subject to tensile stress shall have a smooth transition between the offset surfaces at a slope of no more than 1 in 2–1/2 with the surface of either part. The transition may be accomplished by sloping weld surfaces, by chamfering the thicker part, or by a combination of the two methods (see Figure 5.1).



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)

Notes:

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

Figure 5.1—Transition of Thickness at Butt Joints of Parts Having Unequal Thickness

5.2.2 In butt joints in principal structural weldments between parts of unequal thickness that are subject only to shear or compressive stress, transition of thickness shall be accomplished, as specified in Figure 5.1, when the 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 in 2-1/2 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 specified in 5.2.1.

5.2.3 Butt joints in principal structural weldments 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 in 2-1/2 with the edge of either part or shall be transitioned with a 2.0 ft [0.6 m] minimum radius tangent to the narrower part of the center of the butt joints (see Figure 5.2). An increased stress range may be used for steels having yield stress greater than 90 ksi with details incorporating the radius as compared to the tapered cut.

5.3 Lap Joints.

5.3.1 In principal structural weldments, the minimum overlap of parts in a lap joint shall be five times the thickness of the thinner part, but not less than 1 inch [25 mm] (see Figure 5.3).

5.3.2 Unless lateral deflection of the overlapping parts is prevented, the overlapping parts shall be welded on both sides of the joint by one of the following methods:

- (1) Transverse fillet welds on the end of each lapped member (Figure 5.3).
- (2) At least two transverse lines of plug or slot welds (Figure 5.4 (a) and (b)).
- (3) Two or more longitudinal fillet welds in holes or slots (Figure 5.5).

5.3.3 Longitudinal fillet welds may be either at the edges of the member or in slots or holes. The following provisions for fillet weld lengths and the perpendicular spacing between longitudinal fillet welds apply:

- (1) 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 them (Figure 5.6).

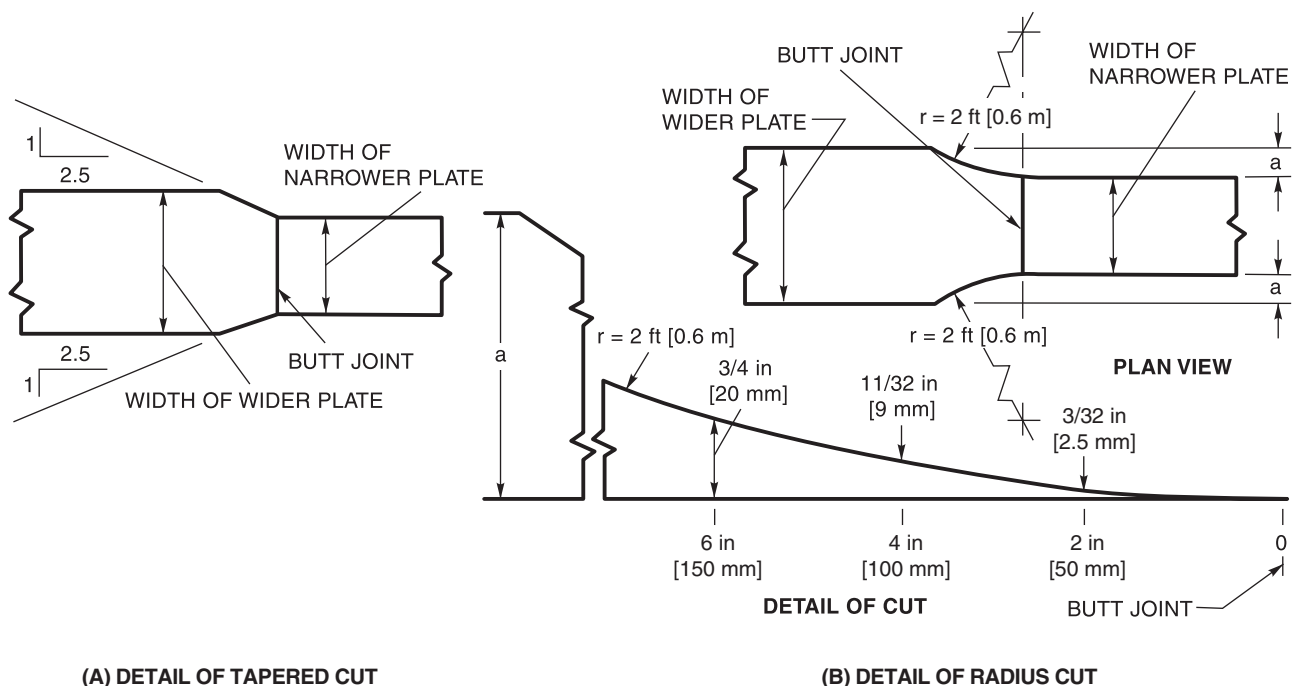
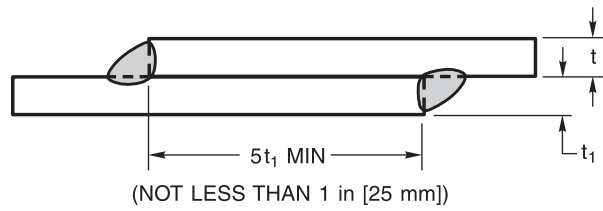


