

Specification for Welding Earthmoving, Construction, Agricultural, and Ground-Based Material Handling Equipment



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Specification for Welding Earthmoving, Construction, Agricultural, and Ground-Based Material Handling Equipment

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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 provides standards for producing structural welds used in the manufacture and repair of earthmoving, construction, agricultural, and ground-based material handling equipment. Such equipment is defined as self-propelled, on- and off-highway machinery and associated implements. Manufacturer's responsibilities are presented as they relate to the welding practices that have been proven successful within the industry in the production of weldments on this equipment. Requirements for basic weld details, base material, filler material, processes, welding procedure qualification and documentation, welding personnel qualification, weld quality, inspection, and repair are included.



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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 It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn.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.

AWS first published the Specification for Welding Earthmoving and Construction Equipment in 1977 to provide a welding specification where none previously existed. By definition, the types of equipment covered by the specification are numerous and varied. Every effort was made to reflect the best welding practices employed by manufacturers within the industry and to incorporate all the various methods which have proven successful by individual manufacturers. This edition builds on these foundations to improve interpretation and effect implementation. Text, tables, and figures have been updated or clarified to reflect more recent developments and promote standardization.

Underlined text or a vertical line in the margin indicates a revision of that item from the previous edition. Revisions to tables, figures, or annexes are marked with a vertical line in the margin.

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

Dedication

The AWS D14 Committee on Machinery and Equipment dedicates this edition of the D14.3/D14.3M, Specification for Welding Earthmoving, Construction, Agricultural, and Ground-Based Material Handling Equipment, to Edward G. Yevick for his significant contributions to the committee and his efforts to advance the science, technology and application of welding.

Ed joined AWS in 1963 and achieved the Life Membership Award with Gold Certificate for more than 51 years of service. He received the Samuel Wylie Miller Memorial Award in 2017 and the Honorary Membership Award in 2014. He served as technical representative for the AWS Pittsburgh Section for 15 years, and as chairman from 1980 to 1981. Ed was an active member of D14 Committee on Machinery and Equipment; D14B Subcommittee on Design of Welded Joints; D14C Subcommittee on Earthmoving, Construction, and Agricultural Equipment; D14E Subcommittee on Cranes and Presses; D14G Subcommittee on Rotating Equipment; D14I Subcommittee on Hydraulic Cylinders; and served as chairman of D14H Subcommittee on Surfacing of Industrial Mill Rolls. In addition to the Machinery and Equipment committee and subcommittees, Ed also served as chairman of the AWS D11 Committee on Welding Iron Castings and was serving his third term on the AWS Technical Activity Committee.

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Specification for Welding Earthmoving, Construction, Agricultural, and Ground-Based Material Handling Equipment

1. General Requirements

1.1 Scope. This specification applies to all structural welds used in the manufacture and repair of earthmoving, construction, agricultural, and ground-based material handling equipment.¹ It reflects the welding practices employed by manufacturers within the industry and incorporates various methods which have been proven successful by individual manufacturers. No restrictions are placed on the use of any welding process or procedure, provided the weld produced meets the qualification requirements of this specification. No attempt is made to limit or restrict the progression of welding technology for earthmoving, construction, agricultural, and/or ground-based material handling equipment manufacturing and repair, nor should any such limitation be inferred. Design criteria for allowable stresses for the base and weld metal and the fatigue analysis for welded joints are not published in the specification. The user shall utilize AWS D14.4/D14.4M, *Specification for the Design of Welded Joints in Machinery and Equipment*, or appropriate engineering practices and principles for design criteria.

1.1.1 The Manufacturer's adherence to this specification shall include responsibility for the following:

- (1) welding, as defined in 1.1.1, in accordance with this specification;
- (2) producing welds as designated on drawings by appropriate symbols and notes, with sufficient detail to show joint preparation compatible with applied processes;
- (3) providing and using written Welding Procedure Specifications (WPSs);
- (4) ensuring that qualified welders are used to make welds;
- (5) recording and maintaining results of all welder performance and procedure qualification tests;
- (6) controlling use of designated base metals and consumables;
- (7) inspecting the welds to the requirements of this specification;
- (8) having a quality system in place. The requirements of AWS B5.17, *Specification for the Qualification of Welding Fabricators* may be used as a guide in establishing this quality program. Accreditation of quality systems of welding fabricators may be obtained through the AWS Certified Welding Fabricator (CWF) or equivalent programs.
- (9) determining the responsible technical authority when the term "Engineer" is used. If the Owner wants to assume engineering responsibility, it shall be specified in the contract documents.

¹ For purposes of this specification, earthmoving, construction, agricultural, and ground-based material handling equipment are described as on- and off-highway machinery and associated implements, as well as support equipment such as conveyors. Products that this specification covers include, but are not limited to, crawlers, tractors, graders, loaders, off-highway trucks, power shovels, backhoes, mobile cranes, draglines, forklifts, power trucks, and similar equipment. Products such as gantry and jib cranes are not within the scope of this specification.

1.1.2 The “Engineer” in this document shall have specific technical expertise, such as but not limited to welding engineering or design engineering.

1.1.2.1 Welding Engineer. The Manufacturer’s technical authority is typically responsible for developing Welding Procedure Specifications (WPS), Procedure Qualification Records (PQR), and Performance Qualification Test Records (PQTR). The Welding Engineer may also have expertise in weld process selection; weld metallurgy and weld filler metal selection; weld joint design and weld sizing; weld fixture design and weld robot programming; weld 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 B5.17 (*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.

1.1.2.2 Design Engineer. The Manufacturer’s technical authority is typically responsible for developing equipment configuration; analyzing stress levels, Finite Element Analysis (FEA), 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 may also provide judgments on weld defect criticality and weld inspection requirements. See AWS D14.4 *Specification for the Design of Welded Joints in Machinery and Equipment* for design criteria for allowable stresses for the base and weld metal and the fatigue analysis for welded joints. 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.

1.2 Units of Measure. This standard makes use of both the 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, and therefore 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 Symbols. Welding symbols shown on drawings shall be compatible with those shown in AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*. In addition, welding symbols not conforming to the requirements of AWS A2.4, but conforming to the requirements of this specification may be allowed on drawings. Special conditions or deviations shall be fully explained by added notes, details, or definitions on the drawings.

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, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying.

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

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

AWS B2.1/B2.1M-BMG, Base Metal Grouping for Welding Procedure and Performance Qualification

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

AWS D14.4/D14.4M, Specification for the Design of Welded Joints in Machinery and Equipment

American Society for Testing and Materials (ASTM) standards:

ASTM E 140, Standard Hardness Conversion Tables for Metals

ASTM E384, Standard Test Method for Knoop and Vickers Hardness of Materials

International Organization for Standardization (ISO) standards:

ISO 9015-1, Destructive tests on welds in metallic materials—Hardness testing—Part 1: Hardness test on arc welded joints

ISO 9016, Destructive tests on welds in metallic materials—Impact tests—Test specimen location, notch orientation and examination

ISO 9606-1, Qualification testing of welders—Fusion welding—Part 1: Steels

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.

consumables. Filler metals, fluxes, and shielding gases used in the welding process.

contract documents. Purchase orders, contracts, technical documents, or drawings.

data variable (D). A welding variable that is required to be listed on a WPS whose change beyond the tolerance listed on the WPS requires a revision in the WPS but not requalification of the WPQR (formerly known as non-essential variable).

effective weld areas

groove welds. The effective area is the effective weld length multiplied by the weld size. (See 4.1 for additional details.)

fillet welds. The effective area is the effective weld length multiplied by the effective throat. (See 4.2 for additional details.)

plug and slot welds. The effective area shall be the nominal area of the hole or slot in the plane of the faying surface.

Engineer. Manufacturer's technical authority. See 1.1.2 for additional information on Engineer responsibilities and qualifications.

equipment modification. An alteration to machinery or equipment that changes the original design.

fracture toughness. The ability of a material to resist fracture when a flaw is present. It is typically measured by Charpy V-notch, dynamic tear, plane-strain fracture toughness, or drop-weight nil-ductility transition temperature tests.

fracture toughness variable (T). A qualification variable that is required when fracture toughness is specified by the Engineer. When fracture toughness is not required, these variables shall be considered data variables (formerly known as Supplementary Essential Variable).

Manufacturer. The organization responsible for the design and fabrication of the end product created utilizing this specification.

operator of automatic welding equipment. Welding personnel who operate equipment that requires only occasional or no observation and no manual adjustment of the controls.

Owner. The person, company, or agency purchasing the equipment.

procedure qualification variable. One of a set of elements that define the qualification limits of a Welding Procedure Specification (WPS).

performance qualification variable. One of a set of requirements that define the qualification limits of welders and welding operators.

qualified person. A person who, by possession of a recognized degree or certificate of professional standing, or who, by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve or resolve problems relating to the subject matter and work.

qualification variable (Q). See **performance qualification variable** and **procedure qualification variable** (formerly known as Essential Variable).

repair. The restoration of machinery or equipment to meet its intended performance without changing the original design.

structural welds. Welds which carry the primary working loads during normal operations.

welding variable. Any controllable detail of a welding procedure which is required to be addressed on the Welding Procedure Specification (WPS)

4. Basic Weld Detail

4.1 Groove Welds

4.1.1 A complete joint penetration (CJP) weld is a groove weld in which weld metal extends through the entire joint thickness. The size of a CJP groove weld shall be the thickness of the thinner part joined.

4.1.2 A partial joint penetration (PJP) weld may be welded from one or both sides and has incomplete joint penetration. The size of a PJP groove weld shall be the joint penetration obtained. Welds in skewed T-Joints having dihedral (ψ) angles less than 60° shall be designed as PJP groove welds (see 4.2.4).

4.1.3 The effective length for any groove weld, square or skewed, shall be the width of the part joined (see Figure 4.1).

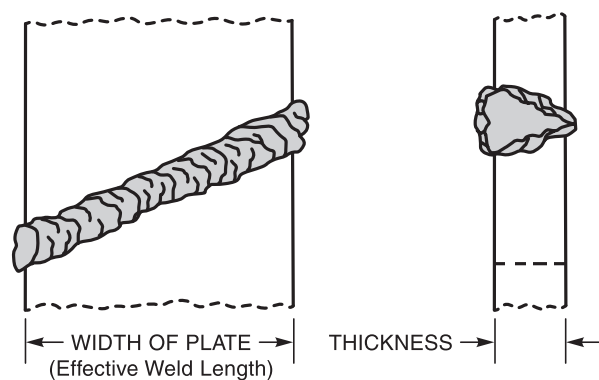
4.1.4 The effective weld area shall be the effective weld length multiplied by the weld size.

