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ANSI/AWS D1.3-89
An American National Standard

**Structural
Welding Code**

Sheet Steel



American Welding Society

Keywords — Sheet steel, allowable stresses, details of welded joints, workmanship, qualification, visual acceptance criteria, stud welding

ANSI/AWS D1.3-89
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Structural Welding Code — **Sheet Steel**

Second Edition

Superseding AWS D1.3-81

Prepared by
AWS Structural Welding Committee

Approved by
AWS Board of Directors

Abstract

This Code covers the requirements associated with welding sheet steel having a minimum specified yield point no greater than 80 000 psi (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 coatings (galvanized). Sections 1 and 2 include rules for the specific jurisdiction of this Code. Sections 3 through 5 constitute a body of rules for the implementation of welding activities. Sections 6 and 7 constitute a body of requirements for the qualification of welding procedure specifications, welders, and welding operators.



American Welding Society

550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135

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This standard is subject to revision at any time by the AWS Structural Welding Committee. It must be reviewed every five years and if not revised, it must be either reapproved or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are requested and should be addressed to AWS Headquarters. Such comments will receive careful considerations by the AWS Structural Welding Committee 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 Structural Welding Committee 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, P.O. Box 351040, Miami, Florida 33135.

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<i>K. K. Verma</i>	Federal Highway Administration, Department of Transportation

*Advisor

**Deceased

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*Advisor

Foreword

(This Foreword is not a part of ANSI/AWS D1.3-89, *Structural Welding Code — Sheet Steel*, but is furnished for information purposes only.)

The preparation of this specification was undertaken in response to many requests for some form of regulatory provisions related exclusively to the arc welding of uncoated, galvanized, or coated sheet steel as used in structures.

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

First, the obligation is placed on the contractor to prepare welding procedure specifications and to qualify them before production use. These procedure specifications must include the classification of the filler metal, its size, and for each type of weld, its melting rate or any other suitable means of current control indicative of melting rate, as applicable. Second, the welder qualification test requires each welder to prove their ability to produce satisfactory welds using these qualified procedures. The fact that the welder may have been successfully qualified on plate or pipe under the provisions of ANSI/AWS D1.1, *Structural Welding Code — Steel*, for structural welding or on plate or pipe under the provisions of other codes governing the welding of specific products does not qualify the welder for welding on sheet steel.

It is anticipated that changes will be needed in this specification as further research is conducted on welded joints, as more experience is gathered, and as new sheet metal applications are developed. Although the specification 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 the quality standards that will maintain the integrity of the supporting structure. The allowable stress provisions of section 2 should be disregarded when the welds are not used in a load-carrying capacity.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Technical Director, American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, FL 33135.

Official interpretations of any of the technical requirements of this standard may be obtained by sending a request, in writing, to the Technical Director, American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, FL 33135 (See Appendix B).

A constructive response from users to each of the distinctive areas of the specification is greatly encouraged. All correspondence should be addressed to: Secretary, Structural Welding Committee, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33135.

Preface

(This Preface is not a part of ANSI/AWS D1.3-89, *Structural Welding Code — Sheet Steel*, but is furnished for information purposes only.)

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

Changes in Numbering Tables and Figures. In order to conform to the AWS uniform numbering system, tables and figures have been numbered sequentially by sections. For example, Table 6.7 in ANSI/AWS D1.3-81 becomes Table 6.1 in ANSI/AWS D1.3-89, and Figure 6.7.2 in ANSI/AWS D1.3-81 becomes Figure 6.2 in ANSI/AWS D1.3-89.

Changes in Code Requirements. Where changes have been made in code requirements, a double vertical line appears in the margin immediately adjacent to the material affected. Major editorial changes in the material are indicated by a single vertical line immediately adjacent to the material affected. Changes in tables and figures have not been so indicated. No new tables or figures have been added to this edition.

Technical Inquiries and Interpretations. Users wishing to make inquiries concerning the Sheet Steel Code are referred to Appendix B, Guidelines for Preparation of Technical Inquiries. This appendix gives an explanation of the procedures that code interpretations must follow and serves as a guideline for preparation of technical inquiries. Anyone desiring an interpretation of ANSI/AWS D1.3-89, *Structural Welding Code — Sheet Steel*, should review the guidelines in Appendix B before preparing their technical inquiry.

Errata. It is the Structural Welding Committee's policy that all errata should be made available to code users. Therefore, any errata (major editorial changes) that have been noted will be published in the July and November issues of the Welding Journal under Society News.

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Structural Welding Code

Sheet Steel

1. General Provisions

1.1 Application

1.1.1 This specification is applicable to the arc welding of sheet steels or strip steels, or both, including cold-formed members, 0.18 in. (4.6 mm) or less in thickness. Such welding may involve sheet steel or strip steel, or both, being welded to supporting structural members.

Note: The following applicable general specifications are cited for information only.

American Concrete Institute — Building Code Requirements for Reinforced Concrete ACI 318-86. American Iron and Steel Institute — Specification for the Design of Cold-Formed Steel Structural Members, 1986 Edition, August 1986. American Institute of Steel Construction — Specification for the Design, Fabrication, and Erection of Structural Steel for Buildings, November 1, 1978.

When sheet steel is welded to primary structural members, the provisions of the latest edition of ANSI/AWS D1.1, *Structural Welding Code — Steel*, shall also apply (e.g., adequate preheat, low hydrogen electrodes, etc.). For arc spot and arc seam welds, see 6.7.2.5 and 6.7.3.5, respectively.

1.1.2 Groove Welds in Butt Joints. As covered by this specification, this type of weld is restricted to the welding of sheet steel to sheet steel in all positions of welding.

1.1.3 Arc Spot Welds (Puddle Welds). As covered by this specification, this type of weld is restricted to the welding of sheet steel to thicker supporting members in the flat position. See Table 1.1. Neither the thickness of a single sheet nor the combined thickness of sheets welded to supporting members shall exceed 0.15 in (3.7 mm).

1.1.4 Arc Seam Welds. As covered by this specification, this type of weld is restricted (see Table 1.1) to the welding of joints involving:

- (1) Sheet to thicker supporting member in the flat position
- (2) Sheet to sheet in the flat or horizontal position (see Table 1.1)

1.1.5 Flare Groove Welds and Fillet Welds. As covered by this specification, these types of welds may be used (see Table 1.1) in any position of welding involving:

- (1) Two sheet steels for flare-V-grooves.
- (2) Two sheet steels as well as a sheet and a thicker steel member for flare-bevel-groove welds and fillet welds (see Table 1.1).

1.1.6 All references to the need for approval shall be interpreted to mean approval by the Building Commissioner, the Engineer,¹ or a duly-designated person who acts for and on behalf of the owners on all matters within the scope of this specification. The term *Building Commissioner* refers to the official or the bureau, by whatever term designated, which is delegated to enforce the local building laws or the specifications or other regulations.

1.1.7 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 may be used for a particular application, provided they are suitably documented by the proposer and approved by the Engineer. These alternate acceptance criteria can 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. The Engineer is the duly designated person who acts for and in behalf of the owner on all matters within the scope of this code.

Table 1.1
Type of Weld and Approved Positions of Welding*
 (see 1.1.3)

Material	Square-Groove Weld in Butt Joint	Arc Spot Weld	Arc Seam Weld	Fillet Weld	Flare-Bevel Groove Weld	Flare-V- Groove Weld
Sheet to sheet	F		F	F	F	F
	H		H	H	H	H
	V		—	V	V	V
	OH		—	OH	OH	OH
Sheet to supporting member		F	F	F	F	
		—	—	H	H	
		—	—	V	V	
		—	—	OH	OH	

*Positions of welding: F = flat, H = horizontal, V = vertical, OH = overhead.

1.1.8 The word "shall", as used in this code, denotes a mandatory requirement. Failure to perform or meet a specified requirement or condition, may result in welds not meeting the acceptance criteria and may adversely affect the reliability of a weld under service conditions.

1.2 Sheet Steel Base Metal

1.2.1 Sheet steel base metals to be welded under this specification shall conform to the requirements of the latest edition of one of the specifications listed below. Any combination of these steels may be welded together. These steels may also be welded to any of the approved steels listed in the latest edition of ANSI/AWS D1.1 — *Structural Welding Code — Steel*.

(1) Specification for Sheet Steel, Zinc-Coated (Galvanized) by the Hot-Dip Process. Structural Physical Quality (ASTM A446 Grades A, B, C, and E).

(2) Specification for Hot-Rolled Steel Sheet and Strip. Structural Quality (ASTM A570).

(3) Specification for Steel Sheet and Strip, Hot-Rolled and Cold-Rolled, High Strength, Low Alloy, with Improved Corrosion Resistance (ASTM A606).

(4) Specification for Steel Sheet and Strip, Hot-Rolled or Cold-Rolled, High Strength, Low Alloy Columbium or Vanadium, or both (ASTM A607 Grades 45, 50, 55, 60, 65, and 70).

(5) Specification for Steel, Cold-Rolled Sheet, Carbon Structural (ASTM A611).

1.2.2 When a steel other than those covered in 1.2.1 is approved under the provisions of the general building code, and such a steel is proposed for welded construction, the weldability of the steel and the procedure for

welding it shall be established by qualification in accordance with the requirements of 6.2 and such other requirements as prescribed by the Engineer.

1.2.3 The provisions of this specification are intended for use with sheet steel having a minimum specified yield point no greater than 80 000 psi (550 MPa).

1.3 Welding Process

1.3.1 This specification provides for welding with the shielded metal arc (SMAW), gas metal arc (GMAW), flux cored arc (FCAW), or submerged arc (SAW) welding processes. (Note: Any variation of gas metal arc welding, including short-circuiting transfer, is acceptable.)

1.3.2 When stud welding through the flat portion of decking or roofing onto supporting structural members, the procedure shall conform to section 7, Stud Welding, of ANSI/AWS D1.1, *Structural Welding Code — Steel*.

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

1.5 Welding Symbols. The welding symbols used in this specification shall be those designated in the latest edition of ANSI/AWS A2.4, *Symbols for Welding and*

Nondestructive Testing. Special conditions shall be fully explained by notes or details.

1.6 Safety Precautions. The safety precautions shall conform to the latest edition of ANSI/ASC Z49.1, *Safety in Welding and Cutting*, 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 Appendix E for additional information relating to the basic elements of safety general to arc welding processes.

1.7 Standard Units of Measurement. The values stated in U. S. customary units are to be regarded as the standard. The metric (SI) equivalent of U. S. customary units given in this specification may be approximate.

2. Allowable Stresses

Note: The provisions of this section should be disregarded when welds, made in accordance with this specification, are not intended to carry calculated stresses.

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 building code.

2.2 Allowable Loads on Welds

2.2.1 Groove Welds in Butt Joints. The allowable unit stress for matching electrode and base metal combinations (see Table 5.1) 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 a weld size equal to the thickness of the base metal is consistently obtained.

2.2.2 Arc Spot Welds (Puddle Welds)

2.2.2.1 Arc spot welds shall be specified as the minimum effective diameter of the fusion zone (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 member shall not exceed:

$$P = 0.88(t) d_a F_u, \text{ for } \frac{d_a}{t} \leq \frac{140}{\sqrt{F_u}} \quad \text{Formula (1)}$$

$$P = 0.122 \left[1 + \frac{960t}{d_a \sqrt{F_u}} \right] t(d_a) F_u, \quad \text{Formula (2)}$$

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

$$P = 0.56(t) d_a F_u, \text{ for } \frac{d_a}{t} \geq \frac{240}{\sqrt{F_u}} \quad \text{Formula (3)}$$

However, the capacity shall not exceed

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

where

P = allowable load capacity of the arc spot weld (kips)

F_w = allowable unit shear stress of weld metal (ksi)
= $0.3F_{xx}$

F_{xx} = strength level of the weld metal designated in AWS electrode classification (ksi)

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

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

t = thickness of sheet steel exclusive of coatings for single sheet or combined thickness of sheet steel for double sheet, in. (see Figure 3.2A)

d = diameter of the weld face of arc spot weld or width of arc seam weld, in. (see Figure 3.2A)

d_a = average diameter of arc spot weld or average width of arc seam weld, in. (see Figure 3.2A)

d_a = $d - t$ (for a single sheet)

d_a = $d - 2t$ (for a double sheet)

d_e = effective diameter of arc spot weld or effective width of arc seam weld at the fusion zone, in. (see Figure 3.2A)

d_e = $0.7d - 1.5t$

Note: If it can be shown by sectioning and measuring that a given welding procedure will consistently give a larger effective diameter (d_e) at the fusion zone, this value may be used providing this particular welding procedure is used.

2.2.2.2 Weld washers are to be used in containing the arc spot welds in sheet steel thinner than 0.028 in. (0.7 mm). See Figure 2.1.

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).

2.2.3 Arc Seam Welds. The allowable load capacity of an arc seam weld used in a lap joint between the sheet and supporting member [see Figure 2.2(A)] made in the flat position or between sheet and sheet [see Figure 2.2(B)] made in the horizontal or flat position with matching filler metals (see Table 5.1) shall not exceed either:

$$P = \left(\frac{d_e^2}{4} + \frac{Ld_e}{3} \right) F_{xx} \quad \text{Formula (5)}$$

$$P = (t) F_u (0.25L + 0.96d_a) \quad \text{Formula (6)}$$

where

L = length of seam weld not including the circular ends, in. [see Figure 2.2(A)]

d_a = width of arc seam weld, in.