Figure 5.2—Transition of Width at Butt Joints of Parts Having Unequal Width



Note: t = thicker member, t_1 = thinner member

Figure 5.3—Minimum Overlap Distance

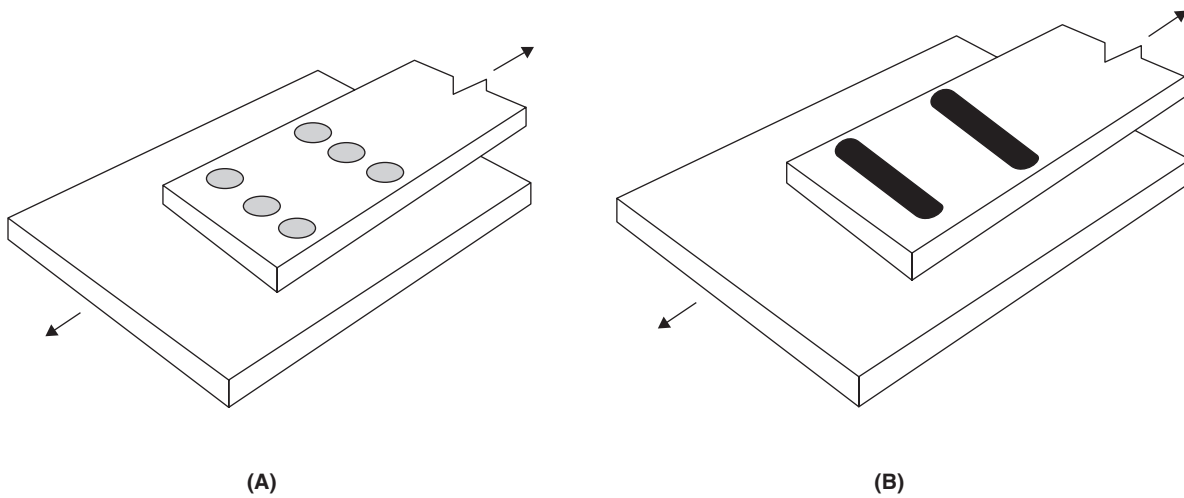


Figure 5.4—Transverse Lines of Plug or Slot Welds

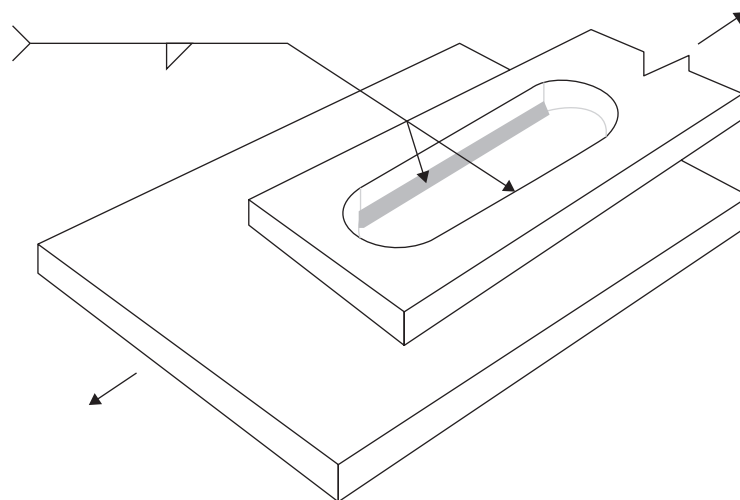


Figure 5.5—Longitudinal Fillet Welds in Holes

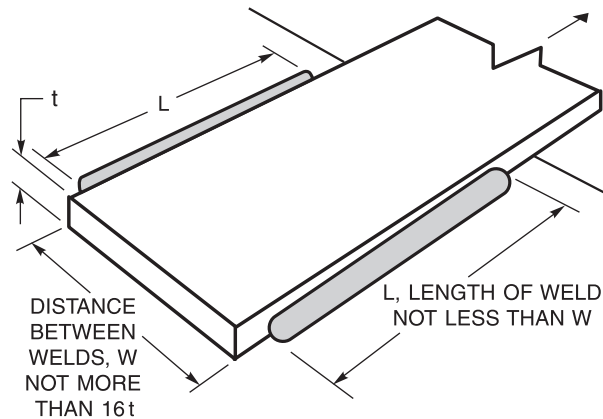


Figure 5.6—Minimum Length of Longitudinal Fillet Welds at the End of a Plate or Flat Bar Members

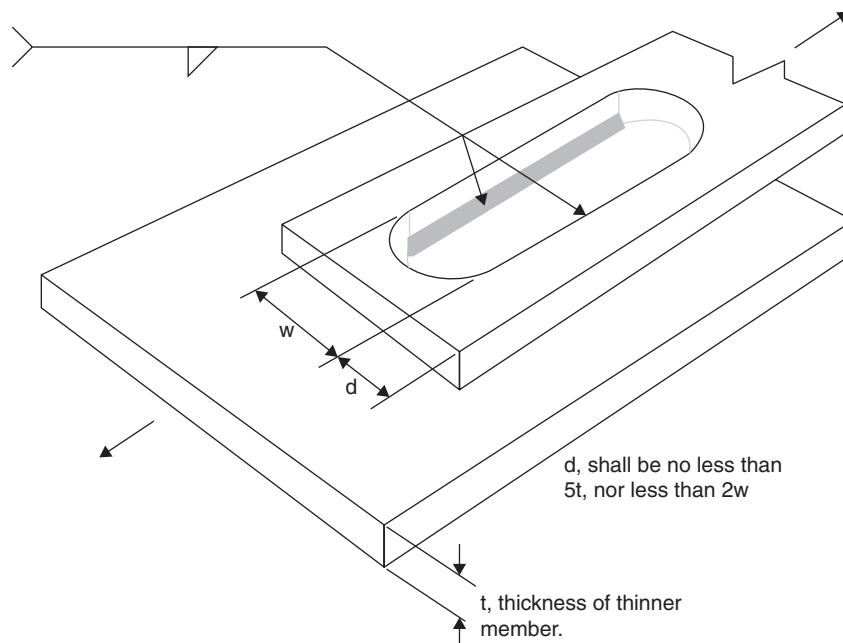


Figure 5.7—Distance to the Edge for Fillet Welds in Slots or Holes

(2) The transverse spacing of longitudinal fillet welds used in end connections 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 longitudinal fillet welds may be either at the edges of the member or in slots.

5.3.4 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 (Figure 5.7). The strength of the part shall be determined from the critical net section of the base metal.

5.4 Complete Joint Penetration (CJP) Groove Welds [Butt Welds].

5.4.1 Details for complete joint penetration groove welds [butt welds] are found in Annex B, Figure B.1 and are subject to the limitations specified in 5.4.2 through 5.4.5.

5.4.2 Dimensional Tolerances. Dimensions of groove welds [butt welds] specified in 5.4.1 may vary on design or detailed drawings within the limits or tolerances shown in the “As Detailed” column in Figure B.1. J- and U-grooves may be prepared before or after assembly.

5.4.3 Joints detailed in Annex B for SMAW [111] may also be used for GMAW [13] or FCAW [114, 13].

5.4.4 Joint Root Openings. Joint root openings may vary as noted in 5.4 and 5.5. However, for automatic or machine welding using the FCAW [13], GMAW [13], and SAW [12] processes, the maximum root opening variation (minimum to maximum opening as fit-up) should not exceed 1/8 in [3 mm]. Variations greater than 1/8 in [3 mm] should be locally corrected prior to automatic or machine welding.

5.4.5 Corner Joints. For corner joints, the outside groove preparation may be in either or both members, provided the basic groove configuration is not changed and adequate edge distance is maintained to support the welding operations without excessive melting.

5.5 Partial Joint Penetration (PJP) Groove Welds [Butt Welds].

5.5.1 Details of partial joint penetration groove welds [butt welds] are found in Annex B, Figure B.2 and are subject to the limitations specified in 5.5.2.

5.5.2 Dimensional Tolerances. Dimensions of groove welds [butt welds] specified in 5.5.1 may vary on design or detailed drawings within the limits or tolerances shown in the “As Detailed” column in Figure B.2. J- and U-grooves may be prepared before or after assembly.

5.5.3 Minimum Weld Size. The minimum weld size of partial joint penetration groove welds [butt welds] required to provide adequate heat input shall be as shown in Table 5.1. The use of minimum weld sizes is not intended to preclude the use of appropriate preheat which could be required because of joint restraint or base metal composition.

Shop or working drawings shall specify the depth of bevel (D) applicable for the weld size (S) required for the welding process and position of welding to be used (see Figure B.2).

5.5.4 Joints detailed in Annex B for SMAW [111] may also be used for GMAW [13] or FCAW [114, 13].

5.6 Fillet Weld Details.

5.6.1 Fillet welds transmitting a tensile force in a direction not parallel to the axis of the weld shall not terminate at corners of parts or members, but shall continue, full size, around the corner for a length equal to twice the weld size as long as this continuation can be made in the same plane. The requirement for boxing shall be indicated on design and detail drawings.

5.6.2 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 5.9).

5.6.3 Details for fillet welds are listed in 5.6.3.1 through 5.6.3.6 and detailed in Figure 5.8.

Table 5.1
Minimum Weld Size for Partial Joint Penetration Groove Welds [Butt Welds]

Base Metal Thickness of Thicker Part Joined in [mm]	Minimum Weld Size ^a in [mm]
1/8 [3] to 3/16 [5] inclusive	1/16 [2]
Over 3/16 [5] to 1/4 [6] inclusive	1/8 [3]
Over 1/4 [6] to 1/2 [13] inclusive	3/16 [5]
Over 1/2 [13] to 3/4 [20] inclusive	1/4 [6]
Over 3/4 [20] to 1 1/2 [40] incl.	5/16 [8]
Over 1 1/2 [40] to 2 1/4 [60] inclusive	3/8 [10]
Over 2 1/4 [60] to 6 [150] inclusive	1/2 [13]
Over 6 [150]	5/8 [16]

^a Except the weld size need not exceed the thickness of the thinner part.