4.2 Fillet Welds

4.2.1 The effective throat for a fillet weld shall be the minimum distance, minus any convexity, between the weld root and the face of a fillet weld (see Figures 4.2, 4.3, and 4.4). When approved by the Engineer, design values based on increased effective throat, as a result of increased joint penetration beyond the joint root, may be used. Welding shall be performed using a WPS qualified in accordance with 7.4.3 Fillet Weld Qualification for Deep Joint Penetration.

4.2.2 The length of a fillet weld shall be the overall length of the full-size fillet, including boxing.

4.2.3 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.



THE DIRECTION OF THE WELD ACROSS THE PLATE IS OTHER THAN 90° TO THE LENGTH OF THE PLATE.

Figure 4.1—Skewed Groove Weld

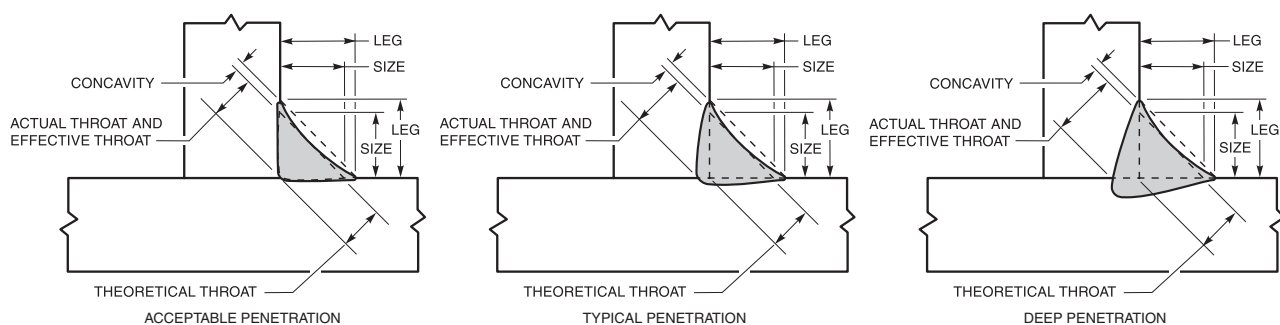


Figure 4.2—Concave Fillet Weld Profiles

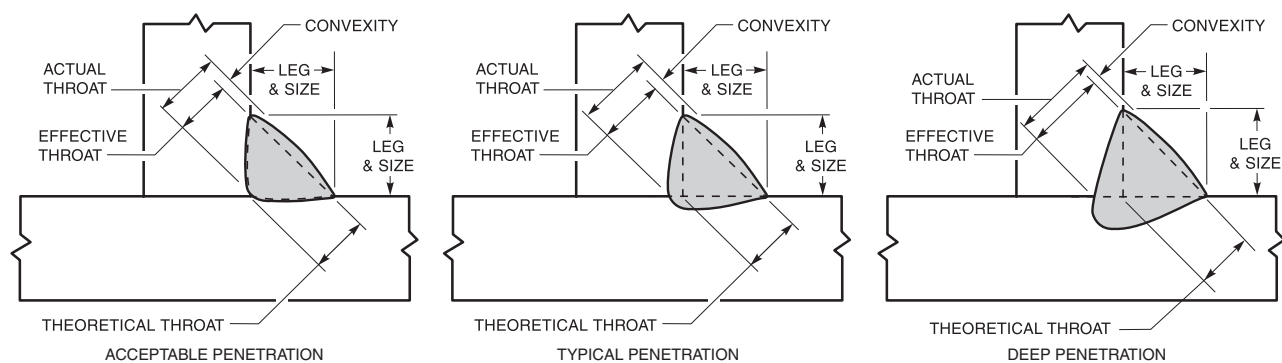


Figure 4.3—Convex Fillet Weld Profiles

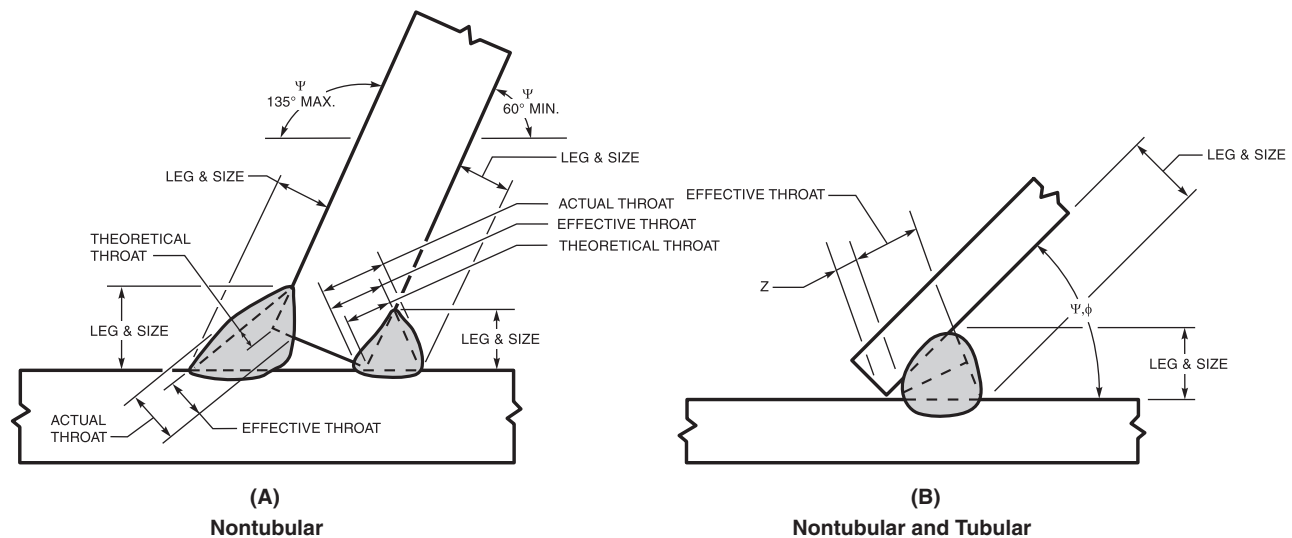


Figure 4.4—Skewed T-Joint

Table 4.1
Z-Loss Dimensions (Nontubular)

Dihedral Angle ψ	Position of Welding—V or OH			Position of Welding—H or F		
	Process	Z(in)	Z(mm)	Process	Z(in)	Z(mm)
$60^\circ > \psi \geq 45^\circ$	SMAW	1/8	3	SMAW	1/8	3
	FCAW-S	1/8	3	FCAW-S	0	0
	FCAW-G	1/8	3	FCAW-G	0	0
	GMAW	N/A	N/A	GMAW	0	0
$45^\circ > \psi \geq 30^\circ$	SMAW	1/4	6	SMAW	1/4	6
	FCAW-S	1/4	6	FCAW-S	1/8	3
	FCAW-G	3/8	10	FCAW-G	1/4	6
	GMAW	N/A	N/A	GMAW	1/4	6

4.2.4 Fillet welds may be used in skewed T-joints having a dihedral angle of not less than 60° nor greater than 135° [see Figure 4.4(A)]. Angles less than 60° may be used; however, such welds are considered to be PJP groove welds [see Figure 4.4(B)] (see 4.1.2 regarding PJP weld joints).

4.2.5 When welding is required in an acute angle that is less than 60° but equal to or greater than 30° [Figure 4.4(B)], the effective throat shall be increased by the Z-loss allowance (Table 4.1 and Table 4.2). The shop drawings shall show the required leg dimensions to satisfy the required effective throat, increased by the Z-loss allowance in Tables 4.1 and 4.2.

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

4.4 Combinations of Groove and Fillet Welds. The effective throat for combinations of groove and fillet welds is the shortest distance from the weld root to the face of the fillet, less any convexity (see Figure 4.5).

4.5 Intermittent Welds

4.5.1 The length of any segment of an intermittent fillet weld shall not be less than four times the weld size, nor less than 1 in [25 mm] in length, whichever is greater.

Table 4.2
Z Loss Dimensions for Calculating PJP T-, Y-, and K-Tubular Connection
Minimum Weld Sizes

Joint Included Angle ϕ	Position of Welding: V or OH			Position of Welding: H or F		
	Process	Z (in)	Z [mm]	Process	Z (in)	Z [mm]
$\phi \geq 60^\circ$	SMAW	0	0	SMAW	0	0
	FCAW-S	0	0	FCAW-S	0	0
	FCAW-G	0	0	FCAW-G	0	0
	GMAW	N/A	N/A	GMAW	0	0
	GMAW-S	0	0	GMAW-S	0	0
$60^\circ > \phi \geq 45^\circ$	SMAW	1/8	3	SMAW	1/8	3
	FCAW-S	1/8	3	FCAW-S	0	0
	FCAW-G	1/8	3	FCAW-G	0	0
	GMAW	N/A	N/A	GMAW	0	0
	GMAW-S	1/8	3	GMAW-S	1/8	3
$45^\circ > \phi \geq 30^\circ$	SMAW	1/4	6	SMAW	1/4	6
	FCAW-S	1/4	6	FCAW-S	1/8	3
	FCAW-G	3/8	10	FCAW-G	1/4	6
	GMAW	N/A	N/A	GMAW	1/4	6
	GMAW-S	3/8	10	GMAW-S	1/4	6

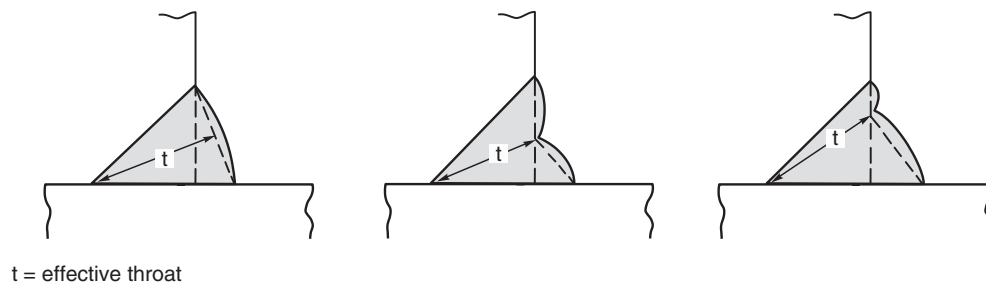


Figure 4.5—Combination of Bevel-Groove and Fillet Weld Profile

4.5.2 If intermittent fillet welds are used, welds should be located at each end of the joint.

4.6 Weld Size Considerations. Individual weld pass sizes considerably less than plate thickness may result in inadequate heat input which can lead to cracking, loss of fracture toughness (degradation of impact properties), and lack of fusion. When final weld sizes (individual or multiple pass) smaller than 30% of plate thickness are to be used, the Engineer shall determine whether testing needs to be performed to ensure that the resulting welded joint properties are consistent with design and quality requirements.