For allowable capacity calculation purposes

$$L \leq 3 d_a$$

The other symbols are defined in 2.2.2.1.

2.2.4 Fillet Welds

2.2.4.1 The allowable load capacity of a fillet weld in lap and T-joints, made in any welding position (see Figure 2.3) for matching filler-metal base-metal combinations (see Table 5.1), shall be governed by the thickness of the sheet steel, provided that an effective throat at least equal to the thickness of the sheet steel is consistently attained. The allowable load capacity shall be the following:

for fillet welds transverse to direction of loading

$$P = 0.4(t)L(F_u) \quad \text{Formula (7)}$$

and for fillet welds longitudinal to direction of loading

$$P = 0.4 \left(1 - 0.01 \frac{L}{t} \right) t(L)F_u, \text{ for } \frac{L}{t} < 25 \quad \text{Formula (8)}$$

$$P = 0.3(t)L(F_u), \text{ for } \frac{L}{t} \geq 25 \quad \text{Formula (9)}$$

where

P = allowable load capacity of a fillet weld (kips)

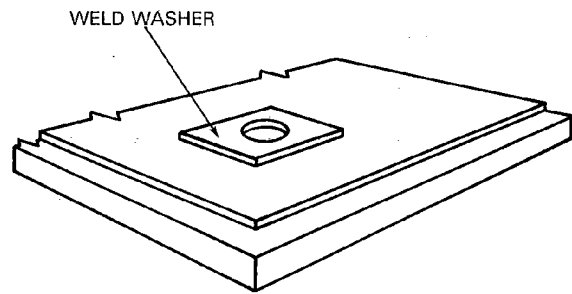


Figure 2.1 — Typical Weld Washer
(See 2.2.2.2)

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

t = thickness of base sheet steel, exclusive of coatings, in.

L = length of fillet weld, in.

2.2.5 Flare-Bevel and Flare-V-Groove Welds. For matching filler metal, base metal combinations (see Table 5.1), 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 is consistently obtained. This capacity shall be determined by one of the applicable formulae that follow:

(1) Loads applied transversely to weld axis

(a) Flare-bevel-groove welds (see Figure 2.4A).

The capacity of the welded joint is given by:

$$P = \frac{t(L)F_u}{3} \quad \text{Formula (10)}$$

(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 2.4B and C)

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

$$P = 0.3(t)L(F_u) \quad \text{Formula (11)}$$

(single shear) (See Figure 2.4B)

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

$$P = 0.6(t)L(F_u) \quad \text{Formula (12)}$$

(double shear) (see Figure 2.4C)

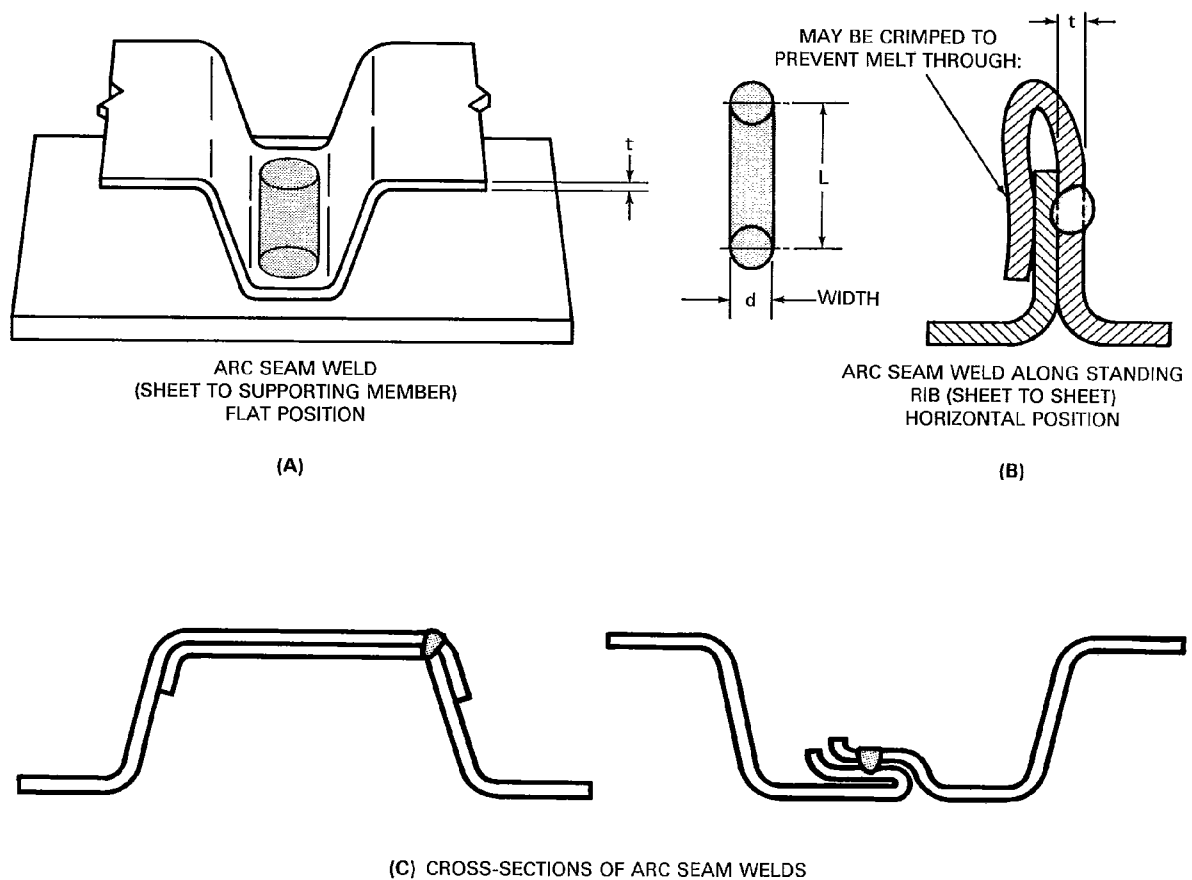


Figure 2.2 — Arc Seam Welds (See 2.2.3)

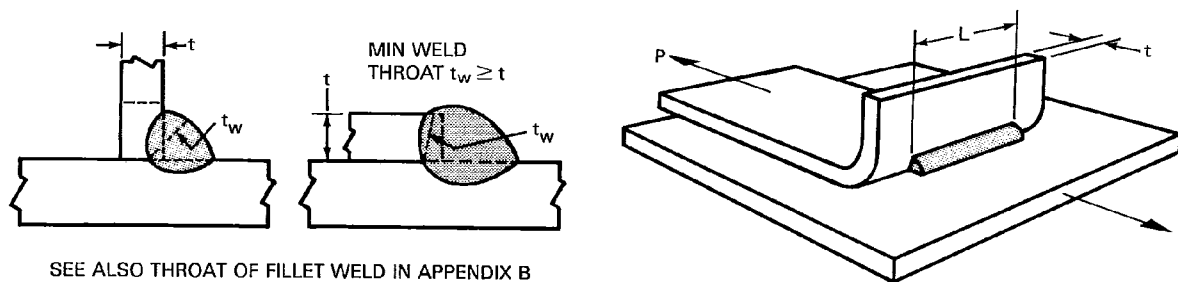


Figure 2.3 — Fillet Welds (See 2.2.4.1)

Figure 2.4A — Single Flare-Bevel Groove Weld (See 2.2.5(1))

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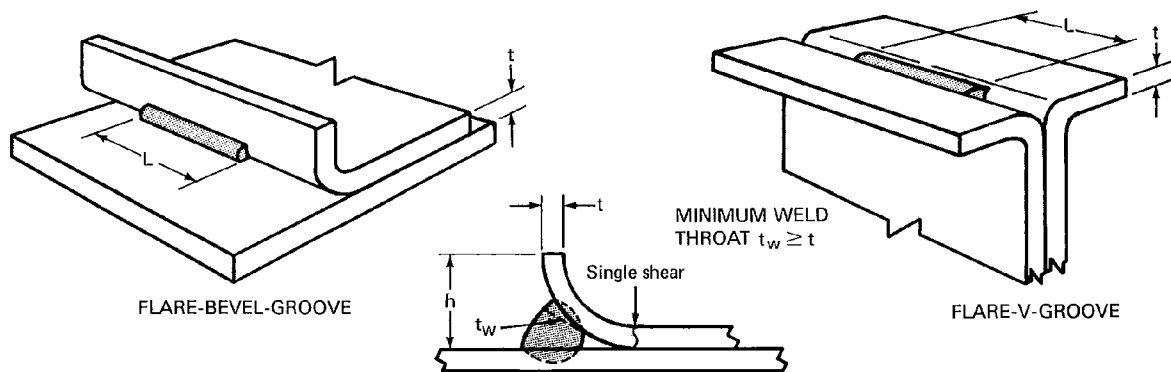


Figure 2.4B — Single Shear in Flare-Groove Welds (See 2.2.5(2))

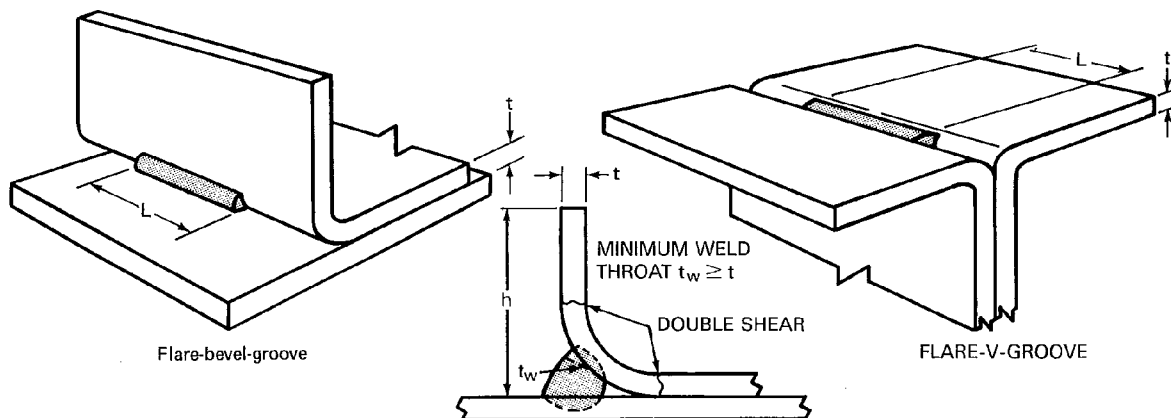


Figure 2.4C — Double Shear in Flare-Groove Welds (See 2.2.5(2))

3. Details of Welded Connections

3.1 General. Welded joints may be made using groove welds in butt joints, arc spot on arc seam welds, lap or fillet welded T-joints and single-flare-bevel or single-flare-V-groove welds when they are within the applicable limitations of 3.2 through 3.7.

3.2 Square Grooves. Square grooves shall be used in butt joints with the welding done preferably in the flat position. Root opening (gap) shall be qualified during the joint welding procedure qualification test and shall be subject to the limitations of 6.6. (see Figure 3.1).

3.3 Arc Spot Welds

3.3.1 Arc spot welds made through one or two thicknesses of sheet steel onto a supporting member shall be performed in the flat position as shown in Figure 3.2A.

For sheets thinner than 0.028 in. (0.7 mm), a steel washer, as shown in Figure 3.2B, shall be used to prevent burn back. The weld metal shall have a diameter of at least 3/8 in. (9 mm) at the fusion zone.

3.3.2 The minimum distance (e) from the center of an arc spot weld to any edge of the sheet material shall not be less than

$$e_{min} = \frac{P}{0.5 F_u t}, \text{ for } \frac{F_u}{F_y} \geq 1.15$$

or

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

but not less than $1.5d$, where d is the face diameter and where P is the force transferred by the arc spot weld. See Figures 3.2A and 3.2C.