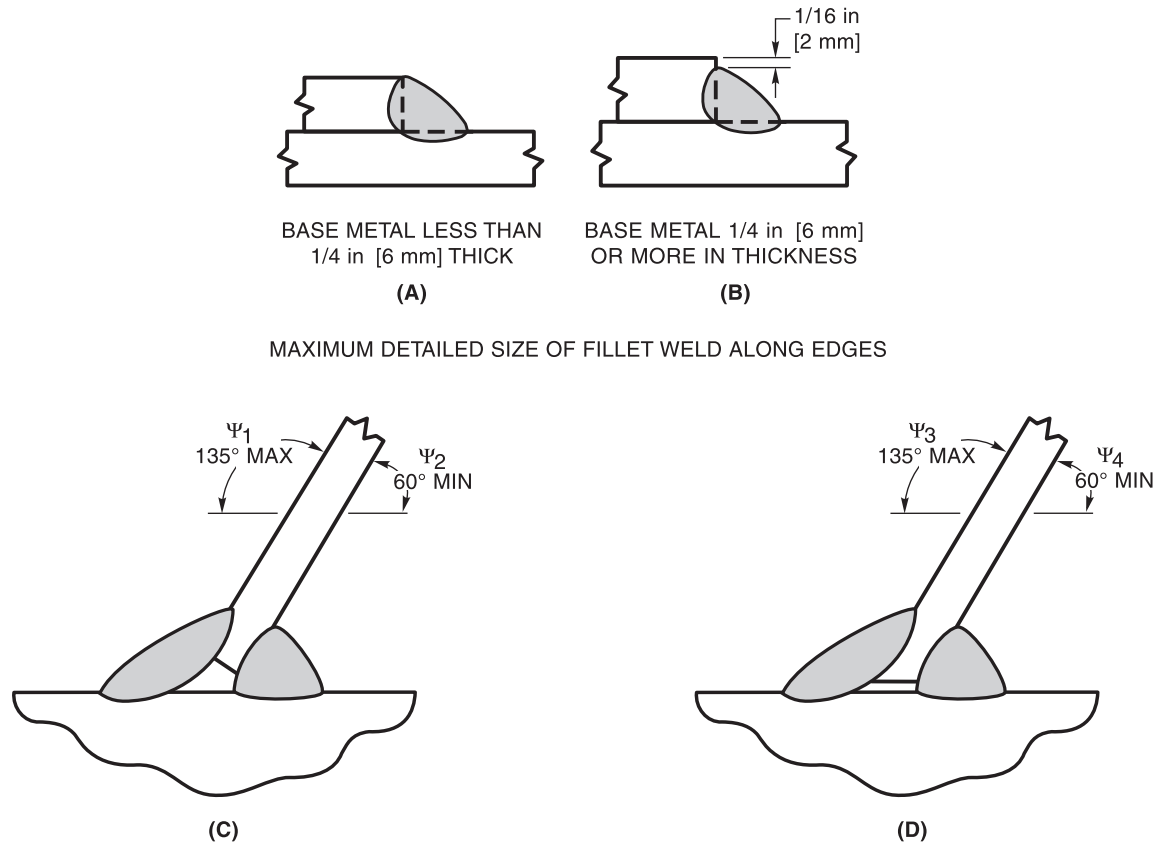


Figure 5.8—Details for Fillet Welds

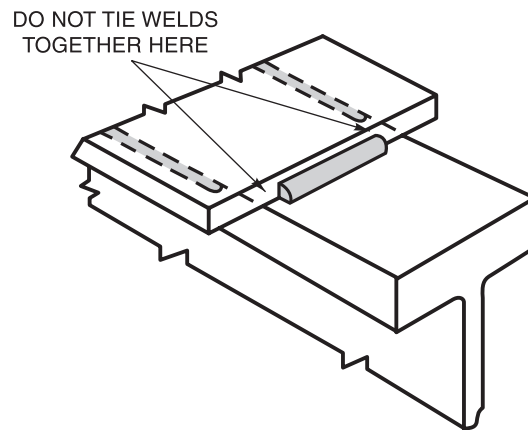


Figure 5.9—Fillet Welds on Opposite Sides of a Common Plane of Contact

5.6.3.1 The minimum single pass fillet weld size that is required to provide adequate heat input, except for fillet welds used to reinforce groove welds [butt welds], shall be as shown in Table 5.2. In both cases, the minimum size applies if it is sufficient to satisfy design requirements. The use of minimum weld sizes is not intended to preclude the use of appropriate preheat which could be required because of joint restraint or base metal composition.

5.6.3.2 The minimum fillet weld size to develop the full strength of the thinner member joined is given in Table 5.3. These values are only applicable when the filler metal is properly matched with the base metal; the welds are loaded statically and the thinner plate or leg is fillet welded continuously on both sides (double fillet weld).

5.6.3.3 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 1/4 in [6 mm] thick as detailed in Figure 5.8(A); or
- (2) 1/16 in [2 mm] less than the thickness of base metal, for metal 1/4 in [6 mm] or more in thickness, as detailed in Figure 5.8(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 less than 1/16 in. [2 mm], provided the weld size is clearly verifiable.

5.6.3.4 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 in 5.9.2.2. Fillet welds in holes or slots are not to be considered as plug or slot welds.

Table 5.2
Minimum Single Pass Fillet Weld Size for Heat Input

Base metal thickness of Thicker part (T) in [mm]	Minimum size ^a of Single pass fillet weld in [mm]
$T \leq 1/4$ [6]	1/8 [3]
$1/4$ [6] < $T \leq 1/2$ [13]	3/16 [5]
$1/2$ [13] < $T \leq 3/4$ [20]	1/4 [6]
$3/4$ [20] < T	5/16 [8]

^a The weld size need not exceed the thickness of the thinner part joined.

Table 5.3
Minimum Size Double Fillet Welds to Develop Full Strength^a

Thinner Plate Thickness (t)		Full Strength ^b Weld ($S = 3/4 t$) ^c		Thinner Plate Thickness (t)		Full Strength ^b Weld ($S = 3/4 t$) ^c	
in	mm	in	mm	in	mm	in	mm
1/4	6	3/16	5	1 3/8	35	1 1/32	26
5/16	8	15/64	6	1 1/2	38	1 1/8	28
3/8	10	9/32	8	1 5/8	41	1 7/32	31
7/16	11	21/64	9	1 3/4	45	1 5/16	34
1/2	13	3/8	10	2	50	1 1/2	38
9/16	14	27/64	11	2 1/8	54	1 19/32	41
5/8	16	15/32	12	2 1/4	57	1 11/16	43
3/4	20	9/16	15	2 3/8	60	1 25/32	45
7/8	22	21/32	16	2 1/2	64	1 7/8	48
1	25	3/4	20	2 5/8	67	1 31/32	50
1 1/8	29	27/32	22	2 3/4	70	2 1/16	53
1 1/4	32	15/16	24	3	75	2 1/4	56

^a The fillet sizes listed do not take into consideration the effective throat thickness obtainable from GMAW [13], FCAW [13, 114] and SAW [12] processes.

^b Filler metal strength shall match that of base metal

^c S = fillet weld size.

5.6.3.5 Fillet welds may be used in skewed T-joints having a dihedral angle of not less than 60° nor greater than 135° (see Figures 5.8(C) and 5.8(D)).

5.6.3.6 When welding is required in an acute angle that is less than 60° but equal to or greater than 30° [Figure 5.10 (Nontubular and Tubular)], the effective throat shall be increased by the Z-loss allowance (Table 5.4 and Table 5.5). The contract documents shall specify the required effective throat. The shop drawings shall show the required leg dimensions to satisfy the required effective throat, increased by the Z-loss allowance in Tables 5.4 and 5.5.

