AWS D1.3/D1.3M:2008
An American National Standard

Structural Welding Code—Sheet Steel

American Welding Society

Approved American National Standard
ANSI

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An American National Standard

Approved by the
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Structural Welding Code—
Sheet Steel

5th Edition

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

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This code covers the requirements associated with welding sheet steel having a minimum specified yield point no greater than 80 ksi [550 MPa]. The code requirements cover any welded joint made from the commonly used structural quality low-carbon hot rolled and cold rolled sheet and strip steel with or without zinc coating (galvanized). Clause 1 includes general provisions, Clause 2 design, Clause 3 prequalification, Clause 4 qualification, Clause 5 fabrication, Clause 6 inspection, and Clause 7 stud welding.

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This standard is subject to revision at any time by the AWS D1 Committee on Structural Welding. It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn.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 required and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the AWS D1 Committee on Structural Welding 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 D1 Committee on Structural Welding 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, 550 N.W. LeJeune Road, Miami, FL 33126.

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Dedication

The D1 Committee on Structural Welding dedicates this edition of AWS D1.3/D1.3M, *Structural Welding Code—Sheet Steel*, to R. D. "Rollie" Block, past chair and vice chair of the D1H Subcommittee on Sheet Steel. The subcommittee is gratefully indebted to Mr. Block's tireless efforts, devotion, and enthusiasm in making this revision of D1.3 possible. The members of D1 and D1H extend a warm "Thank you, Rollie!" in his memory.

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Foreword

This foreword is not part of AWS D1.3/D1.3M:2008, *Structural Welding Code—Sheet Steel*, but is included for informational purposes only.

When the first edition of AWS D1.3, *Specification for Welding Sheet Steel in Structures*, was developed and issued in the 1978, it was anticipated that changes would be needed in the specification as further research was conducted on sheet steel welded joints. After users' experience with the specification and development of new sheet steel applications, it was revised in 1981, 1989, 1998, and 2008. Also, in the 1981 edition, the title of the standard was changed to AWS D1.3, *Structural Welding Code—Sheet Steel*, to conform with the uniform titles now being given to standards developed by the AWS D1 Committee on Structural Welding. The many changes in this document reflect both experience in using the code and the results of research, principally by the American Iron and Steel Institute's Subcommittee on Sheet Steel.

One of the primary objectives of this code is to define the allowable capacities used in sheet steel applications in which transfer of calculated load occurs. The foremost examples of such applications are steel decks, panels, storage racks, and stud and joist framing members. It is a concurrent objective of this code to impose workmanship, technique, and qualification requirements so as to effect consistently sound execution of welding of joints in these categories.

Certain shielded metal arc, gas metal arc, gas tungsten, gas metal arc, and flux cored arc welding procedure specifications (WPSs) when used with certain types of joints, have been tested by users and have a history of satisfaction performance. These WPSs are designated as prequalified, may be employed without further evidence, and include most of those that are commonly used. However, the purpose of defining prequalified WPSs is not to preclude the use of other WPSs as they are qualified.

Then other processes, WPSs, or joints are proposed, they are subject to the applicable provisions of this code and shall be qualified by tests. The obligation is placed on the contractor to prepare WPSs and qualify them before production use.

All WPSs (prequalified and qualified) must include the classification of the filler metal, its size, and for each type of weld, its melting rate or other suitable means of current control indicative of the melting rate, as applicable. The requirements for the qualification of welders and welding operators are also given. Welder qualification test requires each welder prove their ability to produce satisfactory weld using these prequalified or qualified WPSs.

Although this code is essentially directed at those joints that are used to transfer loads, the quality of welds where strength is not a governing consideration should meet quality standards that will maintain the integrity of the supporting structure. The allowable capacity provisions of Clause 2 could be disregarded when the welds are not used in a load-carrying capacity.

Underlined text in the subclauses, tables, or figures indicates an editorial or technical change from the 1998 edition. A vertical line in the margin next to a figure or table indicates a revision from the 1998 edition.

The following is a summary of the most significant technical revisions contained in D1.3/D1.3M:2008:

(1) Addition of a new normative annex listing requirements when welding D1.3 sheet steels to other D1.1 steel product forms.

(2) New Commentary for Clauses 2, 4, 5, and Annex A.

(3) Extensive revisions in Tables 1.2, 4.1, and 4.2.

(4) Addition of new essential variables within Table 4.3.

(5) Addition of Tables 1.1, 3.1, and A.1.

(6) Revisions throughout Figures 2.7, 3.1, 3.2, 3.3, 4.1, and C-2.1.

(7) New equation for SMAW melting rate.

(8) Deletion of Clause 7 Stud Welding.

(9) Weld/base-metal fusion restriction added in weld acceptance criteria.

(10) WPS temperature qualification changed from 60°F [16°C] or higher to 100°F [38°C] or lower.

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

Errata. It is the policy of the AWS D1 Committee on Structural Welding that all errata should be made available to users of this code. Therefore, in the Society News Section of the AWS *Welding Journal*, and errata (major editorial changes) that have been noted will be published in the July and November issues of the *Welding Journal* and posted on the AWS web site.

Suggestions. Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS D1 Committee on Structural Welding, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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Structural Welding Code—Sheet Steel

1. General Provisions

1.1 Scope

This code contains the requirements for arc welding of structural sheet/strip steels, including cold formed members, hereafter collectively referred to as "sheet steel," which are equal to or less than 3/16 in (0.188 in) [4.8 mm] in nominal thickness. When this code is stipulated in contract documents, conformance with all its provisions shall be required, except for those provisions that the Engineer or contract documents specifically modifies or exempts.

When used in conjunction with AWS D1.1, conformance with the applicable provisions of Annex A of AWS D1.3 shall apply (see also Table 1.1). Two weld types unique to sheet steel, arc spot, and arc seam are included in this code.

1.1.1 Applicable Materials. This code is applicable to the welding of structural sheet steels to other structural sheet steels or to supporting structural steel members.

1.1.2 General Stipulations. The fundamental premise of the code is to provide general stipulations applicable to any situation. Acceptance criteria for production welds different from those specified in the code shall be permitted for a particular application, provided they are suitably documented by the proposer and approved by the Engineer. These alternate acceptance criteria shall be based upon evaluation of suitability for service using past experience, experimental evidence, or engineering analysis considering material type, service load effects, and environmental factors.

1.1.3 Approval. All references to the need for approval shall be interpreted to mean approval by the Engineer, defined as the duly designated person who acts for and in behalf of the owner on all matters within the scope of this code. Deviations from code requirements shall require the Engineer's approval.

1.2 Sheet Steel Base Metal

1.2.1 Specified Base Metals. Sheet steel base metals to be welded under this code shall conform to the requirements of the latest edition of one of the specifications listed in Table 1.2, or any sheet steel qualified in conformance with 1.2.2. Any combination of these steels may be welded together. These steels may also be welded to any of the steels listed in the latest edition of AWS D1.1, *Structural Welding Code—Steel*.

1.2.2 Other Base Metals. When a steel other than those covered in 1.2.1 is approved under the provisions of the project or product specification, and such a steel is proposed for welded construction, the weldability of the steel and the WPS for welding it shall be established by qualification in conformance with the requirements of Clause 4 and such other requirements as prescribed by the Engineer.

1.2.3 Minimum Yield Point. The provisions of this code are intended for use with sheet steel having a minimum specified yield point equal to or less than 80 ksi [550 MPa].

1.3 Welding Processes

1.3.1 Approved Processes. This code provides for welding with the shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), gas tungsten arc welding (GTAW), or submerged arc welding (SAW) welding processes. *(NOTE: Any variation of gas metal arc welding (GMAW), including short-circuiting transfer, is acceptable.)*

1.3.2 Stud Welding. When stud welding through the flat portion of sheet steel decking or roofing onto other product forms, the WPS, the studs, and the quality control requirements shall conform with the applicable provisions in the AWS D1.1 code.

1.3.3 Other Processes. Other welding processes may be used when approved by the Engineer. In such case, the Engineer shall specify any additional qualification requirements necessary to assure satisfactory joints for the intended service.

1.4 Weld Metal Requirements

1.4.1 Matching Filler Metals. When using the indicated weld process, the filler metals listed in Table 1.2 provide a weld joint with strengths matching that of the base metal.

1.4.2 Other Base Metal–Filler Metal Combinations. Base metal–filler metal combinations other than those described in 1.4.1 shall be permitted when evaluated and approved by the Engineer. When base metals of dissimilar strengths are welded, the filler metal tensile strength shall be equal to or greater than that of the lowest tensile strength base metal.

1.4.3 Manufacturer's Certification. When requested by the Engineer, the contractor shall furnish an electrode manufacturer's certification stating that the electrode will meet the requirements of the classification.

1.4.4 Electrodes for Shielded Metal Arc Welding (SMAW)

1.4.4.1 AWS Specification. Electrodes for SMAW shall conform to the requirements of the latest edition of AWS A5.1/A5.1M, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*, or to the requirements of AWS A5.5/A5.5M, *Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*.

1.4.4.2 Low-Hydrogen Electrode Control. This control shall be for sheet steel that is welded to a primary structural member which is thicker than 1/4 in [6.4 mm], placing the jurisdiction of this control as specified in AWS D1.1.

1.4.5 Submerged Arc Welding (SAW)

1.4.5.1 AWS Specification. The bare electrodes and fluxes used in combination for SAW shall conform to the requirements of the latest edition of AWS A5.17/A5.17M, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*, or to the requirements of the latest edition of AWS A5.23/A5.23M, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*.

1.4.5.2 Flux. Flux used for submerged arc welding shall be dry and free of contamination from dirt, mill scale, oils, or other foreign material. All flux shall be purchased in packages that can be stored, under normal conditions, for at least six months without such storage affecting its welding characteristics or weld properties. Flux from damaged packages shall be discarded or shall be dried at a minimum temperature of 250°F [120°C] for one hour before use. Flux shall be placed in the dispensing system immediately upon the opening of a package, or if used from an opened package, the top 1 in [25 mm] shall be discarded. Flux that has been wet shall not be used.

1.4.6 Gas Metal Arc Welding, Flux Cored Arc Welding (FCAW), and Gas Tungsten Arc Welding (GTAW) Filler Metals

1.4.6.1 AWS Specification. The filler metals and shielding for GMAW, FCAW, or GTAW shall conform to the requirements of the latest edition of AWS A5.18/A5.18M, *Specification for Carbon Steel Electrodes and Rods for Gas Metal Arc Welding*, or AWS A5.28/A5.28M, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*, AWS A5.20/A5.20M, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*, or AWS A5.29/A5.29M, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding,* as applicable.

1.4.6.2 Shielding Media. A gas or gas mixture used for shielding in GMAW, FCAW when required, or GTAW, shall meet the requirements of AWS A5.32/A5.32M, *Specification for Welding Shielding Gases*. When requested by the Engineer, the gas manufacturer shall furnish certification that the gas or gas mixture meets the requirements of AWS A5.32/A5.32M.

1.5 Weld Types

1.5.1 Square-Groove Welds in Butt Joints. This type of weld is restricted to the welding of sheet steel to sheet steel in all positions of welding.

1.5.2 Fillet Welds. This type of weld may be used in all positions of welding involving sheet steel to sheet steel or a sheet steel to a supporting structural member.

1.5.2.1 Fillet Welds in Lap and T-Joints. Fillet welds in lap and T-joints may be used in all positions (see Table 1.3) involving a sheet steel to sheet steel or a sheet steel to a supporting structural member.

NOTE: When fillet welding sheet steel to a supporting structural member, measures shall be taken to prevent underbead cracking.

1.5.3 Flare-Groove Welds. This type of weld may be used in all positions involving the following:

(1) Two sheet steels for flare-V and flare-bevel grooves

(2) A sheet and a supporting structural member for flare-bevel groove (see Table 1.3)

1.5.4 Arc Spot Welds. This type of weld is a spot weld made by an arc welding process in which the weld is made without preparing a hole in either member. These welds are restricted to the welding of sheet steel to supporting structural member in the flat position (see Table 1.3). *NOTE: Neither the thickness of a single sheet nor the combined thickness of two sheets welded to the thicker supporting structural members shall exceed 0.15 in [3.7 mm].*

1.5.5 Arc Seam Welds. An arc seam weld is made without preparing a slot in either member.

These welds are restricted to the welding of joints involving:

(1) Sheet to sheet in the flat or horizontal position

(2) Sheet to thicker supporting structural member in the flat position (see Table 1.3)

1.5.6 Arc Plug Welds. An arc plug weld is made by filling a circular hole in an outer member or members.

These welds may be used in all positions involving the following:

(1) Multiple layers of sheet steels

(2) Multiple layers of sheet steels and a thicker supporting structural member

1.6 Terms and Definitions

The welding terms used in this specification shall be interpreted in accordance with definitions given in the latest edition of AWS A3.0, *Standard Welding Terms and Definitions*, supplemented by Annex D of this specification.

1.7 Welding Symbols

The welding symbols used in this specification shall be those designated in the latest edition of AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*. Special conditions shall be fully explained by notes or details.

1.8 Safety Precautions

The safety precautions shall conform to the latest edition of ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society.

NOTE: Work performed to this code may involve hazardous operations and materials, such as fumes and solid particles originating from welding consumables, the base metal, and coatings present on the base metal. The code does not purport to address all safety concerns associated with its use. It is the responsibility of the user to establish appropriate safety and health practices. The user should determine the applicability of any regulatory limitations prior to use.

See Annex F for additional information relating to the basic elements of safety general to arc welding processes.

1.9 Standard 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 table and figures. The measurements may not be exact equivalents; therefore, each system must be used independently. Equivalents for gages or fractions are noted within parenthesis throughout the standard.

Table 1.1
Code Application Matrix of D1.3 and D1.1 Codes
Based on Material Thickness Being Joined (see 1.1)

Material Thickness	$t_2 < 1/8$ in [3 mm]	$1/8$ in $\le t_2 \le 3/16$ in [3 mm $\le t_2 \le$ 5 mm]	$t_2 > 3/16$ in. [5 mm]
$t_1 < 1/8$ in [3 mm]	D1.3	D1.3 or Annex A	Annex A
1/8 in. $\le t_1 \le$ 3/16 in [3 mm $\le t_1 \le$ 5 mm]	D1.3 or Annex A	D1.3 or Annex A or D1.1	Annex A or D1.1
$t_1 > 3/16$ in [5 mm]	Annex A	Annex A or D1.1	D1.1

Note: Annex A, Note 1 applications may be used without removal of coating or galvanizing, provided the application meets the requirements of Note 1.

Table 1.2
Matching Filler Metal Requirements (see 1.4.1)

Group No.	ASTM Steel Specifications		Minimum Yield Point ksi	Minimum Yield Point MPa	Minimum Tensile Strength ksi	Minimum Tensile Strength MPa	AWS Filler Metal Specifications
	A109	Temper 4			48	330	SMAW AWS A5.1 E60XX, E70XX
	A570/A570M	Gr 30	30	205	49	340	
		Gr 33	33	230	52	360	
		Gr 36	36	250	53	365	
		Gr 40	40	275	55	380	SMAW AWS A5.5 E70XX-XX (Note a)
		Gr 45	45	310	60	415	
	A572/A572M	Gr 42	42	290	60	415	
	A607	Gr 45	45	310	65	450	SAW AWS A5.17 F6AX-EXXX, F7AX-EXXX, F6AX-ECXXX, F7AX-ECXXX
	A611	Gr A	25	170	42	290	
		Gr B	30	205	45	310	
		Gr C Type 1	33	230	48	330	
		Gr D Type 1	40	275	52	360	
	A653/A653M SS	Gr 33	33	230	45	310	SAW AWS A5.23 F7AX-EXXX-XX, F7AX-ECXX-XX (Note a)
		Gr 37	37	255	52	360	
		Gr 40	40	275	55	380	
	A653/A653M HSLAS	Gr 50 Type A and B	50	340	60	410	
I	A715	Gr 50	50	345	60	415	GMAW/GTAW AWS A5.18 ER70S-X, E70C-XC, E70C-XM
	A792/A792M	Gr 33	33	230	45	310	
		Gr 37	37	255	52	360	
		Gr 40	40	275	55	380	
	A1008/A1008M SS	Gr 25	25	170	42	290	
		Gr 30	30	205	45	310	GMAW/GTAW AWS A5.28 ER70S-XXX, E70C-XXX (Note a)
		Gr 33 Type 1	33	230	48	330	
		Gr 40 Type 1	40	275	52	360	
	A1008/A1008M HSLAS	Gr 45 Class 1 and 2	45	310	55/60	380/410	
	A1008/A1008M HSLAS-F	Gr 50	50	340	60	410	
	A1011/A1011M SS	Gr 30	30	205	49	340	FCAW AWS A5.20 E7XT-X, E7XT-XC, E7XT-XM
		Gr 33	33	230	52	360	
		Gr 36 Type 1	36	250	53	365	
		Gr 40	40	275	55	380	
		Gr 45	45	310	60	410	FCAW AWS A5.29 E6XTX-X, E6XTX-XC, E7XTX-X, E7XTX-XC, E6XTX-XM, E7XTX-XM (Note a)
	A1011/A1011M HSLAS	Gr 45 Class 1 and 2	45	310	55/60	380/410	
		Gr 50 Class 2	50	340	60	410	
	A1011/A1011M HSLAS-F	Gr 50	50	340	60	410	
	A109	Temper 3			55	380	SMAW AWS A5.1 E70XX
	A529/A529M	Gr 50	50	345	70	485	
		Gr 55	55	380	70	485	SMAW AWS A5.5 E70XX-X (Note a)
II	A570/A570M	Gr 50	50	345	65	450	
		Gr 55	55	380	70	480	
	A572/A572M	Gr 50	50	345	65	450	SAW AWS A5.17 F7AX-EXXX, F7AX-ECXXX
		Gr 55	55	380	70	480	

(Continued)

Table 1.2 (Continued)
Matching Filler Metal Requirements (see 1.4.1)

Group No.	ASTM Steel Specifications		Minimum Yield Point ksi	Minimum Yield Point MPa	Minimum Tensile Strength ksi	Minimum Tensile Strength MPa	AWS Filler Metal Specifications
II (Cont'd)	A606		45/50	310/340	65/70	450/480	SAW AWS A5.23 F7AX-EXXX-XX F7AX-ECXXX-XX (Note a)
	A607	Gr 50 Gr 55	50 55	340 380	65 70	450 480	
	A653/A653M HSLAS	Gr 60 Type A and B	60	410	70	480	GMAW/GTAW AWS A5.18 ER70S-X, E70C-XC, E70C-XM
	A653/A653M HSLAS-F	Gr 60	60	410	70	480	
	A715	Gr 60	60	415	70	485	
	A1008/A1008M HSLAS	Gr 50 Class 1 and 2 Gr 55 Class 1 and 2 Gr 60 Class 2	50 55 60	340 380 410	65/60 70/65 70	450/410 480/450 480	GMAW/GTAW AWS A5.28 ER70S-XXX, E70C-XXX (Note a)
	A1008/A1008MHSLAS-F	Gr 60	60	410	70	480	FCAW AWS A5.20 E7XT-X, E7XT-XC, E7XT-XM
	A1011/A1011M SS	Gr 55	55	380	70	480	
	A1011/A1011M HSLAS	Gr 55 Class 1 and 2 Gr 60 Class 1 and 2	55 60	380 410	70/65 75/70	480/450 520/480	FCAW AWS A5.29 E7XTX-X, E7XTX-XC, E7XTX-XM (Note a)
	A1011/A1011M HSLAS-F	Gr 60	60	410	70	480	
III	A572/A572M	Gr 60 Gr 65	60 65	415 450	75 80	520 550	SMAW AWS A5.5 E80XX-X (Note a)
	A607	Gr 60 Gr 65	60 65	415 380	75 82	515 570	SAW AWS A5.23 F8AX-EXXX-XX, F8AX-ECXXX-XX (Note a)
	A653/A653M HSLAS	Gr 70 Type A and B	70	480	80	550	
	A715	Gr 70	70	480	80	550	GMAW/GTAW AWS A5.28 ER80S-XXX, E80C-XXX (Note a)
	A1008/A1008M HSLAS	Gr 60 Class 1 and 2 Gr 65 Class 1 and 2	60 65	410 450	75/70 80/75	520/480 550/520	
	A1008/A1008M HSLAS-F	Gr 70	70	480	80	550	FCAW AWS A5.29 E8XTX-X, E8XTX-XC, E8XTX-XM (Note a)
	A1011/A1011M SS	Gr 36 Type 2	36	250	58-80	400/550	
IV	A607	Gr 70 Class 1 or 2	70	480	85/80	590/550	SMAW AWS A5.5 E90XX-X (Note a)
	A611	Gr E	80	550	82	565	
	A653SS	Gr 80	80	550	82	570	SAW AWS A5.23 F9AX-EXXX-XX, F9AX-ECXXX-XX (Note a)
	A653/A653M HSLAS	Gr 80 Type A and B	80	550	90	620	
	A715	Gr 80	80	550	90	620	
	A792	Gr 80	80	550	82	520	GMAW/GTAW AWS A5.28 ER90S-X, E90C-XXX (Note a)
	A1008/A1008M SS	Gr 80 Type A and B	80	550	82	565	
	A1008/A1008M HSLAS	Gr 70 Class 1 and 2	70	480	85/80	585/550	
	A1008/ A1008M HSLAS-F	Gr 80	80	550	90	620	FCAW AWS A5.29 E9XTX-X, E9XTX-XC, E9XTX-XM (Note a)
	A1011/ A1011M HSLAS-F	Gr 80	80	550	90	620	

(Continued)

Table 1.2 (Continued) Matching Filler Metal Requirements (see 1.4.1)

[a] Only the as-welded condition is applicable, therefore only the following filler metals specification electrode classifications meet the criteria for this table:

1. SMAW: A5.1/A5.1M:2004; A5.5/A5.5M:2006 Electrodes with the following suffixes: -C3, -C3L, -C4, -P1, -NM1, -W1, -W2, -G, -M (when Purchaser and Supplier agree the alloy is to be used in the "as-welded" condition).
2. Only SAW A5.17-97; A5.23-97 Flux/Electrode combinations classified to be used in the "as-welded" condition.
3. GMAW: A5.18/A5.18M;2005; A5.28/A5.28M:2005 Electrodes with the following classification suffixes: -Ni1, -D2, -G (when Purchaser and Supplier agree the alloy is to be used in the "as-welded" condition).
4. FCAW: A5.20/A5.20M:2005; A5.29/A5.29M:2005 Electrodes with the following classification suffixes: -Ni1 (except EXXT5-Ni1), -Ni1M (except EXXT5-Ni1M), -Ni1C (except EXXT5-Ni1C), -Ni2 (except EXXT5-Ni2), -Ni2M (except EXXT5-Ni2M), -Ni2C (except EXXT5-Ni2C), -Ni3 (except EXXT5-Ni3), -D1, -D1M, -D3, -D3M, -K1, -K1M, -K2, -K2M, -K6, -K6M, -K8, -W2, -W2M, -G (when Purchaser and Supplier agree the alloy is to be used in the "as-welded" condition).

Notes:
1. Low hydrogen electrodes shall be used when required by AWS D1.1.
2. The metric MPa values as well as the ksi values are those specified in the individual AWS Filler Metal Specifications.
3. This material is a noncurrent ASTM that was included in the previous code. Existing material may be used as a listed material.

Table 1.3 Welding Positions[a] and Restrictions for WPS (see 1.5.3)

	Square-Groove Weld in Butt Joint	Fillet Weld	Flare-Bevel-Groove Weld	Flare-V-Groove Weld	Arc Spot Weld	Arc Seam Weld	Arc Plug Weld
Sheet to Sheet	F	F	F	F	—	F	F
	H	H	H	H	—	H	H
	V	V	V	V	—	—	V
	OH	OH	OH	OH	—	—	OH
Sheet to Supporting Member	—	F	F	—	F	F	F
	—	H	H	—	—	—	H
	—	V	V	—	—	—	V
	—	OH	OH	—	—	—	OH

[a] Positions of welding: F = flat, H = horizontal, V = vertical, OH = overhead.

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2. Design of Welded Connections

Part A
Allowable Load Capacities

NOTE: For welds not designed to resist external loads, the Engineer may disregard the requirements of this subclause.

Components to be Used in Design Formulae

P = Allowable load capacity (kips)

F_u = Specified minimum ultimate tensile strength of sheet steel (ksi)

F_y = Specified minimum yield strength of sheet steel (ksi)

F_{xx} = Specified minimum tensile strength of AWS electrode classification (ksi)

F_w = Allowable weld shear stress 0.3 F_{xx} (ksi)

t = Thickness of sheet steel thinner member exclusive of coatings (single sheet or combined multiple thicknesses of sheet steels) (in) [mm]

t_w = Weld throat or size (see Figures 2.2, 2.3B, 2.3C, and Annex D for definitions of actual, effective, and theoretical throat of a fillet weld, and for the definition of groove weld size) (in) [mm].