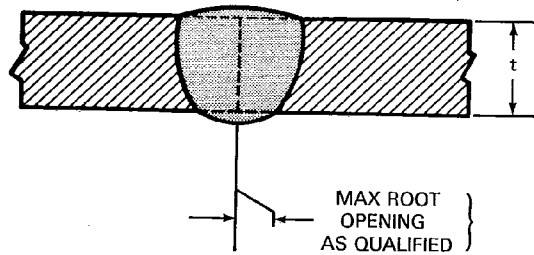


Figure 3.1 — Square-Groove Welds in Butt Joints (See 3.2)

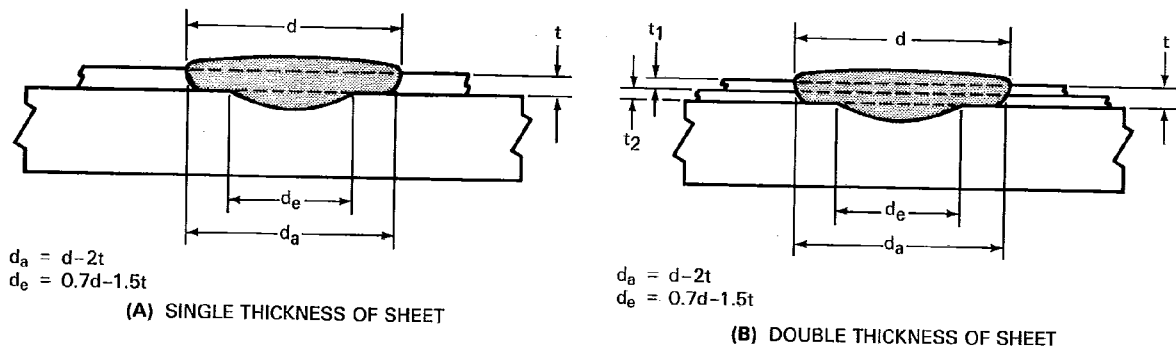


Figure 3.2A — Arc Spot Weld (See 3.3.1)

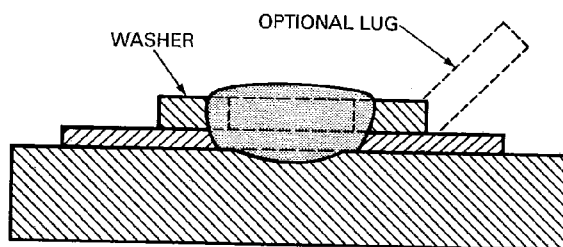


Figure 3.2B — Arc Spot Weld Using Washer (See 3.3.1)

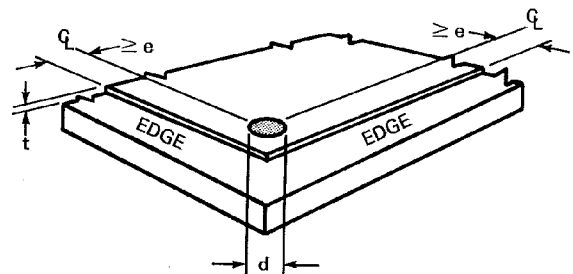


Figure 3.2C — Edge Distances for Arc Spot Welds (See 3.3.2)

3.4 Arc Seam Welds

3.4.1 The minimum width of weld metal at the faying surface of arc seam welds shall be 3/8 in. (9 mm). 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 formula in 3.3.2, but not less than 1.5d. See Figure 3.3A.

3.4.2 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 3.3A. Arc seam welds between the sheet and the support-

ing member shall be made in the flat position. See Figure 3.3B. Arc seam welds between steel sheets may be made in the horizontal position, provided the fit-up is exceptionally good. See Figure 3.3C.

3.5 Fillet Welds. Fillet welds in lap and T-joints shall preferably be made in the horizontal position. The minimum length shall be 3/4 in. (19 mm). See Figures 3.4A and 3.4B.

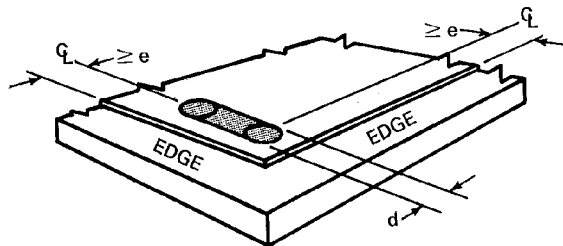


Figure 3.3A — Edge Distances for Arc Seam Welds (See 3.4.1)

3.6 Single-Flare-Bevel-Groove Welds. Single-flare-bevel-groove welds shall preferably be made in the horizontal or flat position. The minimum length shall be 3/4 in. (19 mm). See Figure 3.5.

3.7 Single-Flare-V-Groove Welds. Single-flare-V-groove welds shall preferably be made in the flat position. The minimum length shall be 3/4 in. (19 mm). See Figure 3.6.

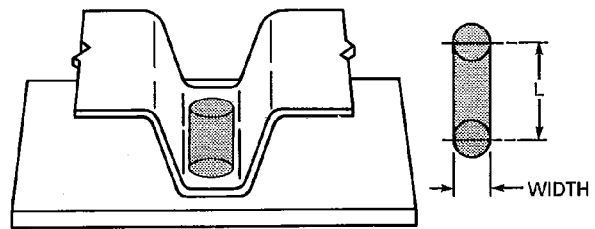


Figure 3.3B — Arc Seam Welds (See 3.4.2)

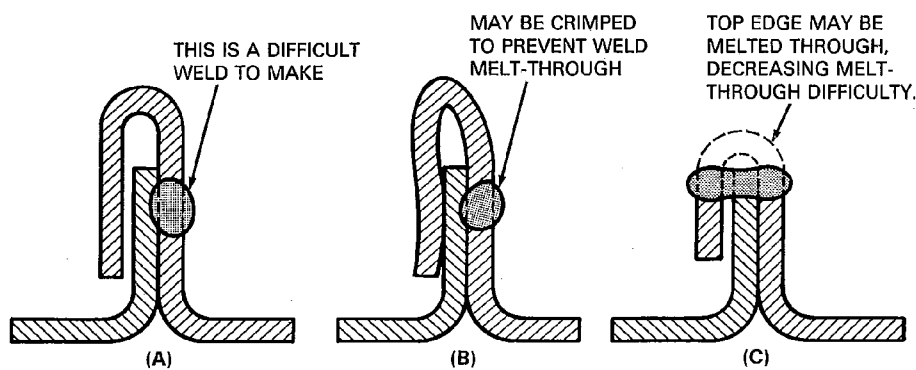
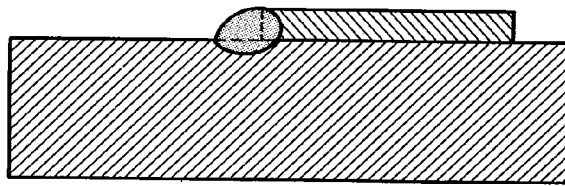
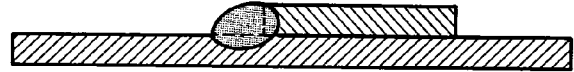


Figure 3.3C — Arc Seam Weld Along Standing Rib (See 3.4.2)

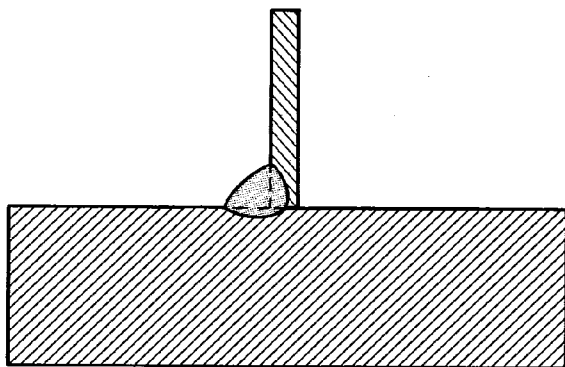


(A) SHEET TO STRUCTURAL MEMBER

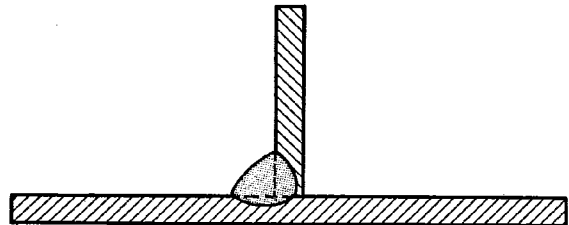


(B) SHEET TO SHEET

Figure 3.4A — Fillet Welds in Lap Joints (See 3.5)



(A) SHEET TO STRUCTURAL MEMBER



(B) SHEET TO SHEET

Figure 3.4B — Fillet Welds in T-Joints (See 3.5)

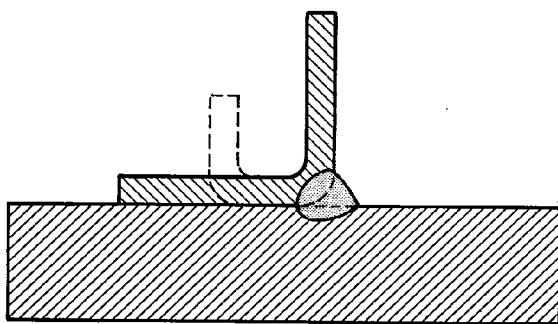


Figure 3.5 — Single-Flare-Bevel-Groove Weld — Horizontal Position (See 3.6)

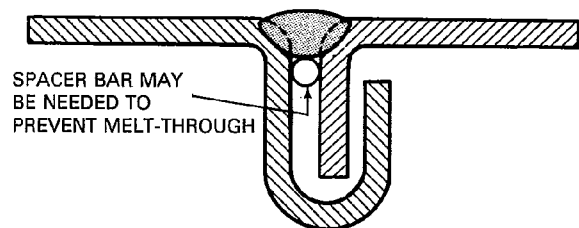


Figure 3.6 — Single-Flare-V-Groove Weld — Flat Position (See 3.7)

4. Workmanship

4.1 Preparation of Material

4.1.1 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.

4.1.2 When galvanized sheet steel or sheet steel having other protective coatings is welded, suitable ventilation shall be provided to prevent the concentration of fumes injurious to the welder (see 8.3 and 8.4 of ANSI/ASC Z49.1, *Safety in Welding and Cutting*, published by the American Welding Society).

4.1.3 Welding shall not be done when the ambient temperature is lower than 0°F (-18°C); or when surfaces are wet or exposed to rain, sleet, snow, or high wind; or when welders are exposed to inclement conditions.

4.2 Assembly

4.2.1 Joint details shall be arranged to provide the most favorable position for welding. (See Appendix C for definitions of the welding positions.)

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

4.3 Proper Setting of Welding Current. In order to obtain consistently sound welds, the welding current must be effectively controlled. For shielded metal arc welding, the welding current shall be controlled to reproduce the electrode melting rate which was established during the procedure qualification (see Commentary, C5.2.4). For flux cored arc welding, gas metal arc welding, or submerged arc welding, the welding current shall be controlled by the wire feed speed or by monitoring with an ammeter.

4.4 Quality of Welds. Welds shall be visually inspected for their location, size, and length in conformance to the drawings and specifications, as well as for their qualities such as bead shape, reinforcement, and undercut.

4.5 Production Weld Acceptance Criteria

4.5.1 Production welds shall be subjected to visual inspection.

4.5.2 A weld shall be acceptable by visual inspection, provided all four of the following criteria are met.

4.5.2.1 The weld has no cracks.

4.5.2.2 The weld has a minimum reinforcement of 1/32 in. (1 mm) for all square groove, arc spot, and arc seam welds.

4.5.2.3 The cumulative length of undercut is 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.

4.5.2.4 Faces of fillet welds shall be flat or slightly convex.

5. Technique

5.1 Filler Metal Requirements

5.1.1 For groove welds in butt joints, the electrodes or electrode and gas or flux combinations shall be in accordance with Table 5.1.

5.1.2 For all other types of welds, the electrodes or electrode and gas or flux combinations used in production shall produce weld metal with a nominal tensile strength at least equal to that of the weaker of the two members being joined.

5.2 Electrodes for Shielded Metal Arc Welding

5.2.1 Electrodes for SMAW shall conform to the requirements of the latest edition of ANSI/AWS A5.1, *Specification for Mild Steel Covered Arc Welding Electrodes*, or to the requirements of ANSI/AWS A5.5, *Specification for Low Alloy Steel Covered Arc Welding Electrodes*.

5.2.2 All electrodes having low hydrogen coverings conforming to ANSI/AWS A5.1 shall be purchased in hermetically-sealed containers or shall be dried for at least two hours between 450°F (230°C) and 500°F (250°C) before they are used. Electrodes having low hydrogen coverings conforming to ANSI/AWS A5.5 shall be purchased in hermetically-sealed containers or shall be dried at least one hour at temperatures between 700°F (370°C) and 800°F (430°C) before being used. Electrodes shall be dried prior to use if the hermetically-sealed container shows evidence of damage. Immediately after the opening of the hermetically-sealed container or removal of the electrode from a drying oven, electrodes shall either be used or stored in ovens held at a temperature of at least 250°F (120°C). E70XX and E70XX-X electrodes that are not used within four

Table 5.1
Matching Filler Metal Requirements
(see 5.1.1)

Steel Specification	Minimum Yield Point		Minimum Tensile Strength		Filler Metal Requirements
	ksi	MPa	ksi	MPa	
A446 Gr A	33	230	45	310	SMAW AWS A5.1 or A5.5 E60XX, E70XX or E70XX-X
Gr B	37	255	52	360	
Gr C	40	275	55	380	
A570 Gr 30	30	205	49	340	SAW AWS A5.17 or A5.23 F6X-EXXX or F7AX-EXXX
Gr 33	33	230	52	360	
Gr 36	36	250	53	365	
Gr 40	40	275	55	380	GMAW AWS A5.18 ER70S-X
Gr 45	45	310	60	415	
Gr 50	50	345	65	450	
A606	45	310	65	450	FCAW AWS A5.20 E60T-X or E70T-X (except 2 and 3)
A607 Gr 45	45	310	60	415	
Gr 50	50	345	65	450	
A611 Gr A	25	175	42	290	SMAW AWS A5.1 or A5.5 E70XX or E70XX-X SAW AWS A5.17 or A5.23 F7AX-EXXX GMAW AWS A5.18 ER70S-X FCAW AWS A5.20 E70T-X (except 2 and 3)
Gr B	30	205	45	310	
Gr C	33	230	48	335	
Gr D	40	275	52	360	
A607 Gr 55	55	380	70	485	SMAW AWS A5.5 E80XX-X SAW AWS A5.23 F8AX-EXXX GMAW AWS A5.28 ER80S FCAW AWS A5.29 E8XT
A446 Gr E	80	550	82	565	
A607 Gr 60	60	415	75	515	
Gr 70	70	485	85	585	
A611 Gr E	80	550	82	565	

Note: Low hydrogen electrodes must be used when required by ANSI/AWS D1.1. See 1.1.1.

hours or E80XX-X electrodes that are not used within two hours after the opening of the hermetically-sealed container or the removal of the electrodes from a drying or storage oven shall be redried before use. Electrodes that have been wet shall not be used.