5.6.3.7 The length of any segment of an intermittent fillet weld shall not be less than four times the fillet weld size. The maximum longitudinal spacing of intermittent primary welds shall not exceed 24 times the thickness of the thinner plate, nor exceed 12 in [305 mm]. Welds less than 1/4 in [6 mm] size shall not be less than 1 in [25 mm] in length.

5.6.3.8 When welded with fillet welds, minimum spacing and dimensions of holes and slots shall conform to the requirements of 5.7.

5.7 Details of Plug and Slot Welds.

5.7.1 The minimum diameter of the hole for a plug weld shall be no less than the thickness of the part containing it plus 5/16 in [8 mm], preferably rounded to the next greater odd 1/16 in [even 2 mm] increment. The maximum diameter shall equal the minimum diameter plus 1/8 in [3 mm], or 2–1/4 times the thickness of the member, whichever is greater.

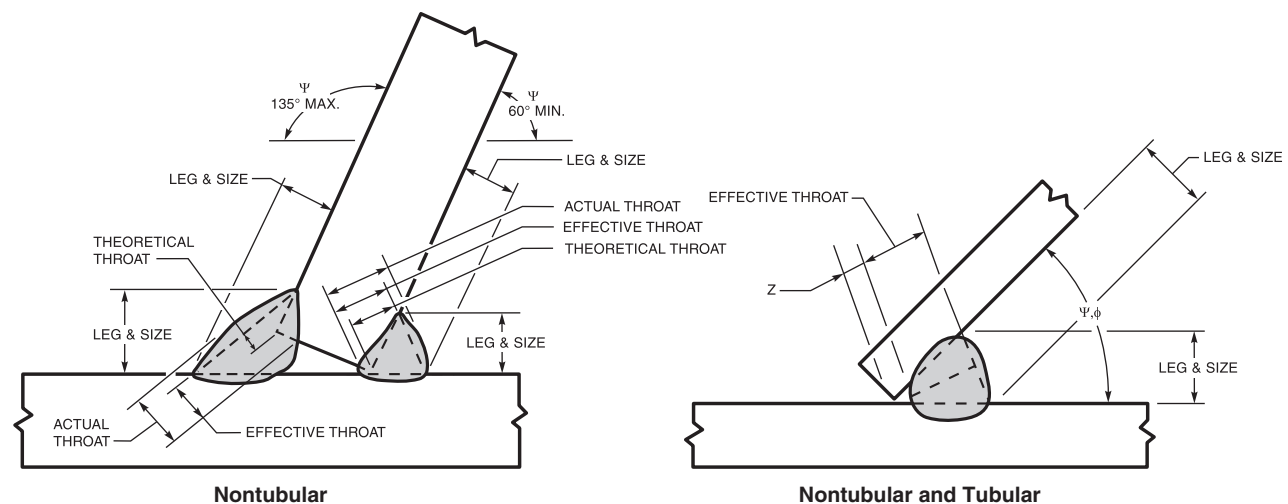


Figure 5.10—Skewed T-Joints

Table 5.4
Z-Loss Dimensions (Nontubular)

Position of Welding: V [PF/PG] or OH [PD/PE]					Position of Welding: H [PB/PC] or F [PA]			
Dihedral Angle ψ	Process	ISO Process	Z (in)	Z [mm]	Process	ISO Process	Z (in)	Z [mm]
		Designator				Designator		
$60^\circ > \psi \geq 45^\circ$	SMAW	<u>111</u>	1/8	3	SMAW	<u>111</u>	1/8	3
	FCAW-S	<u>114</u>	1/8	3	FCAW-S	<u>114</u>	0	0
	FCAW-G	<u>136</u>	1/8	3	FCAW-G	<u>136</u>	0	0
	GMAW	<u>13</u>	N/A	N/A	GMAW	<u>13</u>	0	0
$45^\circ > \psi \geq 30^\circ$	SMAW	<u>111</u>	1/4	6	SMAW	<u>111</u>	1/4	6
	FCAW-S	<u>114</u>	1/4	6	FCAW-S	<u>114</u>	1/8	3
	FCAW-G	<u>136</u>	3/8	10	FCAW-G	<u>136</u>	1/4	6
	GMAW	<u>13</u>	N/A	N/A	GMAW	<u>13</u>	1/4	6

Table 5.5
Z-Loss Dimensions for Calculating PJP T-, Y-, and K-Tubular Connection Minimum Weld Sizes

Dihedral Angle ψ	Position of Welding: V [PF/PG] or OH [PD/PE]				Position of Welding: H [PB/PC] or F [PA]			
	Process	ISO Process Designator	Z (in)	Z [mm]	Process	ISO Process Designator	Z (in)	Z [mm]
$\phi \geq 60^\circ$	SMAW	<u>111</u>	0	0	SMAW	<u>111</u>	0	0
	FCAW-S	<u>114</u>	0	0	FCAW-S	<u>114</u>	0	0
	FCAW-G	<u>136</u>	0	0	FCAW-G	<u>136</u>	0	0
	GMAW	<u>13</u>	N/A	N/A	GMAW	<u>13</u>	0	0
	GMAW-S	<u>13-D</u>	0	0	GMAW-S	<u>13-D</u>	0	0
$60^\circ > \phi \geq 45^\circ$	SMAW	<u>111</u>	1/8	3	SMAW	<u>111</u>	1/8	3
	FCAW-S	<u>114</u>	1/8	3	FCAW-S	<u>114</u>	0	0
	FCAW-G	<u>136</u>	1/8	3	FCAW-G	<u>136</u>	0	0
	GMAW	<u>13</u>	N/A	N/A	GMAW	<u>13</u>	0	0
	GMAW-S	<u>13-D</u>	1/8	3	GMAW-S	<u>13-D</u>	1/8	3
$45^\circ > \phi \geq 30^\circ$	SMAW	<u>111</u>	1/4	6	SMAW	<u>111</u>	1/4	6
	FCAW-S	<u>114</u>	1/4	6	FCAW-S	<u>114</u>	1/8	3
	FCAW-G	<u>136</u>	3/8	10	FCAW-G	<u>136</u>	1/4	6
	GMAW	<u>13</u>	N/A	N/A	GMAW	<u>13</u>	1/4	6
	GMAW-S	<u>13-D</u>	3/8	10	GMAW-S	<u>13-D</u>	1/4	6

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

5.7.3 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 5/16 in [8 mm], preferably rounded to the next greater odd 1/16 in [even 2 mm] increment. The maximum width shall equal the minimum width plus 1/8 in [3 mm] or 2 1/4 times the thickness of the member, whichever is greater.

5.7.4 Plug and slot welds are not permitted in quenched and tempered steels.

5.7.5 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.

5.7.6 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 of any line shall be two times the length of the slot.

5.7.7 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].

5.7.8 The effective area of plug and slot welds (see 5.9.3) is considered to resist shear stresses only.

5.8 Combinations of Welds. If two or more of the general types of welds (groove [butt], fillet, plug, or 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. However, such methods of adding individual capacities of welds do not apply to fillet welds reinforcing groove welds [butt welds] (see 5.9.4).

5.2 Effective Weld Areas, Lengths, and Sizes.

5.2.1 Groove Welds [Butt Welds]. The effective area shall be the effective weld length multiplied by the groove weld [butt weld] size.

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

5.2.1.2 The weld size of a complete joint penetration groove weld [butt weld] shall be the thickness of the thinner part joined. No increase is permitted for weld reinforcement.

5.9.1.3 The weld size of a partial joint penetration groove weld [butt weld] shall be the depth of bevel less 1/8 in [3 mm] for grooves having a groove angle less than 60° but no less than 45° at the root of the groove, when made by shielded metal arc welding (SMAW) [111], submerged arc welding (SAW) [12], gas metal arc welding (GMAW) [13], or flux cored arc welding (FCAW) [114, 132, 136].