L = Length of weld—for fillet, flare-groove, or arc seam welds (in) [mm]

NOTE: For arc seam welds the L dimension does not include the circular ends (see Figure 2.5)

h = Lip height—for flare-groove welds (see Figures 2.3B and 2.3C) (in) [mm]

d = Visible diameter of the weld face of arc spot welds or arc plug welds (see Figures 2.4 and 2.6) or the visible width of arc seam welds (see Figure 2.5) (in) [mm]

d_a = Resultant average diameter of an arc spot weld or arc plug weld (see Figures 2.4 and 2.6) or an average width of an arc seam weld (see Figure 2.5) (in) [mm]

d_e = Effective diameter of an arc spot weld or arc plug weld or an effective width of an arc seam weld at the faying surface (see Figures 2.4, 2.5, and 2.6) (in) [mm]

NOTE: If it can be shown by sectioning and measuring that a WPS will consistently give a larger effective diameter (d_e) at the faying surface, this value may be used providing this particular WPS is used.

2.1 Base-Metal Stresses

The allowable base-metal stresses shall be those specified in the latest edition of the *Specification for the Design of Cold-Formed Steel Structural Members* of the American Iron and Steel Institute or as otherwise specified in the applicable contract specifications.

2.2 Allowable Load Capacities in Weld Joints

2.2.1 Square-Groove Welds in Butt Joints. The allowable unit load capacities for matching electrode and base metal combinations (see Table 1.2) for a groove weld in a butt joint, welded from one side or both sides, shall be that of the lower strength base metal in the joint, provided that the weld size is equal to the thickness of the base metal (see Figure 2.1).

2.2.2 Fillet Welds. The allowable load capacity of a fillet weld in lap and T-joints, made in any welding position (see Figure 2.2) for matching filler-metal base-metal combinations (see Table 1.2), shall be governed by the thickness of the sheet steel, provided that t_w is at least equal to the thickness of the sheet steel. The allowable load capacity shall be the following:

(1) For fillet welds transverse to direction of loading

$$P = 0.4(t)L(F_u) \quad (1)$$

(2) For fillet welds longitudinal to direction of loading

$$P = 0.4\left(1 - 0.01\frac{L}{t}\right)t(L)F_u \text{ for } \frac{L}{t} < 25 \quad (2)$$

$$P = 0.3(t)L(F_u), \text{ for } \frac{L}{t} \geq 25 \quad (3)$$

(3) For cases where $t_w < t$, the allowable load capacity shall not exceed the following value of P:

$$P = 0.3\ t_w L F_{xx} \quad (4)$$

where

t_w = theoretical throat

t_w shall not exceed the thickness of the thinner base material.

2.2.3 Flare-Groove Welds. For matching filler-metal, base-metal combinations (see Table 1.2), the allowable load capacity of flare-groove welds made in any welding position is considered to be governed by the thickness of the sheet steel adjacent to the welds, provided that a weld size at least equal to the thickness of the sheet steel as was obtained with the WPS qualification. This capacity shall be determined by one of the applicable equations that follow:

(1) Loads applied transversely to weld axis

(a) Flare-bevel-groove welds (see Figure 2.3A)

The capacity of the welded joint is given by:

$$P = \frac{t(L)F_u}{3} \quad (5)$$

(b) Flare-V-groove welds. Loads applied transversely to the weld axis have not been considered.

(2) Loads applied longitudinally with weld axis (see Figure 2.3B and Figure 2.3C)

If the weld size (t_w) is equal to or greater than (t) but less than ($2t$), or if the lip height (h) is less than weld length (L), then

$$P = 0.3(t)L(F_u) \quad \frac{\text{single shear}}{\text{see Figure 2.3B}} \quad (6)$$

If (t_w) is equal to or greater than ($2t$) and the lip height (h) is equal to or greater than (L), then

$$P = 0.6(t)LF_u \quad \frac{\text{double shear}}{\text{see Figure 2.3C}} \quad (7)$$

2.2.4 Arc Spot Welds. Arc spot welds shall be specified as the minimum effective diameter at the faying surface (d_e). The minimum allowable effective diameter is 3/8 in [9 mm]. Allowable loads on each arc spot weld between sheet or sheets and supporting structural member shall not exceed:

(1) For nominal shear loading

$$P = 0.88(t)d_a F_u, \text{ for } \frac{d_a}{t} \leq \frac{140}{\sqrt{F_u}} \quad (8)$$

$$P = 0.112\left[1 + \frac{960t}{d_a\sqrt{F_u}}\right]t(d_a)F_u, \quad (9)$$

$$\text{for } \frac{140}{\sqrt{F_u}} < \frac{d_a}{t} < \frac{240}{\sqrt{F_u}}$$

$$P = 0.56(t)d_a F_u, \text{ for } \left(\frac{d_a}{t} \geq \frac{240}{\sqrt{F_u}}\right) \quad (10)$$

However, the capacity shall not exceed

$$P = \frac{(d_e)^2 F_{xx}}{4} \quad (11)$$

(2) For nominal tension (uplift) loading

For $F_u < 55$ ksi

$P_a = (2.64 - 0.043\ \text{in}^2/\text{kip} \times F_u)\ t d_a F_u$

but $P_a < 0.58(t) d_a F_u$

and for $F_u \geq 55$ ksi

$$P_a = 0.28\ t d_a F_u \quad (12)$$

2.2.5 Arc Seam Welds. The allowable load capacity of an arc seam weld used in a lap joint between the sheet and supporting structural member made in the flat position or between sheet and sheet made in the horizontal or flat position with matching filler metals (see Table 1.2, Figure 2.5, and Figure 2.12) shall not exceed either:

$$P = \left(\frac{d_e^2}{4} + \frac{Ld_e}{3}\right)F_{xx} \quad (13)$$

$$P = (t)F_u\ (0.25L + 0.96d_a) \quad (14)$$

For allowable capacity calculation purposes

$L \leq 3\ d_a$

2.2.6 Arc Plug Welds. Arc plug welds (see Figure 2.6) shall be specified as the minimum effective diameter at the faying surface (d_e). The minimum allowable effective diameter is 3/8 in [9 mm]. Allowable loads on each arc plug weld between sheet or sheets and supporting structural member shall not exceed:

(1) For nominal shear loading

$$P = 0.88(t)d_aF_u, \text{ for } \frac{d_a}{t} \le \frac{140}{\sqrt{F_u}} \quad (15)$$

$$P = 0.112\left[1 + \frac{960t}{d_aF_u}\right]t(d_a)F_u, \quad (16)$$

$$\text{for } \frac{140}{\sqrt{F_u}} < \frac{d_a}{t} < \frac{240}{<\sqrt{F_u}}$$

$$P = 0.56(t)d_aF_u, \text{ for } \frac{d_a}{t} \ge \frac{240}{\sqrt{F_u}} \quad (17)$$

However, the capacity shall not exceed

$$P = \frac{(d_e)^2 F_{xx}}{4} \quad (18)$$

(2) For nominal tension (uplift) loading

For $F_u < 55$ ksi

$P_a = (2.64 - 0.043 \text{ in}^2/\text{kip} \times F_u)\, td_a\, F_u$

but $P_a < 0.58(t)d_a\, F_u$

and for $F_u \ge 55$ ksi

$$P_a = 0.28\, td_a\, F_u \quad (19)$$

Part B
Details of Welded Connections

2.3.1 General. Welded joints may be made using square-groove welds in butt joints, arc spot or arc seam welds in lap joints, or fillet welds in lap or T-joints, and single-flare-bevel or single-flare-V groove welds in butt, lap, or T-joints when they are within the applicable limitations of 2.3.2 through 2.3.5.

2.3.2 Square-Groove Welds. Square-groove welds shall be used in butt joints per Table 1.3 (see Figure 2.1).

2.3.3 Fillet Welds

2.3.3.1 Minimum Length. Minimum length shall be 3/4 in [19 mm].

2.3.3.2 Leg Sizes. Leg sizes of lap joint fillet welds shall be equal to the thickness of the thinner sheet steel (see Figure 2.7). The leg size of the T-joint fillet welds shall be equal to the thickness of the thinnest sheet steel (t) (see Figure 2.8).

2.3.4 Flare-Groove Welds

2.3.4.1 Single-Flare-Bevel-Groove Welds. Single-flare-bevel-groove weld positions shall be per Table 1.3. The minimum length shall be 3/4 in [19 mm] (see Figure 2.9).

2.3.4.2 Single-Flare-V-Groove Welds. Single-flare-V-groove weld positions shall be per Table 1.3. The minimum length shall be 3/4 in [19 mm] (see Figure 2.10).

2.3.5 Arc Spot Welds

2.3.5.1 Single or Double Thicknesses. The positions of arc spot welds made through one or double thicknesses of sheet steel onto a supporting member shall be per Table 1.3. The arc spot welds are restricted to only the flat position (see Figure 2.4). The WPS weld metal diameter (d_e) at the fusion surface shall be at least 3/8 in [9 mm].

2.3.5.2 Minimum Edge Distance. The minimum distance (e) from the center of an arc spot weld to any edge of the sheet steel shall not be less than

$$e_{\min} = \frac{P}{0.5F_ut}, \text{ for } \frac{F_u}{F_y} \ge 1.15 \quad (20)$$

or

$$e_{\min} = \frac{P}{0.45F_ut}, \text{ for } \frac{F_u}{F_y} < 1.15 \quad (21)$$

but not less than $1.5d$ (see Figure 2.11A).

2.3.5.3 Weld Washers. Weld washers are to be used in containing the arc spot welds in sheet steel thinner than 0.028 in [0.7 mm] to prevent burnback (see Figures 2.11B and 2.11C). Weld washers shall be made of one of the sheet steels listed in 1.2.1 and shall have a thickness between 0.05 in and 0.08 in [1.3 mm and 2.1 mm], with a minimum prepunched hole diameter of 3/8 in [9 mm].

2.3.6 Arc Seam Welds

2.3.6.1 Positions. Arc seam welds between sheet steels or between sheet steel and supporting members shall be per Table 1.3.

2.3.6.2 Minimum Width. The minimum width of weld metal at the faying surface of arc seam welds shall be 3/8 in [9 mm].

2.3.6.3 Minimum Edge Distance. The distance from the end of the arc seam weld to the edge of the sheet steel shall be measured from the center of the circular portion of the weld (see Figure 2.13A). The minimum distance from the longitudinal axis of an arc seam weld or from the end of an arc seam weld to the edge of the sheet steel shall not be less than that obtained when using the equation in 2.3.5.2, but not less than 1.5d (see Figures 2.5 and 2.12).

2.3.7 Arc Plug Welds

2.3.7.1 Position and WPS Diameter. The position of arc plug welds shall be per Table 1.3 (see Figure 2.6). The WPS weld metal diameter (d_e) at the fusion surface shall be at least 3/8 in [9 mm].

2.3.7.2 Minimum Hole Diameter. For sheet steel thicknesses equal to or less than 20 gage [0.912 mm], the hole shall be 1/4 in [6.4 mm] minimum diameter; for thicknesses greater than 20 gage the hole shall be 5/16 in [8.0 mm] diameter. For multiple thicknesses using arc plug welds, the holes may have to be enlarged to attain the weld metal minimum diameter (d_e) of 3/8 in [9 mm] at the fusion surface.

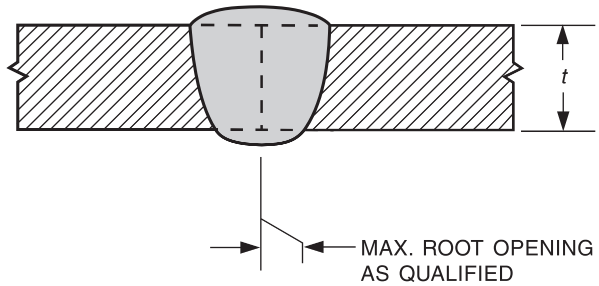
2.3.7.3 Minimum Edge Distance. The minimum distance (e) from the center of an arc plug weld to any edge of the sheet steel shall not be less than

$$e_{\min} = \frac{P}{0.5F_u t}\text{, for } \frac{F_u}{F_y} \le 1.15 \qquad (22)$$

or

$$e_{\min} = \frac{P}{0.45F_u t}\text{, for } \frac{F_u}{F_y} < 1.15 \qquad (23)$$

but not less than 1.5d (see Figure 2.13B).



Note: The groove weld size equals the thickness *t*.

Figure 2.1—Square-Groove Welds in Butt Joints (see 2.2.1 and 2.3.2)

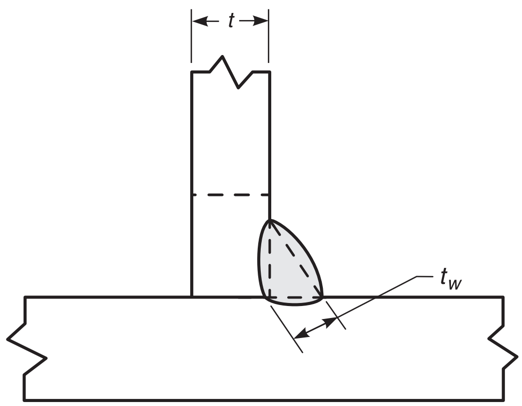


Figure 2.2—Fillet Welds (see 2.2.2)

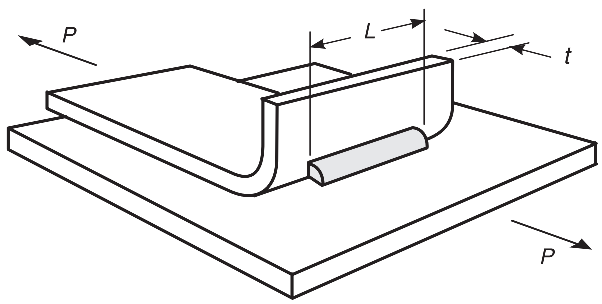


Figure 2.3A—Single-Flare-Bevel-Groove Weld [see 2.2.3(1)]

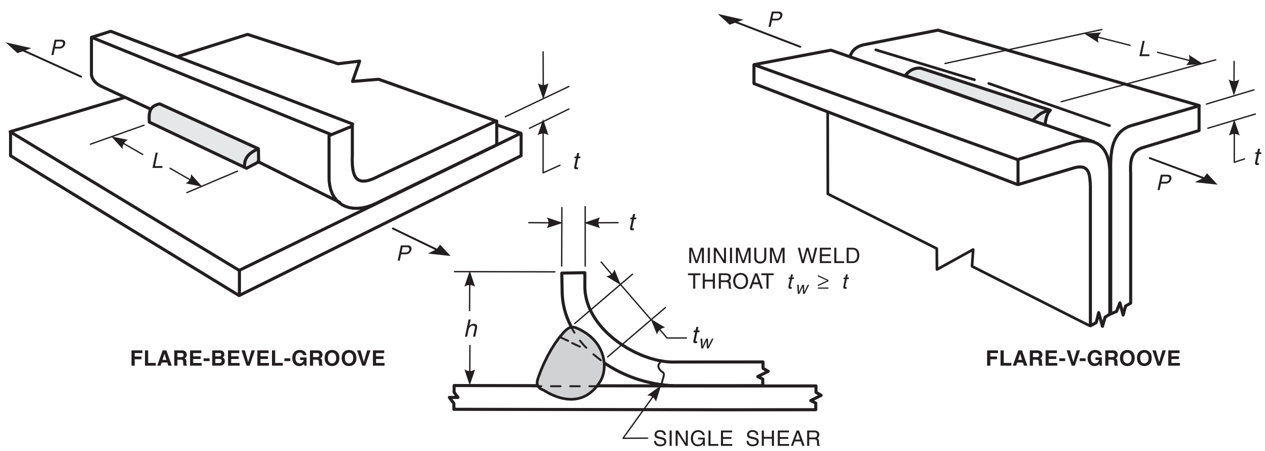


Figure 2.3B—Single-Shear in Flare-Groove Welds [see 2.2.3(2)]

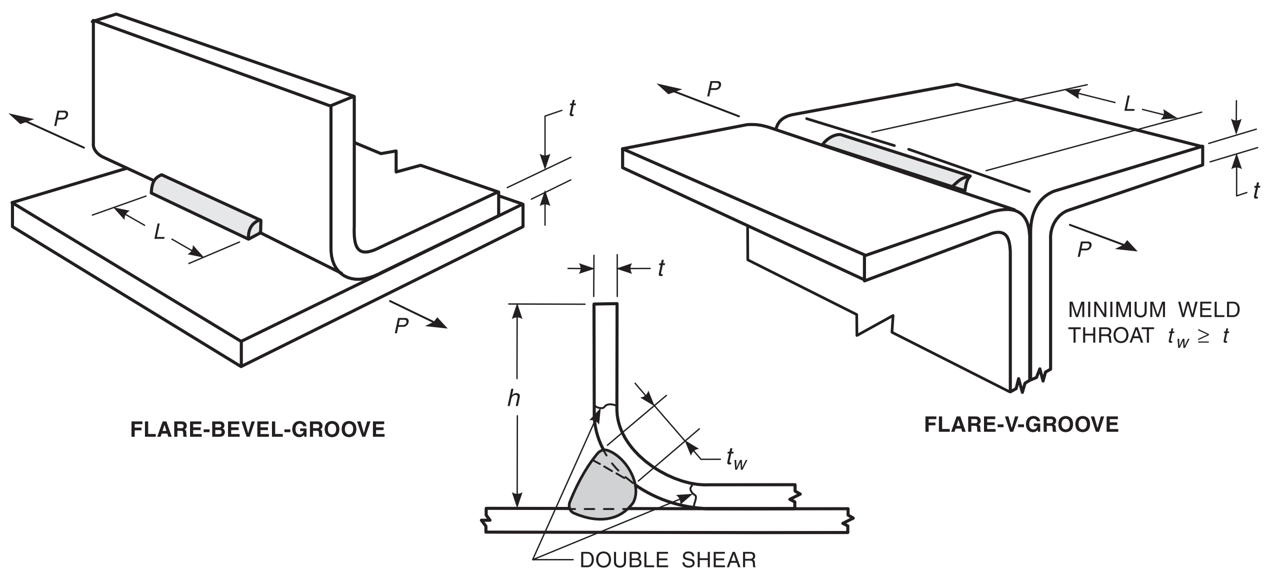


Figure 2.3C—Double-Shear in Flare-Groove Welds [see 2.2.3(2)]

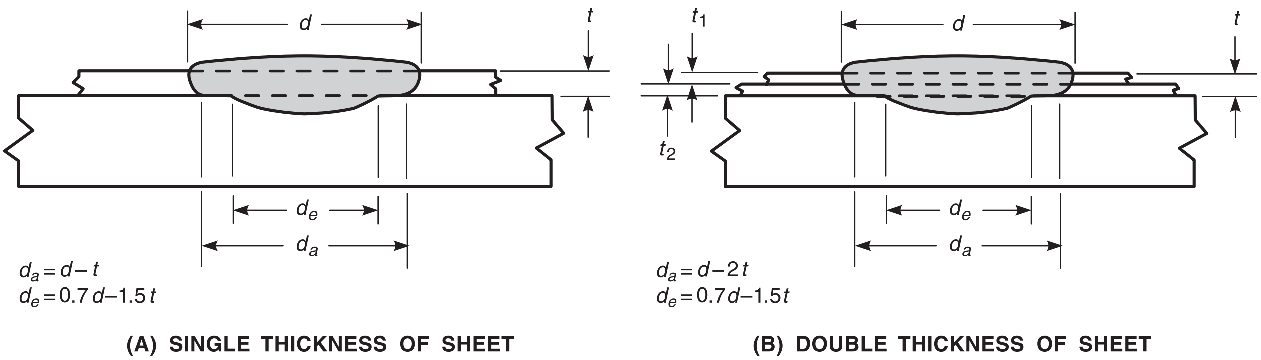


Figure 2.4—Arc Spot Welds (see 2.2.4)

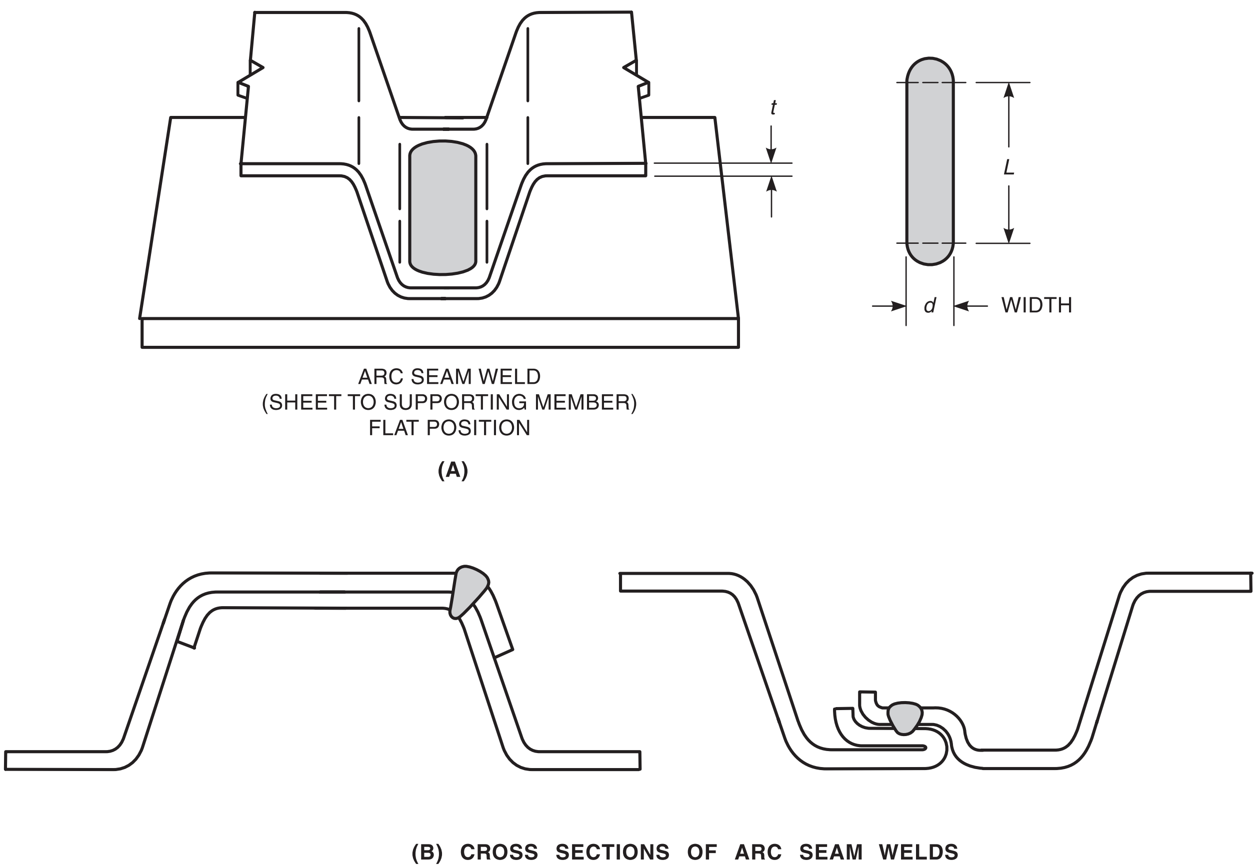


Figure 2.5—Arc Seam Welds (see 2.2.5)

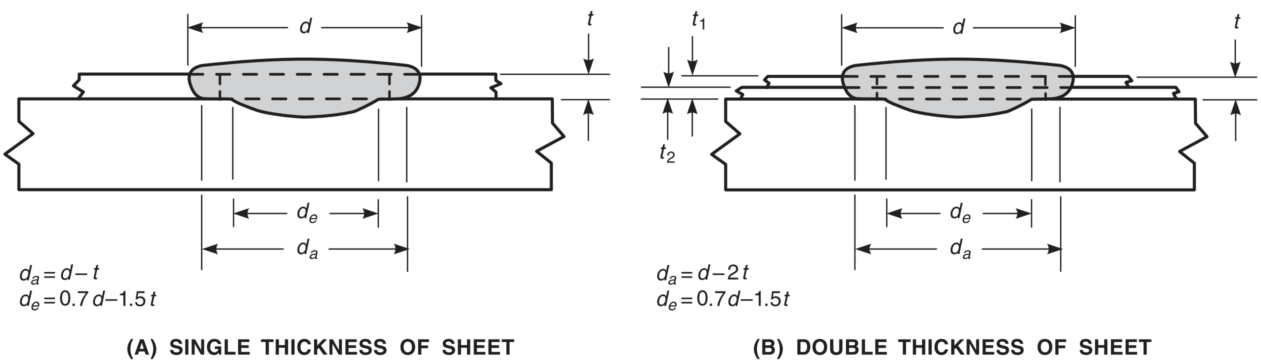


Figure 2.6—Arc Plug Welds (see 2.2.6)