5.2.3 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.

5.2.4 A good measure of welding current can be provided by the melting rate (M) of the electrode.

$$M = \frac{\text{Inches of electrode melted}}{\text{Time in minutes}}$$

The application of this method is described in detail in the Commentary, C5.2.4.

5.3 Submerged Arc Welding

5.3.1 The bare electrodes and fluxes used in combination for submerged arc welding shall conform to the requirements of the latest edition of ANSI/AWS A5.17, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*, or to the requirements of the latest edition of ANSI/AWS A5.23, *Specification for Bare Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*.

5.3.2 When requested by the Engineer, the contractor shall furnish an electrode manufacturer's certification

that the electrode and flux combination will meet the requirements of the classification or grade.

5.3.3 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. Flux fused in welding shall not be reused.

5.4 Gas Metal Arc and Flux Cored Arc Welding Electrodes

5.4.1 The electrodes and shielding for gas metal arc welding or flux cored arc welding for producing weld metal with minimum specified yield strength of 60 000 psi (415 MPa) or less, shall conform to the requirements of the latest edition of ANSI/AWS A5.18, *Specification for Mild Steel Electrodes for Gas Metal Arc Welding*, or ANSI/AWS A5.20, *Specification for Mild Steel Electrodes for Flux Cored Arc Welding*, as applicable.

5.4.2 When requested by the Engineer, the contractor shall furnish the electrode manufacturer's certification that the electrode will meet the above requirements of classification or grade.

5.4.3 A gas or gas mixture used for shielding in gas metal arc welding or flux cored arc welding, shall be of a welding grade having a dew point of -40°F (-40°C) or lower. When requested by the Engineer, the gas manufacturer shall furnish certification that the gas or gas mixture meets the procurement specification and will meet the dew point requirement.

5.5 Stud Welding. When stud welding through decking, or roofing onto supporting structural members, the procedure shall conform to applicable provisions of ANSI/AWS D1.1, *Structural Welding Code — Steel*.

6. Qualification

6.1 Approved Procedures. This specification does not accord prequalified status to any welding procedures for sheet steel.

6.2 Procedure Qualification

6.2.1 Each welding procedure to be employed shall be prepared as a procedure specification for each type of

weld as shown in Table 6.1 and shall be qualified by the contractor. Qualification documentations shall be made available to those authorized to examine them. A suggested form listing the information required in the procedure specification is given in Appendix A; data shall include the established melting rate referred to in 5.2.4.

6.2.2 At the Engineer's discretion, evidence of previous qualification of the welding procedures to be employed on production work may be accepted.

6.3 Responsibility for Tests. Each manufacturer or contractor shall be responsible for utilizing the proper material, joint configuration, setup dimensions, and testing of procedure qualification specimens. These tests may be performed in the contractor's shop, at the jobsite, or by an independent laboratory or other testing agency.

6.4 Procedure Qualification Requirements. Welding procedures shall be qualified for each change in essential variables as listed in 6.6.

However, where a sheet steel is to be welded to a supporting steel member listed in ANSI/AWS D1.1, *Structural Welding Code — Steel*, that sheet steel may be welded to all other ANSI/AWS D1.1 approved steels of an equal strength, or less, provided that the steel used in the qualification procedure has a yield strength of 50 ksi (345 MPa) or less (see ANSI/AWS D1.1, section 5).

6.5 Duration of Qualification. Once a welding procedure has been qualified by a contractor, it shall be considered qualified for that contractor's use indefinitely. However, any change in the essential variables outside the limits provided for in 6.6 shall require requalification.

6.6 Essential Variables — Procedure Qualification. A change in the following variables shall be considered essential changes in a welding procedure and shall require establishing a new procedure by qualification:

(1) A change in the classification of electrode (e.g., a change from E6010 to E6012)

(2) A change increasing the filler metal strength level (a change from E70XX to E80XX-X, for example, but not vice versa)

(3) A change in the size of the electrode

(4) Changes of more than 10% above or below the melting rate, amperage, or wire feed speed used in the procedure qualification test; 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%

(5) A change in the type of welding current (AC or DC) or polarity

(6) 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

(b) For joints other than those in 6.6(6)(a), a change in sheet steel thickness to less than $0.5t$ or greater than $2t$, where t is the thickness of the thinner steel qualified

(c) As an acceptable alternate to 6.6(6)(b) the following qualification tests may be used to cover the complete range of all sheet steel thicknesses

[1] A qualification weld performed on 18 gage sheet steel shall provide qualification for that procedure for sheet steel 16 gage and thinner.

[2] A qualification performed on 10 gage or thicker shall provide qualification for that procedure for sheet steel as thin as 16 gage and thicker, up to $2t$ thickness, where t is the thickness of the thinner sheet steel qualified.

(7) An increase in the root opening of a square groove weld

(8) 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.)

(9) An increase exceeding 30% in the thickness of coating of the sheet steel

(10) A change in the position in which welding is done

(11) In vertical position welding, a change in the progression specified from downward to upward, or vice versa

(12) A change in shielding gas (for GMAW or FCAW)

(13) A change in flux (for SAW)

(14) A change in more than 10% above or below the specified mean arc voltage for each electrode diameter used (for SAW, GMAW, or FCAW)

(15) An increase of 25% or more or a decrease of 10% or more in the rate of flow of shielding gas or mixture (for GMAW or FCAW)

(16) A change in the mode of metal transfer across the arc (for GMAW)

(17) For square groove welds in butt joints, a change in welding from both sides to welding from one side, but not vice versa.

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

6.7 Number of Tests, Methods of Testing, and the Results Required for the Qualification of Welding Procedures

6.7.1 Square Groove Welds in Butt Joints

6.7.1.1 The contractor shall establish a welding procedure for square grooves in butt joints for each position of welding and for each thickness of sheet steel to sheet steel to be welded, in accordance with 6.6(6)(b) or 6.6(6)(c). The test assembly shall be prepared, welded, and tested as follows:

(1) Two rectangular pieces of material to be tested, at least 4 in. (100 mm) wide and long, shall be welded together. The welder shall use a welding procedure that will make sound welds. The joint shall be welded either from one side only or from both sides. Welding from only one side will qualify square groove butt joints welded from one side or from both sides; welding from both sides will qualify only square groove butt joints welded from both sides.

(2) The weld shall be reasonably uniform in appearance and shall be free of cracks, excessive undercut, and excessive reinforcement.

(3) After the test joints have been made, they shall be bent back upon themselves by hammering, the axis of the bend being parallel to the axis of the weld. See Figure 6.1. In case of a joint welded from one side only, the root of the weld shall be on the face of the bend.

(4) A weld shall be considered satisfactory if

(a) No cracks are evident after bending.

(b) Due to the severity of the test, cracks do occur, but the fractured face shows no evidence of defects, and the throat is equal to or greater than the thickness of the sheet steel. Breaks in the base metal shall not be cause for weld rejection.

(5) After each welding procedure has been qualified, it shall be recorded as a welding procedure specification; see the suggested form in Appendix A.

6.7.1.2 Qualification for square groove welds in sheet steels shall qualify for such grooves only for the position used in the test, provided that there is no change in other essential variables.

6.7.2 Arc Spot Welds (Puddle Welds)

6.7.2.1 The contractor shall establish a welding procedure for each single and double thickness of sheet steel to be arc spot welded to a supporting member in the flat position. Two test assemblies shall be prepared, welded, and tested as follows:

(1) Two (or four for a double sheet) rectangular pieces of this material $2\frac{1}{2}$ in. (65 mm) or wider shall be clamped to the top of a flange of a remnant beam, or separate plate at least $\frac{1}{2}$ in. (13 mm) thick, with a narrow edge of the sheet projecting over the edge of the flange or plate by 2 in. (50 mm), as shown in Figure 6.2.

14

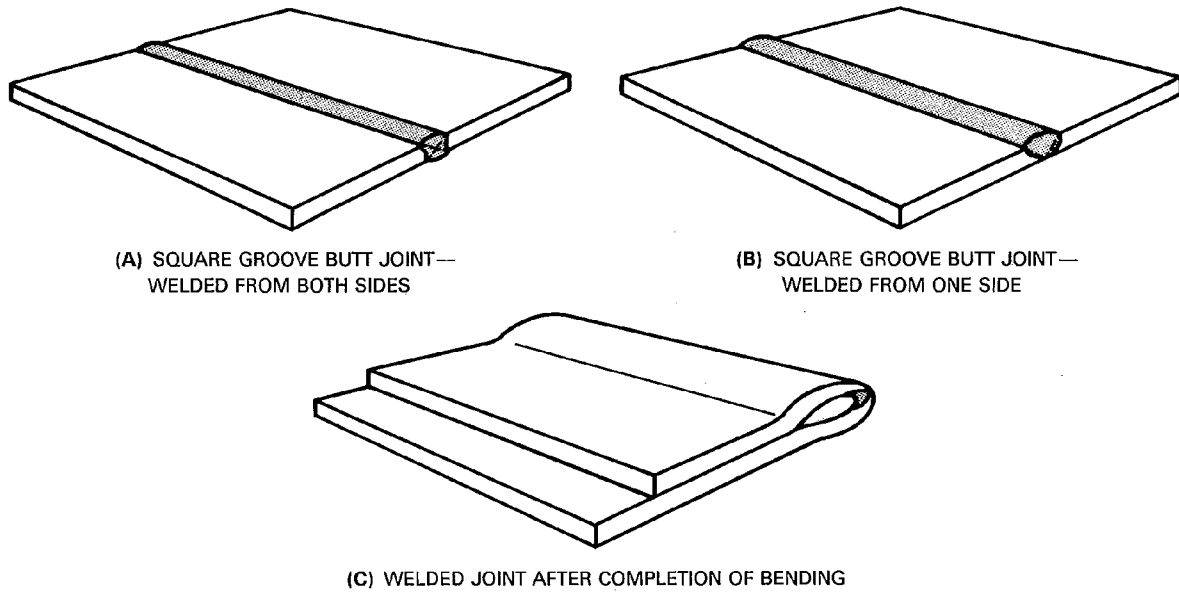


Figure 6.1 — Square-Groove Butt Joints (See 6.7.1.1)

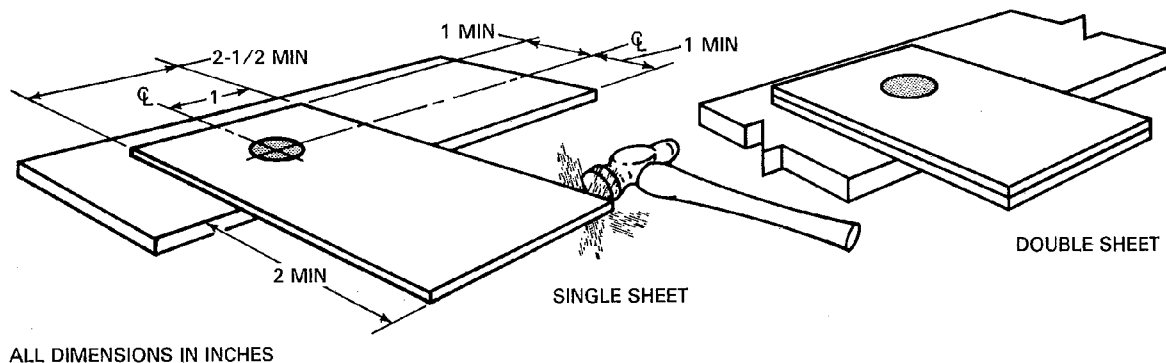


Figure 6.2 — Test for Arc Spot Weld (See 6.7.2.1)

(2) The welder shall make an arc spot weld of the diameter required for procedure qualification, producing a nugget not less than 1/2 in. (13 mm) in diameter. The crater of the spot weld shall be filled and 1/32 in. (1 mm) minimum reinforcement provided.

(3) Weld washers, 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 in containing the arc spot weld in sheet steel thinner than 0.028 in. (0.7 mm).

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

(5) After welds of acceptable quality have cooled, the projecting part of the sheet steel shall be struck repeatedly with a hammer, as shown in Figure 6.2, until the sheet steel around the arc spot weld disengages, either from a break in the weld or the sheet steel. The diameter of the weld nugget remaining in the structural steel shall

be measured for the required minimum diameter of 1/2 in. (13 mm). If such minimum diameter has not been obtained or if the weld is otherwise not satisfactory (see 4.5.2), the welding current shall be adjusted and the test repeated until all requirements are met.

(6) The melting rate for the particular electrode classification and size used in the successful test shall then be measured.² A second successful test shall be performed.

6.7.2.2 When more than one arc spot weld is to be made with one covered electrode, the welder shall melt at least 6 in. (150 mm) of a new electrode using the same melting rate established in 6.7.2.1, and depositing a weld bead on a scrap plate. While the electrode is still hot, the welder shall deposit another arc spot test weld using the assembly shown in Figure 6.2. This weld shall be tested as stipulated in 6.7.2.1, and the results shall be compared with previous tests considered satisfactory. (See Commentary, C6.7.2.2 for background data.) In the case of flux cored arc welding, gas metal arc welding, or submerged arc welding, the welding current or wire feed rate shall be used.

6.7.2.3 After each welding procedure has been qualified, it shall be recorded as a welding procedure specification; see the suggested form in Appendix A.