The weld size of a partial joint penetration groove weld [butt weld] shall be the depth of bevel, without reduction, for grooves having the following:

- (1) A groove angle of 60° or greater at the root of the groove when made by any of the following welding processes: SMAW [111], SAW [12], GMAW [13], FCAW [114, 136]; or
- (2) A groove angle not less than 45° at the root of the groove when made in flat or horizontal positions by GMAW [13] or FCAW [114, 136] if the specific weld joint detail is proven through procedure qualification.

5.9.1.4 The effective weld size for flare-groove welds [butt welds], when filled flush to the radiused member surface such as a round bar, or 90° bend in a formed section, or a rectangular tube, shall be as shown in Table 5.6.

- (1) When required by the Engineer, validation of the weld size shall be made using macroetch test specimens to verify that the effective weld size is consistently obtained.
- (2) For a given set of procedural conditions, if the macroetch examination results demonstrate consistent production of larger effective weld sizes than those shown in Table 5.6, the Manufacturer may establish such larger effective weld sizes by validations.
- (3) Macroetch specimens shall consist of sectioning the radiused member, normal to its axis, at midlength and at the ends of the weld. The sections shall be no closer than one inch from each weld end. Such sectioning shall be made on a number of combinations of material sizes representative of the range used by the Manufacturer in construction or as required by the Engineer.

5.9.2 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.

5.9.2.1 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.

5.9.2.2 The effective length of a curved fillet weld shall be measured along the center line 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 5.9.3, then this latter area shall be used as the effective area of the fillet weld.

5.9.2.3 The minimum effective length of a fillet weld shall be four times the nominal size, or the effective weld size shall not exceed one-fourth its effective length.

5.9.2.4 The effective throat shall be the minimum distance, minus any convexity between the weld root and the face of a fillet weld. Unless demonstrated by sectioning of validation samples, the effective throat shall be considered no greater than the theoretical throat. See 5.6.3.6 for skewed fillet welds.

Table 5.6
Effective Size of Flare-Groove Welds [Butt Welds] Filled Flush

Welding Process	Flare-Bevel-Groove	Flare-V-Groove
SMAW [111] and FCAW-S [114]	5/16R	5/8R
GMAW ^a [13] and FCAW-G [132, 136]	5/8R	3/4R
SAW [12]	5/16R	1/2R

^a Except GMAW-S [13-D].

Note: R = radius of outside surface. For hollow structural shaped tubing, R shall be taken as two times the nominal wall thickness, unless otherwise specified by the Engineer.

5.9.2.5 Stress on the effective throat area of fillet welds (see [5.9.2](#)) is considered as shear stress regardless of the direction of application.

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

5.9.4 Combination Weld. The effective throat of a combination partial joint penetration groove weld [butt weld] and a fillet weld shall be the minimum distance from the joint root to the weld face of the fillet weld minus 1/8 in [3 mm] (see Figure [5.11](#)).

5.10 Principal Structural Weldments-General.

5.10.1 Maximum Allowable Stress. The maximum stress on principal structural weldment connections shall not exceed the values listed in Table [5.7](#).

5.10.2 Prohibited Details. The restrictions of clause [5.12](#) shall apply to all primary welds on principal structural weldments.

5.11 Cyclically Loaded Principal Structural Weldments. To determine the maximum allowable cyclic stress range for all members and connections of cyclically loaded principal structural weldments the Engineer shall use the method specified in clause [5.11.1](#) through [5.11.5](#) or one of the alternative fatigue design methods listed below in (1) or (2):

- (1) IIW-2259-15, *Recommendations for Fatigue Design of Welded Joints and Components*
- (2) Another fatigue design method approved by the Engineer.

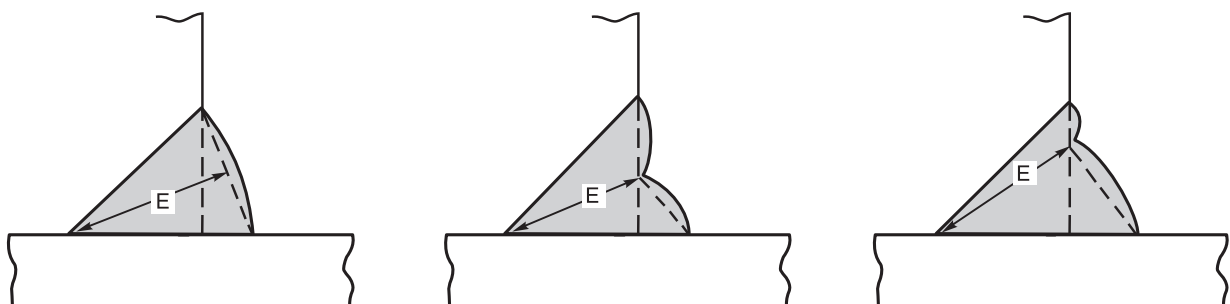
5.11.1 Number of Loading Cycles. For cyclically loaded principal structural weldments, the Engineer shall determine the number of cycles of live load that the weldment is expected to endure in its lifetime.

5.11.2 Stress Ranges. For cyclically loaded principal structural weldments, the Engineer shall determine the stress range applied to all members and connections.

5.11.3 Stress Category. For cyclically loaded principal structural weldments, the Engineer shall determine the applicable stress category, consistent with Figures [5.12](#) and [5.13](#) and Tables [5.8](#) and [5.9](#). Such a determination shall be made for every connection with a primary weld and for every welded attachment made to a principal structural weldment.

5.11.4 The fatigue stress provisions of Figures [5.12](#) and [5.13](#) and Tables [5.8](#) and [5.9](#) may be modified by other rationale analysis such as finite element analysis, when approved by the Engineer.

5.11.5 Base Metal Repairs. For cyclically loaded principal structural weldments, the Engineer shall determine the effect, if any, of base metal repairs on the fatigue performance of the weldment.



Note: The effective throat of a weld (E in this figure) is the minimum distance from the root of the joint to its face, with or without a deduction of 1/8 in [3mm].

Figure 5.11—Combination of Bevel Groove and Fillet Weld Profiles

Table 5.7
Allowable Stresses (see 5.10 and 5.11)

Type of Applied Stress	Allowable Stress	Required Filler Metal Strength Level ^a
CJP Groove [Butt] Welds		
Tension normal to the effective area ^b	Same as base metal	Matching filler metal shall be used ^c
Compression normal to effective area	Same as base metal	Filler metal with a strength level equal to or one classification (10 ksi [70 MPa]) less than matching filler metal may be used.
Tension or compression parallel to axis of the weld ^d	Not a welded joint design consideration	Filler metal with a strength level equal to or less than matching filler metal may be used
Shear on effective area	0.30 × classification tensile strength of filler metal except shear on the base metal shall not exceed 0.40 × yield strength of the base metal	
PJP Groove [Butt] Welds		
Tension normal to the effective area	0.30 × classification tensile strength of filler metal	Filler metal with a strength level equal to or less than matching filler metal may be used
Compression normal to effective area of weld in joints designed to bear	0.90 × classification tensile strength of filler metal, but not more than 0.90 × yield strength of the connected base metal	
Compression normal to effective area of weld in joints not designed to bear	0.75 × classification tensile strength of filler metal	
Tension or compression parallel to axis of the weld ^d	Not a welded joint design consideration	
Shear parallel to axis of effective area	0.30 × classification tensile strength of filler metal except shear on the base metal shall not exceed 0.40 × yield strength of the base metal	
Fillet Welds		
Shear on effective area of weld	0.30 × classification tensile strength of filler metal except that the base metal net section shear area stress shall not exceed 0.40 × yield strength of the base metal ^e	Filler metal with a strength level equal to or less than matching filler metal may be used
Tension or compression parallel to axis of the weld ^d	Not a welded joint design consideration	
Plug and Slot Welds		
Shear parallel to the faying surface on the effective area ^f	0.30 × classification tensile strength of filler metal	Filler metal with a strength level equal to or less than matching filler metal may be used

^a Matching and undermatching filler metal relationships with base materials are listed in the applicable referencing application standard (e.g. AWS D14.3/D14.3M, Specification for Welding Earthmoving, Construction, and Agriculture Equipment).