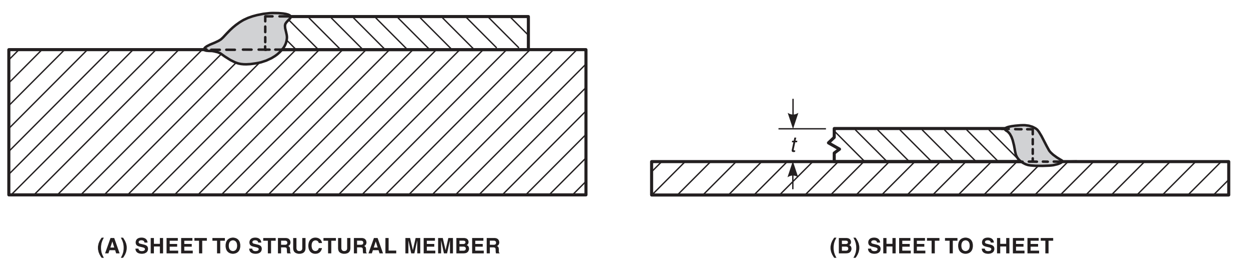


Figure 2.7—Fillet Welds in Lap Joints (see 2.3.3.2)

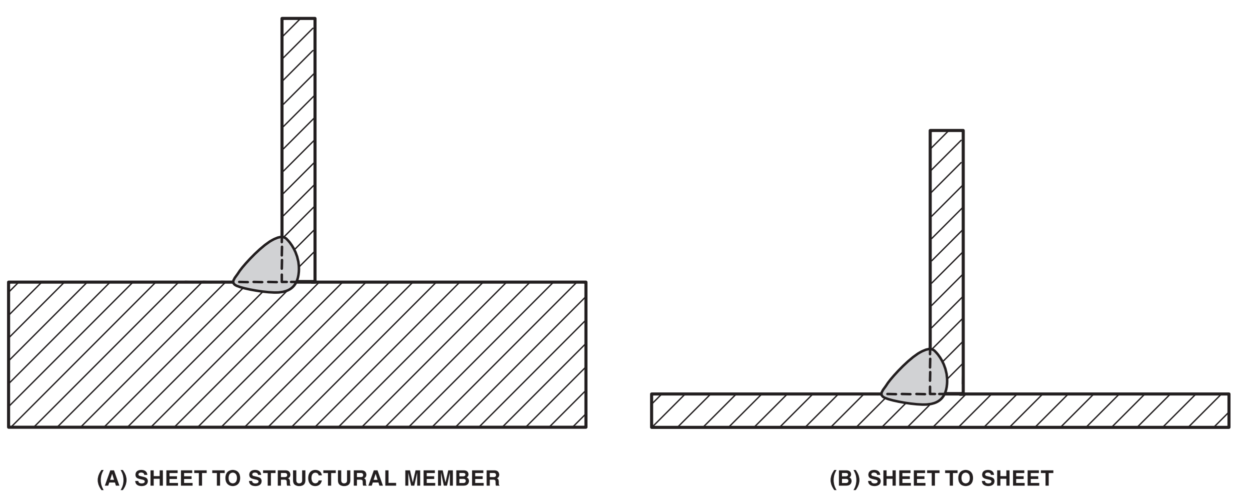


Figure 2.8—Fillet Welds in T-Joints (see 2.3.3.2)

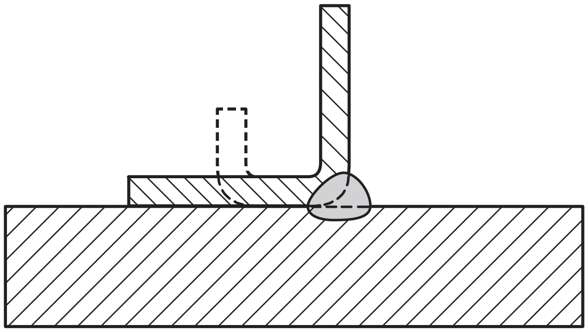


Figure 2.9—Single-Flare-Bevel-Groove Weld (see 2.3.4.1)

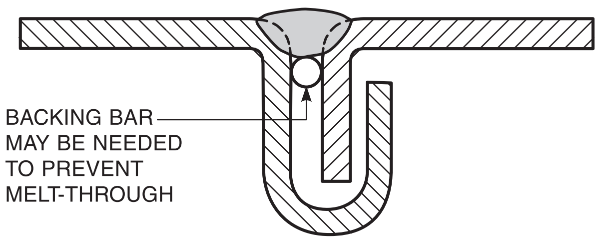


Figure 2.10—Single-Flare-V-Groove Weld (see 2.3.4.2)

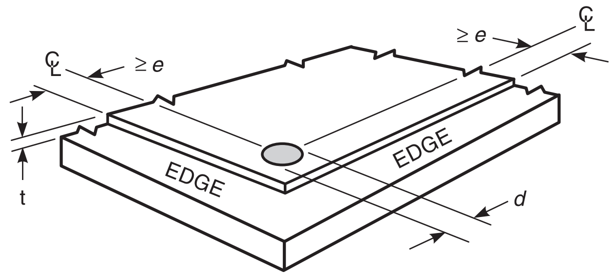


Figure 2.11A—Edge Distances for Arc Spot Welds (see 2.3.5.2)

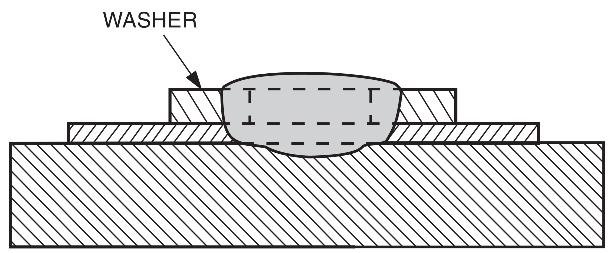


Figure 2.11B—Arc Spot Weld Using Washer (see 2.3.5.3)

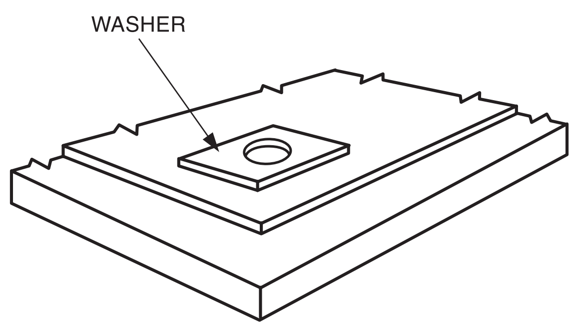


Figure 2.11C—Typical Weld Washer (see 2.3.5.3)

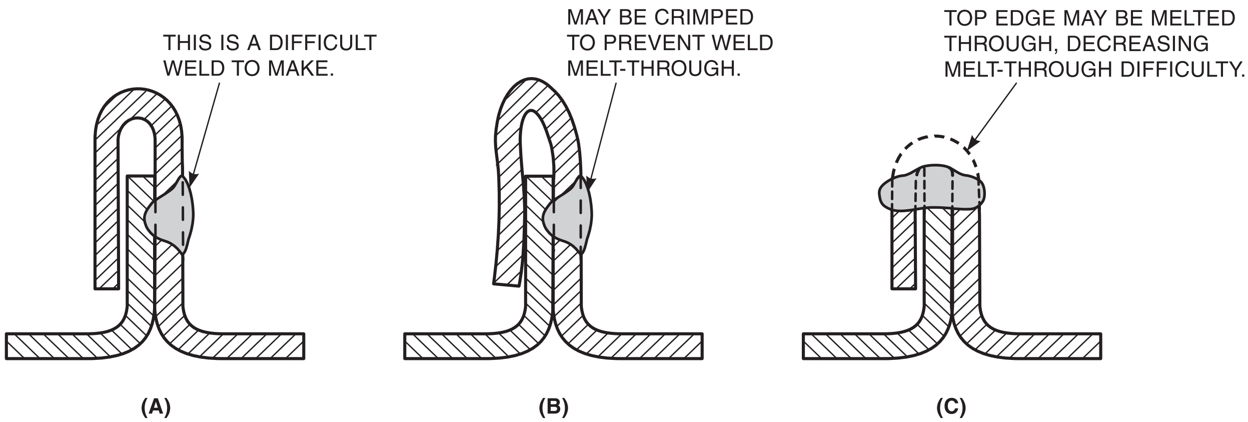


Figure 2.12—Arc Seam Welds Along Standing Rib (see 2.2.5)

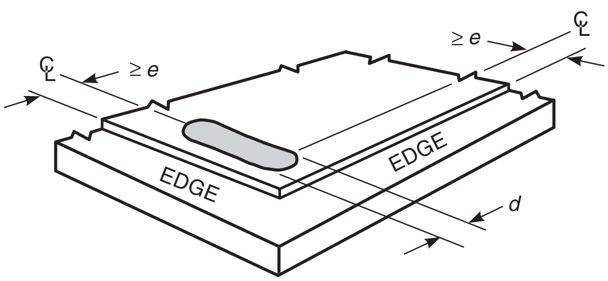


Figure 2.13A—Edge Distances for Arc Seam Welds (see 2.3.6.3)

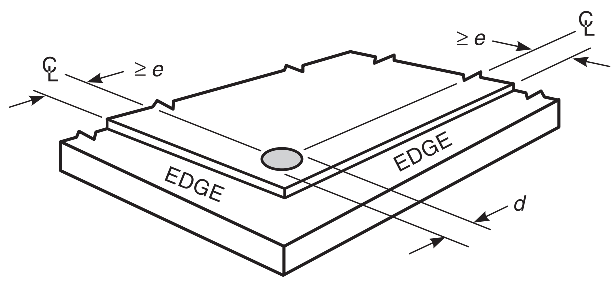


Figure 2.13B—Edge Distances for Arc Plug Welds (see 2.3.7.3)

3. Prequalification of WPSs

3.0 Scope

Prequalification of WPSs (Welding Procedure Specifications) shall be defined as exemption from the WPS qualification testing required in Clause 4. All prequalified WPSs shall be written. In order for a WPS to be prequalified, conformance with all of the applicable requirements of Clause 3 shall be required. The provisions of Clause 3 apply only to welded connections between sheet steel and sheet steel or sheet steel to a supporting structural member with a base-metal thickness equal to or less than 3/16 in [5 mm].

3.1 General

3.1.1 Requirements. A written WPS that includes a recorded value for each of the variable requirements as shown in Table 3.1, is designated as prequalified: This written WPS may follow any convenient format (see Annex A for example). Any change to any of the recorded values on this WPS requires either a new or a revised WPS be written.

3.2 Joint Details

For any departure from the joint details prescribed by Figures 3.1A through 3.3D, the contractor shall submit the proposed WPSs to the Engineer for approval, and demonstrate their adequacy in conformance with Clause 4 and conformance with the applicable provisions of Clause 5.

3.2.1 Square Groove Welds in Butt Joints. Complete joint penetration groove welds (CJP) made by the SMAW, GMAW, GTAW, or FCAW processes in butt or corner joints, which may be used without WPS qualification tests, are detailed in Figures 3.1A and 3.1B.

3.2.2 Fillet Welds. Fillet welds made by the SMAW, GMAW, GTAW, or FCAW processes, which may be used without WPS qualification tests, are detailed in Figures 3.2A, 3.2B, and 3.2C.

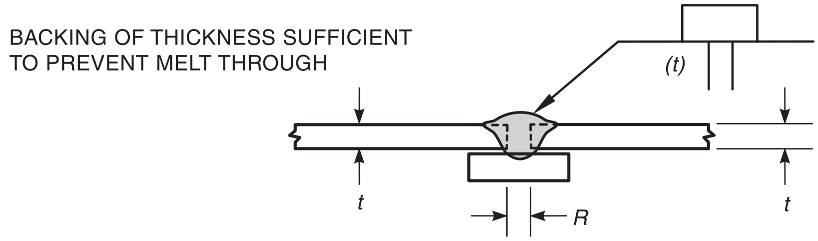
3.2.3 Flare-Groove Welds in Butt or Corner Joints. Flare-groove welds made by the SMAW, GMAW, GTAW, or FCAW processes, which may be used without WPS qualification tests, are detailed in Figures 3.3A, 3.3B, and 3.3C.

3.2.4 Flare-Bevel Groove Welds in Lap Joints. Flare-bevel groove welds made by the SMAW, GMAW, GTAW, or FCAW processes in lap joints, which may be used without WPS qualification tests, are detailed in Figure 3.3D.

Table 3.1
Prequalified WPS Requirements

Variables		Prequalified Figures								
		3.1A	3.1B	3.2A	3.2B	3.2C	3.3A	3.3B	3.3C	3.3D
Thickness (*t*)		X	X	X					X	
Thickness (t_1 and t_2)					X	X	X	X		X
Root Opening (R)		X	X	X	X	X	X	X	X	X
Bend Radii (C)							X	X	X	
Weld Face Width (W)								X	X	
Throats	(*t*)	X	X							
Throats	*t*			X	X	X				
Throats	*E*						X			
Throats	*ET*							X		

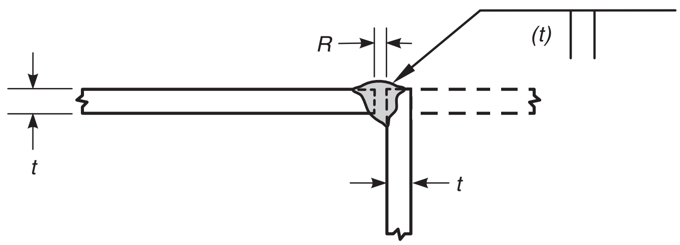
Welding Parameters	Welding Process (See 1.3.1)				
	SMAW	GMAW	FCAW-G	FCAW-S	GTAW
Type of Current	X	X	X	X	X
Polarity	X	X	X	X	X
Electrode Classification	X	X	X	X	X
Base Metal (see Table 1.2)	X	X	X	X	X
Matching Filler Metal (see Table 1.2)	X	X	X	X	X
Welding Position (see Table 1.3)	X	X	X	X	X
Direction of Welding (uphill/downhill) in vertical position	X	X	X	X	X
Filler Metal Diameter	X	X	X	X	X
Amperage	X	X	X	X	X
Wire Feed Speed		X	X	X	X
Voltage	X	X	X	X	X
Travel Speed		X	X	X	X
Shielding Gas—Composition		X	X		X
Shielding Gas—Flow Rate		X	X		X



Welding Process	Thickness	R = Root Opening	Positions
All	18 Ga. MIN., 16 Ga. MAX.	0 MIN., 3/4 *t* MAX.	All
	15 Ga. MIN., 7 Ga. MAX.	3/4 *t* MIN., 1-1/4 *t* MAX.	

Note: See Annex D for metric equivalents of U.S. Customary Units.

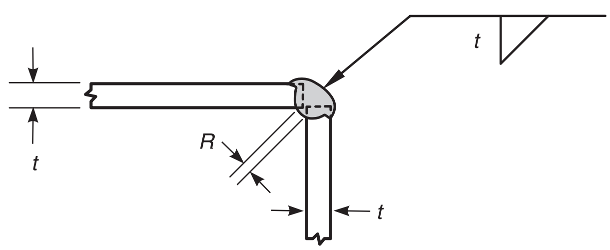
Figure 3.1A—Square Groove Weld in Butt Joint with Steel Backing (see 3.2.1)



Welding Process	Thickness	R = Root Opening	Positions
All	18 Ga. MIN., 12 Ga. MAX.	0 MIN., *t*/2 MAX.	All
	11 Ga. MIN., 7 Ga. MAX.	*t*/2 MIN., *t* MAX.	

Note: See Annex D for metric equivalents of U.S. Customary Units.

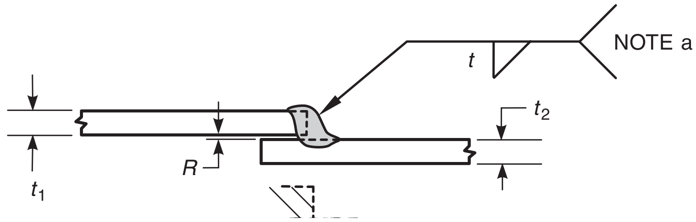
Figure 3.1B—Square Groove Weld in Butt or Corner Joint without Backing (see 3.2.1)



Welding Process	Thickness	R = Root Opening	Positions
All	18 Ga. MIN., 11 Ga. MAX.	0 MIN., *t*/4 MAX.	All

Note: See Annex D for metric equivalents of U.S. Customary Units.

Figure 3.2A—Fillet Weld in Corner Joint (see 3.2.2)

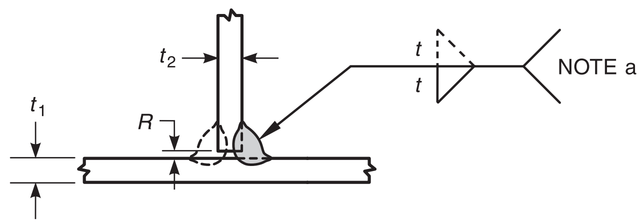


Welding Process	Thickness	R = Root Opening	Positions
All	t_1, t_2 = 18 Ga. MIN., 7 Ga. MAX. and t_2 = t_1/2 MIN., 2t_1 MAX.	0 MIN., t/2 MAX. (See Note a)	All

[a] $t = t_1$ or t_2, whichever is less.

Note: See Annex D for metric equivalents of U.S. Customary Units.

Figure 3.2B—Fillet Weld in Lap Joint (see 3.2.2)

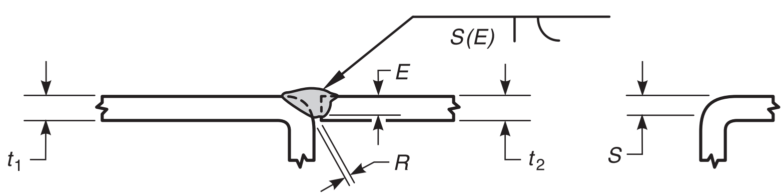


Welding Process	Thickness	R = Root Opening	Positions
All	t_1, t_2 = 18 Ga. MIN., 7 Ga. MAX. and t_2 = t_1/2 MIN., 2t_1 MAX.	0 MIN., t/2 MAX. (See Note a)	All

[a] $t = t_1$ or t_2, whichever is less.

Note: See Annex D for metric equivalents of U.S. Customary Units.

Figure 3.2C—Fillet Weld in T-Joint (see 3.2.2)

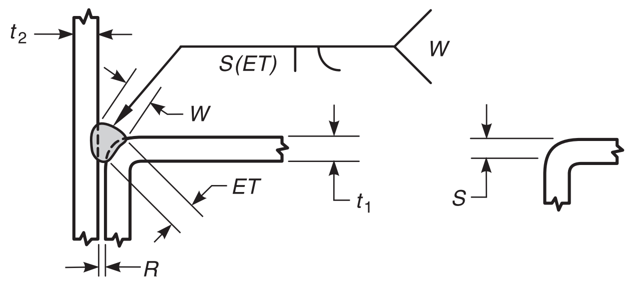


Welding Process	Thickness	R = Root Opening	Positions
All	t_1, t_2 = 18 Ga. MIN., 7 Ga. MAX. and t_2 = t_1/2 MIN., 2t_1 MAX.	0 MIN., t/2 MAX. (See Note a)	All

[a] $t = t_1$ or t_2, whichever is less.

Notes:
1. E (weld size) = 0.5t_2 for ≥ 13 gage
   0.6t_2 for 11 and 12 gages
   0.7t_2 for 7 through 10 gages
2. S (external bend radius) = 2t_1 min.
3. As the radius increases, the "S" dimension also increases. The corner may not be a quadrant of a circle tangent to the sides. The corner dimension, "S," may be less than the radius of the corner.
4. See Annex D for metric equivalents of U.S. Customary Units.

Figure 3.3A—Flare-Bevel-Groove Weld in Butt Joint (see 3.2.3)



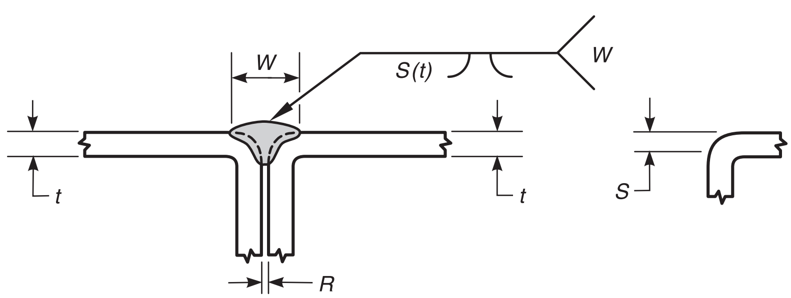
Welding Process	Thickness	R = Root Opening	Positions
All	t_1, t_2 = 18 Ga. MIN., 7 Ga. MAX. and t_2 = t_1/2 MIN., 2t_1 MAX.	0 MIN., t/2 MAX. (See Note a)	All

[a] $t = t_1$ or t_2, whichever is less.

Notes:

1. W (weld face width) = 2t_1 for ≥ 16 gage
   1.5t_1 for 11 through 15 gages
   T_1 for 7 through 10 gages
2. ET (effective throat) = 1.5t_1 for ≥ 11 gage
   t_1 for 7 through 10 gages
3. S (external bend radius) = 2t_1 min.
4. As the radius increases, the “S” dimension also increases. The corner may not be a quadrant of a circle tangent to the sides. The corner dimension, “S,” may be less than the radius of the corner.
5. See Annex D for metric equivalents of U.S. Customary Units.

Figure 3.3B—Flare-Bevel-Groove Weld in Corner Joint (see 3.2.3)



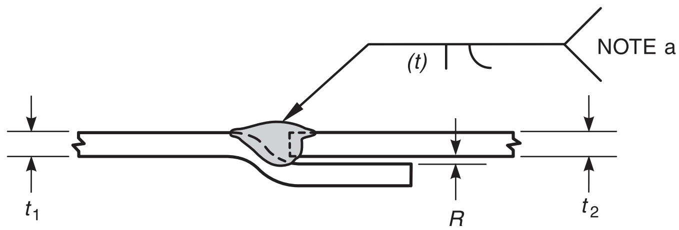
Welding Process	Thickness	R = Root Opening	Positions
All	18 Ga. MIN., 11 Ga. MAX.	0 MIN., t/2 MAX.	All

[a] $t = t_1$ or t_2, whichever is less.

Notes:

1. W (weld face width) = 2t min.
2. S (external bend radius) = 2t min.
3. As the radius increases, the “S” dimension also increases. The corner may not be a quadrant of a circle tangent to the sides. The corner dimension, “S,” may be less than the radius of the corner.
4. See Annex D for metric equivalents of U.S. Customary Units.

Figure 3.3C—Flare-V-Groove Weld in Butt Joint (see 3.2.3)



Welding Process	Thickness	R = Root Opening	Positions
All	t_1, t_2 = 18 Ga. MIN., 7 Ga. MAX. and t_2 = t_1/2 MIN., 2t_1 MAX.	0 MIN., t/2 MAX. (See Note a)	All

[a] $t = t_1$ or t_2, whichever is less.

Note: See Annex D for metric equivalents of U.S. Customary Units.

Figure 3.3D—Flare-Bevel-Groove Weld in Lap Joint (see 3.2.4)

4. Qualification

Part A
General Requirements

4.1 Preparation of a WPS and PQR

A Welding Procedure Specification (WPS) shall be written for each type of weld as shown in Table 4.1, except as permitted in Clause 3, and shall be qualified in conformance with the provisions of Clause 4 by the manufacturer or contractor. A Procedure Qualification Record (PQR) that records the actual values used to qualify a WPS shall be written. Suggested, nonmandatory forms for WPSs and PQRs are given in Annex B. *Note: Melting rate data of SMAW electrodes (see Commentary C-4.6.4.2) may be used as a measure of welding current for the WPS and PQR.*

4.2 Engineer's Approval

Properly documented evidence of previous WPS qualification may be accepted with the Engineer's approval. The Engineer may accept properly documented evidence of previous qualification of the WPSs that are to be employed. The acceptability of qualification to other standards is the Engineer's responsibility, to be exercised based upon the specific structure, or service conditions, or both. AWS B2.1.XXX-XX Series on Standard Welding Procedure Specifications may, in this manner, be accepted for use in this code.

4.3 Responsibility

Each manufacturer or contractor shall be responsible for inspection and testing of WPS qualification test assemblies in conformance with the provisions of Clause 4.

4.4 WPS Requirements

WPSs shall be qualified for each change in essential variables as listed in 4.5.

Part B
Welding Procedure Specification (WPS)

4.5 Essential Variable Limitations

Any of the essential variable changes listed in Table 4.2 shall require WPS requalification.

4.6 Number of Tests, Testing Methods, and Acceptance Standards for WPS Qualification

4.6.1 Square Groove Welds in Butt Joints

4.6.1.1 Qualification Testing. For a square-groove weld in butt joint WPS not conforming to 3.2, qualification testing shall be required in conformance with Table 4.2, Item (10)(b) or Table 4.2, Item (10)(c).