6.7.2.4 The qualification of an arc spot weld between a sheet, (or two sheets) and a supporting member in the flat position, shall qualify (1) arc spot welds, and (2) arc seam welds, having a width equal to the diameter tested. A change in one of the following essential variables, (exceeding the requirements of 6.6) will require requalification: a change in thickness of sheet steel, weld size, electrode classification; for shielded metal arc welding, a change in the melting rate, and a change in the welding current or wire feed rate for flux cored arc welding, gas metal arc welding, or submerged arc welding. See Table 6.1.

6.7.2.5 For arc spot welds, procedures qualified at base metal temperatures of 60°F (16°C) or higher may be used 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.

6.7.3 Arc Seam Welds

6.7.3.1 The contractor shall establish a welding procedure for each single and double thickness of sheet steel to be arc seam welded to a supporting member in the flat position, or for each single thickness of sheet steel to sheet steel to be arc seam welded in the horizontal position. Two test assemblies are required.

2. See Commentary, C5.2.4.

(1) In the case of sheet to supporting member, two rectangular pieces (four for double thicknesses) of material wider than 3 in. (75 mm) shall be clamped to the flange of a remnant beam or separate plate at least 1/2 in. (13 mm) thick, with the narrow edge of the sheet projecting over the edge of the flange or plate by 1/2 in. (13 mm), as shown in Figure 6.3A. The test weld shall be made in the flat position.

(2) In the case of sheet to sheet, a sample of the actual joint shall be welded in the horizontal position (see Figure 6.3B.) The minimum length of the weld shall be 1 in. (25 mm). (See Figure 6.3A.)

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

(4) After cooling, welds of acceptable visual quality shall be tested by bending the sheet back and forth, or by wedging a chisel between the pieces until the weld, or the sheet steel fails.

(5) The fracture surface shall show complete fusion at the faying surface.

6.7.3.2 After each welding procedure has been qualified, it shall be reported as a welding procedure specification. See the suggested form in Appendix A.

6.7.3.3 As an option, the arc seam weld may be qualified, according to 6.7.2.4, by making an arc spot weld having the same diameter as the width of the arc seam weld being considered.

6.7.3.4 The qualification of an arc seam weld between a sheet or two sheets, and a supporting member in the flat position, or an arc seam weld between two sheets in the horizontal position shall qualify only for that particular weld and position tested, and for that given thickness of sheet steel, weld size, electrode classification, and that electrode melting rate (for shielded metal arc welding), or that welding current or wire feed rate (for submerged arc welding, gas metal arc welding, or flux cored arc welding). See Table 6.1.

6.7.3.5 For arc seam welds, procedures qualified at base metal temperatures of 60°F (16°C) or higher may be used 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.

6.7.4 Fillet Welds

6.7.4.1 The contractor shall establish a welding procedure for fillet welds in joints involving:

- (1) sheet steels
- (2) sheet steel and supporting members for each welding process, each position of welding, each thickness of

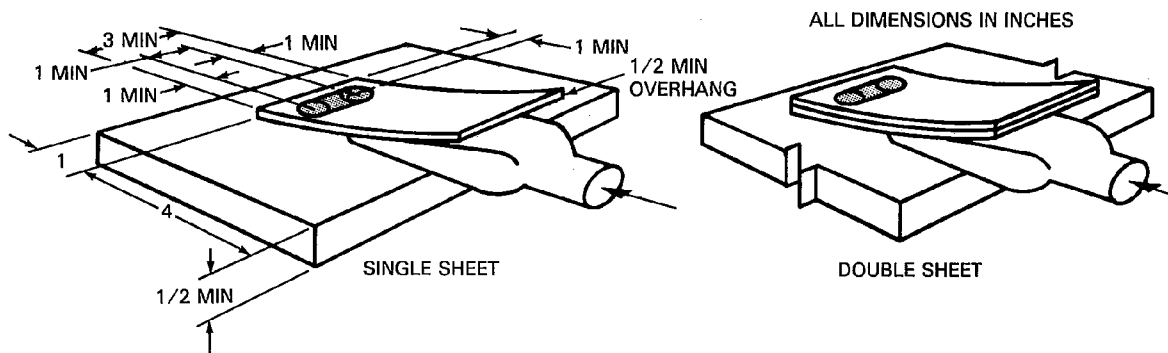


Figure 6.3A — Arc Seam Weld Test — Sheet to Supporting Plate Weld (See 6.7.3.1)

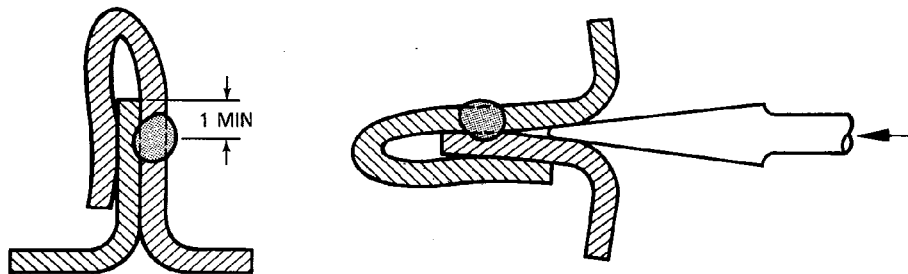


Figure 6.3B — Arc Seam Weld Test — Sheet to Sheet Weld (See 6.7.3.1)

sheet steel in accordance with 6.6(6)(b) or 6.6(6)(c), and each material combination of sheet steels, including supporting members in accordance with 6.4 (see Table 6.1.)

6.7.4.2 Two test assemblies shall be prepared, welded, visually inspected, and tested using either Test A or Test B, described in (1) or (2) as follows:

(1) Test A. Each test assembly shall consist of two rectangular pieces of sheet steel, at least 3 in. (75 mm) wide. A fillet weld 1 in. (25 mm) long shall be deposited in either a lap or a T-joint, whichever is required, using the proper type and size of electrode and welding current. The test assembly is shown in Figure 6.4.

(2) Test B. Each assembly shall consist of a rectangular piece of sheet steel, at least 3 in. (75 mm) wide, and the top of a flange of a remnant beam or separate plate, at least 1/2 in. (13 mm) thick. A fillet weld 1 in. (25 mm) long shall be deposited in either a lap or a T-joint, whichever is required, using the proper type and size of electrode and welding current. The test assembly is shown in Figure 6.4.

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

(4) After cooling, welds of acceptable visual quality shall be tested by bending the sheet back and forth (T-joints), or by wedging a cold chisel between the two pieces (lap joints) until either the weld or the sheet metal fails. See Figure 6.4.

(5) The fractured surface shall show complete fusion at the faying surface.

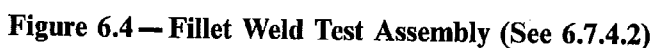
(6) After each welding procedure has been qualified, it shall be recorded as a welding procedure specification; see the suggested form in Appendix A.

6.7.4.3 The validity of qualification shall be as follows (see Figure 6.5):

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

(2) Sheet steel to supporting member qualifies for sheet steel to supporting 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 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.



(b) Test D. 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 remnant 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

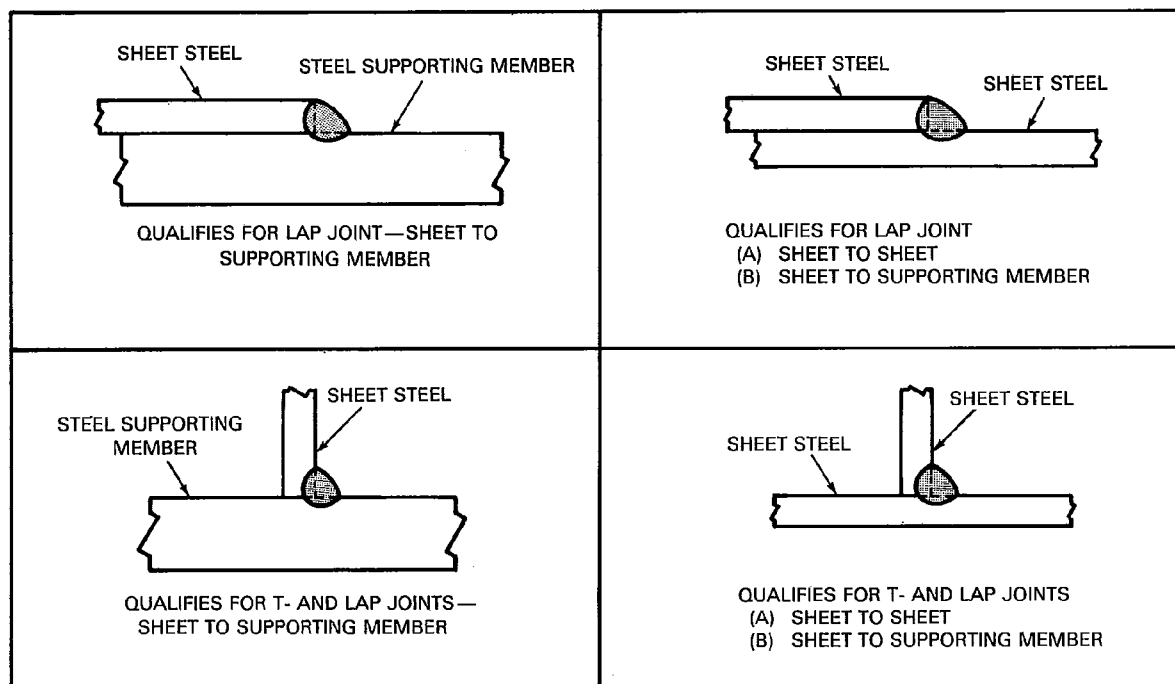


Figure 6.5—Extent of Validity of Fillet Weld Qualification (See 6.7.4.3)

using the proper type and size of electrode and welding current. The test assembly is shown in Figure 6.6B.

(2) For 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 3t, 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 6.6C.

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

(4) 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 6.6C.

(5) The fracture surface shall show complete fusion at the faying surface.

(6) After each welding procedure has been satisfactorily established and qualified, it shall be reported as a

welding procedure specification; see the suggested form in Appendix A.

6.7.5.2 Qualification for flare-bevel-groove welds shall qualify for flare-V-groove welds and vice versa, provided the same essential variables apply. See Figure 6.7.

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

6.7.6 Stud Welds. When qualifying studs to be fused through sheet steels onto structural members, the sheet steel must be placed tightly against the structural member. The quality control requirements of ANSI/AWS D1.1, *Structural Welding Code — Steel*, shall apply.

6.8 Welder Performance Qualification

6.8.1 General. The qualification tests described here-in are specially devised tests to determine the welder's ability to produce sound welds. Welding shall be per-

formed in accordance with the requirements of the procedure specification and recorded on a form similar to that of Appendix A.

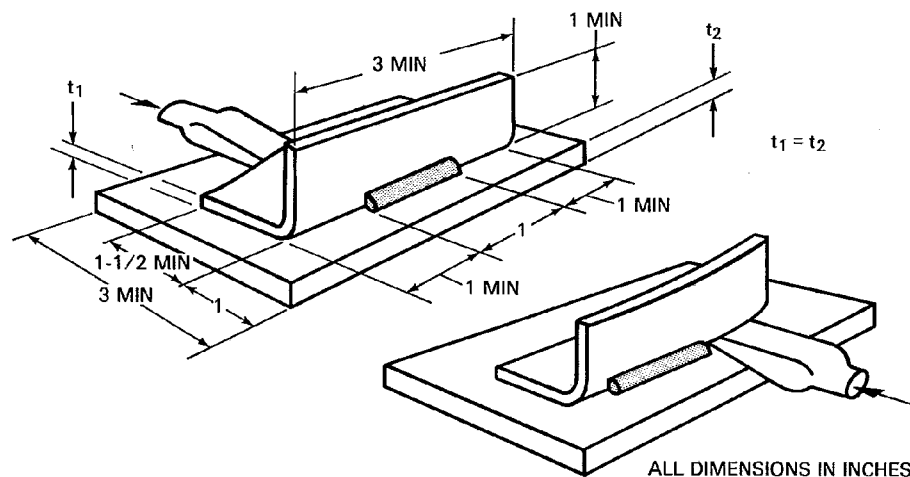
6.8.2 Limitation of Variables

6.8.2.1 Qualification established with any one of the steels permitted by this specification shall be considered as qualification to weld any of the other steels,

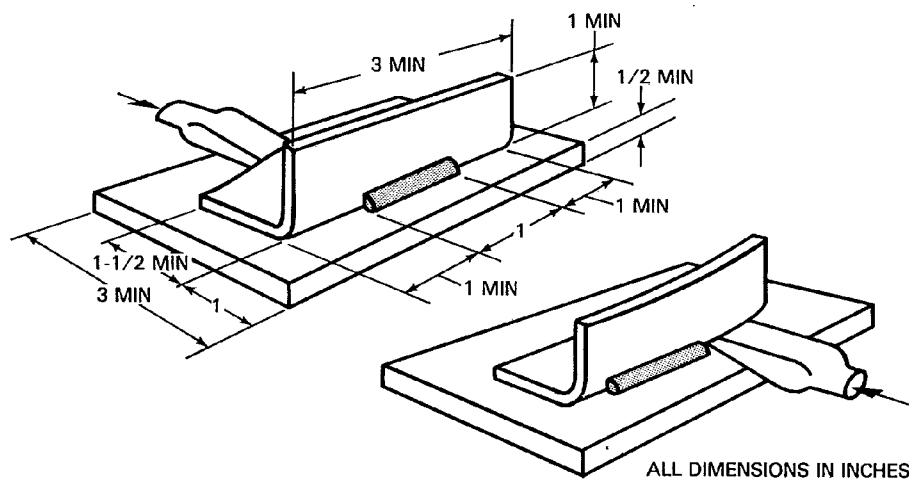
provided they have no coating or have the same coating used in qualification.