^b For definitions of effective areas, see 5.9.

^c For joining base metals of different strength levels, the lower strength level shall determine the matching filler metal tensile series.

^d Fillet welds and Groove Welds [Butt Welds] joining components of built-up members are allowed to be designed without regard to the tension and compression stresses in the connected components parallel to the weld axis although the area of the weld normal to the weld axis may be included in the cross-sectional area of the member.

^e The limitation on stress in the base metal to $0.40 \times$ yield point of base metal does not apply to stress on the diagrammatic weld leg; however, a check shall be made to assure that the strength of the connection is not limited by the thickness of the base metal on the net area around the connection, particularly in the case of double fillet welds on opposite sides of a plate element.

^f The strength of the connection shall also be limited by the tear-out load capacity of the thinner base metal on the perimeter area around the connection.

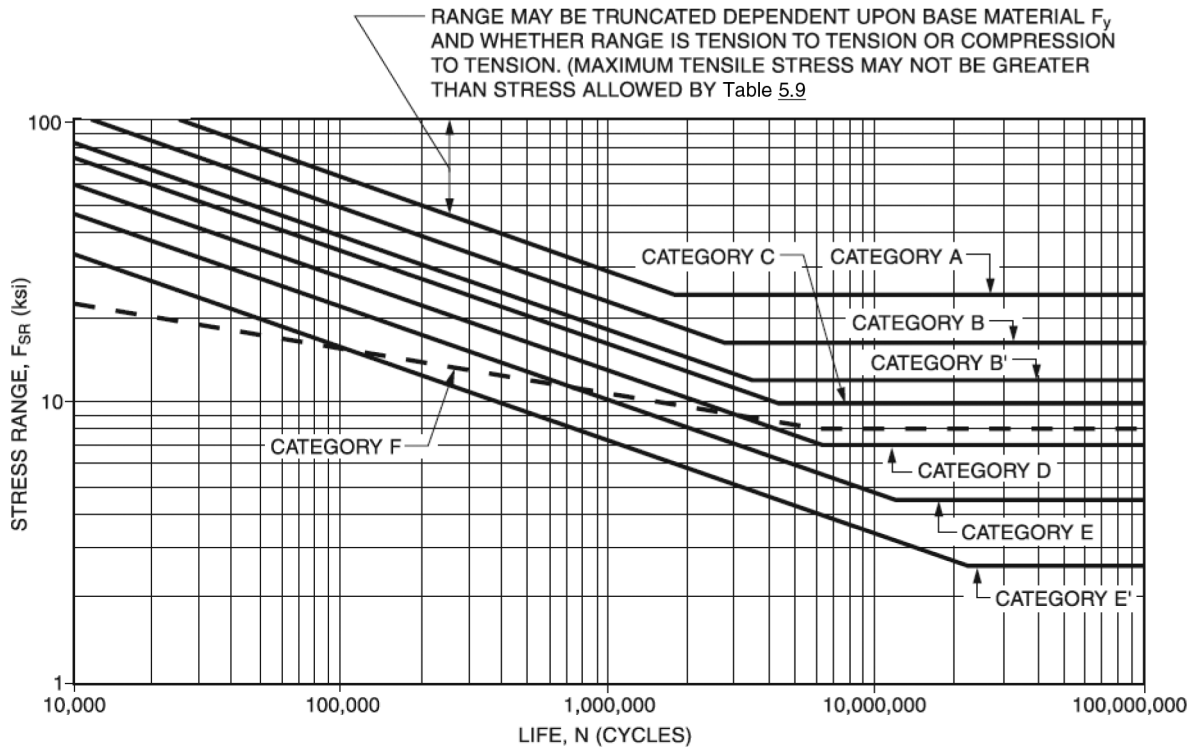


Figure 5.12—Allowable Stress Range for Cyclically Applied Load (Fatigue) – US Customary Units

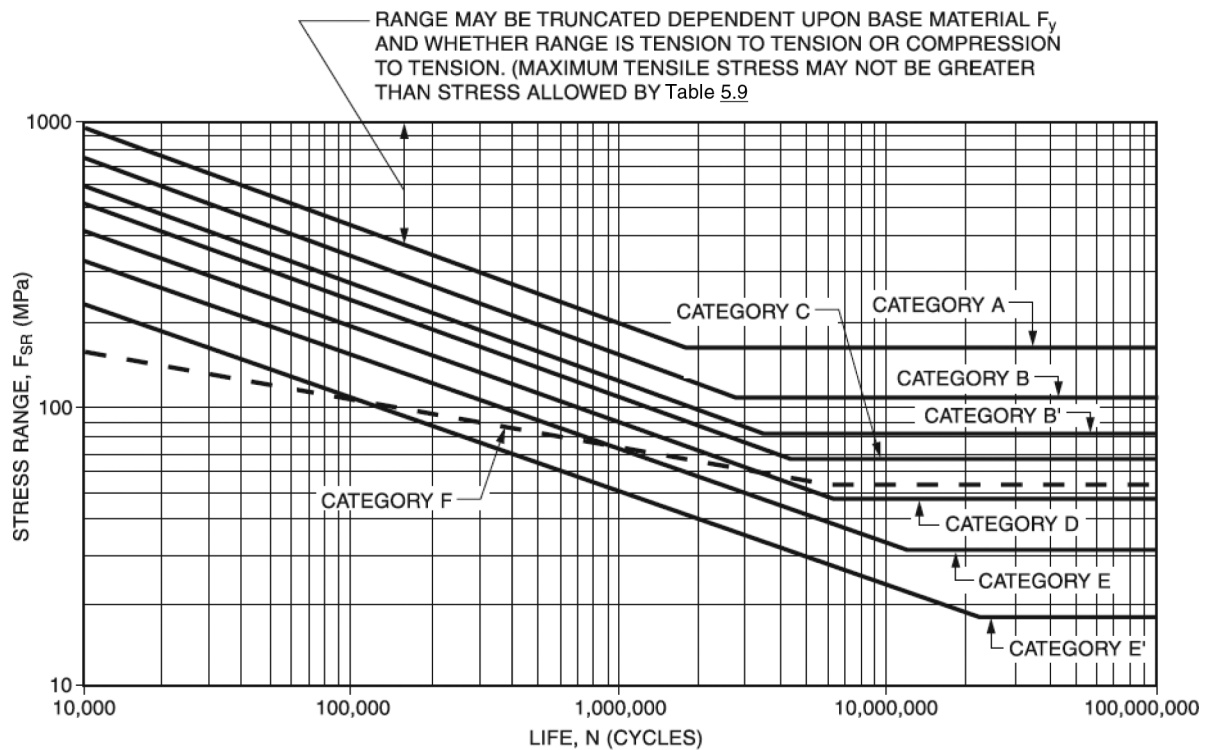
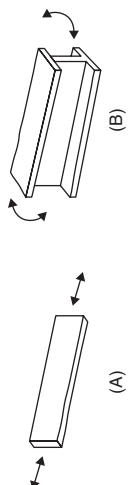
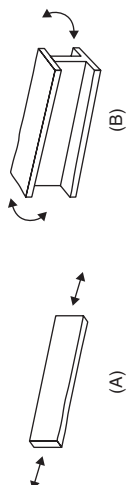
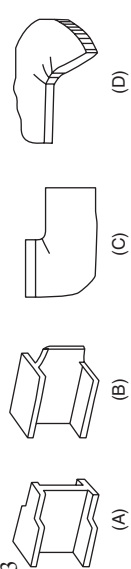
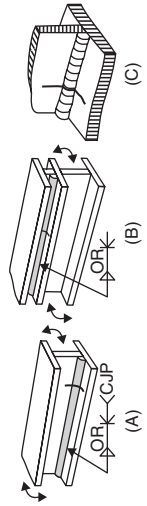