4.6.1.2 Test Assemblies and Examination. The test assembly shall conform to the following:

(1) Sheet steel shall be welded together as shown in Figure 4.1.

(2) The weld shall be uniform in appearance and shall be free of:

(a) cracks

(b) reinforcement not in conformance with 6.1.1.2

(c) undercut not in conformance with 6.1.1.3

(3) The welded test sheets shall be hammered and bent through 180° (see Figure 4.1), the bend axis being coincident with the weld axis. For joints welded from one side only, the root of the weld shall be on the face of the bend.

(4) A weld shall be acceptable if the following criteria are satisfied:

(a) No cracks are visually detected after bending,

or

(b) Weld metal cracks are visually detected and:

(i) The fractured face shows no visually detectable discontinuities (e.g., slag, porosity), and

(ii) The weld size is equal to or greater than the sheet steel thickness

NOTE: Base-metal cracks shall be ignored.

4.6.1.3 Qualification Ranges. A change in any one of the essential variables that exceed the limitations of 4.5 requires requalification.

4.6.2 Fillet Welds

4.6.2.1 Qualification Testing. For a fillet weld WPS not conforming to 3.3, qualification testing shall be required in conformance with Table 4.2, Item (10)(b) or Table 4.2, Item (10)(c).

4.6.2.2 Test Assemblies and Examination. Two test assemblies shall be prepared, welded, visually inspected, and tested using either sheet to sheet or sheet to supporting structural member described in (1) or (2) as follows:

(1) **Sheet to Sheet.** Each test assembly shall conform to Figure 4.2A.

(2) **Sheet to Supporting Structural Member.** Each test assembly shall conform to Figure 4.2A.

(3) **Examination.** A weld shall be acceptable if the following criteria are satisfied:

(a) No weld metal cracks shall be visually detected after bending, or

(b) Weld metal cracks are visually detected after bending and

(i) The fractured face shows no visually detectable discontinuities (e.g., slag, porosity), and

(ii) The weld size t_w is equal to or greater than the sheet steel thickness

NOTE: Base-metal cracks shall be ignored.

(c) After visual inspection of acceptable welds, the two pieces shall be completely separated by either bending the sheets or by hammering a wedge (see Figure 4.2A) until either the weld or sheet metal fails.

(d) The fractured surface shall show complete fusion at the root of the joint.

4.6.2.3 Qualification Ranges. The validity of qualification shall be as follows (see Figure 4.2B):

(1) T-joints shall qualify for lap and T-joints.

(2) Sheet steel to supporting structural member qualifies for sheet steel to supporting structural member for a given position of welding and thickness of sheet steel.

(3) Sheet steel to sheet steel qualifies for sheet steel to sheet steel, and also sheet steel to supporting structural member for a given position of welding and thickness of sheet steel. If there are two thicknesses of sheet steel, the thickness of the thinner sheet will control.

4.6.3 Flare-Groove Welds

4.6.3.1 Qualification Testing. For a flare-groove weld WPS not conforming to 3.4, qualification testing shall be required in conformance with Table 4.2, Item (10)(b) or Table 4.2, Item (10)(c).

4.6.3.2 Test Assemblies and Examination. The following requirements shall be met:

(1) **Flare-Bevel-Groove Welds.** Two test assemblies shall be required, conforming to either sheet to sheet or sheet to supporting structural member as follows:

(a) **Sheet to Sheet.** Each assembly shall consist of two rectangular pieces of sheet steel, at least 2-1/2 in [65 mm] wide, and at least 3 in [75 mm] long. One piece shall be bent through 90° around an inside radius not to exceed $3t$, where t is the thickness of sheet steel; the other piece shall be flat. These shall be fitted together to form a flare-bevel-groove joint. A flare-bevel-groove weld 1 in [25 mm] long shall be deposited using the proper type and size of electrode and welding current. The test assembly is shown in Figure 4.3A.

(b) **Sheet to Supporting Structural Member.** Each test assembly shall consist of a rectangular piece of sheet steel, at least 2-1/2 in [65 mm] wide, and at least 3 in [75 mm] long. One piece shall be bent through 90° around an inside radius not to exceed $3t$, where t is the thickness of sheet steel. It shall be clamped to the top of a flange of a beam or separate plate, at least 1/2 in [13 mm] thick. A flare-bevel-groove weld 1 in [25 mm] long shall be deposited using the proper type and size of electrode and welding current. The test assembly is shown in Figure 4.3B.

(2) **Flare-V-Groove Welds.** Two test assemblies shall be prepared, welded, visually inspected, and tested as follows:

(a) Each test assembly shall consist of two rectangular pieces of sheet steel, at least 2-1/2 in [65 mm] wide, and at least 3 in [75 mm] long, bent through 90° to an inside radius not exceeding 3*t*, where *t* is the thickness of the sheet steel, and fitted together to form a flare-V-groove weld joint.

(b) A flare-V-groove weld 1 in [25 mm] long shall be deposited using the proper type and size electrode and welding current. The test assembly is shown in Figure 4.3C.

(3) **Examination**

(a) The welds shall be reasonably uniform in appearance, and shall be free of overlap, cracks, and excessive undercut.

(b) After cooling, welds of acceptable quality shall be tested by bending the sheet back and forth, or by wedging a cold chisel between the pieces until the weld, or the sheet steel, fails (see Figure 4.3A, 4.3B, or 4.3C).

(c) The minimum weld size shall equal t_w.

4.6.3.3 Qualification Ranges. Qualification for flare bevel groove welds shall qualify for flare-V-groove welds and vice versa, provided the same essential variables apply (see Figure 4.3D).

(1) Sheet steel to supporting member qualifies for sheet steel to supporting structural member for a given position of welding and thickness of sheet steel.

(2) Sheet steel to sheet steel qualifies for sheet steel to sheet steel, and also sheet steel to supporting structural member for a given position of welding and thickness of sheet steel.

4.6.4 Arc Spot Welds

4.6.4.1 Qualification Testing. A WPS is required for each single and double thickness of sheet steel to be arc spot welded to a supporting structural member in the flat position and within the essential variable limitations of 4.5.

4.6.4.2 Test Assemblies and Examination. Two test assemblies are required for each WPS (see Detail 4.4 in Table 4.1), and each assembly shall be prepared, welded, tested, and examined as follows:

(1) One piece (or two pieces for the double thickness) of sheet steel 2-1/2 in [63 mm] or wider shall be clamped to the top of a flange, remnant beam, or a separate plate that is at least 1/2 in [13 mm] thick to form the test assembly (see Figure 4.4). For sheet steels thinner than 0.028 in [0.7 mm], weld washers that are at least 0.060 in [1.5 mm] thick and made of one of the sheet steels listed in 1.2.1 shall be used (see 2.3.5.3).

(2) An arc spot weld with a visible diameter (*d*) [specified in the WPS, and not less than 1/2 in [13 mm] in diameter] shall be produced. The crater shall be filled and a 1/32 in [1 mm] minimum reinforcement provided.

(3) The projecting part of the sheet steel shall be twisted (see Figure 4.4) until the arc spot weld disengages from either member.

(4) A weld shall be acceptable if the following criteria are satisfied:

(a) The resulting nugget's measured diameter d_e shall not be less than 3/8 in [9 mm] or the required WPS diameter, whichever is the greater.

(b) The fractured face shows no visually detectable discontinuities (e.g., slag, porosity).

(c) The weld metal shows no visually detectable cracks.

NOTE: Base-metal cracks shall be ignored.

4.6.4.3 Qualification Ranges. A change in any one of the essential variables that exceed the limitations of 4.5 requires requalification.

4.6.4.4 SMAW Melting Rate. When an SMAW electrode is used to produce a qualified arc spot weld, the melting rate for the particular electrode classification and diameter shall be measured as:

$$M = \frac{\text{in [mm] of electrode melted}}{\text{Time in minutes}}$$

The melting rate shall be recorded on the respective PQR.

4.6.4.5 Arc Seam Option. A PQR for a specific arc spot weld WPS shall also qualify an arc seam weld WPS having a width equal to the arc spot's diameter (*d*).

4.6.5 Arc Seam Welds

4.6.5.1 Qualification Testing. The following requirements shall be met:

(1) **Single or Double Thicknesses for Sheet Steel to Supporting Member.** A WPS is required for each single and double thickness of sheet steel to be arc seam welded to a supporting structural member in the flat position and within the essential variable limitations of 4.5.

(2) **Single Thicknesses for Sheet Steel to Sheet Steel.** A WPS is required for each single thickness of sheet steel to be arc seam welded to another sheet steel in either the flat or horizontal position (see a typical joint configuration in Figure 2.6) and within the essential variables of 4.5.

4.6.5.2 Test Assemblies and Examination. The following requirements shall be met:

(1) **Single or Double Thicknesses for Sheet Steel to Supporting Member.** Two test assemblies are required for each WPS (see Detail 4.5A in Table 4.1), and each assembly shall be prepared and welded as follows:

One piece (or two pieces for the double thickness) of sheet steel 2-1/2 in [63 mm] or wider shall be clamped to the top of a flange, remnant beam, or a separate plate that is at least 1/2 in [13 mm] thick to form the test assembly (see Figure 4.5A). An arc seam weld with a visible width (d) (specified in the WPS, and not less than 1/2 in [13 mm] wide nor less than 1 in [25 mm] in length) shall be produced. The crater shall be filled and 1/32 in [1 mm] minimum reinforcement provided.

(2) **Single Thicknesses for Sheet Steel to Sheet Steel.** A test assembly of the actual joint configuration for each WPS (see typical joint configuration in Figure 4.5B) shall be prepared and welded. An arc seam weld with a visible width (d) (specified in the WPS, and not less than 1/2 in [13 mm] wide nor less than 1 in [25 mm] in length) shall be produced. The crater shall be filled and 1/32 in [1 mm] minimum reinforcement provided.

(3) **Examination.** The projecting part of the sheet steel shall be pried, or bent, or both, through 180° with the bend axis coincident with the weld axis (see Figure 4.5A or Figure 4.5B) until the arc seam weld disengages from either member.

(a) The resulting nugget's measured width (d_a) shall not be less than 1/2 in [13 mm] or the required WPS width, whichever is the greater.

(b) The fractured face shows no visually detectable discontinuities (e.g., slag, porosity).

(c) The weld metal shows no visually detectable cracks.

NOTE: Base-metal cracks shall be ignored.

4.6.5.3 Qualification Ranges. A change in any one of the essential variables that exceed the limitations of 4.5 requires requalification.

4.6.5.4 SMAW Melting Rate. When an SMAW electrode is used to produce a qualified arc seam weld, the melting rate for the particular electrode classification and diameter shall be measured (see 4.6.4.4) and recorded on the respective PQR.

4.6.5.5 Arc Spot Option. A PQR for a specific arc spot weld WPS shall also qualify an arc seam weld WPS having a width equal to the arc spot's diameter (d).

4.6.6 Arc Plug Welds

4.6.6.1 Qualification Testing. The following requirements shall be met:

(1) **Single or Multiple Thicknesses for Sheet Steel to Supporting Member.** A WPS is required for each single and multiple thickness of sheet steel to be arc plug welded to a supporting structural member within the essential variable limitations of 4.5.

(2) **Multiple Thicknesses for Sheet Steel to Sheet Steel.** A WPS is required for each multiple thickness of sheet steel to be arc plug welded to another sheet steel within the essential variables of 4.5.

4.6.6.2 Test Assemblies and Examination. The following requirements shall be met:

(1) **Single or Multiple Thicknesses for Sheet Steel to Supporting Member.** Two test assemblies are required for each WPS (see Detail 4.6 in Table 4.1), and each assembly shall be prepared and welded as follows: One piece (or multiple pieces for multiple thicknesses) of sheet steel 2-1/2 in [63 mm] or wider shall be clamped to the top of a flange, remnant beam, or a separate plate that is at least 1/2 in [13 mm] thick to form the test assembly (see Figure 4.6). An arc plug weld with a visible diameter (d) (specified in the WPS and not less than 1/2 in [13 mm]), shall be produced. The crater shall be filled and a 1/32 in [1 mm] minimum reinforcement provided.

(2) **Multiple Thicknesses for Sheet Steel to Sheet Steel.** Two test assemblies of an actual joint configuration for each WPS (see Figure 4.6 in Table 4.1) shall be prepared and welded. An arc plug weld with a visible diameter (d) (specified in the WPS and not less than 1/2 in [13 mm]), shall be produced. The crater shall be filled and a 1/32 in [1 mm] minimum reinforcement provided.

(3) **Examination.** The projecting part of the sheet steel shall be twisted (see Figure 4.6) until the arc plug weld disengages from either member.

(a) The resulting nugget's measured diameter (d_e) shall not be less than 3/8 in [9 mm] or the required WPS diameter, whichever is the greater.

(b) The fractured face shows no visually detectable discontinuities (e.g., slag, porosity).

(c) The weld metal shows no visually detectable cracks.

NOTE: Base-metal cracks shall be ignored.

4.6.6.3 Qualification Ranges. A change in any one of the essential variables that exceed the limitations of 4.5 requires requalification.

Part C
Welder Performance Qualification

4.7 Essential Variables

4.7.1 General

4.7.1.1 Base Metals. Performance qualification established with any one of the steels permitted by this code shall be considered as performance qualification to weld any of the other steels, provided they have no coating or have the same coating used in qualification.

4.7.1.2 Processes. A welder shall be qualified for each welding process specified in the WPS.

4.7.1.3 SMAW Electrodes. A welder qualified for SMAW with an electrode identified in Table 4.3 shall be considered qualified to weld with any other electrode in the same group designation, and with any electrode listed in a numerically lower group designation.

4.7.1.4 Electrodes and Shielding Media. A welder qualified with an approved electrode and shielding medium combination shall be considered qualified to weld with any other approved electrode and shielding medium combination for the welding process used in the WPS.

4.7.1.5 Position. A change in the position of welding to one for which the welder is not already qualified shall require requalification.

4.7.1.6 Vertical Welding. When welding in the vertical position, a change in the direction of welding shall require requalification.

4.7.2 Specific Conditions. Except as modified by 4.8.2, all welders shall be qualified by making a test weldment for each weld joint type (see Table 4.1) to be used in construction, and for the following conditions:

(1) For each thickness (gage) of sheet steel in the case of arc spot welds or arc seam welds to be used in production.

(2) For minimum thickness of sheet steel in the case of fillet welds, flare-bevel groove welds, and flare-V groove welds.

(3) A change in the sheet steel thickness for square groove welds listed below requires requalification of the welder or welding operator.

(a) A change in sheet steel thickness to less than 0.5*t* or greater than 2*t*, where *t* is the thickness of the thinner sheet qualified.

(b) As an acceptable alternate to 4.7.2(3)(a), the following qualification tests may be used to cover the complete range of all sheet steel thicknesses:

(i) Qualification performed on 18 gage sheet steel shall qualify the welder or welding operator for welding sheet steel 16 gage and thinner.

(ii) Qualification performed on 10 gage sheet steel shall qualify the welder or welding operator for welding sheet steel 16 gage and thicker.

(4) For applicable positions of welding, see Table 4.4.

4.8 Number of Tests and Methods for Welder Performance Qualification

4.8.1 General. The qualification tests described herein are specially devised tests to determine the welder's ability to produce sound welds. Welding shall be performed in conformance with the requirements of the WPS and recorded on a PQR form similar to that of Annex B.

4.8.1.1 WPS Status. The WPS used in the qualification of a welder shall be a qualified or prequalified WPS. The number and type of test assemblies, their method of testing, and the test results shall be the same as for WPS qualification (see Table 4.4).

4.8.1.2 Welder Qualification through WPS Qualification. The welder who completes a successful WPS shall be considered qualified for the welding process, welding position, type of weld, and applicable type of coated sheet steel. In the case of fillet welds or flare groove welds, or both, the welder shall also be considered qualified for thicknesses of material equal to or greater than those used in the test. In the case of arc spot welds, arc seam welds, and square groove welds, the qualification shall be limited to the thickness (gage) used in this test (see Table 4.4).

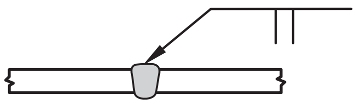
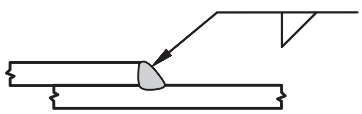
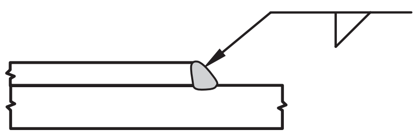
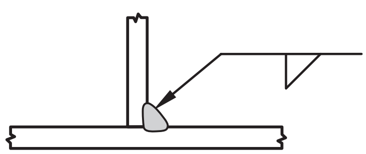
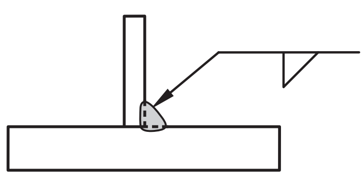
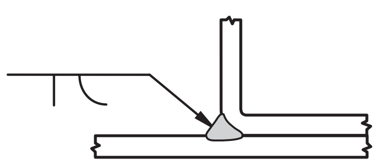
4.8.1.3 Records. Records of test results shall be kept by the manufacturer, or contractor, and shall be available to those authorized to examine them. A form similar to that used in Annex B may be used.

4.8.2 Specific Conditions. Separate welder qualifications shall be required for welding galvanized sheet steel or sheet steel with other coating.

4.9 Duration of Qualification

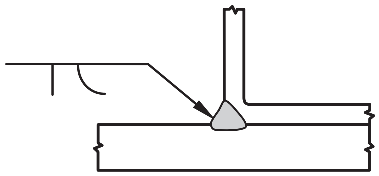
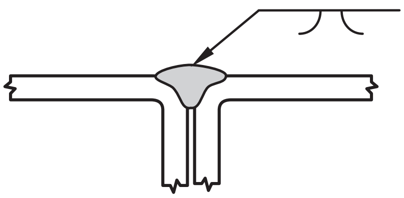
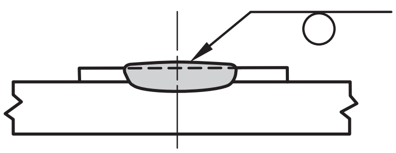
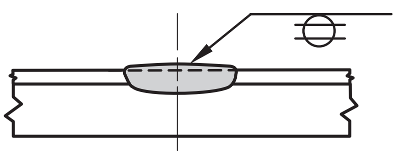
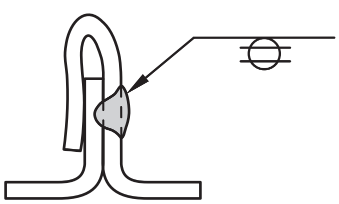
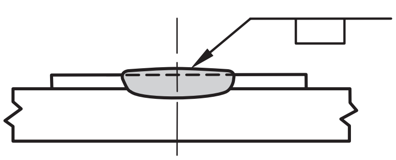
The welder's qualification shall be considered as remaining in effect indefinitely, unless (1) the welder is not engaged in a given process of welding for which the welder is qualified for a period exceeding six months, or (2) there is some specific reason to question a welder's ability.

Table 4.1
WPS Qualification Tests[a] (see 4.6)

Test Assemblies Shown in Figure:	Type of Welded Joint Tested	Type of Test	Position Tested	Position Qualified	Qualified Welded Joint
4.1 	Square groove weld in butt joint—sheet to sheet	Bend	F H V OH	F H V OH	Square groove weld in butt joint—sheet to sheet
4.2A 	Fillet weld in lap joint—sheet to sheet	Bend	F H V OH	F F, H V OH	Fillet weld in lap or corner joint—sheet to sheet, and sheet to supporting structural member
4.2B 	Fillet weld in lap joint—sheet to supporting structural member	Bend	F H V OH	F F, H V OH	Fillet weld in lap or corner joint—sheet to supporting structural member
4.2C 	Fillet weld in T-joint—sheet to sheet	Bend	F H V OH	F F, H V OH	Fillet weld in T-, lap, or corner joint—sheet to sheet, and sheet to supporting structural member
4.2D 	Fillet weld in T-joint— sheet to supporting structural member	Bend	F H V OH	F F, H V OH	Fillet weld in T-, lap, or corner joint—sheet to supporting structural member
4.3A 	Flare-bevel-groove weld—sheet to sheet	Bend	F H V OH	F F, H V OH	Flare-bevel-groove weld—sheet to sheet and sheet to supporting structural member, and flare-V-groove weld—sheet to sheet

(Continued)

Table 4.1 (Continued)
WPS Qualification Tests[a] (see 4.6)

Test Assemblies Shown in Figure:	Type of Welded Joint Tested	Type of Test	Position		Qualified Welded Joint
			Tested	Qualified	
4.3B 	Flare-bevel-groove weld—sheet to supporting structural member	Bend	F H V OH	F F, H V OH	Flare-bevel-groove weld—sheet to supporting structural member
4.3C 	Flare-V-groove weld—sheet to sheet	Bend	F H V OH	F H V OH	Flare-V-groove weld—sheet to sheet and flare-bevel-groove weld—sheet to sheet and sheet to supporting structural member
4.4 	Arc spot weld—sheet to supporting structural member	Torsion	F	F	Arc spot and arc seam weld—sheet to supporting structural member
4.5A 	Arc seam weld—sheet to supporting structural member	Bend	F	F	Arc seam weld—sheet to supporting structural member
4.5B 	Arc seam weld—sheet to sheet	Bend	H	H	Arc seam weld—sheet to sheet
4.6 	Arc plug weld—sheet to supporting structural member	Torsion	F H V OH	F H V OH	Arc plug weld—sheet to sheet, and sheet to supporting structural member

[a] Two tests shall be required for each welding position, thickness, and type of coating (see 4.5 for essential variable limitations).

Table 4.2
PQR Essential Variable Changes[a] Requiring WPS Requalification for SMAW, GMAW, FCAW, GTAW, and SAW (see 4.5)

Essential Variable Changes to PQR Requiring Requalification	SMAW	GMAW	FCAW	GTAW	SAW
(1) A change in classification of electrode (e.g., change from E6010 to E6012)	X				
(2) A change in filler metal or electrode/flux classification not covered in AWS A5.18 or AWS A5.28 (GMAW/GTAW), AWS A5.20 or AWS A5.29 (FCAW), or AWS A5.17 or AWS A5.23 (SAW)		X	X	X	X
(3) A change in tungsten electrode type per AWS A5.12				X	
(4) A change increasing the filler metal strength level (a change from E70XX to E80XX-X, for example, but not vice versa)	X	X	X	X	X
(5) A change in the diameter of the electrode	X	X	X	X	X
(6) A change of more 1/16 in [1.6 mm] in the nominal diameter of filler wire				X	
(7) The addition or deletion of filler metal				X	
(8) Changes of more than 10% above or below the melting rate, amperage, or wire feed speed; in the case of arc spot, or arc seam welds, a reduction in melting rate, welding current, or wire feed speed of more than 5%.	X	X	X	X	X
(9) A change in the type of welding current (AC or DC) or polarity	X	X	X	X	X
(10) A change in sheet steel thickness listed below:					
(a) A change in base metal thickness of sheet steel by more than 10% for arc spot weld and arc seam welds	X	X	X	X	X
(b) For joints other than those in (10)(a), a change in sheet steel thickness to less than 0.5*t* or greater than 2*t*, where *t* is the thickness of the thinner steel qualified	X	X	X	X	X
(c) As an acceptable alternate to (10)(b), the following qualification tests (d and e) may be used to cover the complete range of all sheet steel thicknesses:					
(d) A qualification weld performed on 18 gage sheet steel shall provide qualification for that WPS for sheet steel 16 gage and thinner	X	X	X	X	X
(e) A qualification weld performed on 10 gage or thicker shall provide qualification for that WPS for sheet steel as thin as 16 gage and thicker, up to 2*t* thickness, where *t* is the thickness of the thinner sheet steel qualified	X	X	X	X	X
(11) An increase in the root opening of a square-groove weld	X	X	X	X	X
(12) A change in the type of coating material, or the addition, but not deletion, of coating material on the base metal. *(NOTE: Anti-spatter compound is not considered a coating material.)*	X	X	X	X	X
(13) An increase exceeding 30% in the thickness of coating of the sheet steel	X	X	X	X	X
(14) A change in position not qualified per Table 4.1	X	X	X	X	X
(15) In vertical position welding, a change in the progression specified from downward to upward, or vice versa	X	X	X	X	
(16) A change in shielding gas		X	X	X	

(Continued)

Table 4.2 (Continued)
PQR Essential Variable Changes[a] Requiring WPS Requalification for SMAW, GMAW, FCAW, GTAW, and SAW (see 4.5)

Essential Variable Changes to PQR Requiring Requalification	SMAW	GMAW	FCAW	GTAW	SAW
(17) The deletion, but not the addition, of backing gas		X	X	X	
(18) The deletion, but not the addition, of permanent or removable backing	X	X	X	X	X
(19) A change in AWS flux/electrode classification					X
(20) A change in more than 10% above or below the specified mean PQR arc voltage for each electrode diameter used		X	X		X
(21) An increase of 25% or more or a decrease of 10% or more in the rate of flow or shielding gas or mixture		X	X	X	
(22) A change in the mode of metal transfer across the arc		X			
(23) A change from cold wire feed to hot wire feed or vice versa				X	
(24) For square groove welds in butt joints, a change in welding from both sides to welding from one side, but not vice versa	X	X	X	X	X
(25) For arc spot and arc seam welds, a decrease in weld design of size *d*	X	X	X	X	X
(26) For arc spot welds, a decrease in weld time.	X	X	X	X	X
(27) For arc seam welds, an increase in travel speed	X	X	X	X	X

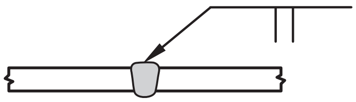
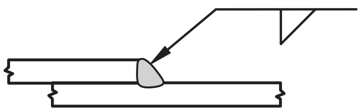
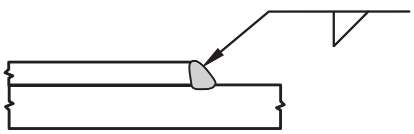
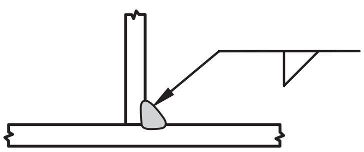
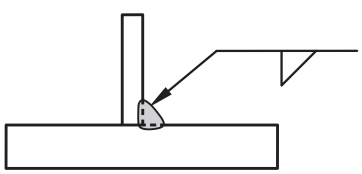
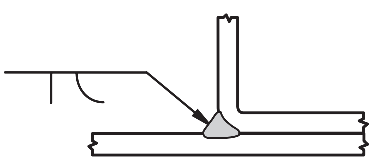
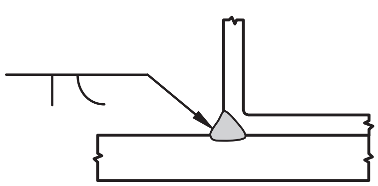
[a] An "X" indicates applicability for the process: a shaded area indicates nonapplicability.