6.8.2.2 A welder must be qualified for each welding process to be used in fabrication.

6.8.2.3 A welder qualified for shielded metal arc welding with an electrode identified in the following table shall be considered qualified to weld with any other



**Figure 6.6A — Standard Test Assembly for Flare-Bevel-Groove Welds;
Test C — Sheet to Sheet (See 6.7.5.1)**



**Figure 6.6B — Standard Test Assembly for Flare-Bevel-Groove Welds;
Test D — Sheet to Supporting Plate (See 6.7.5.1)**

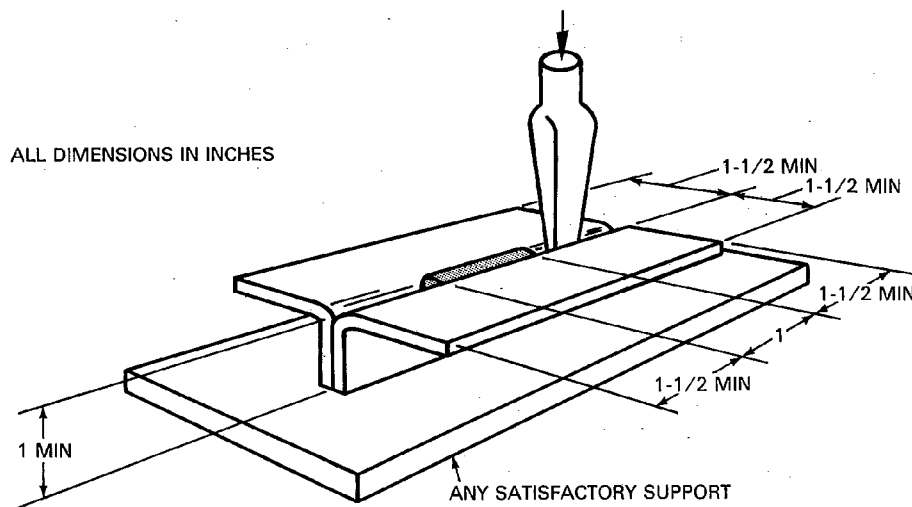


Figure 6.6C — Standard Test Assembly for Flare-V-Groove Welds (See 6.7.5.1)

electrode in the same group designation, and with any electrode listed in a numerically lower group designation.

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, (60, 70, etc.) of electrodes.

6.8.2.4 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 qualification test.

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

6.8.2.6 When welding in the vertical position, a change in the direction of welding shall require requalification.

6.8.2.7 Except as modified by 6.8.2.8, all welders shall be qualified by making a test weldment for each type of weld 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 $0.5t$ or greater than $2t$, where t is the thickness of the thinner sheet qualified.

(b) As an acceptable alternate to 6.8.2.7(2)(a), the following qualification tests may be used to cover the complete range of all sheet steel thicknesses.

[1] Qualification performed on 18 gage sheet steel shall qualify the welder or welding operator for welding sheet steel 16 gage and thinner.

[2] 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 as shown in Table 6.2.

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

6.8.2.9 The welding procedure used in the qualification of a welder shall be a qualified welding procedure. The number and type of test assemblies, their method of testing, and the test results shall be the same as for procedure qualification. See Table 6.2.

6.8.2.10 The welder who completes a successful procedure qualification shall be considered qualified for the welding process, welding position, type of weld, and

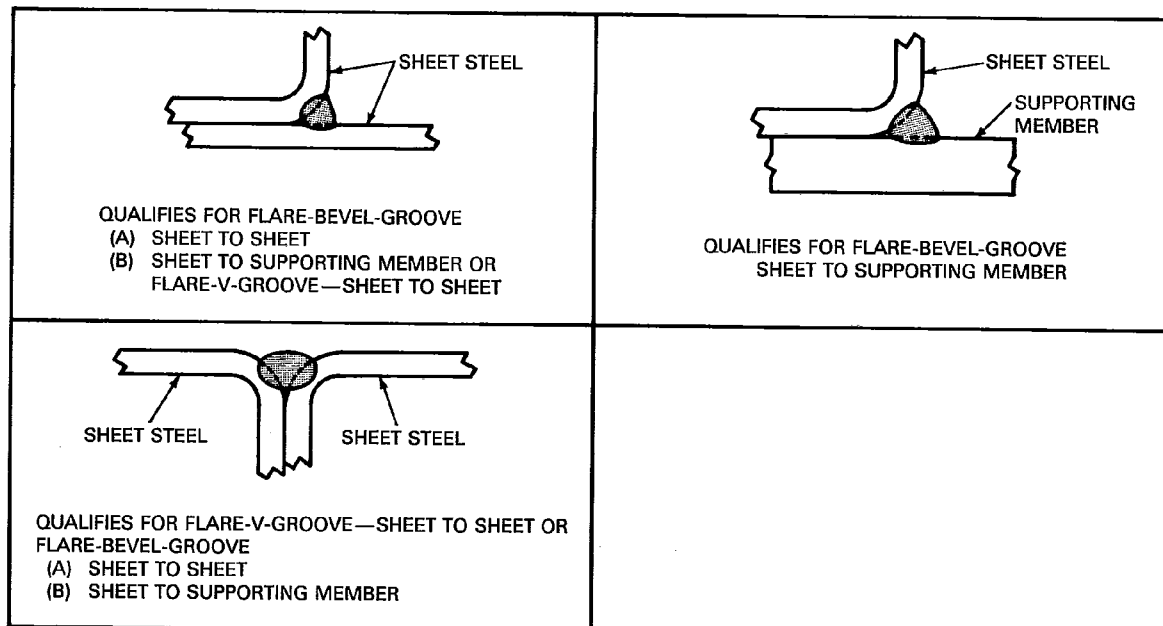


Figure 6.7 — Flare-Groove Weld Qualification (See 6.7.7.2)

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 6.2.

6.8.2.11 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.

6.8.2.12 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 Appendix A may be used.

7. Inspection

7.1 General. Welds shall be inspected visually and shall meet the quality requirements of 4.5.

7.2 Inspection of Welding Procedure and Welding Qualifications

7.2.1 The inspector shall make certain, prior to welding, that qualified and valid welding procedure specifications applicable to the contract are available, as required by this specification, and that all welders are qualified and are thoroughly familiar with these procedures.

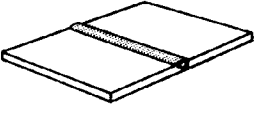
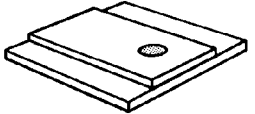
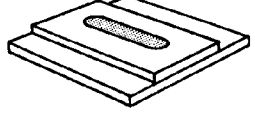
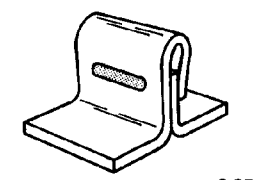
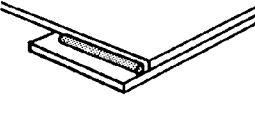
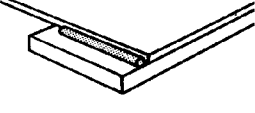
7.2.2 At the Engineer's discretion, evidence of welding procedures previously qualified by the contractor and applicable to a given contract may be accepted. However, if the Engineer does not accept such evidence, the contractor shall qualify the procedures in accordance with this specification. The contractor's weld tests shall be successfully completed before any permanent welding is done on the contract.

7.3 Inspection of Work

7.3.1 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 welding procedure 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.

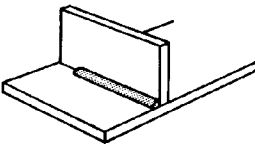
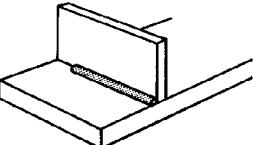
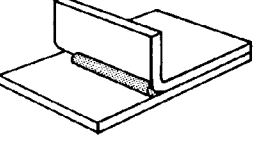
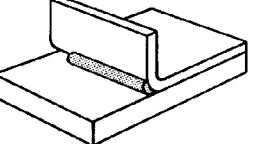
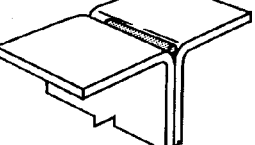
7.3.2 When the quality of a welder's work is judged by the inspector to be below the requirements of this specification, requalification of the welder may be required.

Table 6.1 — Procedure Qualification Tests (See 6.2.1)

Test Assemblies Shown In Figure:	Type of Welded Joint Tested:	Number of tests re- quired for each welding position, thickness, and type of coating*:	Type of Test:	Qualifies For:
 6.1	Square groove butt joint Sheet to sheet, each position of welding	2	Bend	Square groove butt joint, sheet to sheet, position used in test
 6.2	Arc spot weld Sheet to supporting member, flat position	2	Twist	Arc spot weld and arc seam weld, sheet to supporting member, flat position
 6.3A	Arc seam weld Sheet to supporting member, flat position	2	Bend	Arc seam weld, sheet to sup- porting member, flat position
 6.3B	Arc seam weld Sheet to sheet, horizontal position	2	Bend	Arc seam weld, sheet to sheet, horizontal position
 6.4	Fillet welded lap joint Sheet to sheet, any position	2	Bend	Fillet welded lap joint, sheet to sheet, or sheet to supporting member, position tested
 6.4	Fillet welded lap joint Sheet to supporting member, any position	2	Bend	Fillet welded lap joint, sheet to supporting member, position tested

*Within the limits of essential variables

Table 6.1 (Continued) — Procedure Qualification Tests (See 6.2.1)

Test Assemblies Shown In Figure:	Type of Welded Joint Tested:	Number of Tests Required for Each Welding Position, Thickness, and Type of Coating*:	Type of Test:	Qualifies For:
 6.4	Fillet welded T-joint, sheet to sheet, any position	2	Bend	Fillet welded T- or lap joint, sheet to sheet, or sheet to supporting member, position tested
 6.4	Fillet welded T-joint, sheet to supporting member, any position	2	Bend	Fillet welded T- or lap joint, sheet to supporting member, position tested
 6.6A	Flare bevel, sheet to sheet, any position	2	Bend	Flare-bevel-groove weld, sheet to sheet, or sheet to supporting member or flare-V-groove weld, sheet to sheet, position tested
 6.6B	Flare bevel, sheet to supporting member, any position.	2	Bend	Flare-bevel-groove weld, sheet to supporting member, position tested
 6.6C	Flare-V, sheet to sheet, any position	2	Bend	Flare-V-groove weld, sheet to sheet or flare-bevel-groove weld, sheet to sheet, or sheet to supporting member, position tested

*Within the limits of essential variables

Table 6.2 — Welder Qualification Tests (See 6.8.2.9)

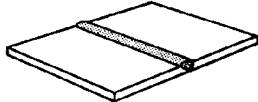
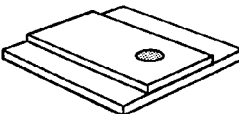
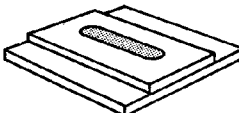
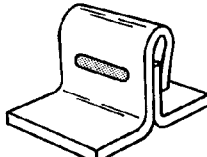
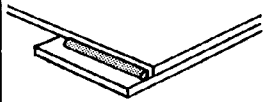
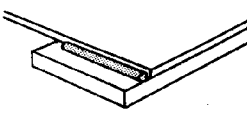
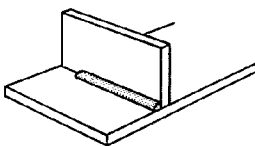
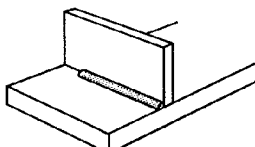
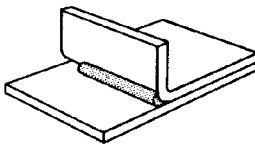
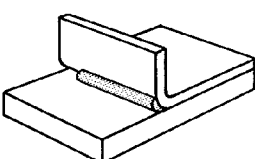
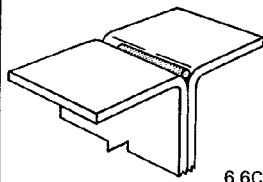
Test Assemblies Shown In Figure:	Type of:		Qualifies for:			Number of Tests	Type of Test:
	Welded Joint	Welding Position	Welding Position	Type of Welded Joint	Thickness		
 6.1	Square groove butt joint, sheet to sheet	F H V OH	F F H F H V F H OH	Square groove butt joint, sheet to sheet	Thickness tested (except as modified by 6.8.2.7(2))	2	Bend
 6.2	Arc spot weld, sheet to supporting member	F	F	Arc spot weld and arc seam weld, sheet to supporting member	Thickness tested	2	Twist
 6.3A	Arc seam weld, sheet to supporting member	F	F	Arc seam weld, sheet to supporting member	Thickness tested	2	Bend
 6.3B	Arc seam weld, sheet to sheet	H	H	Arc seam weld, sheet to sheet	Thickness tested	2	Bend
 6.4	Fillet welded lap joint, sheet to sheet	F H V OH	F F H F H V F H OH	Fillet welded lap joint, sheet to sheet, or sheet to supporting member	Thickness tested and thicker	2	Bend
 6.4	Fillet welded lap joint, sheet to supporting member	F H V OH	F F H F H V F H OH	Fillet welded lap joint, sheet to supporting member	Thickness tested and thicker	2	Bend

Table 6.2 (Continued) — Welder Qualification Tests (See 6.8.2.9)

Test Assemblies Shown In Figure:	Type of:		Qualifies for:			Number of Tests	Type of Test:
	Welded Joint	Welding Position	Welding Position	Type of Welded Joint	Thickness		
 6.4	Fillet welded T-joint, sheet to sheet	F H V OH	F F H F H V F H OH	Fillet welded T- or lap joint, sheet to sheet, or sheet to supporting member	Thickness tested and thicker	2	Bend
 6.4	Fillet welded T-joint, sheet to supporting member	F H V OH	F F H F H V F H OH	Fillet welded T- or lap joint, sheet to supporting member	Thickness tested and thicker	2	Bend
 6.6A	Flare-bevel, sheet to sheet	F H V OH	F F H F H V F H OH	Flare-bevel groove weld, sheet to sheet, or sheet to support- ing member; or flare-V-groove weld, sheet to sheet	Thickness tested and thicker	2	Bend
 6.6B	Flare-bevel, sheet to supporting member	F H V OH	F F H F H V F H OH	Flare-bevel-groove weld, sheet to supporting member	Thickness tested and thicker	2	Bend
 6.6C	Flare-V, sheet to sheet	F H V OH	F F H F H V F H OH	Flare-V-groove weld, sheet to sheet; or flare-bevel- groove weld, sheet to sheet, or sheet to supporting member	Thickness tested and thicker	2	Bend

Appendix A

Sample Welding Forms

(Nonmandatory Information)

(This Appendix is not a part of ANSI/AWS D1.3-89, *Structural Welding Code — Sheet Steel*, but is included for information purposes only.)