5. Base Metals

5.1 Structural Steels and Nonferrous Metals. Structural steel, steel castings and forgings, and nonferrous metals used in the weldments of earthmoving, construction, agricultural, and ground-based material handling equipment shall be identified by a specification. Specifications developed by the Manufacturer or commonly used industry-wide specifications developed by organizations such as ASTM International (ASTM), American Iron and Steel Institute (AISI), Society of Automotive Engineers (SAE), and American Foundrymen's Society (AFS) may be used. A list of commonly used

structural steels, steel castings, forgings, and non-ferrous metals can be found in AWS B2.1/B2.1M, *Specification for Welding Procedure and Performance Qualification*, and AWS B2.1/B2.1M-BMG, *Base Metal Grouping for Welding Procedure and Performance Qualification*. If a base metal has the same UNS number designation as a base metal listed in AWS B2.1/B2.1M, that base metal is also assigned that M-number or M-number plus Group Number.

5.2 Properties. Base metal specifications shall designate the chemical composition of the material to be used and shall include the mechanical properties and/or heat treatment of the material when required for proper identification. Base metals are expected to be compatible with the welding process and consumables recommended in this specification.

It is not the intent of this specification to restrict base metal selection, but to ensure weldability factors have been considered.

5.3 Weldability and Welding Procedure Qualification. The weldability and procedure for welding base metals shall be established by qualification in accordance with the requirements of Clause 7.

6. Welding Processes and Consumables

6.1 Processes

6.1.1 All welding processes and methods recognized by AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying* may be used in the construction, fabrication, and repair of earthmoving, construction, agricultural, and ground-based material handling equipment.

6.1.2 Processes which are not classified or recognized by AWS may be used, provided the Manufacturer can show evidence that the process used produces welds which meet the requirements of Clause 7.

6.2 Consumables

6.2.1 Consumables that meet the requirements of AWS filler metal specifications need not be tested by the user.

6.2.2 Consumables which are not classified in accordance with AWS A5 requirements may be used, provided the Manufacturer can show evidence that the consumables used will consistently produce welds which meet the requirements of Clause 7.

6.2.3 Consumables shall be protected and stored so that their characteristics or welding properties are not adversely affected. Consumable manufacturer's recommendations shall be applied. Annex C contains general practices for storage and the use of SMAW, FCAW, GMAW, and SAW consumables employed for application within the scope of this specification.

6.2.4 When a gas or gas mixture is used for shielding in any gas-shielded process, it shall meet the requirements of AWS A5.32M/A5.32 (ISO 14175 MOD) *Welding Consumables-Gases and Gas Mixtures for Fusion and Allied Processes*.

7. Welding Procedure Qualification

7.1 Scope. A written qualified Welding Procedure Specification (WPS) shall be followed for each weld made in accordance with this specification. For WPS forms see AWS B2.1/B2.1M. Variations of these forms are permissible, provided all the required variables of 7.1.2 are documented. The qualification method shall be as addressed in 7.1.1 and the welding variables shall be per 7.1.2.

7.1.1 Qualification Method. Each Manufacturer shall be responsible for the choice of qualification method as listed in 7.1.1.1 and 7.1.1.2:

7.1.1.1 Standard Welding Procedure Specifications (SWPSs), as published by the AWS B2 Committee on Procedure and Performance Qualification, are accepted as qualified in accordance with this specification, within the limits of 7.1.4.

7.1.1.2 Methods of Qualification:

- (1) Method I – Prototype Testing (see 7.3)
- (2) Method II – Procedure Qualification by Standard Testing Methods (see 7.4)
- (3) Method III – Prequalified Welding Procedure (see 7.5)

7.1.2 Welding Variables The following matrix lists the welding variables that are in addition to those listed in the variable tables of AWS B2.1/B2.1M, and are required to be addressed on both the Welding Procedure Qualification Record (WPQR) and Welding Procedure Specification (WPS).

The types of welding variables found in this matrix are qualification (Q), data (D), and fracture toughness (T), as defined in Clause 3. A change in a qualification variable beyond that allowed in this document and those specified in AWS B2.1/B2.1M requires requalification of the WPS. If fracture toughness is required, a change in a fracture toughness variable (T) beyond that allowed in this document and those specified in AWS B2.1/B2.1M requires requalification of the WPS. If fracture toughness is not required, all variables noted as fracture toughness variables (T) shall be treated as a data variable (D).

Where there are conflicting requirements, the requirements of this specification take precedence over AWS B2.1/B2.1M. A change in a data variable (D) may be made without requalification, but a revised WPS or new WPS shall be prepared. For welding processes not specifically addressed in the following matrix, the Engineer shall determine the welding variables and data variable (D) limits. When using Method III, use Table 7.8 for welding variables.

WELDING PROCESSES						
		GMAW	FCAW	GTAW	SAW	SMAW
Joint Design						
7.1.2.1	(1) A change in Groove type (e.g., single-V to double-V) except qualification of any CJP groove weld qualifies any groove welded joint design conforming to the requirements of Figures A.1 and A.2. Qualification of any PJP groove weld qualifies any groove welded joint design conforming to the requirements of A.2	Q	Q	Q	Q	Q
	(2) For joints other than those shown in Annex A, a change involving: a) A decrease in the groove angle b) A decrease in the root opening c) For CJP's only, an increase in the root face	Q	Q	Q	Q	Q
Filler Metal						
7.1.2.2	(1) A change from one of the following filler metal product forms to another: (a) flux cored (b) bare (solid) or metal cored (c) flux covered or coated electrode (d) any filler metal product form not mentioned above in (a), (b), or (c)	Q	Q	Q	Q	
	(2) A change in the number of electrodes	Q	Q	Q	Q	
Shielding						
7.1.2.3	(1) A change in the specified nominal backing (purge) gas composition	Q	Q	Q		
	(2) The deletion of a trailing gas	Q	Q	Q		
	(3) A change in shielding as a result of an addition or deletion of flux or a change in the flux type	Q	Q	Q		
	(4) Deletion of backing (purge) gas	Q	Q	Q		
Electrical Characteristics						
7.1.2.4	(1) The addition or deletion of pulsing current	Q	Q	Q	Q	
	(2) Any change in pulsing parameters range	D	D	D	D	
	(3) A change in the current range greater than $\pm 10\%$ from that qualified	D	D	D	D	D
	(4) A change in the wire feed speed range greater than $\pm 10\%$ from that qualified	D	D	D	D	
	(5) A change exceeding $\pm 7\%$ in the voltage from that qualified	D	D	D	D	
	(6) A change in the mode of metal transfer	Q	Q			
Other Variables						
7.1.2.5	(1) A change in the cup size or nozzle size	D	D	D	D	
	(2) A change exceeding $\pm 10\%$ in travel speed for mechanized or automatic welding	D	D	D	D	
	(3) A change in vertical progression	Q	Q	D		Q
	(4) A change in electrode extension	D	D		D	
	(5) A change from stringer to weave or vice versa	T	T	T		T
	(6) For mechanized or automated circumferential welding in a singular plane a change in range of the torch angle and/or work angle	D	D	D	D	

Note: Adapted from AWS D14.9/D14.9M:2013, *Specification for the Welding of Hydraulic Cylinders*

7.1.3 Test Weld Inspection. Qualification test weldments shall be visually examined on all surfaces. Workmanship and quality requirements shall be in accordance with Clause 9.

7.1.4 Standard Welding Procedure Specifications (SWPSs)

7.1.4.1 The Manufacturer may use AWS Standard Welding Procedure Specifications (SWPSs) without any further qualification by the Manufacturer.

7.1.4.2 The Manufacturer may use an SWPS without modification, if it provides sufficient direction for use in production. The Manufacturer may supplement the SWPS with additional information or requirements, provided the welding variables remain within the range shown on the SWPS.

7.1.4.3 Prior to use of an SWPS, the Manufacturer shall signify acceptance of responsibility for the production application of the procedure by signing and dating the SWPS. SWPSs published under the current and previous editions of AWS B2.1/B2.1M are acceptable for use.

7.1.4.4 Welding variables shall not be changed beyond the ranges specified in the SWPS.

7.1.4.5 Multiple SWPSs shall not be combined to perform a single production weld.

7.1.4.6 SWPSs shall not be combined with or used to supplement the Manufacturer's qualified WPS.

7.1.4.7 The Manufacturer's Welding Procedure Qualification Record (WPQR) shall not be used to modify an SWPS.

7.2 General Requirements

7.2.1 Base Metal and Its Preparation. Test specimen base metal and its preparation for welding, shall comply with the WPS. The test specimen required for all types of welded joints shall be such that the length of the weld and the dimensions of the base metal are sufficient for testing.

7.2.2 Position of Test Welds. All welds that will be encountered in actual construction shall be classified as being (1) flat, (2) horizontal, (3) vertical, or (4) overhead, in accordance with the definitions of welding positions given in Figures [7.1](#) and [7.2](#).

7.2.2.1 Groove Welds

(1) Position 1G (flat)—The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the upper side, as illustrated in Figure [7.3\(A\)](#).

(2) Position 2G (horizontal)—The test plates shall be placed in an approximately vertical plane with the welding groove approximately horizontal, as illustrated in Figure [7.3\(B\)](#).

(3) Position 3G (vertical)—The test plates shall be placed in an approximately vertical plane with the welding groove, approximately vertical, as illustrated in Figure [7.3\(C\)](#).

(4) Position 4G (overhead)—The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the underside, as illustrated in Figure [7.3\(D\)](#).

7.2.2.2 Fillet Welds

(1) Position 1F (flat)—The test plates shall be placed so that each fillet weld is deposited with its axis approximately horizontal and its throat approximately vertical, as illustrated in Figure [7.4\(A\)](#).