Table 4.3
Electrode Classification Groups

Group Designation	AWS Electrode Classification
F4	EXX15, EXX16, EXX18, EXX15-X, EXX16-X, EXX18-X
F3	EXX10, EXX11, EXX10-X, EXX11-X
F2	EXX12, EXX13, EXX14, EXX13-X

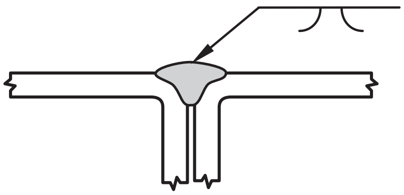
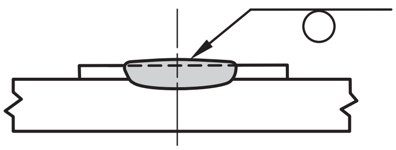
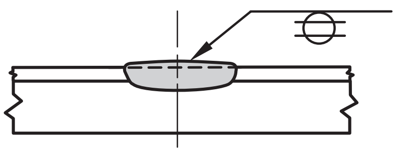
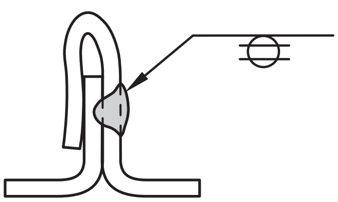
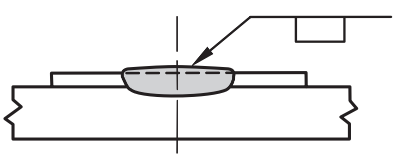
Note: The letters XX, used in the classification designation in this table, stand for the various strength levels, (e.g., 60, 70, etc.) of electrodes.

Table 4.4
Welder Performance Qualification Tests[a] (see 4.8)

Test Assemblies Shown in Figure:	Type of Welded Joint Tested	Type of Test	Position Tested	Position Qualified	Qualified Welded Joint	Qualified Thickness
4.1 	Square-groove weld in butt joint—sheet to sheet	Bend	F H V OH	F F, H F, H, V F, H, OH	Square-groove weld in butt joint—sheet to sheet	Thickness tested [except as modified by 4.7.2(3)]
4.2A 	Fillet weld in lap joint—sheet to sheet	Bend	F H V OH	F F, H F, H, V F, H, OH	Fillet weld in lap or corner joint—sheet to sheet, and sheet to supporting structural member	Thickness tested and thicker
4.2B 	Fillet weld in lap joint—sheet to supporting structural member	Bend	F H V OH	F F, H F, H, V F, H, OH	Fillet weld in lap or corner joint—sheet to supporting structural member	Thickness tested and thicker
4.2C 	Fillet weld in T-joint—sheet to sheet	Bend	F H V OH	F F, H F, H, V F, H, OH	Fillet weld in T-, lap, or corner joint—sheet to sheet, and sheet to supporting structural member	Thickness tested and thicker
4.2D 	Fillet welded T-joint, sheet to supporting member	Bend	F H V OH	F F, H F, H, V F, H, OH	Fillet welded T-, lap, or corner joint, sheet to supporting member	Thickness tested and thicker
4.3A 	Flare-bevel-groove weld—sheet to sheet	Bend	F H V OH	F F, H F, H, V F, H, OH	Flare-bevel-groove weld—sheet to sheet and sheet to supporting structural member, and flare-V-groove weld—sheet to sheet	Thickness tested and thicker
4.3B 	Flare-bevel-groove weld—sheet to supporting structural member	Bend	F H V OH	F F, H F, H, V F, H, OH	Flare-bevel-groove weld—sheet to supporting structural member	Thickness tested and thicker

(Continued)

Table 4.4 (Continued)
Welder Performance Qualification Tests[a] (see 4.8)

Test Assemblies Shown in Figure:	Type of Welded Joint Tested	Type of Test	Position Tested	Position Qualified	Qualified Welded Joint	Qualified Thickness
4.3C 	Flare-V-groove weld—sheet to sheet	Bend	F H V OH	F F, H F, H, V F, H, OH	Flare-V-groove weld—sheet to sheet and flare-bevel-groove weld—sheet to sheet, and sheet to supporting structural member	Thickness tested and thicker
4.4 	Arc spot weld—sheet to supporting structural member	Torsion	F	F	Arc spot and arc seam weld—sheet to supporting structural member	Thickness tested
4.5A 	Arc seam weld—sheet to supporting structural member	Bend	F	F	Arc seam weld—sheet to supporting structural member	Thickness tested
4.5B 	Arc seam weld—sheet to sheet	Bend	H	H	Arc seam weld—sheet to sheet	Thickness tested
4.6 	Arc plug weld—sheet to supporting structural member	Torsion	F H V OH	F F, H F, H, V F, H, OH	Arc plug weld—sheet to sheet, and sheet to supporting structural member	Thickness tested

[a] Two tests shall be required for each assembly.

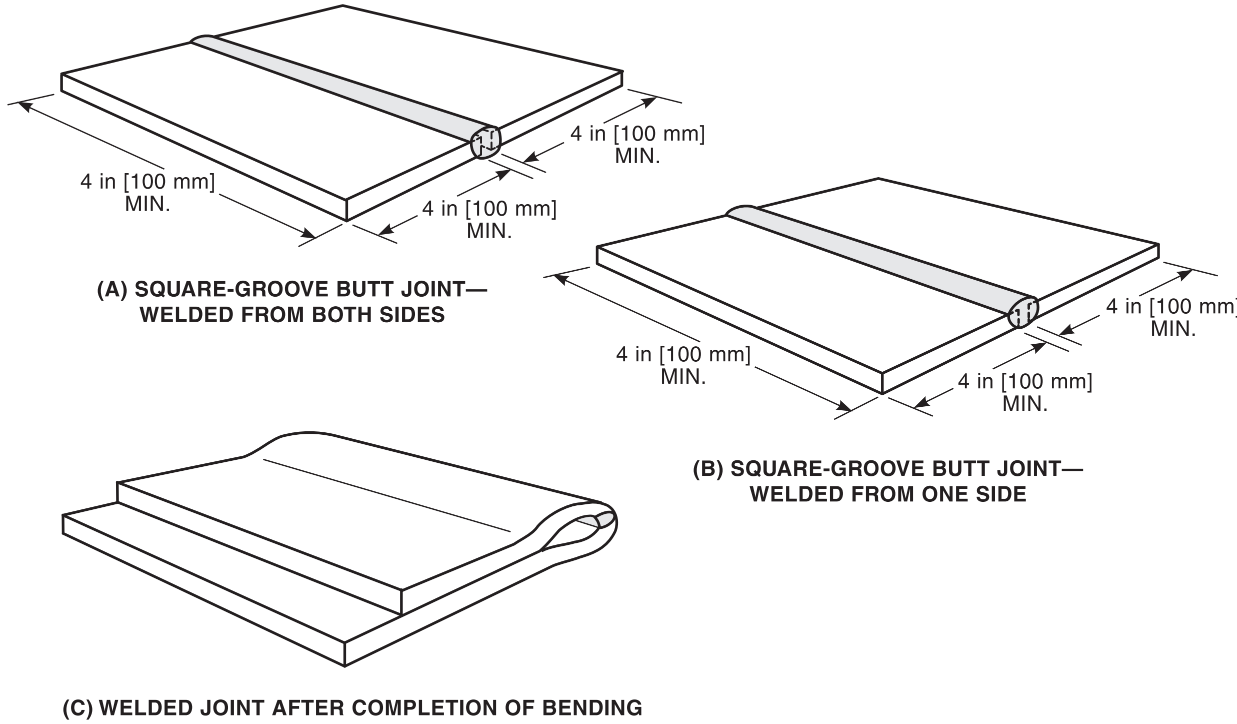


Figure 4.1—Test for Square-Groove Welds in Butt Joints [see 4.6.1.2(1)]

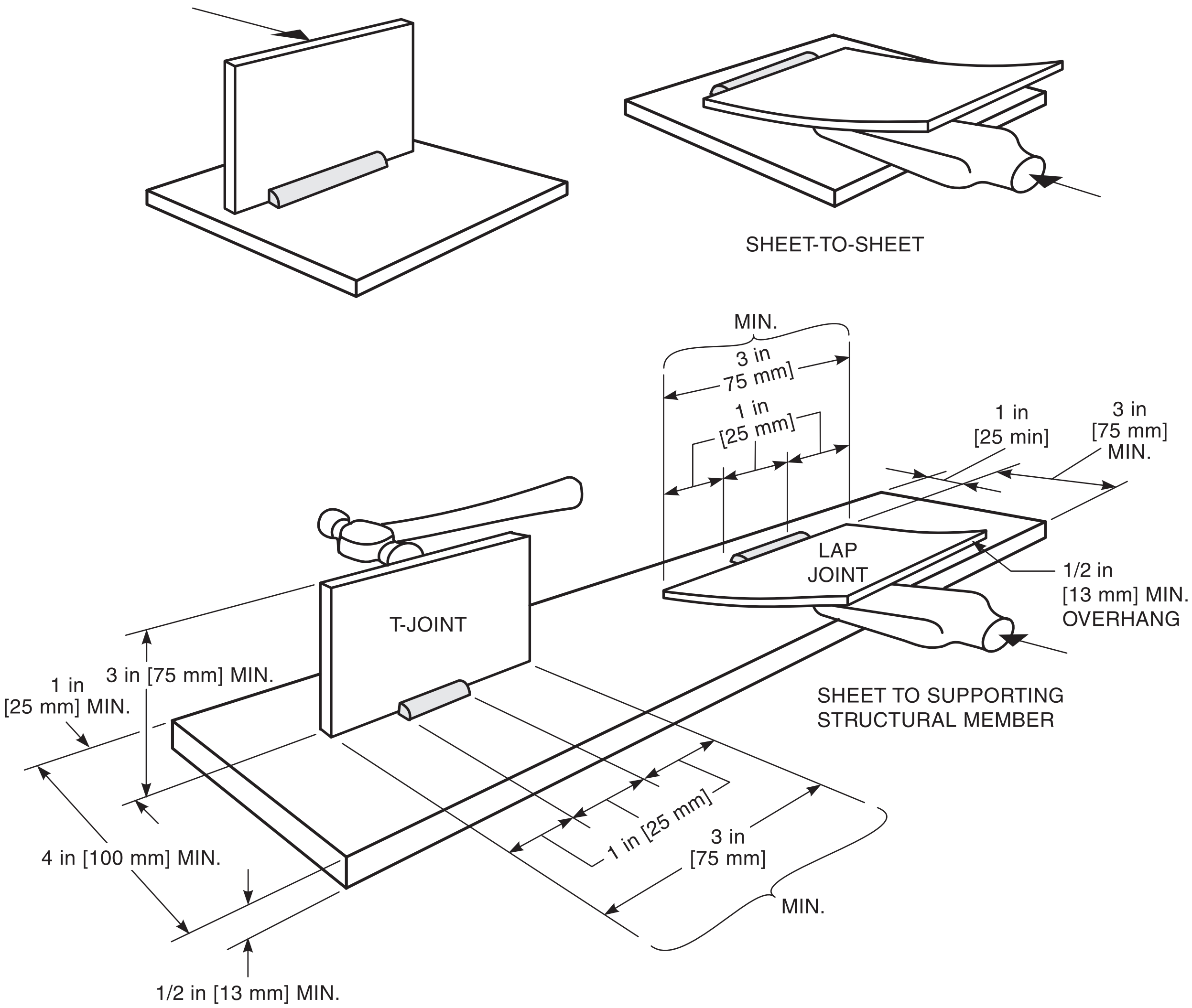


Figure 4.2A—Test for Fillet Welds [see 4.6.2.2(1)]

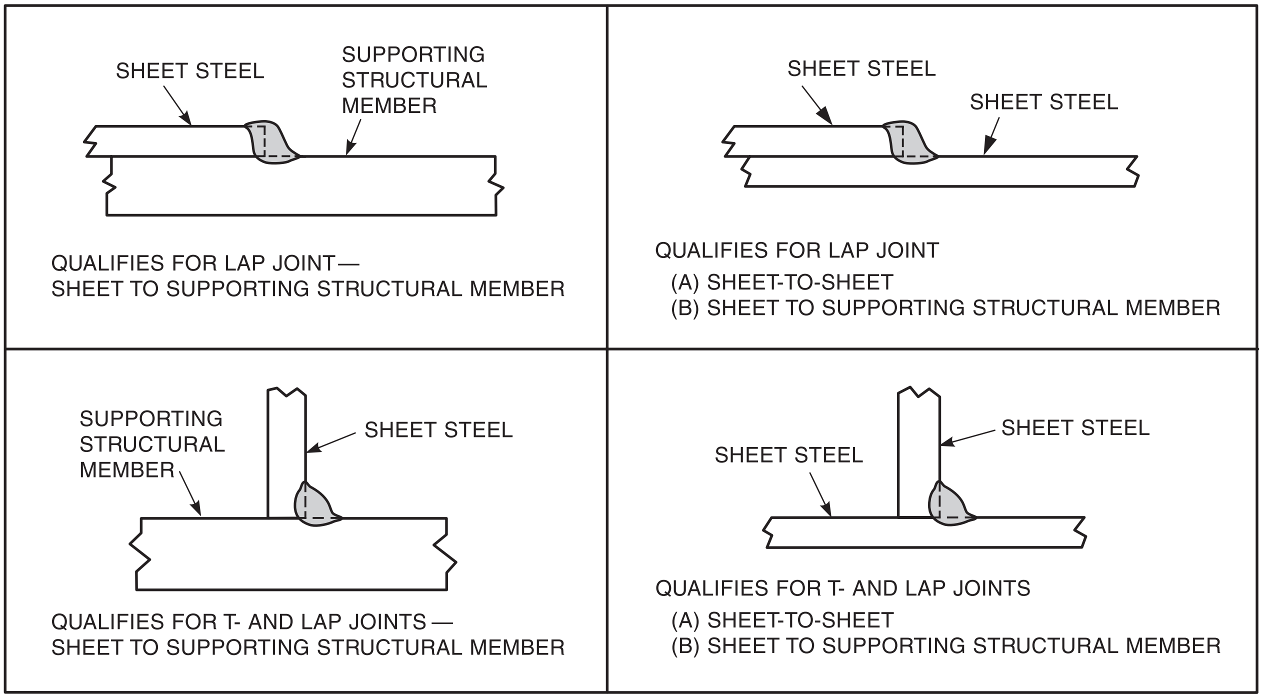


Figure 4.2B—Extent of Validity of Fillet Weld Qualifications (see 4.2.2.3)

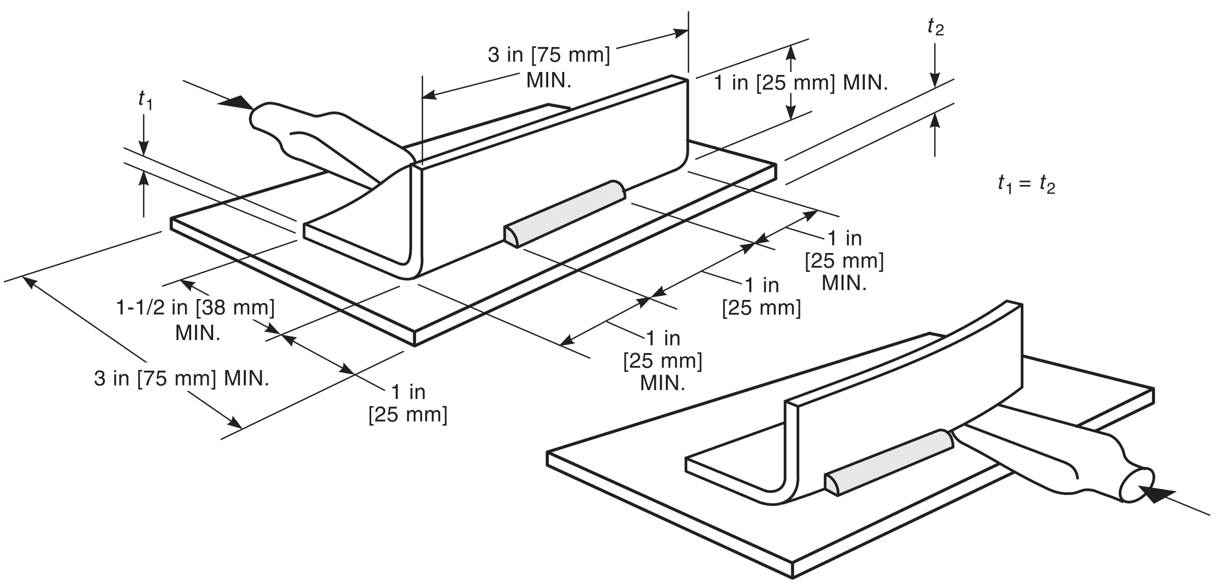


Figure 4.3A—Test for Sheet to Sheet Flare-Bevel-Groove Welds [see 4.6.3.2(1)(a)]

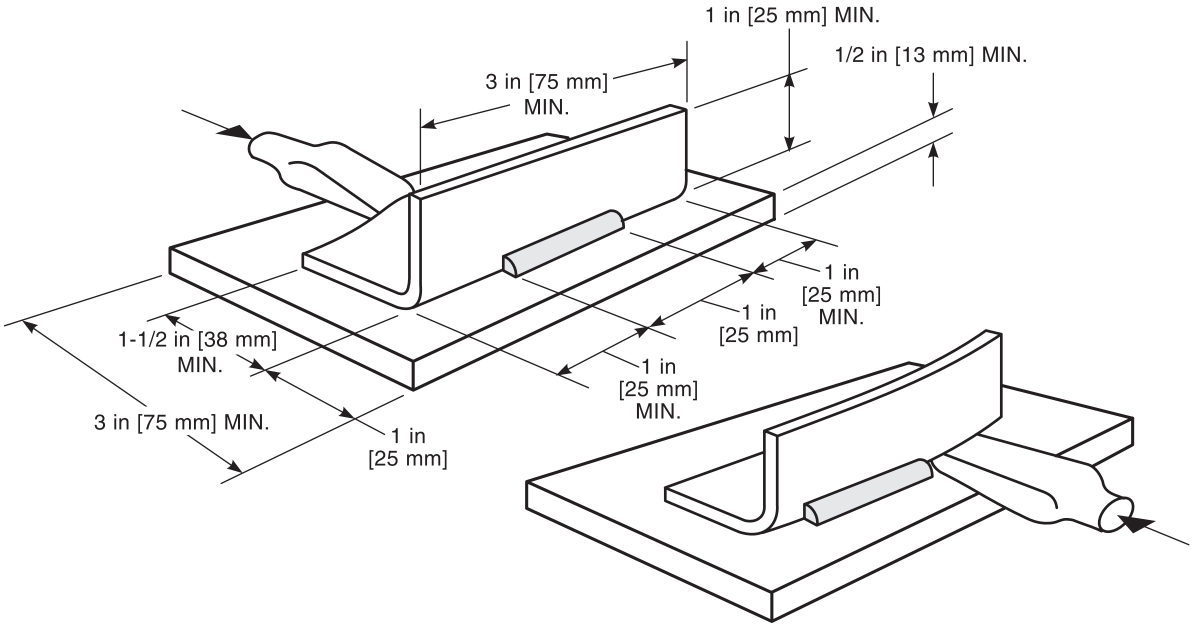


Figure 4.3B—Test for Sheet to Supporting Structural Member Flare-Bevel-Groove Welds [see 4.6.3.2(1)(b)]

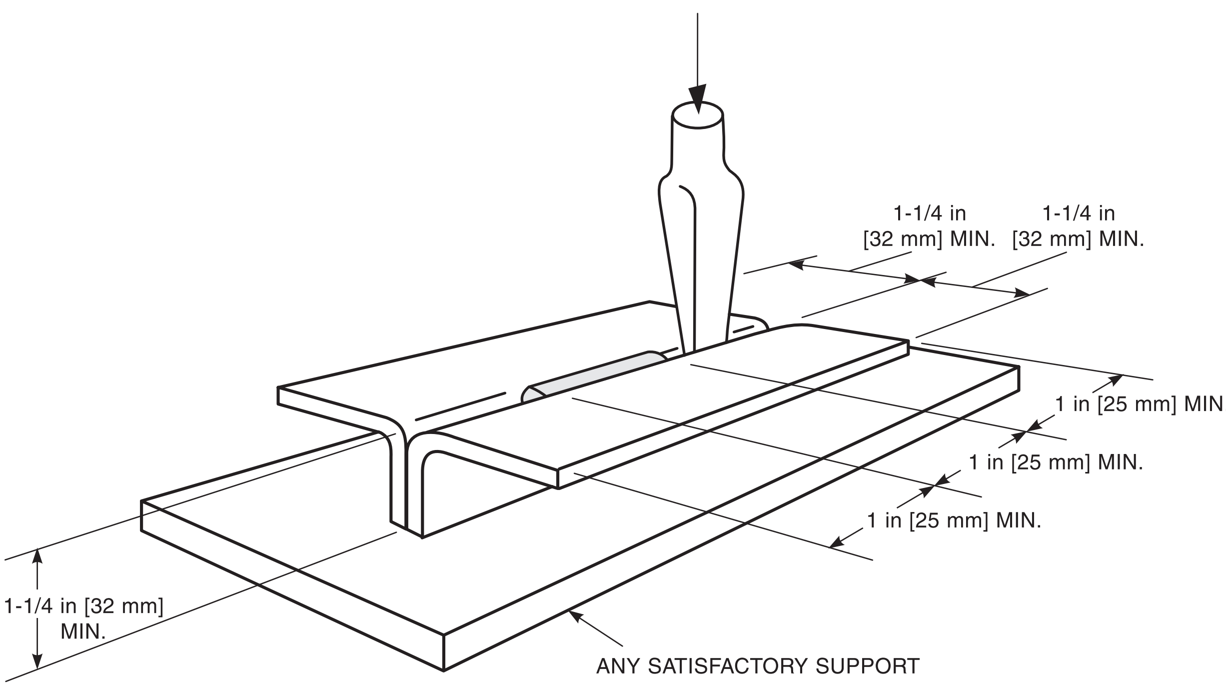


Figure 4.3C—Test for Flare-V-Groove Welds [see 4.6.3.2(2)(b)]