This appendix contains three forms that the Structural Welding Committee 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 6.1)

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 1.1)

Position of Groove _____
 Position of Fillet _____
 Progression _____

GAS (6.6)

Shielding Gas _____ Flow Rate _____
 Percent Mixture _____

FLUX (6.6)

Filler Metal (Table 5.1):
 Specification _____
 Classification _____

COATINGS(S):

Type _____
 Thickness _____

VISUAL EXAMINATION RESULTS (6.7):

Sketch of Joint Details

Specimen 1 _____
 Specimen 2 _____
 Diam of Arc Spot Nugget _____

Test Conducted by _____
 per _____
 Lab Test No. _____
 Date of Test _____

TECHNIQUE

Pass No.	Electrode Size	Welding Current		Travel Speed	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 6.7 of ANSI/AWS D1.3 (____), Structural Welding Code — Sheet Steel.
 (Year)

Authorized by _____ Date _____

Form A-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 6.1)

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 5.1):

Specification _____
Classification _____

POSITIONS (Table 1.1)

Position of Groove _____
Position of Fillet _____
Progression _____

PREHEAT (1.1.1 and 4.1.3):

Preheat Temperature Min _____
Preheat Temperature Max _____

GAS (6.6)

Shielding Gas _____ Flow Rate _____
Percent Mixture _____

FLUX (6.6)**TECHNIQUE**

Pass No.	Electrode Size	Welding Current		Travel Speed	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 ANSI/AWS D1.3 (____), Structural Welding Code — Sheet Steel.
(Year)

Authorized by _____ Date _____

Form A-2

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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:		
Material Specification	_____	_____
Sheet Steel	_____ to _____	_____ to _____
Supporting Steel	_____	_____
Sheet Thickness:	_____	_____
Groove	_____	_____
Fillet	_____	_____
Arc Spot	_____	_____
Arc Seam	_____	_____
COATING(S):		
Type	_____	_____
Thickness	_____	_____
POSITION:		
Groove	_____	_____
Fillet	_____	_____
Arc Spot	_____	_____
Arc Seam	_____	_____
Progression	_____	_____
GAS		
_____	_____	_____
ELECTRODE:		
Size	_____	_____
Group Designation	_____	_____

VISUAL EXAMINATION RESULTS (6.7)

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 welds were prepared and tested in accordance with the requirements of 6.7 of ANSI/AWS D1.3 (____), Structural Welding Code — Sheet Steel.
 (Year)

Company _____ Authorized By _____

Form A-3

Appendix B

Guidelines for Preparation of Technical Inquiries for the Structural Welding Committee

(Nonmandatory Information)

(This Appendix is not a part of ANSI/AWS D1.1-89, *Structural Welding Code — Sheet Steel*, but is included for information purposes only.)

B1. Introduction

The AWS Board of Directors has adopted a policy whereby all official interpretations of AWS standards will be handled in a formal manner. Under that policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is 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.

B2. Procedure

All inquiries must be directed to:

Technical Director
American Welding Society
550 N.W. LeJeune Road
Post Office Box 351040
Miami, FL 33135

All inquiries must contain the name, address, and affiliation of the inquirer, and they must provide enough information for the committee to fully understand the point of concern in the inquiry. Where that point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and should also be in the format used here.

B2.1 Scope. Each inquiry must address one single provision of the code, unless the point of the inquiry involves

two or more interrelated provisions. That provision must be identified in the scope of the inquiry, along with the edition of the code that contains the provisions or that the inquirer is addressing.

B2.2 Purpose of the Inquiry. The purpose of the inquiry must be stated in this portion of the inquiry. The purpose can be either to obtain an interpretation of a code requirement, or to request the revision of a particular provision in the code.

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 appendix), which bear on the inquiry must 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.

B2.3 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.

B2.3.1 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 chairman 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 will

be an official interpretation of the Society, and the secretary will transmit the response to the inquirer and to the *Welding Journal* for publication.

B2.3.2 Publication of Interpretations. All official interpretations will appear in the *Welding Journal*.

B2.3.3 Telephone Inquiries. Telephone inquiries to AWS Headquarters concerning the ANSI/AWS D1.3, *Structural Welding Code — Sheet Steel*, should be limited to questions of a general nature or to matters directly related to the use of the code. The Board of Directors' Policy requires that all 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. The Headquarters Staff can not provide con-

sulting services. The Staff can, however, refer a caller to any of those consultants whose names are on file at AWS Headquarters.

B2.3.4 The Structural Welding Committee. The Structural Welding Committee's activities, in regard to 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 the committee nor the Staff is 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.

Appendix C

Terms and Definitions

(Nonmandatory Information)

(This Appendix is not a part of ANSI/AWS D1.3-89, *Structural Welding Code — Sheet Steel*, but is included for information 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 2.2.

arc spot weld. A spot weld made by an arc welding process. See Figure 3.2A.

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 3.1

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 approxi-

mately 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 C8(D).

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 2.4A.

single-flare-V-groove weld. A weld in a groove formed by two members with curved surfaces. See Figure 3.6.

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 3.1.

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 3.4B

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.

Appendix D

Gage Numbers and Equivalent Thicknesses

(Nonmandatory Information)

(This Appendix is not a part of ANSI/AWS D1.3-89, *Structural Welding Code — Sheet Steel*, but is included for information purposes only)

Table D1
Gage Numbers and Equivalent Thicknesses
Hot-Rolled and Cold-Rolled Sheet

Manufacturers' 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 D1 is for information only. This product is commonly specified to decimal thickness, not to gage number.

Table D2
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 D2 is for information only. This product is commonly specified to decimal thickness, not to gage number.

Appendix E

Safe Practices

(Nonmandatory Information)

(This Appendix is not a part of ANSI/AWS D1.3-89, *Structural Welding Code — Sheet Steel*, but is included for information purposes only.)

This appendix 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.

E1. 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.

E2. 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 con-

sumables, 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.

E3. 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.

E4. 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 contact with hot items or handling electrical equipment.

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

E5. 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, liquids, 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, liquids, 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.

E6. 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 non-ionizing (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 non-ionizing 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.

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Commentary on Structural Welding Code — Sheet Steel

Second Edition

Prepared by
AWS Structural Welding Committee

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Commentary on Structural Welding Code — Sheet Steel

Note: All references to numbered paragraphs, tables, and figures, unless otherwise indicated, refer to subsections, tables, or figures in ANSI/AWS D1.3, Structural Welding Code — Sheet Steel. References to subsections, tables, or figures in this Commentary are prefixed with a C. For example, 5.2.4 is in ANSI/AWS D1.3, while C5.2.4 is in this commentary.

C1. General Provisions

C1.1 Introduction. The purpose of the Commentary is to provide information and background data supporting the provisions of some sections of this specification. These sections are duly identified.

C1.1.1 In terms of types of welds, this specification covers:

- (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 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.

C2. Allowable Stresses

C2.2.2 Arc Spot Welds. As already noted in C1.1.1, 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 C1(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 C1(B)] Evidence obtained from conducted tests suggests that this buckling condition occurs when the following relationship exists:

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

There are three formulas with a transition at:

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

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

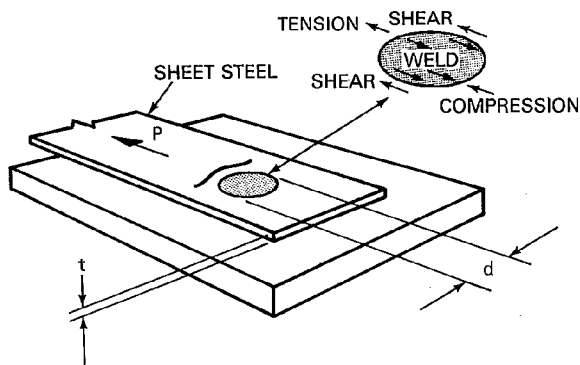
thickness (t) from the outside diameter of the weld (d). See Figure C1(C).

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 C1(D). Such reduction provides a slope of 45° at the top of the weld.

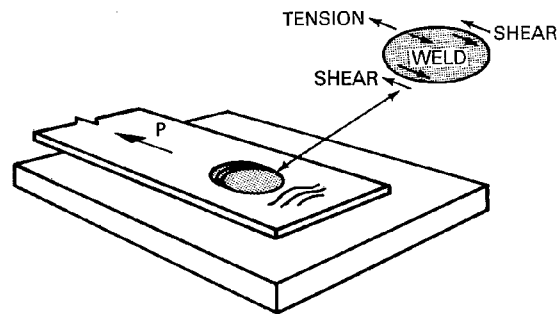
For a given overall thickness, there is less heat transferred through a double sheet than through a single sheet. For this reason, the average diameter (d_a) and the effective diameter, (d_e) will be smaller when a double sheet is used.

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.

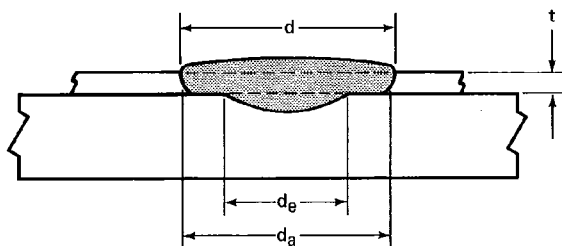
In cases where the effective diameters of the arc spot welds become too small, it is possible for them to shear



(A) TENSION, COMPRESSION, AND SHEAR STRESS



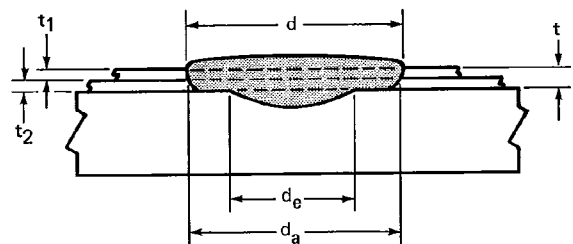
(B) TENSION AND SHEAR STRESS



$$d_a = d - t$$

$$d_e = 0.7d - 1.5t$$

(C) SINGLE THICKNESS OF SHEET



$$d_a = d - 2t$$

$$d_e = 0.7d - 1.5t$$

(D) DOUBLE THICKNESS OF SHEET

Figure C1 — Arc Spot Welds

out of the base metal. The following formulae provides a lower bound to prevent such failure. See Figure C3.

$$P = \frac{\pi(d_e)^2 F_w}{4} \text{ or } P = \frac{(d_e)^2 F_{xx}}{4}$$

where

$$d_e = 0.7d - 1.5t$$

C2.2.3 Arc Seam Welds. Some decks are made with narrow flutes which may restrict the size [effective diameter, d_e (E)] of the arc spot weld that can be made. In this case, an oblong arc spot weld, called an arc seam weld, is made. Its additional length makes up for the

smaller diameter. The minimum length of the weld is 1-1/2 in. (38 mm) and is measured between the centers of the circular portions of the weld. See Figure C4.