(2) Position 2F (horizontal)—The test plates shall be placed so that each fillet weld is deposited on the upper side of the horizontal surface and against the vertical surface, as illustrated in Figure [7.4\(B\)](#).

(3) Position 3F (vertical)—Each fillet weld shall be made vertically, as illustrated in Figure [7.4\(C\)](#).

(4) Position 4F (overhead)—The test plates shall be placed so that each fillet weld is deposited on the underside of the horizontal surface and against the vertical surface, as illustrated in Figure [7.4\(D\)](#).

7.2.3 Impact Requirements

7.2.3.1 The Engineer is responsible for determining if fracture toughness requirements are applicable for any portion of the product design.

7.2.3.2 If fracture toughness requirements exist, the Manufacturer shall qualify a CJP groove weld by Method II (standard test) using AWS B2.1/B2.1M within the limits of 7.1.2 and 7.2.

7.2.3.3 Method I—Prototype Testing, except as allowed by ISO 3471, is not permitted for qualifying welding procedures to be used on products or components having fracture toughness requirements.

7.2.3.4 Welding Procedure Qualification Tests performed in accordance with 7.4.2 Partial Joint Penetration (PJP) Groove Welds, 7.4.3 Fillet Weld Qualification for Deep Joint Penetration and 7.5 Method III—Prequalified Welding Procedures are not permitted for qualifying welding procedures to be used on products or components having fracture toughness requirements.

7.2.3.5 AWS Standard Welding Procedure Specifications may be used for production of products and components that require fracture toughness if the SWPSs meets the fracture toughness requirements specified by the Engineer.

7.2.3.6 Users of D14.3 should refer to AWS B4.0, *Standard Methods for Mechanical Testing of Welds* for specific requirements regarding fracture toughness testing for welding procedure qualifications.

7.2.3.7 Users of D14.3M should refer to ISO 9016, *Destructive tests on welds in metallic materials—Impact tests—Test specimen location, notch orientation and examination* for specific requirements regarding fracture toughness testing for welding procedure qualifications.

NOTE: Use of ISO 9016 may provide results that differ from the methods used in AWS B4.0.

7.2.4 Heat Input Limitations. Where heat input is determined to be critical to maintain mechanical properties, the heat input limitation is to be specified in the WPS. The limitation shall be determined by (a), (b), or (c) for nonwaveform controlled welding, or by (b) or (c) for waveform controlled welding. The formulas for calculating heat input from welding are as follows:

(a) Heat input (J/in [J/mm])

$$= \frac{\text{Voltage} \times \text{Amperage} \times 60}{\text{Travel Speed (in/min [mm/min])}}$$

(b) Volume of weld metal measured by

(1) an increase in bead size (width × thickness), or

(2) a decrease in length of weld bead per unit length of electrode.

(c) Heat input determined using instantaneous energy or power by

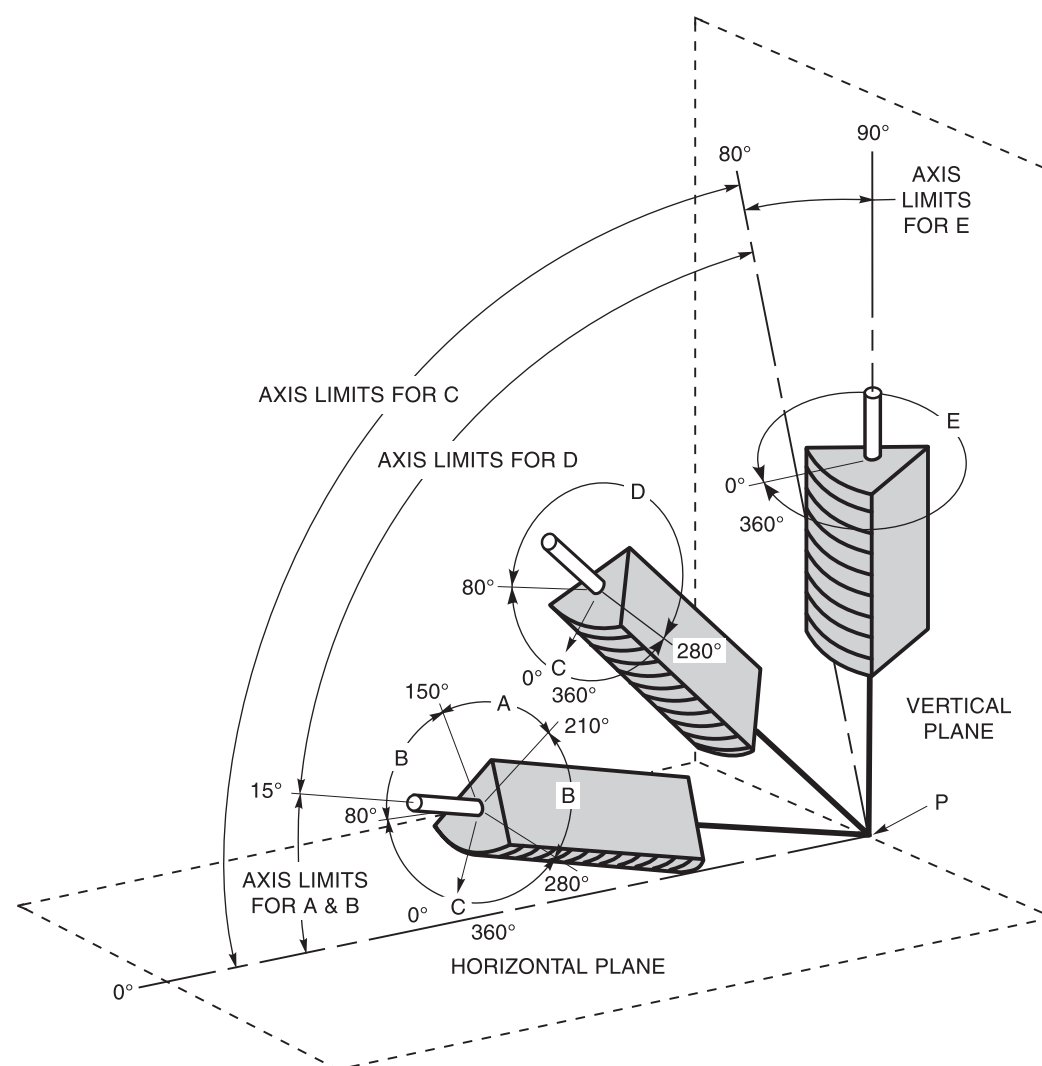
(1) for instantaneous energy measurements in joules (J) Heat input (J/in [J/mm])

$$= \frac{\text{Energy (J)}}{\text{Weld Bead Length (in [mm])}}$$

(2) for instantaneous power measurements in joules per second (J/s) or watts (W)

Heat input (J/in [J/mm])

$$= \frac{\text{Power (J/s or W)} \times \text{arc time (s)}}{\text{Weld Bead Length (in [mm])}}$$

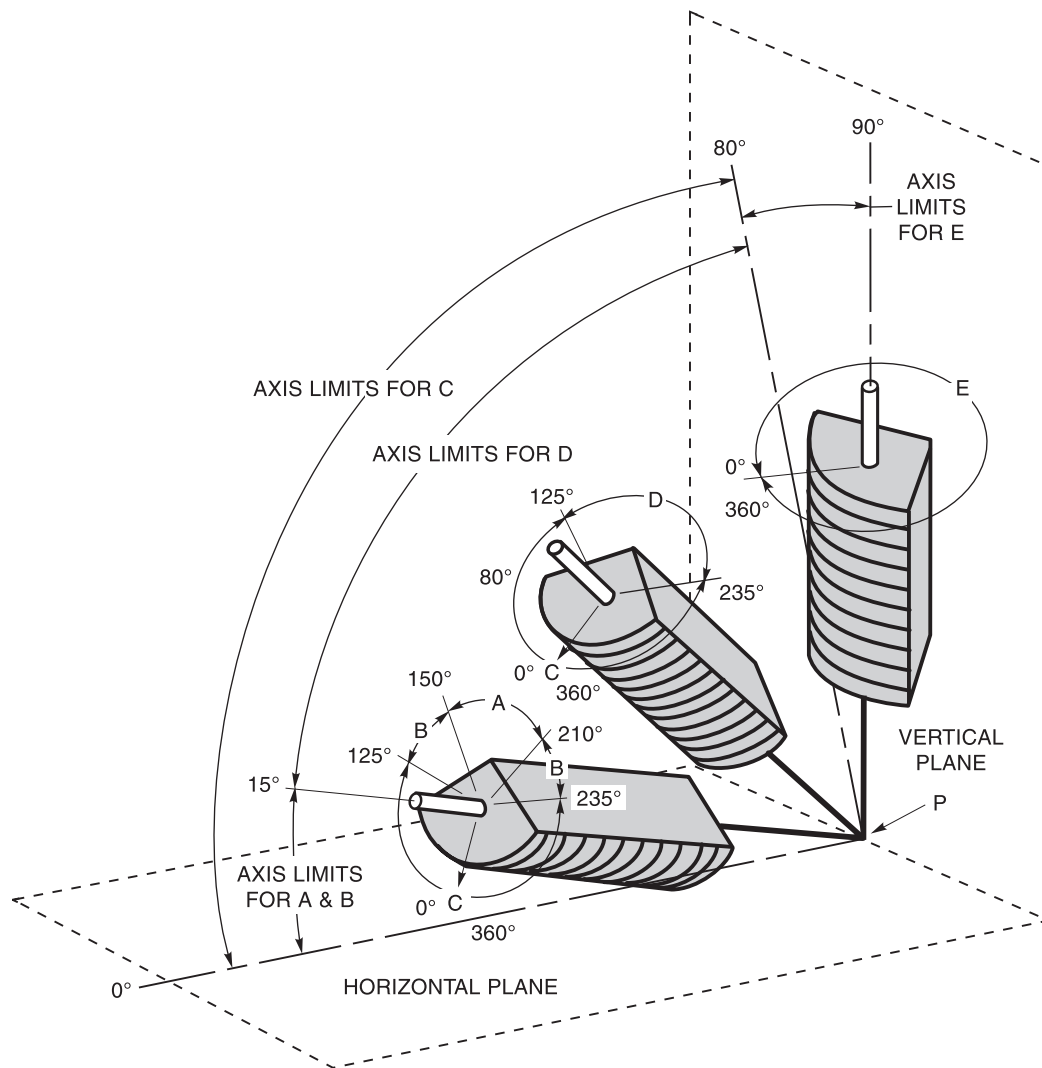


Tabulation of Positions of Groove Welds			
Position	Diagram Reference	Inclination of Axis	Rotation of Face
Flat	A	0° to 15°	150° to 210°
Horizontal	B	0° to 15°	80° to 150° 210° to 280°
Overhead	C	0° to 80°	0° to 80° 280° to 360°
Vertical	D E	15° to 80° 80° to 90°	80° to 280° 0° to 360°

Notes:

1. The horizontal reference plane is always taken to lie below the weld under consideration.
2. The inclination of axis is measured from the horizontal reference plane toward the vertical reference plane.
3. The angle of rotation of the face is determined by a line perpendicular to the theoretical face of the weld which passes through the axis of the weld. The reference position (0°) of rotation of the face invariably points in the direction opposite to that in which the axis angle increases. When looking at point P the angle of rotation of the face of the weld is measured in a clockwise direction from the reference position (0°).