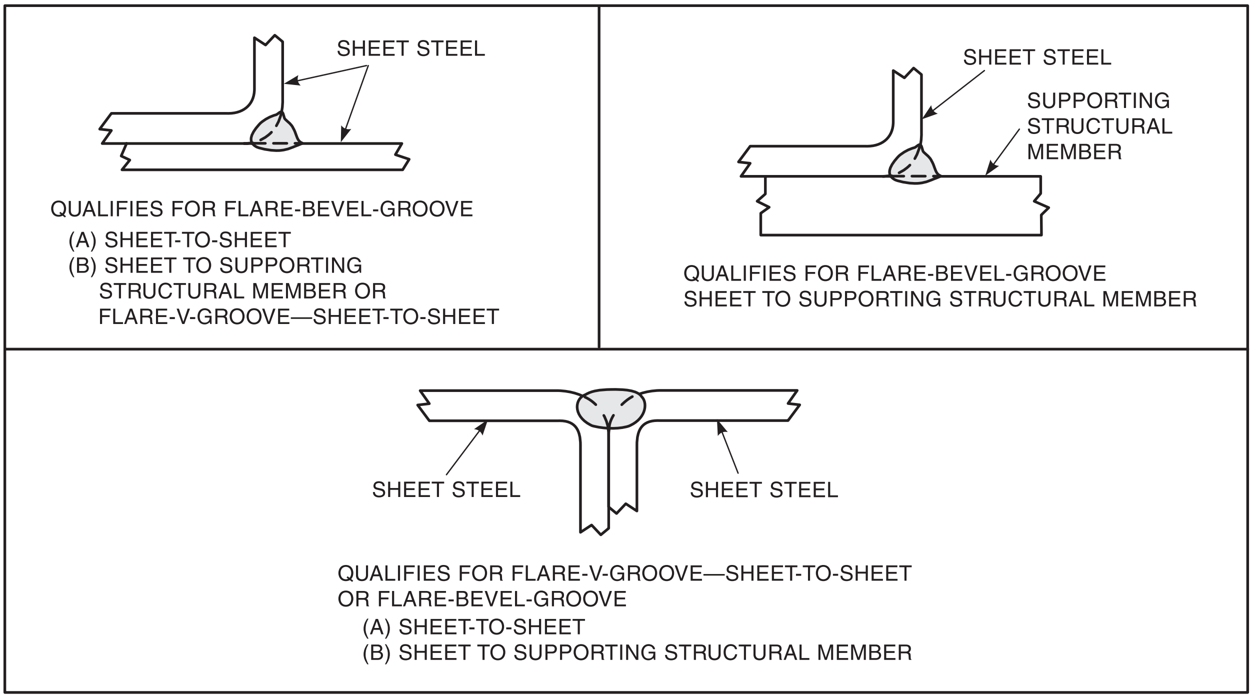


Figure 4.3D—Extent of Validity of Flare-Groove Weld Qualifications (see 4.6.3.3)

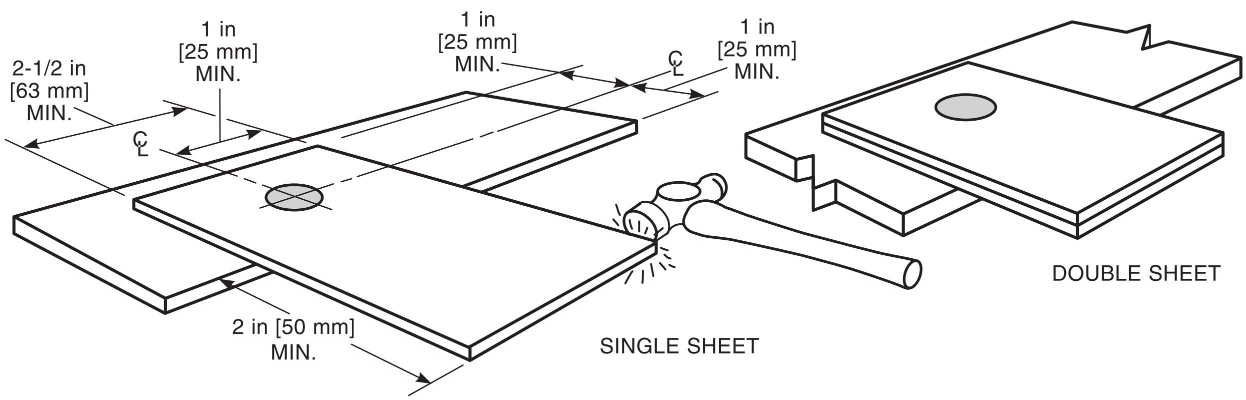


Figure 4.4—Test for Arc Spot Welds [see 4.6.4.2(1)]

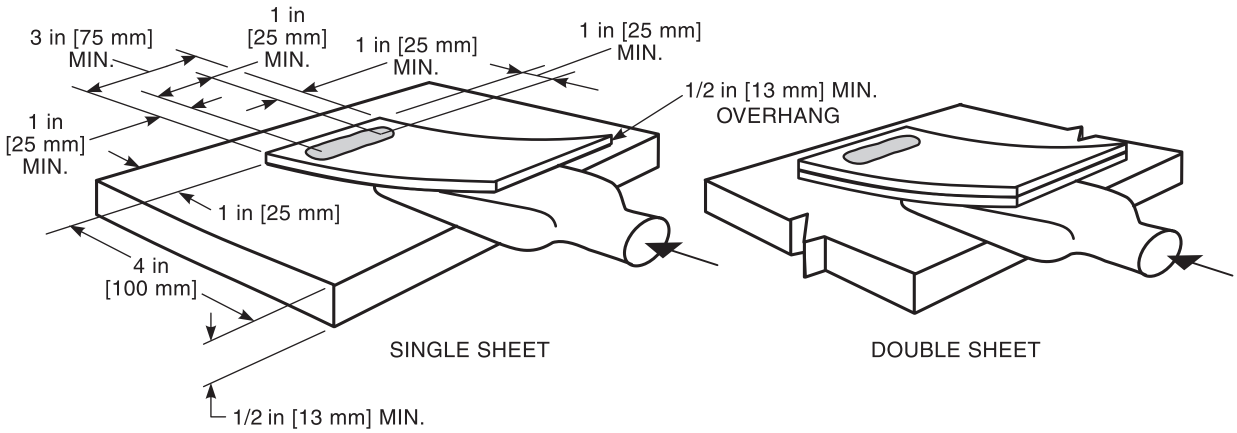


Figure 4.5A—Test for Sheet to Supporting Structural Member Arc Seam Welds [see 4.6.5.2(1)]

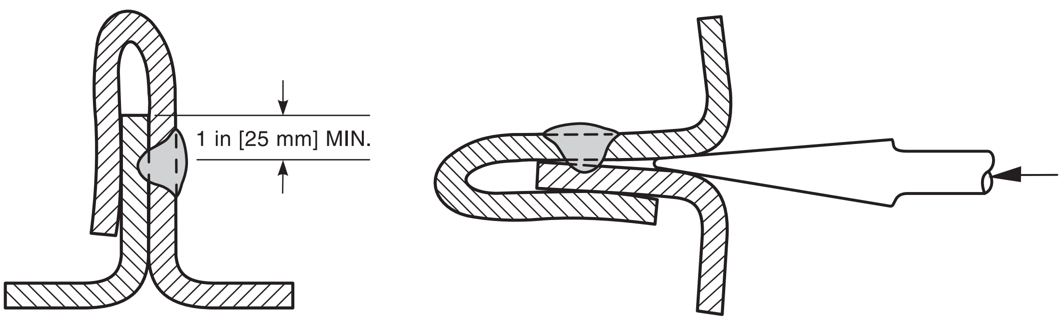
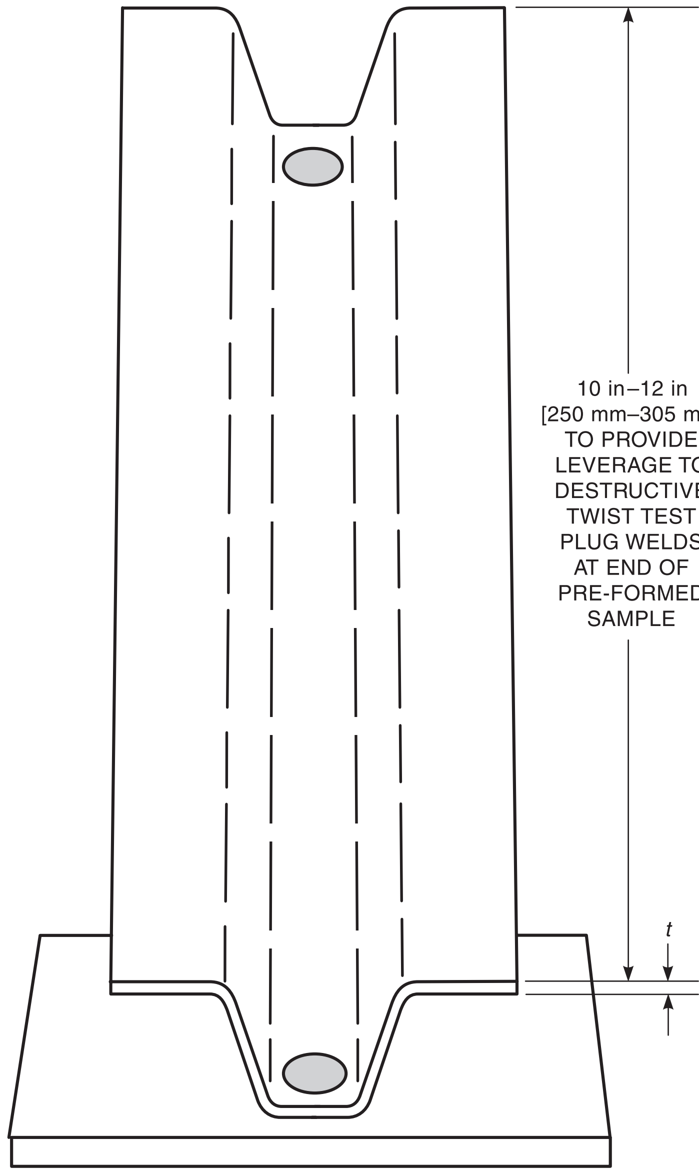


Figure 4.5B—Test for Sheet to Sheet Arc Seam Welds [see 4.6.5.2(2)]



Typical for multi-ply sheet to supporting structural member or sheet-to-sheet—also used for horizontal, vertical, and overhead positions.

Figure 4.6—Test for Arc Plug Welds [see 4.6.6.2(1)]

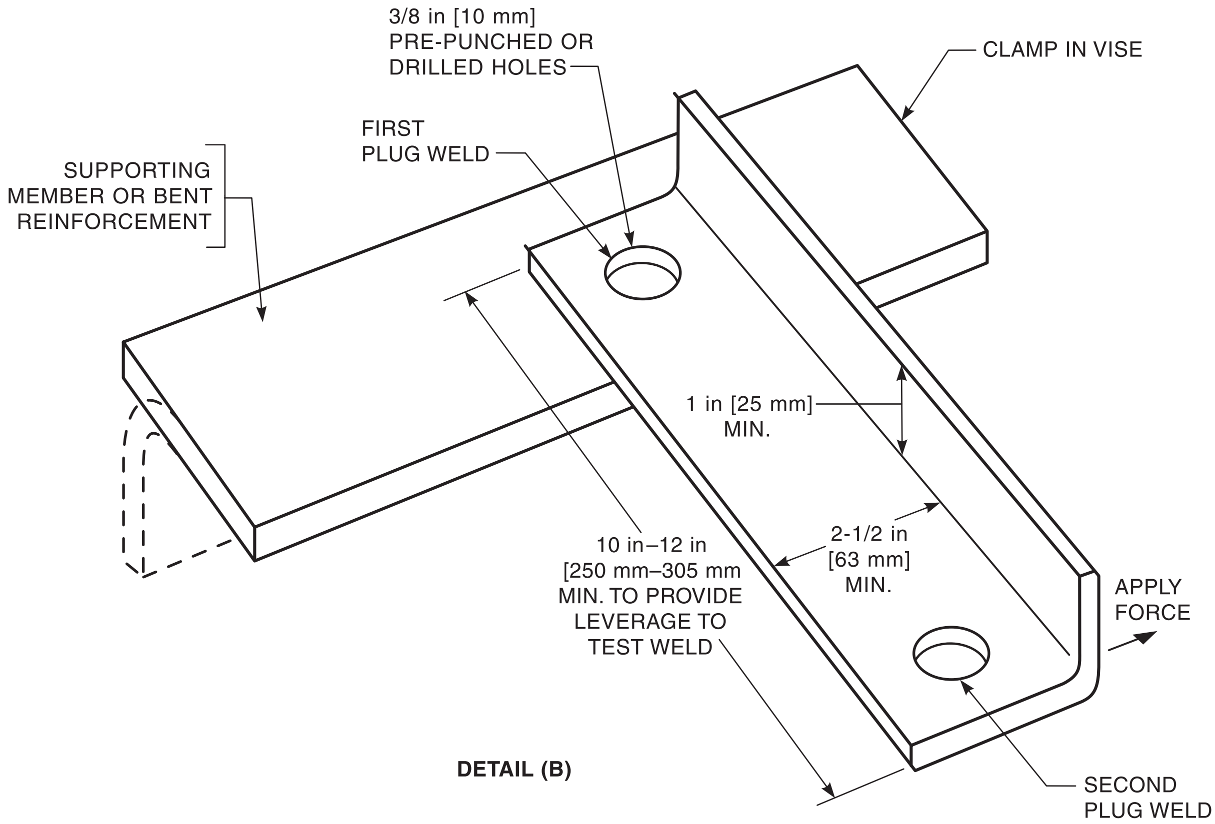


Figure 4.6 (Continued)—Test for Arc Plug Welds [see 4.6.2.2(1)]

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5. Fabrication

5.1 General

Unless adequate weather protection is provided, the production welding shall not be performed when:

(1) Ambient air temperature is below 0°F [–18°C], or

(2) When the base metal to be welded is exposed to moisture (e.g., snow, rain, etc.), or

(3) For GMAW, FCAW-G, and GTAW, wind in excess of 5 mph [8 km/hr].

5.2 Preparation of Material

Surfaces to be welded shall be smooth, uniform, and free from fins, tears, cracks, or other imperfections which would adversely affect the quality or strength of the weld. Surfaces to be welded and surfaces adjacent to a weld shall also be free from loose or thick scale, slag, rust, moisture, grease, or other foreign material that would prevent proper welding or produce objectionable fumes. Mill scale that withstands vigorous wire brushing, a thin rust-inhibitive coating, a galvanized coating, or an antispatter compound may remain.

5.3 Assembly

5.3.1 Joint Detail Positions. Joint details shall be arranged to provide the most favorable position for welding (see Annex D for definitions of the welding positions).

5.3.2 Close Contact. The parts to be joined by welding shall be brought into close contact to facilitate complete fusion between them.

5.3.3 Backing. The use of steel backing conforming to ASTM A 109 Temper 3 or 4 may be used without requiring a WPS base material qualification test.

5.4 Allowable Deviation from WPS for Lower Temperatures Using Annex A, Note 1

5.4.1 Arc Spot Welds. For arc spot welds, WPSs qualified at a base-metal temperature of 100°F [38°C] or lower shall be permitted at temperatures as low as 32°F [0°C] by increasing the weld time by 20% or by increasing amperage settings by 10% from that established and recorded at the time of qualification. WPSs qualified at a base metal temperature of 100°F [38°C] or lower shall be permitted at temperatures less than 32°F [–0°C] to as low as 0°F [–18°C] by increasing the weld time by 30% or by increasing the amperage setting by 15% from that established and recorded at the time of qualification. For arc spot welds, a decrease in weld time requires requalification.

NOTE: See Bibliographical Reference "Calculated Cooling Rates of Arc Spot Welds."

5.4.2 Arc Seam Welds. For arc seam welds, WPSs qualified at base-metal temperature of 100°F [38°C] or lower shall be permitted at temperatures as low as 32°F [0°C] by decreasing the travel speed by 20% or by increasing amperage settings by 10% from that established and recorded at the time of qualification. WPSs qualified at base metal temperature of 100°F [38°C] or lower shall be permitted at temperatures less than 32°F [0°C] to as low as 0°F [–18°C] by decreasing the travel speed by 30% or by increasing the amperage setting by 15% from that established and recorded at the time of qualification.

5.4.3 Arc Plug Welds. For arc plug welds, WPSs qualified at base-metal temperature of 100°F [38°C] or lower shall be permitted at temperatures as low as 32°F [0°C] by increasing the weld time by 20% or by increasing amperage settings by 10% from that established and recorded at the time of qualification. WPSs qualified at base metal temperature of 100°F [38°C] or lower shall be permitted at temperatures as low as 0°F [–18°C] by increasing the weld time by 30% or by increasing the amperage setting by 15% from that established and recorded at the time of qualification.

NOTE: See commentary for further information and reference data.

6. Inspection

Part A
Acceptance Criteria

6.1 Production Weld Acceptance Criteria

6.1.1 Visual Inspection. A weld shall be acceptable by visual inspection, provided the following criteria are met:

6.1.1.1 No Cracks. The weld shall have no cracks.

6.1.1.2 Weld/Base-Metal Fusion. There shall be no evidence of lack of fusion at the toes of weld passes.

6.1.1.3 Minimum Reinforcement. The weld shall have minimum reinforcement of 1/32 in [1 mm] for all square groove, arc spot, and arc seam welds.

6.1.1.4 Undercut. The cumulative length of undercut shall be no longer than L/8, where L is the specified length of the weld or in the case of arc spot welds, the circumference, provided fusion exists between the weld metal and the base metal. Depth of undercut is not a subject of inspection and need not be measured. Melt-through that results in a hole is unacceptable.

6.1.1.5 Fillet Weld Face. Faces of fillet welds shall be flat or slightly convex.

6.1.1.6 Contract Document Conformance. Location, size, and length of weld shall be in conformance with drawings or other contract document requirements.

Part B
Contractor's Responsibility

6.2 Inspection of WPS and Welder Qualifications

6.2.1 The Inspector shall ascertain that in performing work to this code, only qualified or prequalified WPSs are used, and all welders are qualified.

6.2.2 WPSs previously qualified or prequalified by the manufacturer or contractor may be used, if approved by the Engineer. However, if the Engineer does not accept such evidence, the contractor shall qualify the WPSs in conformance with this code. The contractor's weld tests shall be successfully completed before any permanent welding is done on the contract.

6.3 Inspection of Work

6.3.1 Requests. At any time, and specifically while arc spot welds or arc seam welds are being made, the Inspector may request that the melting rate of the electrodes, wire feed speed, or welding current be compared with that established in the WPS qualification test. If these melting rates are 5% or more below those specified, new welds using the correct current shall be made adjacent to those welds made with the inadequate current.

6.3.2 Work Quality. When the quality of a welder's work is judged by the Inspector to be below the requirements of this specification, requalification of the welder may be required.

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Annex A (Normative)

Applicable Provision Requirements When Welding D1.3 Sheet Steels to D1.1 Other Steel Product Forms

This annex is part of AWS D1.3/D1.3M:2008, *Structural Welding Code—Sheet Steel*, and includes mandatory elements for use with this standard.

Table A.1
Applicable Provision Requirements When Welding D1.3 Sheet Steels to D1.1 Other Steel Product Forms

	D1.3:2008	D1.1:2006
Clause 1—General Provisions		
SMAW—Low-Hydrogen Electrode Control		5.3.2 through 5.3.2.5
SAW—Electrodes and Fluxes		5.3.3
GMAW/FCAW—Electrodes		5.3.4
GTAW		5.3.5
Shielding Gas	1.4.6.2	
Fillet Welds	1.5.2	
Flare-Bevel-Groove Welds	1.5.3(2)	
Arc Spot Welds	1.5.4	
Arc Seam Welds	1.5.5(2)	
Arc Plug Welds	1.5.6(2)	
Clause 2—Design of Welded Connections		
Square Groove Welds in Butt Joints	N/A	N/A
Fillet Welds	2.2.2/2.3.3	
Flare-Groove Welds	2.2.3/2.3.4	
Arc Spot Welds	2.2.4/2.3.5	
Arc Seam Weld	2.2.5/2.3.6	
Arc Plug Welds	2.2.6/2.3.7	
Clause 3—Prequalification of WPS	N/A	N/A

(Continued)

Table A.1 (Continued)
Applicable Provision Requirements When Welding D1.3 Sheet Steels to D1.1 Other Steel Product Forms

	D1.3:2008	D1.1:2006
Clause 4—Qualifications		
WPS Qualification Tests		
Square Groove Welds in Butt Joints	N/A	N/A
Fillet Welds	4.6.2—Tables 4.1 & 4.4, Figures 4.2A(2) and 4.2A(4)	
Flare-Groove Welds	4.6.3—Tables 4.1 and 4.4, Figure 4.3B	
Arc Spot Welds	4.6.4—Tables 4.1 and 4.4, Figure 4.4	
Arc Seam Welds	4.6.5—Tables 4.1 and 4.4, Figure 4.5A	
Arc Plug Welds	4.6.6—Tables 4.1 and 4.4, Figure 4.6	
Essential Variables	Table 4.2 (8), (10), (12), (13), (25)	Table 4.2, except Item (27)
Clause 5—Fabrication		
Arc Spot Welds	5.4.1	
Arc Seam Welds	5.4.2	
Arc Plug Welds	5.4.3	
Preheat & Interpass Temperature	Note 1	5.6 (refer to Note 1 of Annex 1 for exceptions to D1.1, 5.6)
Heat Input—Q & T Steels		5.7
Clause 6—Inspection		
Visual		
Minimum Reinforcement—Arc Spot & Arc Seam	6.1.1.2	
Undercut—other than Arc Spot & Arc Seam		Table 6.1(7)
Undercut—Arc Spot Welds & Arc Seam	6.1.1.3	
Weld Profile—Fillet Weld Face	6.1.1.4	
Time of inspection		Table 6.1(5)
Clause 7—Stud Welding		
Stud welding	7	

Note:
1. When welding "decking" or roofing in the flat position, using arc spot welds, arc seam welds, arc plug welds, or a combination of arc spot and arc plug welds, the rules of D1.1, subclause 5.6 shall not apply if the requirements of either: (1) 1A, 2, 3, and 4, or (2) 1B, 2, 3, and 4 are met.

   These rules may be used for coated, galvanized, or uncoated sheet steel (D1.3) welded to coated, galvanized or uncoated structural materials (D1.1) provided the qualification meets the requirements of D1.3, Table 4.2(12). The requirements of AWS D1.1, subclause 5.15 shall not apply (Ref. 2).

   1A. The WPS has been qualified per AWS D1.3 Clause 4 using non-low hydrogen SMAW electrodes and the ambient temperature is ≥32°F (0°C).
   1B. The WPS has been qualified per AWS D1.3 Clause 4 using SMAW using low hydrogen welding electrodes or GTAW, GMAW, FCAW, SAW and the ambient temperature is ≥0°F [–18°C].
   2. The production WPS has been adjusted for temperature below the procedure qualification temperature according to AWS D1.3, Clause 5.4 (see commentary reference "Blodgett, O. W.—Calculated cooling rates of arc spot welds," a paper presented at the 68th Annual AWS Meeting, Chicago, Illinois, March 1987) for temperatures to 32°F [0°C], or CSICC Industry Research Project No. 180 for temperatures below 32°F [0°C] to 0°F[–18°C].
   3. Combinations of arc spot welds and arc plug welds have been qualified as a combination to ensure that the required arc spot weld size has been met.
   4. The supporting structural member is listed in AWS D1.1, Table 3.1, as a Group I or II base material.

Annex B (Informative)

Sample Welding Forms

This annex is not part of AWS D1.3/D1.3M:2008, *Structural Welding Code—Sheet Steel*, but is included for informational purposes only.

This annex contains three forms that the AWS D1 Committee on Structural Welding has approved for the recording of the welding procedure qualification test record (PQR), welding procedure specification, and welder or welding operator qualification test record data required by this code.

It is suggested that the qualification information required by this code be recorded on these forms or similar forms which have been prepared by the user. Variations of these forms to suit the user's needs are permissible.

SAMPLE FORM FOR WELDING PROCEDURE QUALIFICATION TEST RECORD (PQR)

Company Name ____________________

Procedure Qualification Test Record No. ____________ Date ____________

Welding Procedure Specification No. ____________ Rev ______ Date ____________

Welding Process(es) ____________ Type ____________
(Automatic, manual, etc.)

Mode of Transfer for GMAW ____________________
(Short circuiting, spray, etc.)

JOINTS (Table 4.1)

Type of Welded Joint(s) ____________

____

Backing Yes ☐ No ☐

Backing Material Type ____________

Groove Welded From:

one side ______ both sides ______

BASE METAL (1.2)

Material specification type and grade:

Sheet steel ______ to ______

Thickness ____________

Support Steel

Thickness ____________

Base Metal Preparation ____________

POSITIONS (Table 1.3)

Position of Groove ____________

Position of Fillet ____________

Progression ____________

GAS (1.4.6.2)

Shielding Gas ______ Flow Rate ______

Percent Mixture ____________

FLUX (1.4.5.2)

Filler Metal (Table 1.2):

Specification ____________

Classification ____________

COATING(S)

Type ____________

Thickness ____________

VISUAL EXAMINATION RESULTS (4.6)

Specimen 1 ____________

Specimen 2 ____________

Diam of Arc Spot Nugget ____________

Test Conducted by ____________

per ____________

Lab Test No. ____________

Date of Test ____________

Sketch of Joint Details

TECHNIQUE

Pass No.	Electrode Size	Welding Current		Travel Speed (or Weld Time for Arc Spot Welds)	Melting Rate	Wire Feed Speed
		Amperes	Volts			

Welder or Welding Operator Name ____________________

Identification No. ____________ Date of Qualification ____________

Welder's Social Security No. ____________________

The undersigned certifies that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of 4.6 of AWS D1.3 (__________), *Structural Welding Code—Sheet Steel.*
(year)

Authorized by ____________________ Date ____________

Form B-1

SAMPLE FORM FOR WELDING PROCEDURE SPECIFICATION (WPS)

Company Name ______________________________ By ______________
Welding Procedure Specification No. ______________ Rev ________ Date ______________
Supporting Procedure Qualification Test Record(s) No. ______________________________
Welding Process(es) ______________________ Type ______________________
(Automatic, manual, etc.)
Mode of Transfer for GMAW ______________________________
(Short circuiting, spray, etc.)