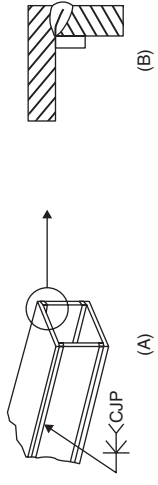
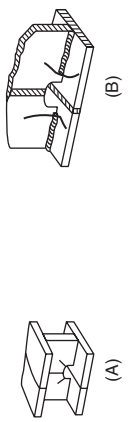
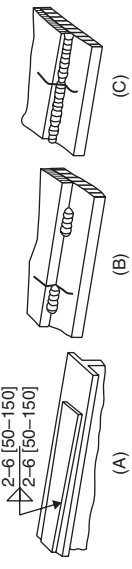
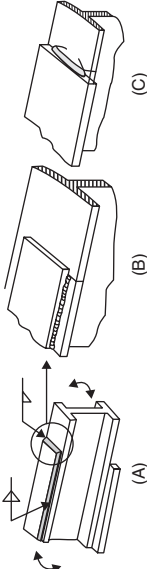
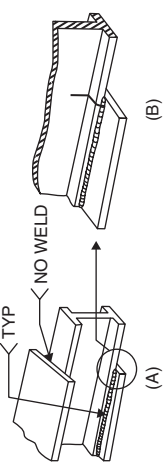
Figure 5.13—Allowable Stress Range for Cyclically Applied Load (Fatigue) – SI Units

Table 5.8
Fatigue Stress Design Parameters (see 5.11)

Description	Stress Category	Inspection Class	Potential Crack Initiation Point	Illustrative Examples
Section 1—Plain Material Away from Any Welding				
1.1 Base metal, except non-coated weathering steel, with rolled or cleaned surface and rolled or thermal -cut edges with ANSI smoothness of 1000 or less, but without reentrant corners.	A	N.A.	Away from all welds or structural connections	1.1/1.2 
1.2 Non-coated weathering steel base metal with rolled or cleaned surface and with rolled or thermal-cut edges with ANSI smoothness of 1000 or less.	B	N.A.	Away from all welds or structural connections	
1.3 Thermal-cut reentrant corners, except weld access holes, meeting the requirements ANSI smoothness of 1000 or less.	B	N.A.	From irregularities in surface of reentrant corner	1.3 
1.4 Weld access holes made to the requirements of 5.24.	C	N.A.	From irregularities in surface of reentrant corner of weld access hole	1.4 
Section 2—Connected Material in Mechanically Fastened Joints—Not Used^a				
Section 3—Welded Joints Joining Components of Built-Up Members				
3.1 Base metal and weld metal in members without attachments built-up or plates or shapes connected by continuous longitudinal CJP groove welds [butt welds], backgouged and welded from second side, or by continuous fillet welds.	B	III	From surface or internal discontinuities in weld away from end of weld	3.1 

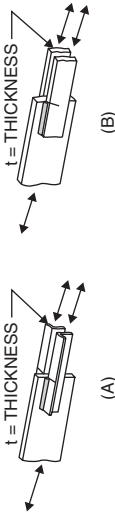
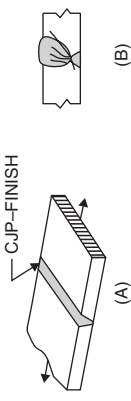
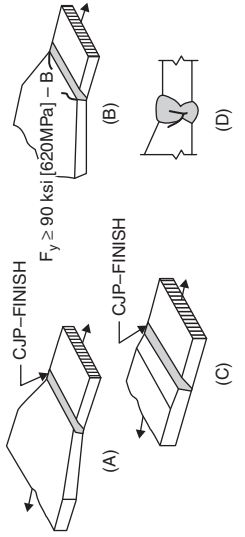
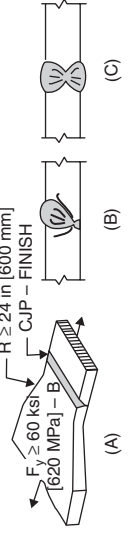
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Table 5.8 Continued
Fatigue Stress Design Parameters (see 5.11)

Description	Stress Category	Inspection Class	Potential Crack Initiation Point	Illustrative Examples
3.2 Base metal and weld metal in members without attachments built-up of plates or shapes connected by continuous longitudinal CJP groove welds [butt welds] with backing not removed, or by continuous PJP groove welds [butt welds].	B'	III	From surface or internal discontinuities in weld, including weld attaching backing	
3.3 Base metal and weld metal at termination of longitudinal fillet at weld access holes in built-up members.	D	IV	From the weld termination into the web or flange	
3.4 Base metal at ends of longitudinal intermittent fillet weld segments.	E	IV	In connected material at start and stop locations of any weld deposit	
3.5 Base metal at ends of partial length welded cover plates narrower than the flange having square or tapered ends, with or without welds across the ends or coverplates wider than the flange with welds across the ends. Flange thickness ≤ 0.8 in [20 mm] Flange thickness > 0.8 in [20 mm]	E E'	IV IV	In flange at toe of end weld or in flange at termination of longitudinal weld or in edge of flange with wide coverplates	
3.6 Base metal at ends of partial length welded cover plates wider than the flange without welds across the ends.	E'	IV	In edge of flange at end of coverplate weld	

(Continued)

Table 5.8 Continued
Fatigue Stress Design Parameters (see 5.11)

Description	Stress Category	Inspection Class	Potential Crack Initiation Point	Illustrative Examples
Section 4—Longitudinal Fillet Welded Connections				
4.1 Base metal at junction of axially loaded members with longitudinally welded end connections. Welds lengths shall be proportioned on each side of axis to balance weld stresses. $t \leq 0.8$ in [20 mm] $t > 0.8$ in [20 mm]	E E'	IV IV	Initiating from end of any weld termination extending into the base metal	
Section 5—Welded Joints Transverse to Direction of Stress				
5.1 Base metal and weld metal in or adjacent to CJP groove welded [butt welded] splices in rolled or welded cross section with welds ground essentially parallel to the direction of stress.	B	I	From internal discontinuities in weld metal or along fusion boundary	
5.2 Base metal and filler metal in or adjacent to CJP groove welded [butt welded] splices with welds ground essentially parallel to the direction of stress at transitions in thickness or width made on a slope no greater than 1 to 2-1/2. $F_y < 90$ ksi [620 MPa] $F_y \geq 90$ ksi [620 MPa]	B B'	I I	From internal discontinuities in weld metal or along fusion boundary or at start of transition when $F_y \geq 90$ ksi [620 MPa]	
5.3 Base metal with F_y equal to or greater than 90 ksi [620 MPa] and filler metal in or adjacent to CJP groove welded [butt welded] splices with welds ground essentially parallel to the direction of stress at transitions in width made on a radius of not less than 2 ft [600 mm] with the point of tangency at the end of the groove weld [butt weld].	B	I	From internal discontinuities in filler metal or discontinuities along the fusion boundary	