Figure 7.1—Positions of Groove Welds



Tabulation of Positions of Fillet Welds			
Position	Diagram Reference	Inclination of Axis	Rotation of Face
Flat	A	0° to 15°	150° to 210°
Horizontal	B	0° to 15°	125° to 150°
			210° to 235°
Overhead	C	0° to 80°	0° to 125°
			235° to 360°
Vertical	D	15° to 80°	125° to 235°
	E	80° to 90°	0° to 360°

Figure 7.2—Positions of Fillet Welds

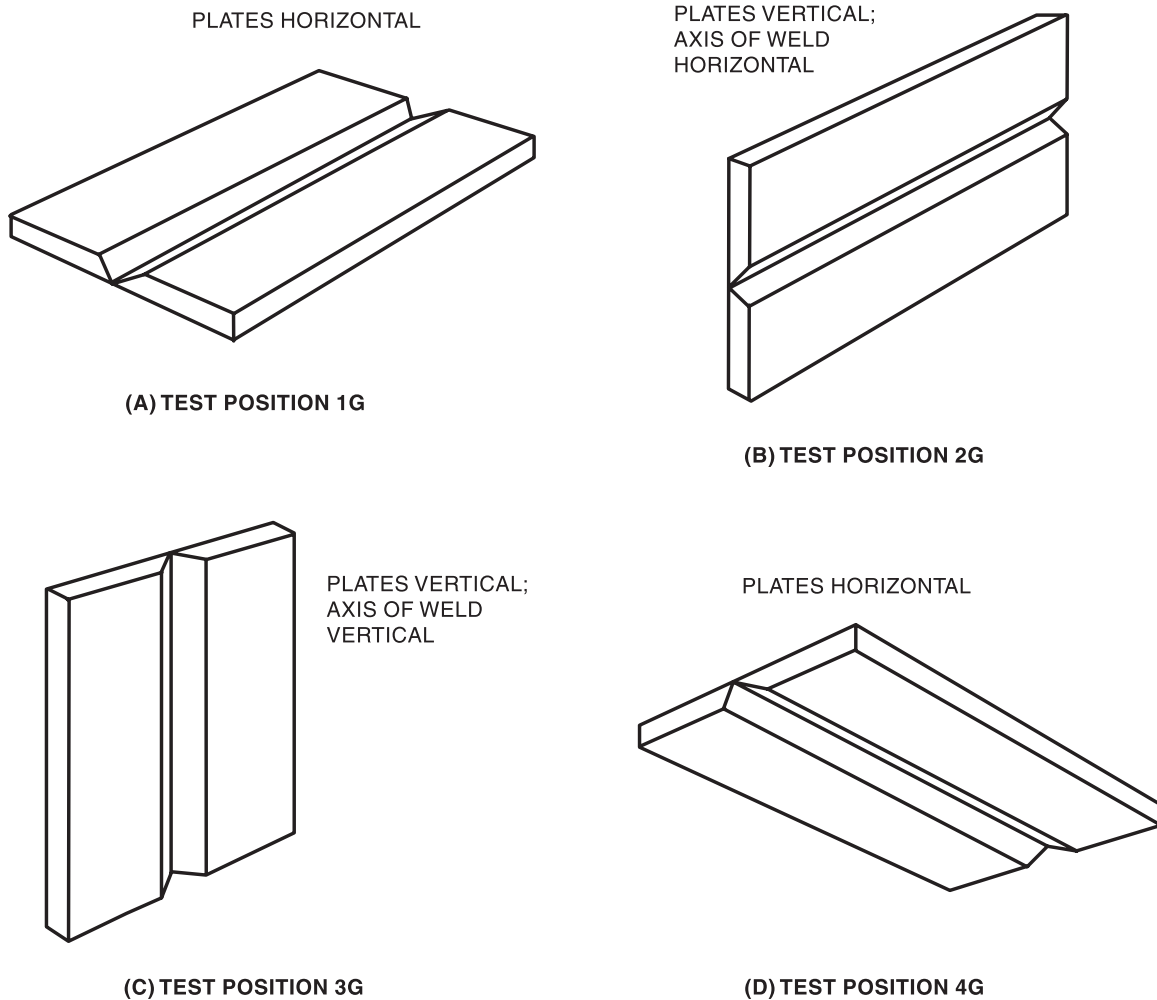


Figure 7.3—Positions of Test Plates for Groove Welds

7.2.5 Preheat and Interpass Temperature Requirements.

7.2.5.1 For qualified welding procedures the Engineer shall determine if preheat and interpass temperature controls are required to prevent crack formation, fusion defects or adverse brittle microstructure.

7.2.5.2 For prequalified welding procedures see 7.5.4 for preheat and interpass temperature requirements.

7.2.5.3 For SWPS the preheat and interpass temperatures shall be as detailed in the SWPS

7.2.6 Heat Affected Zone (HAZ) Hardness Testing Requirements.

7.2.6.1 When qualifying to Method II, with one or more of the base materials being joined having a carbon content that exceeds 0.30% or a Carbon Equivalence (CE) that exceeds 0.48, the Engineer shall determine if HAZ hardness testing is required.

7.2.6.2 The International Institute of Welding (IIW) formula shown below shall be used for calculating CE:

$$CE = \%C + \%Mn/6 + (\%Cu + \%Ni)/15 + (\%Cr + \%Mo + \%V)/5$$

7.2.6.3 Cross-Section Methodology. When hardness testing is required, a minimum of three cross-sections of the weld, HAZ and base metal shall be prepared and etched with a suitable solution to give a clear definition of the weld and HAZ.

7.2.6.4 HAZ Hardness Testing Procedure. Micro-hardness testing procedures shall meet the requirements of AWS B4.0, *Standard Methods for Mechanical Testing of Welds*, ISO 9015-1, *Destructive tests on welds in metallic*

materials—Hardness testing—Part 1: Hardness test on arc welded joints, or other standards as approved by the Engineer.

7.2.6.5 Location of Hardness Testing. At a minimum, HAZ hardness measurements shall be taken in the area of the root pass and final pass as illustrated in Figure 7.5. The number and exact location of hardness tests indentations shall be determined by the Engineer.

7.2.6.6 HAZ Hardness Acceptance Criteria. Acceptability of brittle phases in the HAZ shall be evaluated on the basis of their effect on appropriate mechanical properties of the design. Acceptable HAZ hardness values shall be as follows:

- (1) Heat affected zone hardness values that are less than 410 Vickers (HV) (42 HRC converted) shall be acceptable.
- (2) With the Engineer's approval, the hardness of the HAZ may exceed 410 HV (42 HRC converted).

7.2.7 There may be instances where additional factors such as hydrogen content of the weld metal, joint restraint, plate thickness and joint geometry need to be evaluated in addition to the weld heat affected zone hardness. In such instances, it is recommended that the Engineer consult and adopt one of the methods to avoid cold cracking as described in AWS D14.8M (ISO/TR 17844 IDT), *Standard Methods for the Avoidance of Cold Cracks*.