JOINTS (Table 4.1)
Type of Welded Joint(s) ______________________
____
Backing Yes ☐ No ☐
Backing Material Type ______________________
Groove Welded From:
one side __________ both sides __________

COATING(S)
Type ______________________
Thickness ______________________

Sketch of Joint Details

BASE METAL (1.2)
Material specification type and grade:
Sheet steel ________ to ______________
Support steel ______________________
Thickness Range:
Sheet Steel ______________________
Support Steel ______________________
Thickness ______________________
Base Metal Preparation ______________________

FILLER METAL (Table 1.2)
Specification ______________________
Classification ______________________

POSITIONS (Table 1.3)
Position of Groove ______________________
Position of Fillet ______________________
Progression ______________________

PREHEAT (1.1.1 AND 5.1)
Preheat Temperature Min ______________________
Preheat Temperature Max ______________________

GAS (1.4.6.2)
Shielding Gas ______________________
Flow Rate ______________________
Percent Mixture ______________________

FLUX (1.4.5.2) ______________________

TECHNIQUE

Pass No.	Electrode Size	Welding Current		Travel Speed (or Weld Time for Arc Spot Welds)	Melting Rate	Wire Feed Speed
		Amperes	Volts			

This procedure may vary due to fabrication sequence, fit-up, pass size, etc. within the limitation of variables given in AWS D1.3 (__________), *Structural Welding Code—Sheet Steel.*
(year)

Authorized by ______________________________ Date ______________

Form B-2

SAMPLE FORM FOR WELDER AND WELDING OPERATOR QUALIFICATION TEST RECORD

Welder or Welding Operator's Name ____________________

Identification No. ____________________ Qualification Date ____________________

Welder's Social Security No. ____________________

In Accordance with WPS No. ____________________ Revision ____________________

Welding Process(es) ____________________ Type ____________________

(Automatic, manual, etc.)

Mode of Transfer for GMAW ____________________

(Short circuiting, spray, globular)

VARIABLE	ACTUAL VARIABLE USED IN QUAL.	QUALIFICATION RANGE
JOINT		
Joint Type	________	________
Backing Material Type	________	________
Groove Welded From:		
one side or both sides	________	________
BASE METAL (4.7.1.1)		
Material Specification		
Sheet Steel	____ to ____	____ to ____
Supporting Steel	________	________
Sheet Thickness (4.7.2)		
Groove	________	________
Fillet	________	________
Arc Plug	________	________
Arc Spot	________	________
Arc Seam	________	________
COATING(S)	________	________
Type	________	________
Thickness		
POSITION (4.7.1.5 and 4.7.1.6)		
Groove	________	________
Fillet	________	________
Arc Plug	________	________
Arc Spot	________	________
Arc Seam	________	________
Progression	________	________
GAS (4.7.1.4)	________	________
ELECTRODE (4.7.1.3 and 4.7.1.4)	________	________
Size	________	________
Group Designation	________	________

VISUAL EXAMINATION RESULTS (4.6)

Specimen 1 ____________________ Specimen 2 ____________________

Appearance __________ Cracks __________ Undercut __________

Reinforcement ____________________ Diam of Arc Spot Nugget ____________________

Test Conducted By ____________________ Per ____________________

Laboratory Test No. ____________________ Date of Test ____________________

The undersigned certify that the statements in this record are correct and that the test welds were prepared and tested in accordance with the requirements of 4.6 of AWS D1.3 (__________), *Structural Welding Code—Sheet Steel*.

(year)

Company ____________________ Authorized By ____________________

Form B-3

Annex C (Informative)

Guidelines for the Preparation of Technical Inquiries for the Structural Welding Committee

This annex is not part of AWS D1.3/D1.3M:2008, *Structural Welding Code—Sheet Steel*, but is included for informational purposes only.

C1. Introduction

The American Welding Society (AWS) Board of Directors has adopted a policy whereby all official interpretations of AWS standards are handled in a formal manner. Under this policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is directed through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

C2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

All inquiries shall contain the name, address, and affiliation of the inquirer, and they shall provide enough information for the committee to understand the point of concern in the inquiry. When the point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and in the format specified below.

C2.1 Scope. Each inquiry shall address one single provision of the code, unless the point of the inquiry involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the inquiry along with the edition of the code that contains the provision(s) the inquirer is addressing.

C2.2 Purpose of the Inquiry. The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be either to obtain an interpretation of a code's requirement, or to request the revision of a particular provision in the code.

C2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to quickly and fully understand the point of the inquiry. Sketches should be used when appropriate and all paragraphs, figures, and tables (or the Annex), which bear on the inquiry shall be cited. If the point of the inquiry is to obtain a revision of the code, the inquiry must provide technical justification for that revision.

C2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry, or the wording for a proposed revision, if that is what inquirer seeks.

C3. Interpretation of Code Provisions

Interpretations of code provisions are made by the Structural Welding Committee. The secretary of the committee refers all inquiries to the chair of the particular subcommittee that has jurisdiction over the portion of the code addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire Structural Welding Committee for review and approval. Upon approval by the committee, the interpretation is an official interpretation of the Society, and the secretary transmits the response to the inquirer and to the *Welding Journal* for publication.

C4. Publication of Interpretations

All official interpretations shall appear in the *Welding Journal* and will be posted on the AWS web site.

C5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning the *Structural Welding Code* should be limited to questions of a general nature or to matters directly related to the use of the code. The AWS Board of Directors' policy requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can be obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

C6. The Structural Welding Committee

The activities of the Structural Welding Committee regarding interpretations are limited strictly to the interpretation of code provisions or to consideration of revisions to existing provisions on the basis of new data or technology. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on: (1) specific engineering problems, or (2) code requirements applied to fabrications outside the scope of the code or points not specifically covered by the code. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

Annex D (Informative)

Terms and Definitions

This annex is not part of AWS D1.3/D1.3M:2008, *Structural Welding Code—Sheet Steel*, but is included for informational purposes only.

NOTE: The terms and definitions in this glossary are divided into two categories: (1) General welding terms compiled by the AWS Committee on Definitions and Symbols, and (2) other terms, preceded by asterisks, which are defined as they relate to this specification.

A

actual throat. The shortest distance between the weld root and the face of a fillet weld.

arc seam weld. A seam weld made by an arc welding process (see Figure 2.5).

arc spot weld. A spot weld made by an arc welding process (see Figure 2.11A).

automatic welding. Welding with equipment that performs the welding operation without adjustment of the controls by a welding operator. The equipment may or may not load and unload the workpieces. See also **mechanized welding**.

axis of a weld. See **weld axis**.

B

***burn back.** This condition occurs where the sheet steel melts back and does not become a part of the weld, leaving a void between the weld metal and the sheet steel.

butt joint. A joint between two members aligned approximately in the same plane (see Figure 2.1).

butt weld. A nonstandard term for a weld in a butt joint.

C

***coating.** A thin layer, equal to or less than 0.004 in [0.1 mm] of material applied by surfacing for the purpose of corrosion prevention, resistance to high temperature scaling, wear resistance, lubrication or other purposes.

complete fusion. Fusion which has occurred over the entire base metal surface intended for welding and between all adjoining weld beads.

complete joint penetration. A penetration by weld metal for the full thickness of the base metal in a joint with a groove weld.

corner joint. A joint between two members located approximately at right angles to each other.

crater. A depression at the termination of a weld bead.

D

double-square-groove weld. A type of groove weld.

downhand. A nonstandard term for **flat position**.

E

edge joint. A joint between the edges of two or more parallel or nearly parallel members.

effective length of weld. The length throughout which the correctly proportioned cross section of the weld exists. In a curved weld, it shall be measured along the weld axis.

effective throat. The minimum distance minus any convexity between the weld root and the face of a fillet weld.

F

faying surface. The mating surface of a member that is in contact with or in close proximity to another member to which it is to be joined.

filler metal. The metal to be added in making a welded, brazed, or soldered joint.

fillet weld size. For equal leg fillet welds, the leg lengths of the largest isosceles right triangle which can be inscribed within the fillet weld cross section. For unequal leg fillet welds, the leg lengths of the largest right triangle that can be inscribed within the fillet weld cross section.

fillet weld leg. The distance from the joint root to the toe of the fillet weld.

flat position. The welding position used to weld from the upper side of the joint; the face of the weld is approximately horizontal.

flux cored arc welding (FCAW). An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. Shielding is provided by a flux contained within the tubular electrode. Additional shielding may or may not be obtained from an externally supplied gas or gas mixture.

fusion. The melting together of filler metal and base metal (substrate), or of base metal only, which results to produce a weld.

fusion zone. The area of base metal melted as determined on the cross section of a weld.

G

gas metal arc welding (GMAW). An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. Shielding is obtained entirely from an externally supplied gas.

groove weld. A weld made in a groove between the workpieces.

groove weld size. The joint penetration of a groove weld.

***groove weld size.** For sheet steel welding, this is assumed to be the thickness of the sheet steel.

H

horizontal position (fillet weld). The position in which welding is performed on the upper side of an approximately horizontal surface and against an approximately vertical surface.

horizontal position (groove weld). The position of welding in which the weld axis lies in an approximately horizontal plane and the weld face lies in an approximately vertical plane.

I

intermittent weld. A weld in which the continuity is broken by recurring unwelded spaces.

J

joint. The junction of members or the edges of members which are to be joined or have been joined.

joint root. That portion of a joint to be welded where the members approach closest to each other. In cross section, the joint root may be either a point, a line, or an area.

***joint welding procedure.** The materials, detailed methods, and practices employed in the welding of a particular joint.

L

lap joint. A joint between two overlapping members in parallel planes.

leg of a fillet weld. See **fillet weld leg**.

M

machine welding. A nonstandard term for mechanized welding.

manual welding. A welding operation performed and controlled completely by hand. See also **automatic welding**, **machine welding**, **and semiautomatic arc welding**.

mechanized welding. Welding with equipment that requires manual adjustment of the equipment controls in response to visual observation of the welding, with the torch, gun, or electrode holder held by a mechanized device.

***melting rate.** The length of electrode melted in one minute.

N

***nugget size (arc welding).** The diameter or width of the nugget measured in the plane of the interface between the pieces joined.

O

overhead position. The position in which welding is performed from the underside of the joint (see Figure C-5.1).

overlap. The protrusion of weld metal beyond the weld toes or weld root.

P

partial joint penetration. Joint penetration that is intentionally less than complete.

plug weld. A weld made in a circular hole in one member of a joint, fusing that member to another member. A fillet-welded hole is not to be construed as conforming to this definition.

positioned weld. A weld made in a joint that has been placed as to facilitate making the weld.

procedure qualification. The demonstration that welds made by a specific procedure can meet prescribed standards.

***puddle weld.** A nonstandard term for term **arc spot weld**.

R

reinforcement of weld. See **weld reinforcement**.

root face. That portion of the groove face adjacent to the joint root.

root of joint. See **joint root**.

root opening. The separation at the joint root between the workpieces.

root of weld. See **weld root.**

S

seam weld. A continuous weld made between or upon overlapping members, in which coalescence may start and occur on the faying surfaces, or may have proceeded from the outer surface of one member. The continuous weld may consist of a single weld bead or a series of overlapping spot welds.

semiautomatic arc welding. Manual welding with equipment that automatically controls one or more of the welding conditions.

shielded metal arc welding (SMAW). An arc welding process that produces coalescence of metals by heating them with an arc between a covered metal electrode and the workpieces. Shielding is obtained from decomposition of the electrode covering. Pressure is not used, and filler metal is obtained from the electrode.

single-flare-bevel-groove weld. A weld in a groove formed by a member with a curved surface in contact with a planar member (see Figure 2.3A).

single-flare-V-groove weld. A weld in a groove formed by two members with curved surfaces (see Figure 2.10).

size of weld. See **weld size.**

spatter. The metal particles expelled during fusion welding that do not form a part of the weld.

square-groove weld. A type of groove weld (see Figure 2.1).

stud arc welding (SW). An arc welding process that uses an arc between a metal stud, or similar part, and the other workpiece. When the surfaces to be joined are properly heated, they are brought together under pressure. Partial shielding may be obtained by the use of a ceramic ferrule surrounding the stud. Shielding gas or flux may or may not be used.

submerged arc welding (SAW). An arc welding process that uses an arc or arcs between a bare metal electrode or electrodes and the weld pool. The arc and molten metal are shielded by a blanket of granular, fusible material on the workpieces. Pressure is not used, and filler metal is obtained from the electrode and sometimes from a supplemental source (welding rod, flux, or metal granules).

T

tack weld. A weld made to hold parts of a weldment in proper alignment until the final welds are made.

theoretical throat. The distance from the beginning of the joint root perpendicular to the hypotenuse of the largest right triangle that can be inscribed within the cross section of a fillet weld. This dimension is based on the assumption that the root opening is equal to zero.

T-joint. A joint between two members located approximately at right angles to each other in the form of a T (see Figure 2.8B).

throat of a fillet weld. See **actual throat**, **effective throat**, and **theoretical throat**.

***throat of a fillet weld.** For sheet steel welding, this is assumed to be the thickness of the sheet steel.

throat of a groove weld. A nonstandard term for **groove weld size**.

toe of weld. See **weld toe**.

U

undercut. A groove melted into the base metal adjacent to the weld toe or weld root and left unfilled by weld metal.

V

vertical position. The position of welding in which the weld axis is approximately vertical.

W

***weld washer.** A washer used for containing arc spot welds on sheet metal thinner than 0.028 in [0.7 mm].

weld. A localized coalescence of metals or nonmetals produced either by heating the materials to the welding temperature, with or without the application of pressure, or by the application of pressure alone, with or without the use of filler metal.

***weld**. As applied here to sheet metal welding, a localized coalescence of metal produced by heating to suitable temperatures with or without the use of filler metal. The filler metal has a melting point approximately the same as the base metals.

weld axis. A line through the length of a weld, perpendicular to and at the geometric center of its cross section.

welder. One who performs a manual or semiautomatic welding operation.

welder performance qualification. The demonstration of a welder's ability to produce welds meeting prescribed standards.

welding machine. Equipment used to perform the welding operation: For example, spot welding machine, arc welding machine, and seam welding machine.

welding operator. One who operates machine or automatic welding equipment.

welding procedure. The detailed methods and practices involved in the production of a weldment. See also **welding procedure specification**.

welding procedure specification (WPS). A document providing, in detail, the required variables for a specific application to assure repeatability by properly trained welders and welding operators.

weldment. An assembly whose component parts are joined by welding.

weld reinforcement. Weld metal in excess of the quantity required to fill a joint. See also **face reinforcement** and **root reinforcement**.

weld root. The points, as shown in cross section, at which the back of the weld intersects the base metal surfaces.

weld size. See **groove weld size** and **fillet weld size**.

weld toe. The junction of the weld face and the base metal.

Annex E (Informative)

Gage Numbers and Equivalent Thicknesses

This annex is not part of AWS D1.3/D1.3M:2008, *Structural Welding Code—Sheet Steel*, but is included for informational purposes only.

Table E.1
Gage Numbers and Equivalent Thicknesses Hot-Rolled and Cold-Rolled Sheet

Manufacturer's Standard Gage Number	Thickness Equivalent	
	in	mm
3	0.2391	6.073
4	0.2242	5.695
5	0.2092	5.314
6	0.1943	4.935
7	0.1793	4.554
8	0.1644	4.176
9	0.1495	3.800
10	0.1345	3.416
11	0.1196	3.038
12	0.1046	2.657
13	0.0897	2.278
14	0.0747	1.900
15	0.0673	1.709
16	0.0598	1.519
17	0.0538	1.366
18	0.0478	1.214
19	0.0418	1.062
20	0.0359	0.912
21	0.0329	0.836
22	0.0299	0.759
23	0.0269	0.660
24	0.0239	0.607
25	0.0209	0.531
26	0.0179	0.455
27	0.0164	0.417
28	0.0149	0.378

Note: Table E.1 is for information only. This product is commonly specified to decimal thickness, not to gage number.

Table E.2
Gage Numbers and Equivalent Thicknesses Galvanized Sheet

Galvanized Sheet Gage Number	Thickness Equivalent	
	in	mm
8	0.1681	4.270
9	0.1532	3.891
10	0.1382	3.510
11	0.1233	3.132
12	0.1084	2.753
13	0.0934	2.372
14	0.0785	1.993
15	0.0710	1.803
16	0.0635	1.613
17	0.0575	1.460
18	0.0516	1.311
19	0.0456	1.158
20	0.0396	1.006
21	0.0366	0.930
22	0.0336	0.853
23	0.0306	0.777
24	0.0276	0.701
25	0.0247	0.627
26	0.0217	0.551
27	0.0202	0.513
28	0.0187	0.475
29	0.0172	0.437
30	0.0157	0.399
31	0.0142	0.361
32	0.0134	0.340

Note: Table E.2 is for information only. This product is commonly specified to decimal thickness, not to gage number.

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Annex F (Informative)

Safe Practices

This annex is not part of AWS D1.3/D1.3M:2008, *Structural Welding Code—Sheet Steel*, but is included for informational purposes only.

This annex covers many of the basic elements of safety general to arc welding processes. It includes many, but not all, of the safety aspects related to structural welding. The hazards that may be encountered and the practices that will minimize personal injury and property damage are reviewed here.

F1. Electrical Hazards

Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. Read and understand the manufacturer's instructions and recommended safe practices. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpiece should be grounded. A separate connection is required to ground the workpiece. The work lead should not be mistaken for a ground connection.

To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Dry gloves and rubber soled shoes should be worn. The welder should stand on a dry board or insulated platform.

Cables and connectors should be kept in good condition. Worn, damaged, or bare cables should not be used. In case of electric shock, the power should be turned off immediately. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived (see References 8, 7, and 10).

F2. Fumes and Gases

Many welding, cutting, and allied processes produce fumes and gases which may be harmful to one's health. Fumes and solid particles originate from welding consumables, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Everyone associated with the welding operation should acquaint themselves with the effects of these fumes and gases.

The possible effects of over-exposure to fumes and gases range from irritation of eyes, skin, and respiratory system to more severe complications. Effects may occur immediately or at some later time. Fumes can cause symptoms such as nausea, headaches, dizziness, and metal fume fever.

Sufficient ventilation, exhaust at the arc, or both, should be used to keep fumes and gases from breathing zones and the general work area.

For more detailed information on fumes and gases produced by the various welding processes, see References 1, 4, and 11.

F3. Noise

Excessive noise is a known health hazard. Exposure to excessive noise can cause a loss of hearing. This loss of hearing can be either full or partial, and temporary or permanent. Excessive noise adversely affects hearing capability. In addition, there is evidence that excessive noise affects other bodily functions and behavior.

Personal protective devices such as ear muffs or ear plugs may be employed. Generally, these devices are only accepted when engineering controls are not fully effective (see References 1, 5, and 11).

F4. Burn Protection

Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used.

Workers should wear protective clothing made of fire-resistant material. Pant cuffs or clothing with open pockets or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top boots. Helmets or hand shields that provide protection for the face, neck, and ears, should be worn, as well as a head covering to protect the head.

Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance is spilled on clothing, it should be replaced with clean fire resistant clothing before working with open arcs or flame.

Appropriate eye protection should be used at all times. Goggles or equivalent also should be worn to give added eye protection.

Insulated gloves should be worn at all times when making contact with hot items or handling electrical equipment.

For more detailed information on personal protection References 2, 3, 8, and 11 should be consulted.

F5. Fire Prevention

Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause fire or explosion if precautionary measures are not used.

Explosions have occurred where welding or cutting has been performed in spaces containing flammable gases, vapors, liquid, or dust. All combustible material should be removed from the work area. Where possible, move the work to a location well away from combustible materials. If neither action is possible, combustibles should be protected with a cover of fire resistant material. All combustible materials should be removed or safely protected within a radius of 35 ft [11 m] around the work area.

Welding or cutting should not be done in atmospheres containing dangerously reactive or flammable gases, vapors, liquid, or dust. Heat should not be applied to a container that has held an unknown substance or a combustible material whose contents when heated can produce flammable or explosive vapors. Adequate ventilation should be provided in work areas to prevent accumulation of flammable gases, vapors or dusts. Containers should be cleaned and purged before applying heat.

For more detailed information on fire hazards from welding and cutting operations, see References 6, 8, 9, and 11.

F6. Radiation

Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. Everyone should acquaint themselves with the effects of this radiant energy.

Radiant energy may be ionizing (such as X-rays) or nonionizing (such as ultraviolet, visible light, or infrared). Radiation can produce a variety of effects such as skin burns and eye damage, if excessive exposure occurs.

Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc when used properly), laser welding and torch welding, cutting, brazing, or soldering can produce quantities of nonionizing radiation such that precautionary measures are necessary.

Protection from possible harmful radiation effects include the following:

(1) Welding arcs should not be viewed except through welding filter plates (see Reference 2). Transparent welding curtains are not intended as welding filter plates, but rather, are intended to protect passersby from incidental exposure.

(2) Exposed skin should be protected with adequate gloves and clothing as specified (see Reference 8).

(3) The casual passerby to welding operations should be protected by the use of screens, curtains, or adequate distance from aisles, walkways, etc.

(4) Safety glasses with ultraviolet protective side shields have been shown to provide some beneficial protection from ultraviolet radiation produced by welding arcs.

References Cited

1. American Conference of Governmental Industry Hygienists (ACGIH). *Threshold limit values for chemical substances and physical agents in the workroom environment*. Cincinnati, Ohio: American Conference of Governmental Industry Hygienists (ACGIH).

2. American National Standards Institute. *Practice for occupational and educational eye and face protection*, ANSI/ASC Z87.1. New York: American National Standards Institute.

3. ——. *Personal Protection—Protective Footwear*, ANSI/ASC Z41.1. New York: American National Standards Institute.

4. American Welding Society. *Fumes and gases in the welding environment*, AWS report. Miami, Florida: American Welding Society.

5. ——. *Method for sound level measurement of manual arc welding and cutting processes*, ANSI/AWS F6.1. Miami, Florida: American Welding Society.

6. ——. *Recommended safe practices for the preparation for welding and cutting containers and piping*, ANSI/AWS F4.1. Miami, Florida: American Welding Society.

7. ——. *Safe Practices*. (Reprint from Welding Handbook, Volume 1, Eighth Edition) Miami, Florida: American Welding Society.

8. ——. *Safety in welding, cutting, and allied processes.* ANSI Z49.1. Miami, Florida: American Welding Society.

9. National Fire Protection Association. *Fire prevention in use of cutting and welding processes*, NFPA Standard 51B. Quincy, Massachusetts: National Fire Protection Association.

10. ——. National Electrical Code. NFPA No. 70. Quincy, Massachusetts: National Fire Protection Association.

11. Occupational Safety and Health Administration. *Code of Federal Regulations*, Title 29 Labor, Chapter XVII, Subtitle B Part 1910; Occupational Safety and Health Standards. Washington, DC: U.S. Government Printing Office.

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Annex G (Informative)

Reference Documents

This annex is not part of AWS D1.3/D1.3M:2008, *Structural Welding Code—Sheet Steel*, but is included for informational purposes only.

The following applicable general specifications and journal article are cited for information only.

1. American Concrete Institute—*Building Code Requirements for Reinforced Concrete ACI 318*.
2. American Iron and Steel Institute—*Specification for the Design of Cold-Formed Steel Structural Members*
3. American Institute of Steel Construction—*Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings*.
4. AWS *Welding Journal*, December, 1987 pages 17–31 "Calculated Cooling Rates of Arc Spot Welds" authored by Omer Blodgett.

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Commentary on Structural Welding Code—Sheet Steel

4th Edition

Prepared by the
AWS D1 Committee on Structural Welding

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

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Commentary on Structural Welding Code—Sheet Steel

NOTE: All references to numbered subclauses, tables, and figures, unless otherwise indicated, refer to subclauses, tables, or figures in AWS D1.3/D1.3M:2008, Structural Welding Code—Sheet Steel. *References to subclauses, tables, or figures in this Commentary are prefixed with a C-.*

C-1. General Requirements

The purpose of the commentary is to provide information and background data supporting the provisions of some clauses of this specification. These clauses are duly identified.