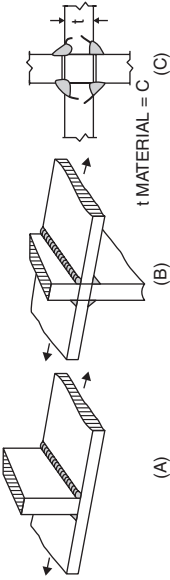
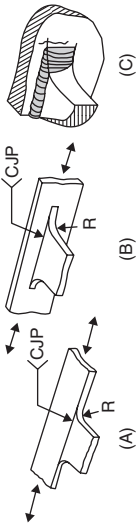
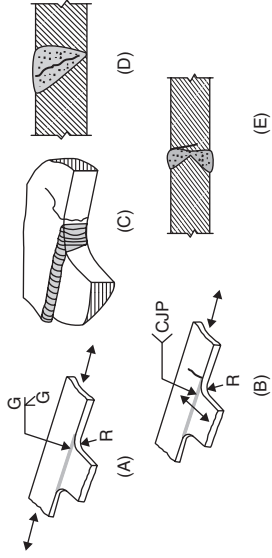
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Table 5.8 Continued
Fatigue Stress Design Parameters (see 5.11)

Description	Stress Category	Inspection Class	Potential Crack Initiation Point	Illustrative Examples
5.4 Base metal and filler metal in or adjacent to the toe of CJP, T- or corner joints with backing removed or splices, with or without transitions in thickness having slopes no greater than 1 to 2-1/2 when weld reinforcement is not removed.	C	II	From surface discontinuity at weld toe extending into base metal or along fusion boundary	
5.4.1 Base metal and filler metal in or adjacent to CJP groove welded butt splices with backing left in place. Tack welds inside groove Tack welds outside the groove and not closer than 1/2 in [12 mm] to edge of base metal	D E	IV IV	From the toe of the groove weld [butt weld] or the toe of the weld attaching backing	
5.5 Base metal and filler metal at transverse end connections of tension- loaded plate elements using PJP butt, T-, or corner joints, with reinforcing or contouring fillet welds. Crack initiating from weld toe Crack initiating from weld root	C C'	IV IV	Initiating from discontinuity at weld toe extending into base metal or initiating from root due to tension extending up and then out through the weld	
5.6 Base metal and weld metal at transverse end connections of tension- loaded plate elements using double fillet welds on opposite sides of the plate. Crack initiating from weld toe Crack initiating from weld root	C C''	IV IV	Initiating from discontinuity at weld toe extending into base metal or initiating from root due to tension extending up and then out through the weld	

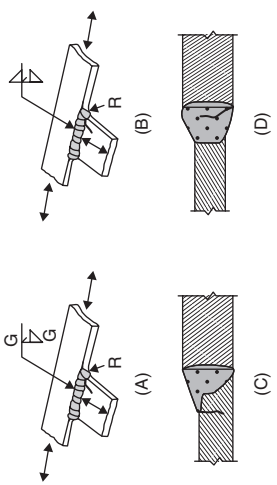
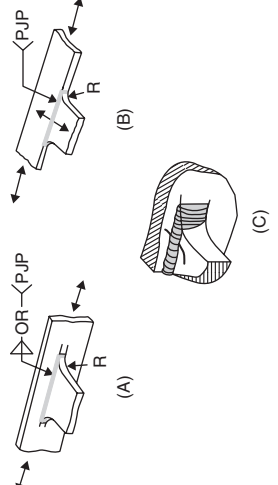
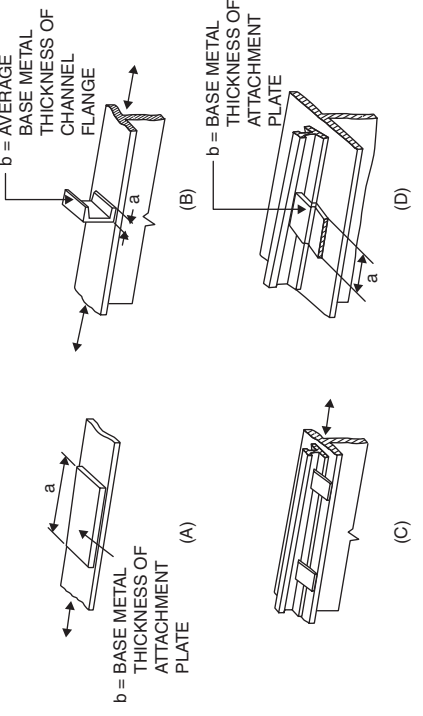
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Table 5.8 Continued
Fatigue Stress Design Parameters (see 5.11)

Description	Stress Category	Inspection Class	Potential Crack Initiation Point	Illustrative Examples
5.7 Base metal of tension loaded plate elements at toes of transverse fillet welds, and, base metal at toe of welds on girders and rolled beam webs or flanges adjacent to welded transverse stiffeners.	C	IV	From geometric discontinuity at fillet weld toe extending into base metal	
Section 6—Base Metal at Welded Transverse Member Connections				
6.1 Base metal at details attached by CJP groove welds [butt welds] subject to longitudinal loading only when the detail embodies a transition radius, R, with the weld termination ground smooth. $R \geq 24$ in [600 mm] 24 in [600 mm] $> R \geq 6$ in [150 mm] 6 in [150 mm] $> R \geq 2$ in [50 mm] 2 in [50 mm] $> R$	B C D E	III IV IV IV	Near point of tangency of radius at edge of member	
6.2 Base metal at details of equal thickness attached by CJP groove welds [butt welds] subject to transverse loading with or without longitudinal loading when the detail embodies a transition radius, R, with the weld termination ground smooth. When weld reinforcement is removed: $R \geq 24$ in [600 mm] 24 in [600 mm] $> R \geq 6$ in [150 mm] 6 in [150 mm] $> R \geq 2$ in [50 mm] 2 in [50 mm] $> R$ When weld reinforcement is removed: $R \geq 24$ in [600 mm] 24 in [600 mm] $> R \geq 6$ in [150 mm] 6 in [150 mm] $> R \geq 2$ in [50 mm] 2 in [50 mm] $> R$	B C D E C C D E	III IV IV IV IV IV IV IV	Near points of tangency of radius or in the weld or at fusion boundary or member or attachment At toe of the weld either along edge of member or the attachment	

(Continued)

Table 5.8 Continued
Fatigue Stress Design Parameters (see 5.11)

Description	Stress Category	Inspection Class	Potential Crack Initiation Point	Illustrative Examples
6.3 Base metal at details of unequal thickness attached by CJP groove welds [butt welds] subject to transverse loading with or without longitudinal loading when the detail embodies a transition radius, R, with the weld termination ground smooth. When weld reinforcement is removed:			At weld toe along edge of thinner material	
$R > 2$ in [50 mm] $R \leq 2$ in [50 mm] When weld reinforcement not removed: Any radius	D E E	 IV IV IV		
6.4 Base metal subject to longitudinal stress at transverse members, with or without transverse stress, attached by fillet or PJP groove welds [butt welds] parallel to direction of stress when the detail embodies a transition radius, R, with weld termination ground smooth.			In weld termination or from the weld toe extending into member	
$R > 2$ in [50 mm] $R \leq 2$ in [50 mm]	D E	IV IV		
Section 7—Base Metal at Short Attachments^b				
7.1 Base metal subject to longitudinal loading at details attached by fillet welds parallel or transverse to direction of stress where the detail embodies no transition radius, and with detail length in direction of stress, a, and attachment height normal to the surface of the member b:			In the member at the end of the weld	
$a < 2$ in [50 mm] 2 in [50 mm] $\geq a \geq 12b$ or 4 in [100 mm]	C D	IV IV		
$a > 12b$ or 4 in [100 mm] when b is ≤ 1 in [25 mm] $a > 12b$ or 4 in [100 mm] when b is > 1 in [25 mm]	E E'	IV IV		

(Continued)