7.2.8 Production welding shall comply in all respects to the assigned Welding Procedure Specification (WPS).

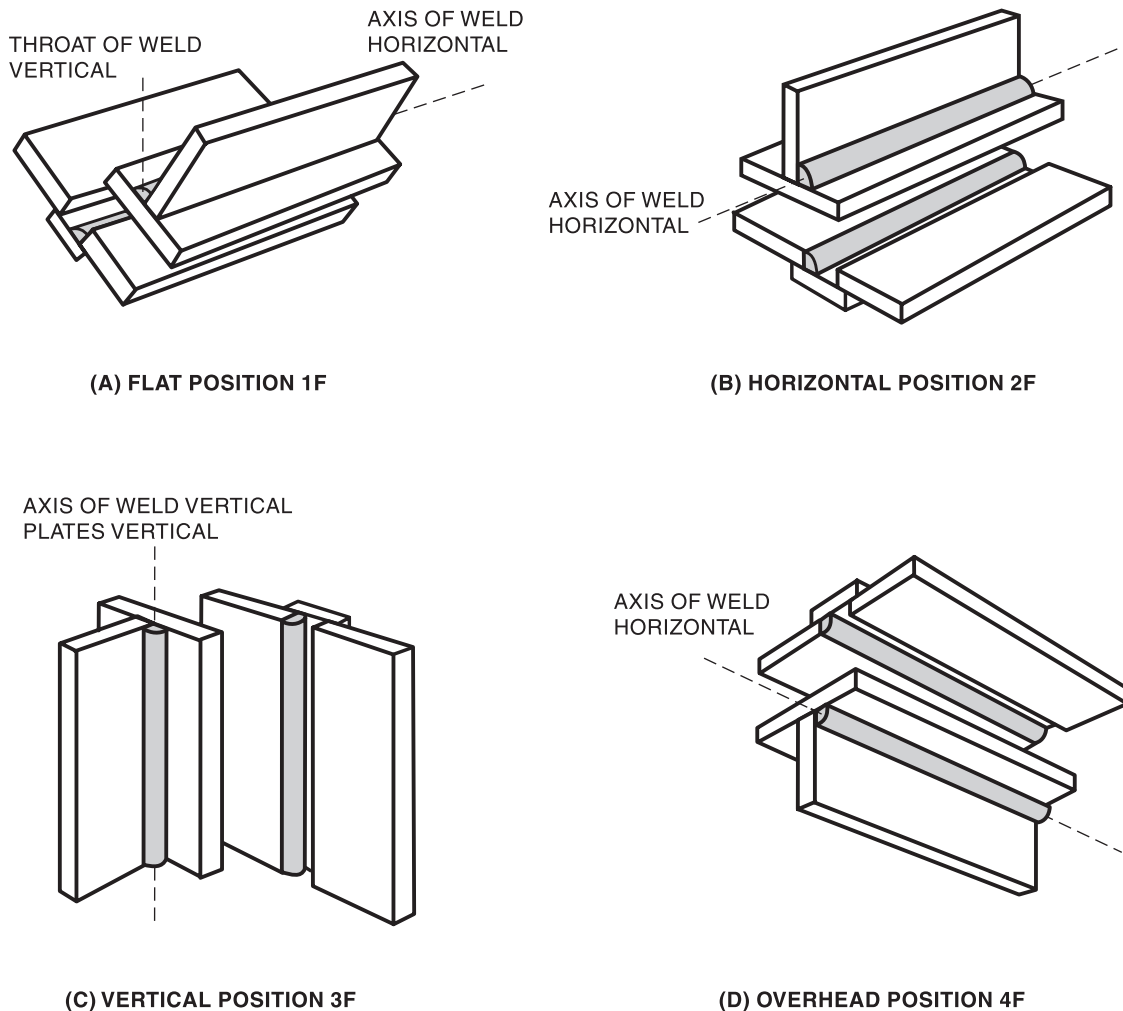
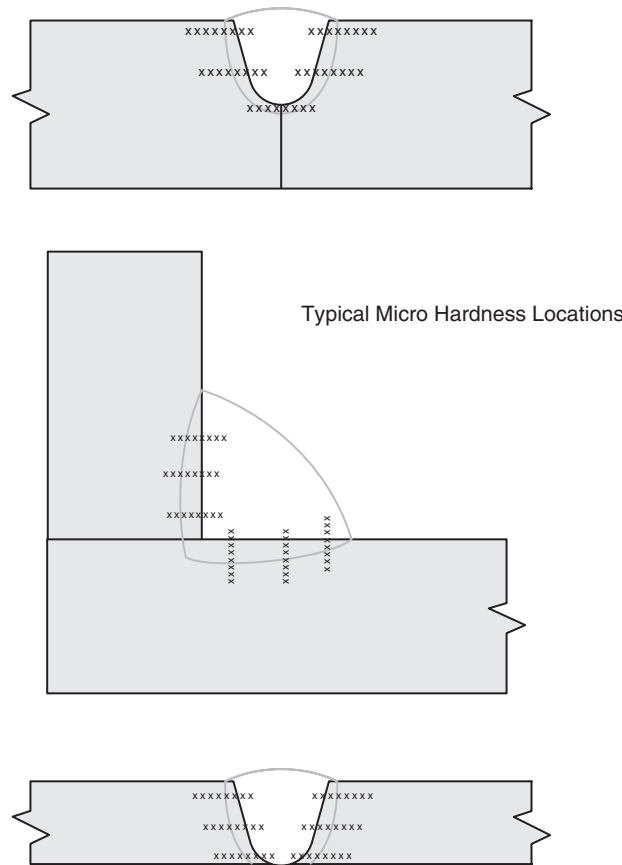


Figure 7.4—Positions of Test Plates for Fillet Welds



Note: Figure 7.5 provides recommended zones to take micro hardness readings. The actual locations and number of readings shall be determined by the Engineer as stated in 7.2.6.5.

Figure 7.5—Typical Micro Hardness Locations

7.3 Method I—Prototype Testing

7.3.1 Scope. Welding procedure specifications may be qualified by testing weldments under simulated service tests or actual field tests. WPSs qualified by Prototype Testing shall demonstrate compliance with all the requirements of 7.3.

7.3.2 Service Tests. Service tests shall consist of tests that replicate service loading. Service tests shall be conducted in an environment that represents service conditions.

7.3.2.1 Simulated Service Tests. Simulated service tests shall apply loads to the weldment that represent the most demanding conditions that the weldment is expected to endure under normal operation. Examples of service tests include required specification performance tests such as SAE or ISO criteria for Rollover Protection System (ROPS) and Falling Object Protection System (FOPS) structures, tests of lift arm safety devices, steering frame locks, industrial power mower housings, etc. Service testing may include impact loading, loading in bending, static loading, or fatigue testing to duplicate the type of loading the weld joint will be subjected to in service.

7.3.2.2. Actual Service Tests. An actual services test is a test of the welded assembly on a machine that is loaded and performing the work for which it was designed.

7.3.3 For Method I WPS qualification testing, the following shall be documented and recorded:

- (1) The WPS or WPSs that are to be qualified by the service test.
- (2) The weldment drawing number to which the test part or assembly was made.

- (3) The material specifications of all items included in the assembly.
- (4) The WPS variables used to manufacture the test unit (see 7.1.2)
- (5) For simulated service tests, the type of loading applied, direction and magnitude of forces (by calculation or instrumentation), frequency, and total number of applications or specific duration of the test. For actual service tests, the pertinent load conditions, functional cycles, strain gage values, stress coat results, and any other data documenting the actual test conditions.
- (6) The results of visual, and when applicable, nondestructive or destructive examination of all welds after the weldment has been subjected to the service test.

7.3.4 The WPS employed for the weldment shall be accepted as qualified provided:

7.3.4.1 Visual and any required nondestructive or destructive examinations, conducted prior to service testing shall meet the quality requirements of 9.5 Quality of Welds.

7.3.4.2 Visual and any required nondestructive or destructive examinations, conducted after service testing shall meet the quality requirements of 9.5 Quality of Welds.

7.3.5 The qualification of the WPS shall be limited to welding of the same joints as were welded on the test weldment.

7.3.6 The WPS qualified on the basis of Prototype testing may vary within the limits of 7.1.2. Requalification includes welding and testing the number of units required to confirm consistent application of the revised WPS.

7.3.7 Limits on Changes to Production Weldments

7.3.7.1 The Engineer shall determine when changes to the production weldment as compared to the prototype test necessitate requalification of WPS(s).

7.3.7.2 In no case shall changes in production weldments result in calculated stresses that are greater than 20% higher than those used in the prototype tests.

7.4 Method II—Welding Procedure Qualification by Standard Testing Methods

7.4.1 Complete Joint Penetration (CJP) Groove and Fillet Welds. Qualification by standard test using AWS B2.1/B2.1M shall be within the limits of 7.1.2 and 7.2.

7.4.2 Partial Joint Penetration (PJP) Groove Welds. Welding Procedures for PJP Groove Welds may be qualified by welding a test plate using the groove design desired to be used in production while following a CJP welding procedure qualified per 7.4.1. The test plate shall be cross-sectioned and macroetched to demonstrate that the designed weld characteristics are obtained in accordance with requirements of 9.5.1. The depth of groove need not exceed 1 in [25 mm].

7.4.2.1 Macroetch Test. A minimum of three specimens shall be prepared and etched with a suitable solution to give a clear definition of the weld. Guidelines for macroetch procedures may be found in the Annex of AWS B2.1/B2.1M.

7.4.2.2 Test Acceptance Criteria. The requirements for the test results shall be as follows:

- (1) Visual Examination. Visual examination shall meet the visual quality requirements of 9.5.1.
- (2) Macroetch Tests. The macroetched specimens shall be free of defects, as described in Clause 9. The qualification test weld shall show fusion through the specified weld size and shall be free from fusion defects.

7.4.3 Fillet Weld Qualification for Deep Joint Penetration. Welding procedure specifications for fillet welds that rely on joint penetration to extend beyond the root of the joint to satisfy design requirements, shall be qualified by welding a minimum of three test plates using the joint geometry and welding parameters to be used in production. Fillet welds are defined in 4.2.

7.4.3.1 The test plates shall be visually inspected and meet the requirements of Clause 9.

7.4.3.2 A minimum of three section specimens from each test plate shall be prepared and etched with a suitable solution to give a clear definition of the weld. Guidelines for macroetch procedures may be found in the Annex of AWS B2.1/B2.1M.

7.4.3.3 The macroetched specimens shall demonstrate that the specified depth of penetration and the required effective throat have been achieved (see Figures 4.2 and 4.3).

7.4.3.4 The measured actual throat of the weld cross section shall not exceed the face width of the fillet weld.

7.4.3.5 Production WPSs shall not deviate from test conditions for the following variables:

- (1) Base metal surface condition (e.g., hot rolled scale, blast cleaned, etc.)
- (2) Nominal fillet weld leg size
- (3) Joint configuration (e.g., lap, tee or corner)

7.4.3.6 Limitations of Variables. Production fillet weld WPSs qualified in accordance with 7.4.3 may not deviate from test conditions, except as follows:

- (1) The welding current shall not be less than 95% of the value used in the test.
- (2) The thickness(es) of the steel(s) shall not exceed 105% of the value(s) used in the test.
- (3) The dihedral angle shall not vary by more than 5 degrees from tested condition.
- (4) The root opening shall not be less than the tested condition.

7.4.4 Other Weld Configurations. Where the welding process does not lend itself to making basic groove or fillet welds, or both, because of the process (such as resistance welding, solid-state welding, and other processes) or because of the configuration (such as in plug or slot welds or forgings), test pieces conforming to the actual production joint in size, mass, and material shall be made and sectioned to determine whether the procedure provides the specified minimum penetration, fusion, and weld profile.

7.4.4.1 The welds shall be visually examined and meet the quality requirements of Clause 9.

7.4.4.2 The Engineer shall specify the number and location of cross-sections and if hardness testing is required (see 7.2.6.1).

7.4.4.3 The cross-sections shall be etched with a suitable solution to give a clear definition of the weld. Guidelines for macroetch procedures may be found in the Annex of AWS B2.1/B2.1M.

7.4.4.4 The macroetch specimens shall meet the quality requirements of Clause 9.

7.4.5 The WPS qualified on the basis of Method II may vary within the limits of 7.1.2 (with the exception of the added limits for fillet welds with deep joint penetration in 7.4.3.5 and 7.4.3.6).

7.5 Method III—Prequalified Welding Procedures

Prequalification of WPSs (Welding Procedure Specifications) shall be defined as exempt from the WPS qualification testing required in 7.1, 7.3, and 7.4. All prequalified WPSs shall be written. In order for a WPS to be prequalified, conformance with all of the applicable requirements of 7.5 shall be required. WPSs that do not conform to the requirements of 7.5 may be qualified by tests in conformance with 7.1, 7.3, or 7.4.