C-1.1 Scope

In terms of types of welds, this specification covers the following:

(1) Welds customarily used in production work

(2) Welds for which conventional methods of measuring sizes cannot be used.

NOTE: The constructive response of the users (designers, fabricators, etc.) in each of the areas covered by the specification is greatly encouraged.

The following will amplify the above statements.

By definition, a plug weld is a circular weld in a lap joint made through a hole in one member. In this specification, the equivalent provisions are also made for arc spot welds; these are circular welds fused through one sheet onto supporting material without the use of a hole. To obtain proper penetration and fusion between the two materials, it is necessary to use sufficient welding current.

Also, the size of a fillet weld in a T-corner, or lap joint in thick material can be measured with suitable gages, and the allowable load capacity is based on the theoretical throat which is the shortest distance between the root of the joint, and the face of the diagrammatic weld. In this case, it is assumed that the weld is as strong as the material to which it is attached because of the relatively deeper penetration; therefore, the allowable load capacity of the joint will essentially depend upon the thickness of the material, its strength, and the length of the weld.

C-1.4.4.1 AWS Specification. AWS A5.1/A5.1M and AWS A5.5/A5.5M specifications cover mild steel and low-alloy electrodes.

It is possible to produce satisfactory welds in sheet metal with electrodes of many types. However, some electrode classifications have better penetration than others and assist naturally in making arc spot welds and arc seam welds. Other electrode classifications are noted for their limited penetration and lesser tendency for undercutting and, therefore, would perform better on fillet and flare-groove welds on thinner materials.

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C-2. Design of Welded Connections

C-2.2.2 Fillet Welds. Presently, the allowable stress for fillet welds in static applications other than in sheet steel is based on 0.30 of the minimum specified tensile strength of the weld metal (0.30 F_{xx}). This stress is assumed to be applied on the throat of the fillet (t) irrespective of the direction of the applied loads. For fusion faces having an included angle of 90°, the throat (t) is equal to 0.707 times the leg size (w). The allowable shear stress of the throat of the weld is $F_w = 0.30\ (F_{xx})$ (see Figure C-2.1). However, AWS D1.1, *Structural Welding Code—Steel*, also recognizes that the allowable stress of the attaching plate shall not be exceeded.

However, the behavior of fillet welded joints in sheet steel is markedly different. The strength of the weld does not usually govern the capacity of the joint, because it usually has a strength greater than the sheet steel. This is due to the weld metal having typically greater strength than the sheet steel, to the large amount of penetration (in T-joints), and to typically convex weld profile. For this reason, calculations of the load capacity of a fillet-welded joint in sheet steel are based on thickness and on the specified minimum tensile strength of the sheet steel immediately adjacent to the weld (see Figure C-2.2 and Equations (1), (2), and (3), which give the load capacities for such joints). Equations (1), (2), and (3) have been established as result of research conducted on galvanized sheet steel lap joints where the maximum thickness of the cover sheet was 12 Ga. (0.108 in) [2.74 mm].

Research data have indicated that in longitudinally loaded fillet welds, the unit load capacity for shorter fillet welds is greater than that calculated in Equation (3) and has led to the empirical Equation (2). Equation (4) covers cases where joint capacity is governed by weld strength. The relation $t_w < t$ may occur in T-joints and in lap joints, especially in cases where cover plate is thicker than 12 Ga. (0.108 in) [2.74 mm] and single pass weld is used.

C-2.2.4 Arc Spot Welds. As already noted in C1.1, an arc spot weld resembles a plug weld on plate, except that the sheet material is not punched and the weld metal is fused through the sheet into the supporting material or member. For plate welding, the strength of a plug weld depends upon the cross-sectional area of the weld fused with the surface of the supporting member. For sheet steel welding, the ratio of the diameter of the weld to the thickness of sheet material is many times larger than that applicable to a plug weld in plate welding. Any strength calculation based upon this area would be larger than the actual strength of the joint because failure would occur by the tearing of the sheet from the weld. For this reason, the load capacity of an arc spot weld in sheet steel is based on some measurement of the diameter of the weld, and the thickness and strength of the sheet steel. This fact has been confirmed by actual testing of the welds.

The sheet steel around the circumference of the arc spot weld is subjected to various stresses as it sets up a resisting force. The stress in the material is a tensile stress at the leading edge, becoming a shear stress along the sides, and eventually, becoming a compressive stress at the trailing edge of the weld. With progressively increasing loads, the tensile stress at the leading edge will cause transverse tearing to occur in the materials next to the weld and will extend it across the material, leading to eventual failure [see Figure C-4(A)].

If the sheet steel is sufficiently thin, there may be a tendency for it to buckle near the trailing edge of the arc spot weld. This will decrease the resisting force of the joint, and failure will occur initially by tension at the leading edge and, then, tearing out in shear along the sides [see Figure C-2.3(B)]. Evidence obtained from conducted tests suggests that this buckling condition occurs when the following relationship exists:

$$\frac{d}{t} \geq \frac{240}{F_u}$$

There are three equations with a transition at:

$$\frac{d}{t} = \frac{140}{F_u} \text{ and } \frac{d}{t} = \frac{240}{F_u}$$

The diameter of the fused section of the weld at the face of supporting material (d_e) is less than the surface diameter (d) of the arc spot weld. Since the surface of the weld is the only portion accessible for measurement, some reduction of this measurement must be made when calculating the load capacity of the weld.

A convenient way to affect this reduction, showing good correlation with test results, is to subtract one thickness (t) from the outside diameter of the weld (d) [see Figure C-2.3(C)].

In the case of a double thickness of material, this reduction of the outside diameter of weld (d) amounts to twice the combined thickness of the material (t) [see Figure C-2.3(D)]. Such reduction provides a slope of 45° at the top of the weld.

For a given overall thickness, there is less heat transferred through a double sheet than through a single sheet. For this reason, the average diameter (d_a) and the effective diameter, (d_e) will be smaller when a double sheet is used.

If sheet steel is galvanized, the thickness of galvanizing should be deducted from the overall thickness of the sheet. If the thickness of the galvanizing is not shown, an arbitrary 0.0015 in [0.04 mm] should be deducted from the thickness of each sheet.

In cases where the effective width of the arc seam weld becomes too small, as shown in Figure C-2.4, it is possible for the weld to shear out of the base metal. The following equation provides a lower bound, intended to preclude such failure.

$$P = \left[\frac{(d_e)^2}{4} + \frac{Ld_e}{3}\right]F_{xx}$$

where

$$d_e = 0.7d - 1.5t$$

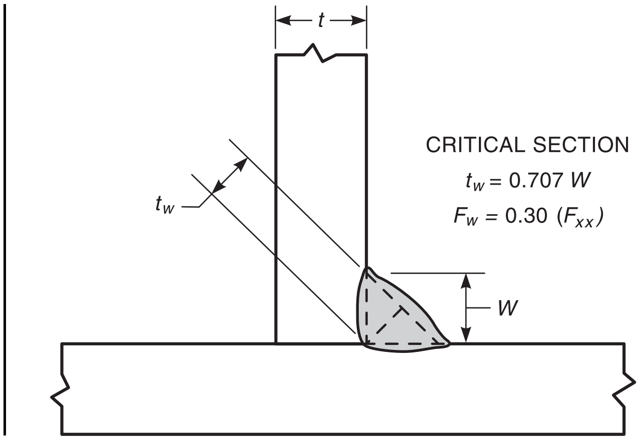

Figure C-2.1—Allowable Stress for Fillet Welds

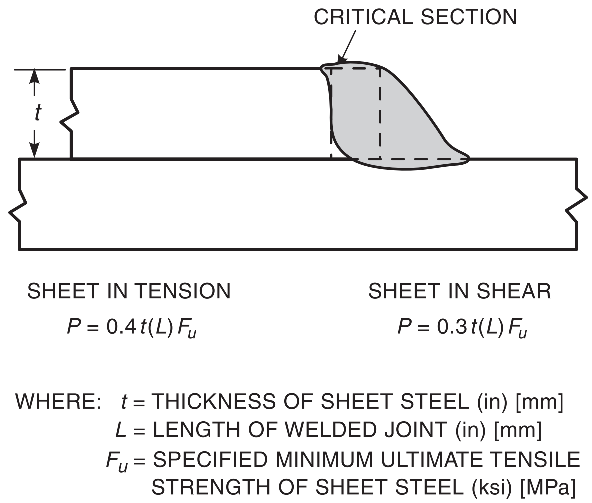

Figure C-2.2—Load Capacity of Fillet Welds

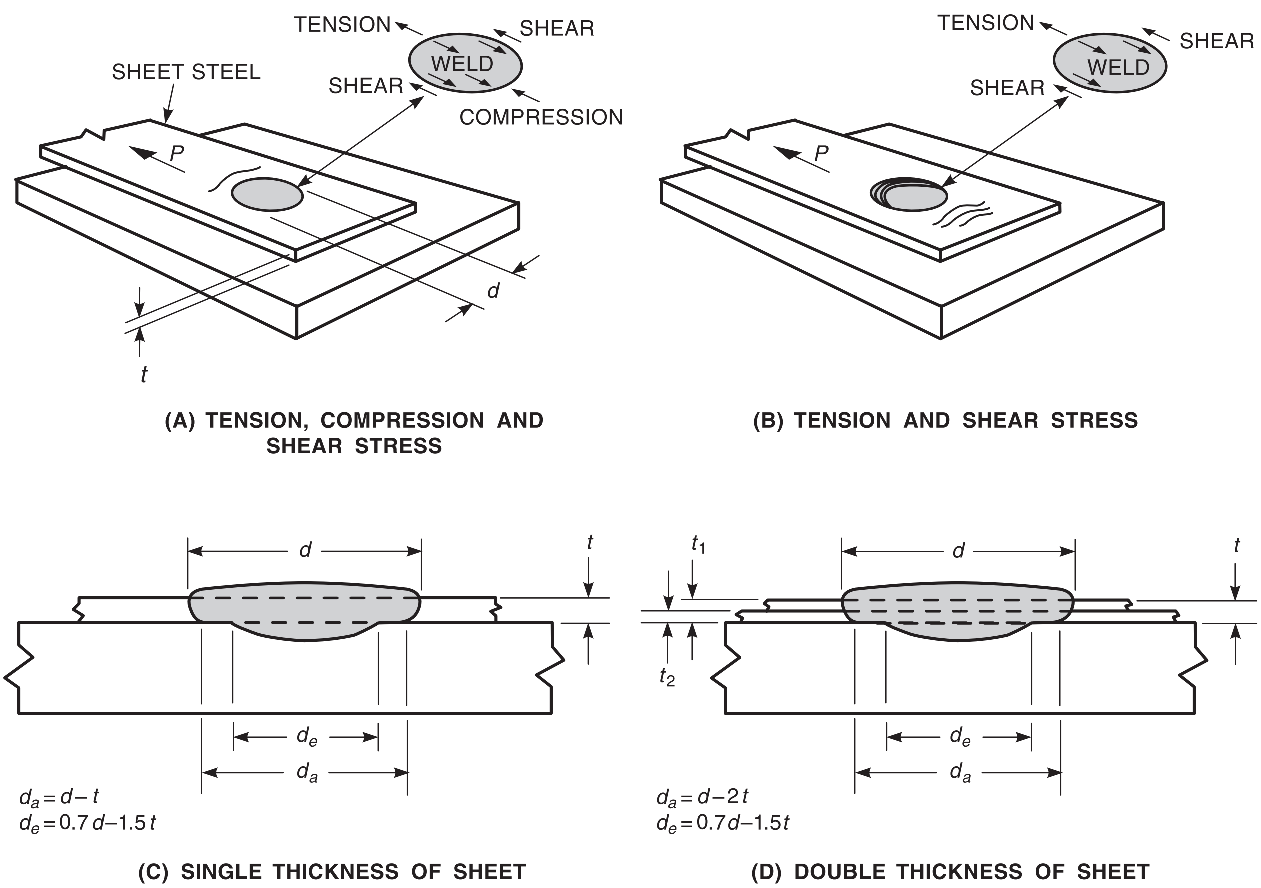

Figure C-2.3—Arc Spot Welds

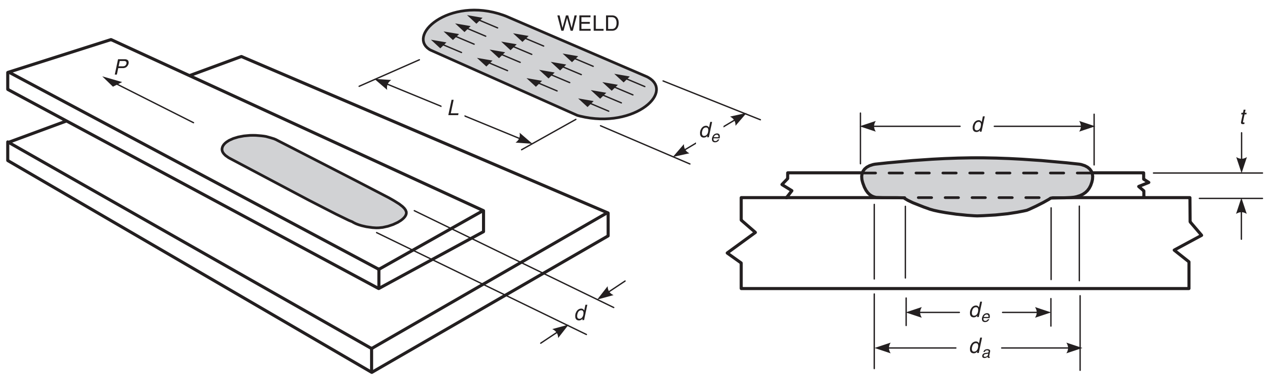

Figure C-2.4—Arc Seam Weld in a Supporting Plate

C-4. Workmanship

C-4.5 Essential Variable Limitations

NOTE: Permissible ranges for variations of other variables have not been introduced into this code at this time. This omission is due to insufficient data available to support such ranges. It is anticipated that the use of this code will result in the flow of information which will eventually provide a basis for appropriate modifications.

C-4.6.4 Arc Spot Welds. The objective of the requirement of 4.6.4 is to check on the ability of the electrode to produce sound welds in rapid succession at elevated current levels characteristic of currents used in making spot welds. At the relatively high current, the coating of some covered electrodes may break down and, as a result, produce penetration more shallow than that required. This tendency may be rectified by limiting the number of welds made in rapid succession with one electrode.

The required current level shall have been established during the procedure qualification testing program. The current shall be used to measure the electrode melting rate as described here, which shall therefore be used to give evidence that the proper current level is being used in production welding.

C-4.6.4.4 SMAW Melting Rate. Melting rate as a method of measuring welding current has long been in use. Many published shielded metal arc welding (SMAW) procedures still include the melting rate (M) along with the welding current and other data needed.

Once the welding current for a given size and classification of SMAW electrode has been established, the welder should place a new electrode into its holder. The welder should proceed to weld at this current level for one minute (60 seconds) and then measure the length of electrode melted during this time interval. This can easily be done by placing a steel measuring tape along the electrode stub, as shown in Figure C-4.1. The tape is positioned so that the number representing the initial length of the electrode is lined up with the end of the electrode in the holder (position 1). The number on the side which is opposite the melted end of the electrode should then be read (position 2). This number represents the electrode melting rate in inches per minute, and is designated (M).

For most welding procedures on sheet steel, it will take less than 60 seconds to melt off the electrode. In such a case, a shorter welding time should be used. For example, the electrode may be melted for 30 seconds, and the melted length of electrode should be multiplied by two. A 20 second period may be used with a multiplier of three, or a 15 second period, with a multiplication factor of four.

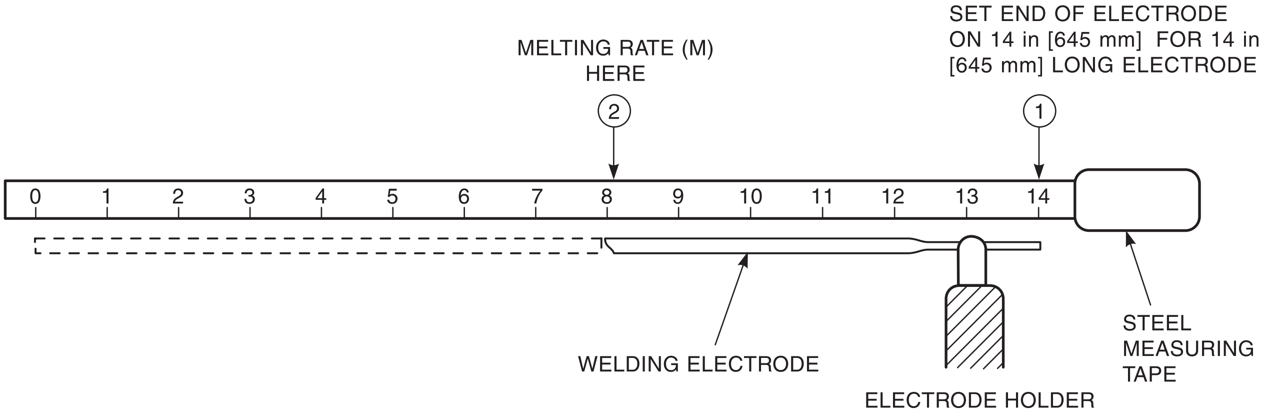

Figure C-4.1—Melting Rate Measurement Illustrated

C-5. Technique

C-5.3.1 Joint Detail Positions. Position of welding. The sketches in Figure C-5.1 should assist in the proper understanding of the positions of welding.

C-5.3.3 Commercially available backing rings are commonly made of ASTM A 109 Temper 3 or 4.

C-5.4 Allowable Deviation from WPS for Lower Temperatures using Annex A, Note 1. These adjustments to WPSs qualified at room temperature and applied a much lower temperature are based on the "Calculated Cooling Rates of Arc Spot Welds" work by Omer Blodgett. In the referenced works performed in Canada, it was found that it was not always possible to increase the welding current for a given welding electrode size the amount necessary to achieve the required welding current increase for the lower temperature. This should be considered when extending the application temperature range. For arc spot welds and arc plug welds, the best solution may be a combination of increased current and increased weld time. For arc seam welds, the best solution may be a combination of increased welding current and decreased travel speed.

C-5.4.1 and C-5.4.2 Arc Spot and Arc Seam Welds. Arc spot welding and arc seam welding are commonly used to attach sheet steel material, such as roof decking and floor decking, to thicker structural members. Preheating is generally not used. A number of research studies[1] on arc spot welds have been made by the Canadian Sheet Steel Industries Construction Council, the Canadian Sheet Steel Building Institute, and the Welding Institute of Canada to determine the strength of welds and their effect on the strength and fracture resistance of the underlying structural steel.

Computer analysis[2] has shown the same cooling rate will be obtained down to 32°F [0°C] by increasing the welding time by 20% or by increasing the amperage settings by 10%.

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[1] Thorn, K., et al. *Fracture tests on arc spot welds.* Report RC163 for Canadian Sheet Steel Building Institute. Oakville, Ontario: Welding Institute of Canada, May 1986.

[2] Blodgett, O. W. *Calculated cooling rates of arc spot welds.* Paper presented at 68th Annual AWS Meeting, Chicago, Illinois. March 1987.

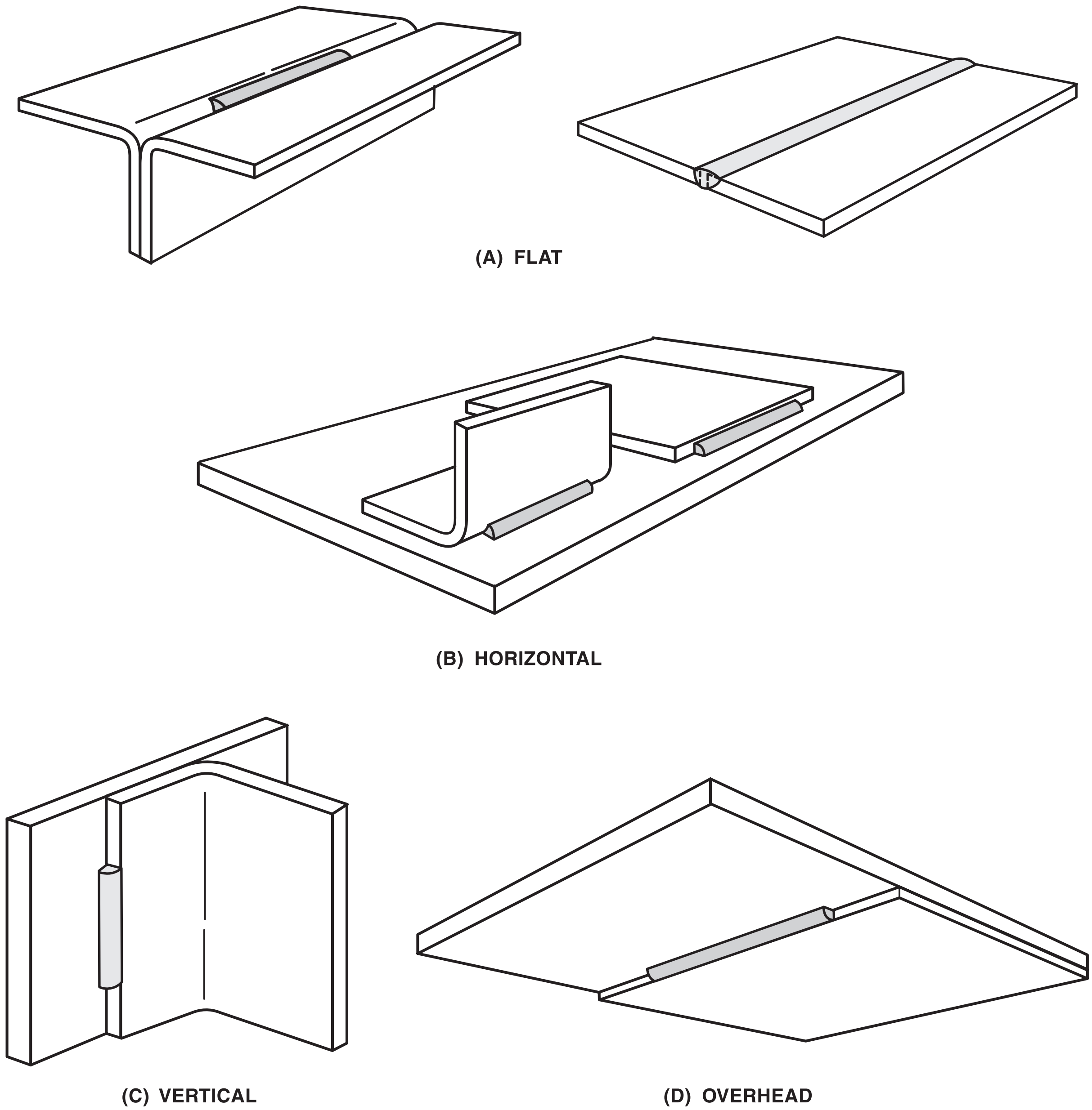

Figure C-5.1—Positions of Welding

C-Annex A

C-A. Applicable Provision Requirements When Welding D1.3 Sheet Steels to D1.1 Other Steel Product Forms

Subclause 1.1 and Annex A address the simultaneous application of the AWS D1.1 and AWS D1.3 codes to the welding of sheet steel to structural steel. Subclause 1.1 and Annex A clearly specify the relationships between AWS D1.1 and AWS D1.3. The exemptions to AWS D1.1 are clearly defined and based on specific connection tests (the referenced works) and associated years of service of existing fabricated structures. These specific connection tests indicate that if welding procedures are kept within the allowances of Annex A, welding at ambient temperatures ≥0°F [–18°C] will provide sound welds. Experience with these procedures and controls indicates that these temperatures are adequate to avoid localized cracking or excessive hardness and adding preheat is not justified (see References 1, 2, 3, and 4).

References

1. Blodgett, O. W. *Calculated cooling rates of arc spot welds*. Paper presented at 68th Annual AWS Meeting, Chicago, Illinois. March 1987.
2. *Strength of Arc Spot Welds in Sheet Steel Construction*—CISCC Industry Research Project 175 (1978).
3. *Study of Hardness and Cooling Rates in Arc Spot Welds*—Canadian Sheet Steel Building Institute (1980).
4. *Fracture Tests on Arc Spot Welds*—Report RC163—Canadian Sheet Steel Building Institute (1983).

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List of AWS Documents on Structural Welding

Designation	Document
D1.1/D1.1M	*Structural Welding Code—Steel*
D1.2/D1.2	*Structural Welding Code—Aluminum*
D1.3/D1.3M	*Structural Welding Code—Sheet Steel*
D1.4/D1.4M	*Structural Welding Code—Reinforcing Steel*
D1.5/D1.5M	*Bridge Welding Code*
D1.6/D1.6M	*Structural Welding Code—Stainless Steel*
D1.8/D1.8M	*Structural Welding Code—Seismic supplement*
D1.9/D1.9M	*Structural Welding Code—Titanium*

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