When used on single or double sheet steel, the respective load capacity is given by the following formula:

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

If the 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 known, 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 C5, it is possible

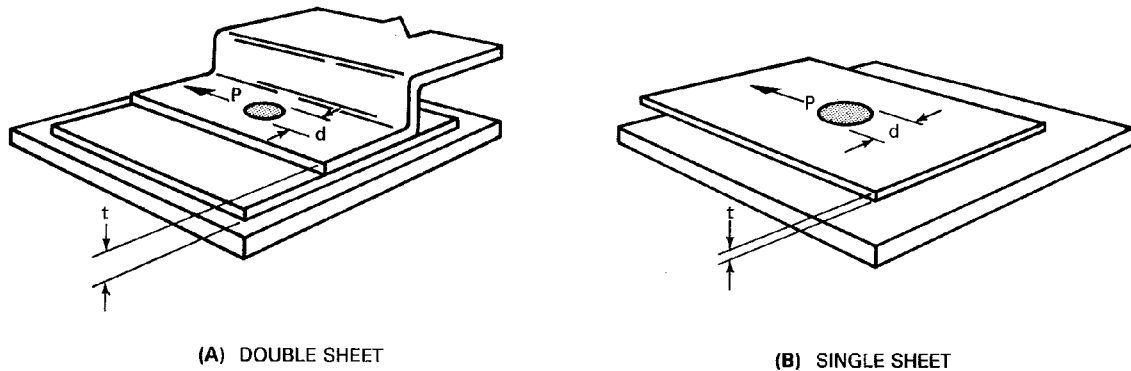


Figure C2—Load Capacities of Single and Double Sheets in Arc Spot Welds

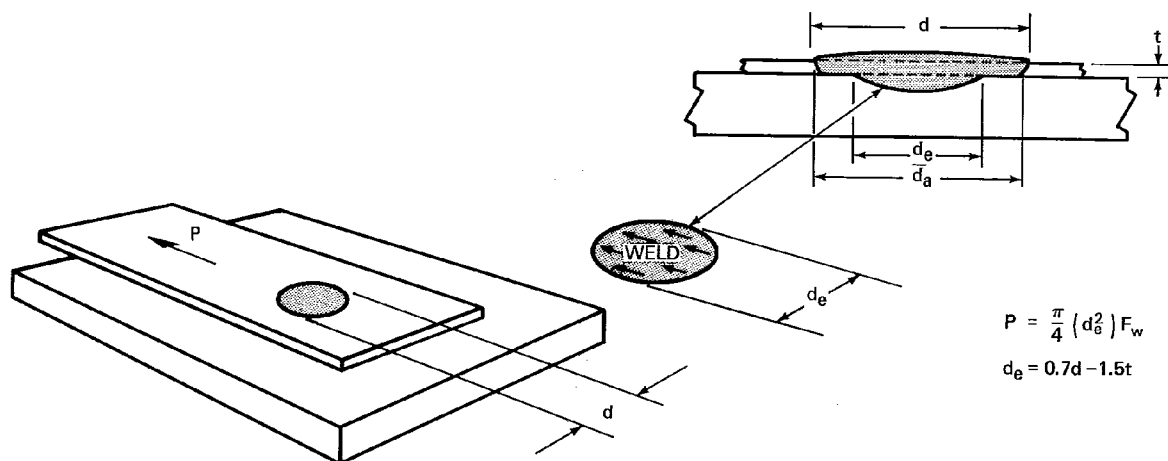


Figure C3—Small Arc Spot Welds—Shearing Action

for the weld to shear out of the base metal. The following formula provides a lower bound, intended to preclude such failure.

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

where

$$d_e = 0.7d - 1.5t$$

C2.2.4 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 C6.) However, ANSI/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 partly due to the weld metal having greater strength than the sheet steel and partly due to the large amount of penetration. For this reason, the load capacity of a fillet-welded joint in sheet steel is assumed to depend on the sheet steel immediately adjacent to the weld. See Figure C7. Formulae (7) and (8) give the load capacities for such joints.

For fillet welds on sheet steel loaded longitudinally, and having lengths less than $25 t$,

$$P = 0.4 \left(1 - 0.01 \frac{L}{t} \right) t (L) F_u$$

Research data have indicated that the unit load capacity for shorter fillet welds is greater than that calculated in the formulae in 2.2.4.1 and has led to the empirical formula shown above.

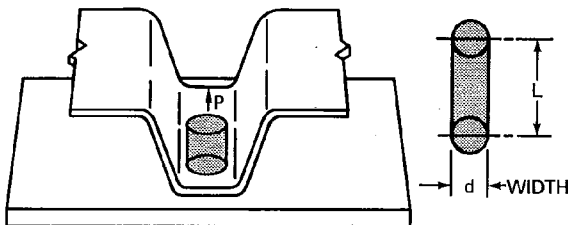


Figure C4—Arc Seam Weld in Narrow Deck Flute

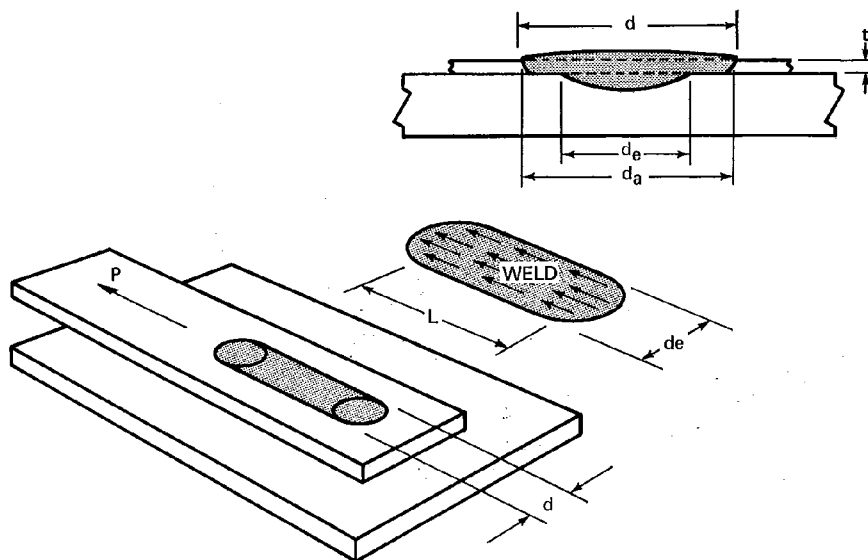
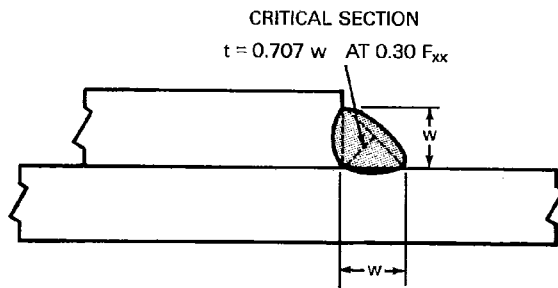
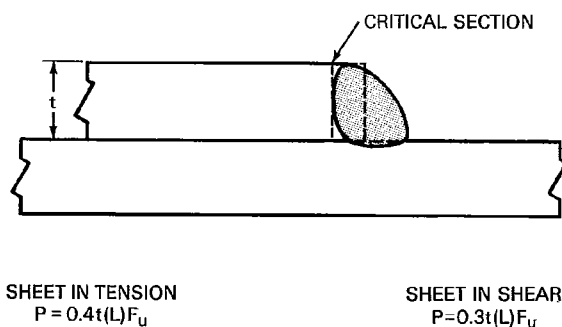


Figure C5—Arc Seam Weld in Supporting Plate



NOTE: PLATE TO PLATE APPLICATION SHOWN HERE

Figure C6 — Allowable Stress for Fillet Welds



WHERE: t = thickness of sheet steel (in.)
 L = length of welded joint (in.)
 F_{ux} = specified minimum ultimate tensile strength of sheet steel (ksi)

Figure C7 — Load Capacity of Fillet Welds

C4. Workmanship

C4.2.1 Position of Welding. The sketches in Figure C8 should assist in the proper understanding of the positions of welding.

C4.3 Proper Setting of Welding Current. In view of the fact that there are several factors which affect the value of the welding current at the arc, some positive means to set or restore the same current conditions, irrespective of these factors, had to be included in the Code. The method suggested is the melting rate of the electrode. The application of this method is described in detail in comments to 5.2.4.

The objectives of such positive current control shall be the following:

(1) To establish optimum current conditions for welding procedures which, upon qualification, fully meet strength requirements as set for the individual types of welds by the applicable code.

(2) To provide for consistent reproduction of the same optimum current conditions independent of time and factors known to affect such conditions. These factors are known to be the following:

- (a) Change in the type of power sources
- (b) Fluctuation in power supply
- (c) Effectiveness of electrical welding circuit system
- (d) Length and size of welding leads
- (e) Thickness of material and variety of protective coating
- (f) Size and type of electrodes
- (g) Type of welds

C5. Technique

C5.2.1 ANSI/AWS A5.1 and ANSI/AWS A5.5 specifications cover mild steel and low alloy electrodes.

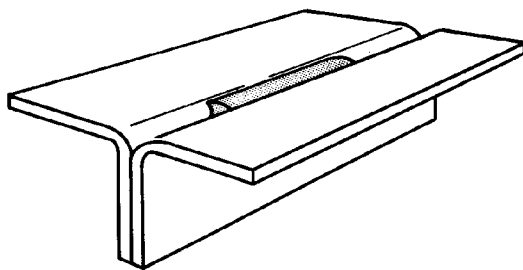
It is possible to produce satisfactory welds in sheet metal with electrodes of many types. However, some electrode classifications have better penetration than others and assist naturally in making arc spot welds and arc seam welds. Other electrode classifications are noted for their limited penetration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

C5.2.4 Melting rate as a method of measuring welding current has long been in use. Many published shielded metal arc welding procedures still include the melting rate (M) along with the welding current and other data needed.

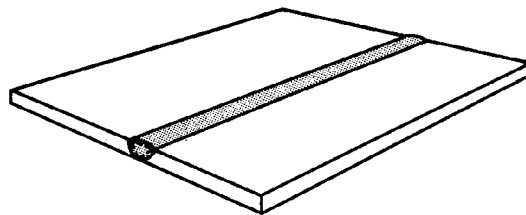
Once the welding current for a given size and classification of shielded metal arc electrode has been established, the welder should place a new electrode into its holder. The welder should proceed to weld at this current level for one minute (60 seconds) and then measure the length of electrode melted during this time interval. This can easily be done by placing a steel measuring tape along the electrode stub, as shown in Figure C9. 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

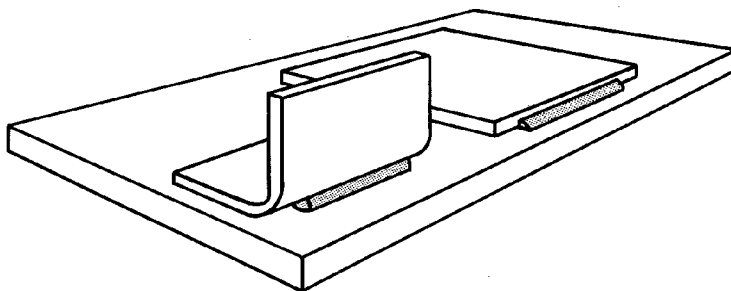
50



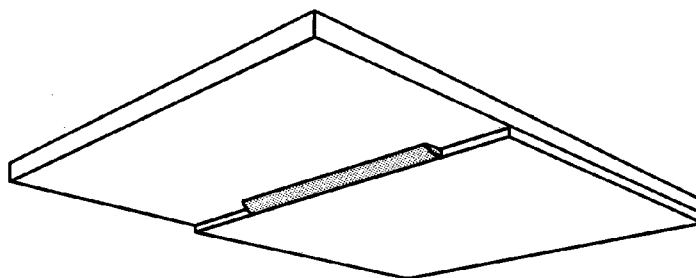
(A) FLAT



(B) HORIZONTAL



(C) VERTICAL



(D) OVERHEAD

Figure C8 — Positions of Welding

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.

C6. Qualification

C6.7.2.2 The objective of the requirement of 6.7.2.2 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. This current shall be used to measure the electrode melting

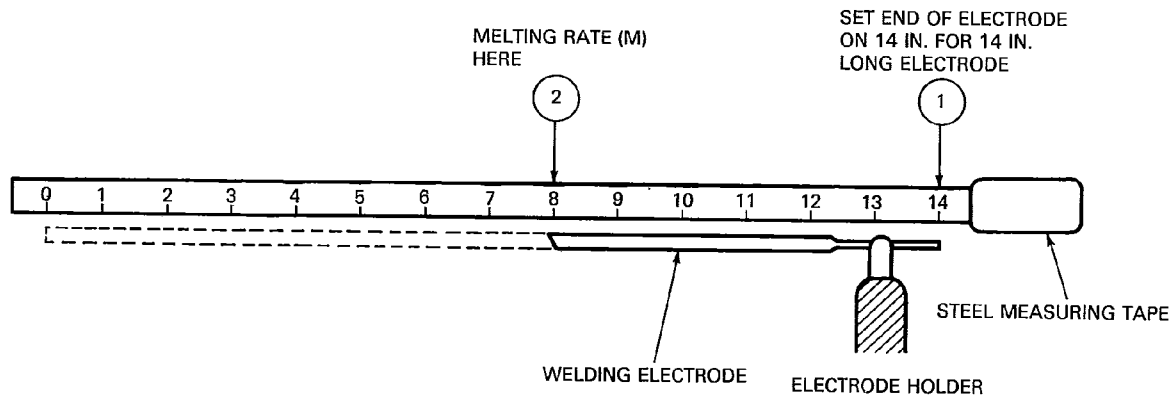


Figure C9 — Melting Rate Measurement Illustrated

rate as described here, which shall therefore be used to give evidence that the proper current level is being used in production welding.

C6.7.2.5 and C6.7.3.5 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 studies¹ on arc spot welds have been made by the Canadian Sheet Steel Industries Construc-

tion 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 analysis² 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%.

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.