7.5.1 Welding Processes

7.5.1.1 Prequalified Processes. SMAW, SAW, GMAW (except GMAW-S), and FCAW WPSs which conform to all of the provisions of 7.5 shall be deemed as prequalified and are therefore approved for use without performing WPS qualification tests for the process.

7.5.1.2 Other Welding Processes. Other welding processes not covered by 7.5.1.1 may be used, provided the WPSs are qualified by applicable tests as described in 7.1, 7.3, or 7.4.

7.5.1.3 FCAW and GMAW Power Sources. FCAW and GMAW that is done with prequalified WPSs shall be performed using Constant Voltage (CV) power supplies. Pulsed gas metal arc welding (GMAW-P) may also be used in prequalified welding procedures provided that the average current and voltage are sufficient to promote the spray or globular modes of metal transfer.

7.5.2 Base Metal/Filler Metal Combinations

7.5.2.1 Only base metals and filler metals listed in Tables 7.1, 7.3, and 7.5 may be used in prequalified WPSs. (For the qualification of listed base metals and filler metals, and for base metals and filler metals not listed in these Tables, see 7.1, 7.3, and 7.4.)

7.5.2.2 Steels listed in AWS B2.1/B2.1M that have the same M number and group number as those steels identified in Table 7.1 or defined in Table 7.3 (within the limitations of 7.5.2.3 and 7.5.2.4) are also prequalified, provided the preheat and interpass temperatures used are no lower than those listed in Table 7.4.

7.5.2.3 No nitrogen containing steel other than ASTM A572, A607, A656, and A715 are prequalified under Class III.

7.5.2.4 Only ASTM A572, A607, A656, and A715 (alloyed with some combination of niobium, vanadium, and nitrogen) are prequalified under Class IV.

7.5.2.3 The base metal/filler metal strength relationships in Table 7.2 shall be used in conjunction with Table 7.5 and 7.5M to determine whether matching or undermatching filler metals are required.

7.5.3 Engineer's Approval for Auxiliary Attachments

Unlisted materials for auxiliary attachments which fall within the chemical composition range of a steel listed in 7.5.2 may be used in a prequalified WPS when approved by the Engineer. The filler metal and minimum preheat shall be in conformance with 7.5.2 and 7.5.4, based upon the similar material strength and chemical composition.

7.5.4 Minimum Preheat and Interpass Temperature Requirements

The preheat and interpass temperature shall be sufficient to prevent cracking. Table 7.4 shall be used to determine the minimum preheat and interpass temperatures for steels listed in the specification.

7.5.4.1 Base Metal/Thickness Combination. The minimum preheat or interpass temperature applied to a joint composed of base metals with different minimum preheats from Table 7.4 (based on classification and thickness) shall be the highest of these minimum preheats.

7.5.4.2 Alternate SAW Preheat and Interpass Temperatures. Preheat and interpass temperatures for parallel or multiple electrode SAW shall be selected in conformance with Table 7.4. For single-pass groove or fillet welds, for combinations of metals being welded and the heat input involved, and with the approval of the Engineer, preheat and interpass temperatures may be established which are sufficient to reduce the hardness in the HAZs of the base metal to less than 225 HV for steel having a minimum specified tensile strength not exceeding 60 ksi [415 MPa], and 280 HV for steel having a minimum specified tensile strength greater than 60 ksi [415 MPa], but not exceeding 70 ksi [485 MPa].

NOTE: The Vickers hardness number shall be determined in conformance with ASTM E384. If another method of hardness is to be used, the equivalent hardness number shall be determined from ASTM E140, and testing shall be performed according to the applicable ASTM specification.

7.5.5 Limitation of WPS Variables

All prequalified WPSs to be used shall be prepared by the Manufacturer as written prequalified WPSs and shall be available to those authorized to use or examine them. The written WPS may follow any convenient format (see AWS B2.1/B2.1M for examples). The welding variables set forth in Table 7.8 shall be specified on the written WPS, and for variables with limits, within the range shown. Changes to the variables beyond those permitted by Table 7.8 shall require a new or revised prequalified WPS, or shall require that the WPS be qualified by test in accordance with 7.1, 7.3, or 7.4.

7.5.5.1 Combination of WPSs. A combination of qualified and prequalified WPSs may be used without qualification of the combination, provided the limitation of variables applicable to each process is observed.

7.5.6 General WPS Requirements

All the requirements of Table 7.7 shall be met for prequalified WPSs.

7.5.6.1 Vertical-Up Welding Requirements. The progression for all passes in vertical position welding shall be upward, except that undercut may be repaired vertically downwards when preheat is in conformance with Table 7.4, but not lower than 70 °F [20 °C].

7.5.6.2 Width/Depth Pass Limitation. 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 the weld pass (see Figure 7.6).

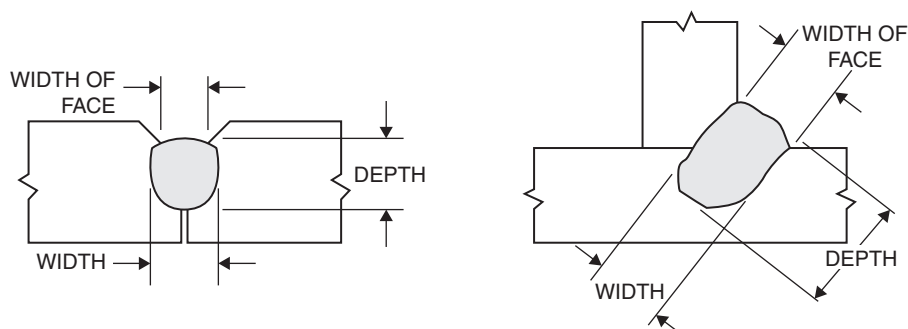


Figure 7.6—Weld Bead in which Depth and Width Exceed the Width of the Weld Face

7.5.6.3 Shielding Gas. Shielding gases for GMAW and FCAW-G shall conform to AWS A5.32/A5.32M (ISO 14175:2008 MOD), and one of the following:

- (1) The shielding gas used for electrode classification per the applicable AWS A5 specification, A5.18/A5.18M, A5.20/A5.20M, A5.28/A5.28M, or A5.29/A5.29M.
- (2) For AWS A5.36/A5.36M fixed classifications of carbon steel gas shielded FCAW and GMAW, and low-alloy steel FCAW qualified with M21 shielding gas shall be limited to the mixed shielding gas requirements of AWS A5.20/A5.20M, A5.18/A5.18M, or A5.29/A5.29M, M21-ArC-20-25 (SG-AC-20-25).
- (3) For all AWS A5.36/A5.36M open classifications, the classification shielding gas shall be limited to the shielding gas designator used for classification(s) and not the range of the shielding gas classification.
- (4) A shielding gas recommended for use with the specific electrode by the electrode manufacturer. Such recommendations shall be supported by tests which demonstrate that the electrode/shielding gas combination is capable of meeting all the mechanical and chemical property requirements for the electrode classification when tested in accordance with the applicable AWS A5 specification. Documentation of such testing shall be supplied when requested by the Engineer.

7.5.7 Common Requirements for Parallel Electrode and Multiple Electrode SAW

7.5.7.1 GMAW Root Pass. Welds may also be made in the root of groove or fillet welds using GMAW, followed by parallel or multiple electrode submerged arcs, provided that the GMAW conforms to the requirements of this section, and providing the spacing between the GMAW arc and the following SAW arc does not exceed 15 in [380 mm].

7.5.8 Fillet Weld Requirements See Table 7.9 for minimum fillet weld sizes.

7.5.8.1 Joint Details. See Figures A.3 and A.5 for the limitations for prequalified fillet welds.

7.5.8.2 Skewed T-Joints. Skewed T-joints shall be in conformance with Figure A.11.

- (1) **Dihedral Angle Limitations.** The obtuse side of skewed T-joints with dihedral angles greater than 100° shall be prepared as shown in Figure A.11, Detail C, to allow placement of a weld of the required size. The amount of material removed in preparing the edge of the member should not be more than that required to achieve the required weld size (W) as shown in Figure A.11, Detail C.
- (2) **Minimum Weld Size for Skewed T-Joints.** For skewed T-joints, the minimum weld size for Details A, B, and C in Figure A.11 shall be in conformance with Table 7.9.

7.5.9 Plug and Slot Weld Requirements The details of plug and slot welds made by the SMAW, GMAW (except GMAW-S), or FCAW processes are described in AWS D14.4/D14.4M, *Specification the Design of Welded Joints in Machinery and Equipment*, and they may be used without performing the WPS qualification described in 7.1, 7.3, and 7.4 of this specification, provided the workmanship provisions of Clause 9 of this specification are met.

7.5.10 Common Requirements of PJP and CJP Groove Welds

7.5.10.1 Corner Joint Preparation. 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.

7.5.10.2 Root Openings. Joint root openings may vary as noted in 7.5.11.3 and 7.5.12.1. However, for automatic or mechanized welding using FCAW, GMAW, and SAW processes, the maximum root opening variation for the as-fit tolerance shall not exceed 1/8 in [3 mm]. Variations greater than 1/8 in [3 mm] shall be locally corrected prior to automatic or mechanized welding.

7.5.11 PJP Requirements PJP groove welds shall be made using the joint details described in Figure A.2. The joint dimensional limitations described in 7.5.11.3 shall apply.

7.5.11.1 Definition. Except as provided in 7.5.12.5 and Figure A.1 (B-L1-S), groove welds without steel backing, welded from one side, and groove welds welded from both sides, but without backgouging, are considered PJP groove welds. See 4.1.2 for PJP Skewed T-Joint basic weld details.

7.5.11.2 Prequalified Weld Sizes.

- (1) The weld size (S) of a prequalified PJP groove shall be as shown in Figure A.2 for the particular welding process, joint designation, groove angle, and welding position proposed for use in welding fabrication.
- (2) The minimum weld size of PJP single- or double-V, bevel-, J-, and U-groove welds, types 2 through 9, shall be as shown in Table 7.10. The base metal thickness shall be sufficient to incorporate the requirements of the joint details selected, conforming to the variances outlined in 7.5.11.3 and the requirements of Table 7.10.
- (3) The maximum base metal thickness shall not be limited.
- (4) The PJP square groove weld B-P1 and flare-bevel groove welds BTC-P10 minimum weld sizes shall be calculated from Figure A.2.
- (5) Shop or working drawings shall specify the design grooves depths (D) applicable for the weld size (S) required per 7.5.11.2. (Note that this requirement shall not apply to the B-P1 and BTC-P10 details.)

7.5.11.3 Joint Dimensions

- (1) Dimensions of groove welds specified in 7.5.11 may vary on design drawings within the limits of tolerances shown in the "As Detailed" column in Figure A.2.
- (2) Fit-up tolerances of Figure A.2 may be applied to the dimensions shown on the design drawing. However, the use of fit-up tolerances does not exempt the user from meeting the minimum weld size requirements of 7.5.11.2(2).
- (3) J- and U-grooves may be prepared before or after assembly.

7.5.11.4 Details (Tubular). Details for PJP tubular groove welds that are accorded prequalified status shall conform to the following provisions:

- (1) PJP tubular groove welds, other than T-, Y-, and K-connections, may be used without performing the WPS qualification tests, when these may be applied, and shall meet all of the joint dimension limitations as described in Figure A.2.
- (2) PJP T-, Y-, and K-tubular connections, welded only by the SMAW, GMAW, or FCAW process, may be used without performing the WPS qualification tests, when they may be applied, and shall meet all of the joint dimension limitations as described in Figure A.4. These details may also be used for GMAW-S qualified in conformance with AWS B2.1/B2.1M.

7.5.11.5 Matched Box Connections. Details for PJP groove welds in these connections, the corner dimensions and the radii of the main tube are shown in Figure A.4(C). Fillet welds may be used in toe and heel zones (see Figure A.5). If the corner dimension or the radius of the main tube, or both are less than as shown in Figure A.4(C), a sample joint of the side details shall be made and sectioned to verify the weld size. The test weld shall be made in the horizontal position. This requirement may be waived if the branch tube is beveled as shown for CJP groove welds in Figure A.6.

7.5.12 CJP Groove Weld Requirements CJP groove welds which may be used without performing the WPS qualification test described in 7.1, 7.3, or 7.4 shall be as detailed in Figure A.1; and are subject to the limitations described in 7.5.12.1.

7.5.12.1 Joint Dimensions. Dimensions of groove welds specified in 7.5.12 may vary on design drawings within the limits or tolerances shown in the “As Detailed” column in Figure A.1. Fit up tolerances of these figures may be applied to the dimension shown on the design drawing.

7.5.12.2 Backing. Prequalified CJP groove welds made from one side only, except as allowed for tubular structures, shall have steel backing. Other backing may be used, if qualified in conformance with 7.1, 7.3, or 7.4.

7.5.12.3 Double-Sided Groove Preparation. J- and U-grooves and the other side of partially welded double-V and double-bevel grooves may be prepared before or after assembly. After backgouging, the other side of partially welded double-V or double-bevel joints should resemble a prequalified U or J-joint configuration at the joint root.

7.5.12.4 Butt Joints in Tubular Members. For groove welds in tubular members to be given prequalified status, the following conditions shall apply:

(1) **Prequalified WPSs.** Where welding from both sides or welding from one side with backing is possible, any WPS and groove welded joint detail that is appropriately prequalified in conformance with 7.5 may be used, except that SAW is only prequalified for diameters greater than or equal to 24 in [600 mm]. Welded joint details shall be in conformance with 7.5.

(2) **Nonprequalified Joint Details.** There are no prequalified joint details for CJP groove welds in butt joints made from one side without backing.

7.5.12.5 Tubular T-, Y-, and K-Connections. Details for CJP groove welds welded from one side without backing in tubular T-, Y-, and K-connections used in circular tubes are described in this section. The applicable circumferential range of Details A, B, C, and D are described in Figures A.6 and A.7, and the ranges of local dihedral angles, $[\Psi]$, corresponding to these are described in Table 7.6.

Joint dimensions including groove angles are described in Table 7.6 and Figure A.8. Alternative weld profiles that may be required for thicker sections are described in Figure A.9. In the absence of special fatigue requirements, these profiles shall be applicable to branch thicknesses exceeding 5/8 in [16 mm].

Improved weld profiles are described in Figure A.10. In the absence of special fatigue requirements, these profiles shall be applicable to branch thicknesses exceeding 1-1/2 in [38 mm] (not required for static compression loading).

Prequalified details for CJP groove welds in tubular T-, Y-, and K-connections, utilizing box sections, are further described in Figure A.6. The foregoing details are subject to the limitation of 7.5.12.4.

The joint dimensions and groove angles shall not vary from the ranges detailed in Table 7.6 and shown in Figure A.6 and Figures A.8 through A.10. The root face of joints shall be zero unless dimensioned otherwise. It may be detailed to exceed zero or the specified dimension by not more than 1/16 in [2 mm]. It may not be detailed less than the specified dimensions.

These details may be used for prequalified welding procedures for SMAW and FCAW only. These details may also be used for other processes, including GMAW-S, when qualified in accordance with AWS B2.1/B2.1M.

7.5.13 Postweld Heat Treatment (PWHT) Postweld Heat Treatment (PWHT) shall be prequalified, provided that it shall be approved by the Engineer and the following conditions shall be met:

(1) The specified minimum yield strength of the base metal shall not exceed 50 ksi [345 MPa].

(2) The base metal shall not be manufactured by Quenching and Tempering (Q&T), Quenching and Self-Tempering (Q&ST), Thermo-Mechanical Controlled Processing (TMCP) or where cold working is used to achieve higher mechanical properties (e.g., certain grades of ASTM A500 tubing).

(3) There shall be no requirements for fracture toughness testing of the base metal, HAZ, or weld metal.

(4) There shall be data available demonstrating that the weld metal shall have adequate strength and ductility in the PWHT condition (e.g., as can be found in the relevant AWS A5.X filler metal specification and classification or from the filler metal manufacturer).

(5) PWHT shall be conducted in conformance with AWS D14.4/D14.M, *Specification for the Design of Welded Joints in Machinery and Equipment*.

Table 7.1^a
Weldability Classification—Typical Steel Products

Class I	AISI/SAE 1005, 1006, 1008, 1010, 1012, 1016, 1017, 1018, 1020 ASTM A 366, A 569; SAE J-525
Class II	AISI/SAE 1021, 1025, 1026; ASTM A 36, A 53 Grade B, A 53 Grade F, A 106, A 131, ^b A 139, A 500, A 501, A 516, A 524, A 529, A 570 Grades 30, 33, 36, 40, 45, 50, and 55, A 606
Class III	ASTM A 242, A 441, A 500 Grade C, A 537 Class 1 and 3, A 572 Grades 42 and 50, A 588 ^c A 607 Grades 45 and 50, A 618, A 633 Grades A, B, C, D, and E API 5LX Grade 42; ABS Grades AH, DH and EH
Class IV	ASTM A 572 Grades 60 and 65, A 607 Grades 60 and 70, A 656 Grades 50, 60, 70 and 80, A 715 Grades 50, 60, 70 and 80
Class V	ASTM A 514 ^d and A 517 ^e

^a See 7.5.2.

^b Except ASTM A 131 Gr. AH, DH, and EH.

^c Except ASTM A 588 Gr. G.

^d Except ASTM A 514 Gr. E, P, and Q.

^e Except ASTM A 517 Gr. E, P, and Q.

Table 7.2
Base Metal/Filler Metal Strength Relationships

Relationship	Base Metal(s)	Filler Metal Strength Relationship Required
Matching	Any steel to itself or any steel to another in the same group	Any filler metal listed in the same group
	Any steel in one group to any steel in another	Any filler metal listed for <u>either</u> strength group. [SMAW electrodes shall be the low-hydrogen classification]
Undermatching	Any steel to any steel in any group	Any filler metal listed <u>in a</u> strength group <u>below the lower strength group</u> . [SMAW electrodes shall be the low-hydrogen classification]

Note: See information on allowable stress in welds available in D14.4/D14.4M, *Specification for the Design of Welded Joints in Machinery and Equipment* to determine the filler metal strength requirements to match or undermatch base metal strength.

Table 7.3
Weldability Classification^a

	Structural Carbon Steel		High-Strength Low Alloy Steels		Quench and Tempered Steels
	Class I	Class II	Class III ^b	Class IV ^b	Class V
Yield Strength, ksi ^c	30–46	35–55	40–45	50–80	90–100
Yield Strength, MPa ^c	205–315	240–380	275–380	345–550	620–690
maximum CE ^d	0.38	0.48	0.63	—	0.74
Maximum Chemical Limits ^e					
Carbon	0.23	0.30	0.24	—	0.22
Manganese	0.90	1.35	1.65	—	1.50
Phosphorus	0.04	0.04	0.04	—	0.04
Sulfur	0.05	0.05	0.05	—	0.05
Silicon	0.60	0.60	0.90	—	0.90
Nickel	—	—	1.25	—	1.50
Chromium	—	—	1.00	—	2.00
Molybdenum	—	—	0.25	—	0.65
Vanadium ^{f,g}	—	—	0.10 ^{f,g}	—	0.08 ^g
Titanium	—	—	0.07	—	0.10
Zirconium	—	—	0.15	—	0.15
Niobium (Columbium) ^f	—	—	0.04 ^f	—	—
Copper	—	—	1.00	—	0.50
Boron	—	—	—	—	0.006

^a Use the highest classification allowed by yield strength of base metal, calculated CE value, and typical chemical composition.

^b Only ASTM A 572, A 607, A 656, and A 715 (alloyed with some combination of niobium, vanadium, and nitrogen) are prequalified under Class IV. No nitrogen containing steel other than A 572, A 607, A 656, and A 715 are prequalified under Class III.

^c Minimum yield strengths are generally values published by the producer, or in the case where values are not published, then the value that is used for design purposes.

^d Carbon Equivalent, CE. The maximum CE values shown are based on the maximum composition limits of the materials, plus the check tolerance; therefore, caution must be used when the maximum limits are approached.

Reference: IIW Formula for CE for Carbon and Low Alloy Steels is:

$$CE = C + Mn/6 + (Cu + Ni)/15 + (Cr + Mo + V)/5$$

^e In weight %.

^f Maximum for the sum of niobium + vanadium = 0.10.

^g When welds are to be thermally stress relieved, the deposited weld metal shall not exceed 0.05% vanadium.