

AWS D1.4/D1.4M:2005
An American National Standard

Structural Welding Code— Reinforcing Steel



American Welding Society



Key Words—Allowable stress, inspection,
qualification, reinforcing steel,
structural details, welded joint details

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An American National Standard

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Structural Welding Code— Reinforcing Steel

Including
Metal Inserts and Connections
in Reinforced Concrete
Construction

Sixth Edition

Supersedes ANSI/AWS D1.4-98

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

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This code covers the requirements for welding reinforcing steel in most reinforced concrete applications. It contains a body of rules for the regulations of welding reinforcing steel and provides suitable acceptance criteria for such welds.



American Welding Society

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Foreword

This foreword is not a part of AWS D1.4/D1.4M:2005, *Structural Welding Code—Reinforcing Steel*, but is included for informational purposes only.

In 1961, the American Welding Society published its first reinforcing steel welding standard, AWS D12.1-61, *Recommended Practices for Welding Reinforcing Steel, Metal Inserts and Connections in Reinforced Concrete Construction*. The D12 Committee was disbanded some time after publication of the 1961 code and before publication of the 1975 edition.

The 1961 document was replaced with a greatly revised version, AWS D12.1-75, *Reinforcing Steel Welding Code*, with the format patterned after the AWS D1.1-72, *Structural Welding Code*. The 1975 code was produced by the AWS Structural Welding Committee but was not renumbered to reflect this committee change. As with ANSI/AWS D1.1, AWS D12.1-75 was designed as a self-contained code, including within it the qualification of welders and procedures, and requirements for workmanship, quality, and inspection.

The listings of materials and welding processes were revised in the D12.1-75 code. Items newly introduced were the carbon equivalent method for determining preheat, the parenthetical inclusion of metric (SI) conversions, and the two different methods of joint strength determination.

The AWS D12.1-75 document was revised and the title changed to ANSI/AWS D1.4-79, *Structural Welding Code—Reinforcing Steel*. Since the 1979 edition of ANSI/AWS D1.4, *Structural Welding Code—Reinforcing Steel*, was issued, further use by designers, engineers, and fabricators has necessitated a number of changes to the requirements; the 1992 and 1998 editions reflected these changes. This edition, AWS D1.4/D1.4M:2005, has additional revisions.

The following is a summary of the significant technical revisions in this edition:

Subsection 1.3.1—Deleted ASTM specifications from listed steels: ASTM A 184, A 185, A 497, A 616, and A 617.

Table 5.2—Addresses bar sizes up to and including #6 [19] for C.E. over 0.75.

Section 5.4—New section added on weld cleaning.

Subsections to Section 6.3—Several subsections added to address welder qualification requirements and testing for fillet welds.

Subsection 7.7.3 and Section 7.9—Comprehensive approach for radiographic testing of reinforcing steel was added.

Annex A—Sample welding, testing, and inspection forms were updated.

Changes in Code Requirements. Technical and editorial changes in the text are indicated by underlining; changes to tables and figures are indicated by a single vertical line in the adjacent margin. Tables and figures have been revised, and two tables and one figure have been added.

Errata. It is the Structural Welding Committee's Policy that all errata should be made available to users of the code. Therefore, in the Society News Section of the *AWS Welding Journal*, any errata (major changes) that have been noted will be published in the July and November issues of the *Welding Journal* and posted on the AWS website at: <http://www.aws.org/technical/d1/>.

Suggestions. Your comments for improving the *Structural Welding Code—Reinforcing Steel* are welcome. Submit comments to the Managing Director, Technical Services Division, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; telephone (305) 443-9353; fax (305) 443-5951; e-mail info@aws.org; or via the AWS web site <<http://www.aws.org>>.

Errata

The following Errata have been identified and incorporated into the current reprint of this document.

Page 14—Figure 3.5, Detail C: figure on right side, upper dimension line for “NOT TO EXCEED WELD SIZE + 1/8 in. [3 mm]” moved down parallel to the bottom of the reinforcing bar.

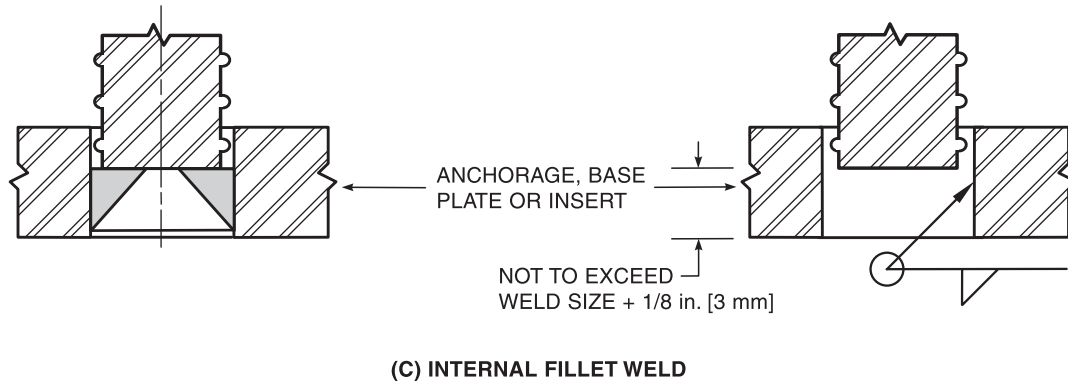


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Structural Welding Code— Reinforcing Steel

1. General Provisions

1.1 Scope

The code shall apply to the welding of:

1. Reinforcing steel to reinforcing steel, and
2. Reinforcing steel to carbon or low-alloy structural steel.

When the code is stipulated in contract documents, conformance with all provisions shall be required, except for those provisions that the Engineer or contract documents specifically modifies or exempts.

1.2 Application

1.2.1 This code shall be used in conjunction with the prescribed general building code requirements and is applicable to all welding of reinforcing steel, using the processes listed in 1.4, and performed as a part of reinforced concrete construction.

1.2.2 The weldments specified in this code shall not be used where impact properties are a requirement of the general specification. Impact testing requirements of welded reinforcing bars are not included in this code.

1.2.3 All references to the need for approval shall be interpreted to mean approval by the Engineer.

1.3 Reinforcing Steel Base Metal

1.3.1 Reinforcing steel base metal in this code shall conform to the requirements of the latest edition of one of the ASTM specifications listed within this paragraph. Combinations of any of these reinforcing steel base metals, when welded, shall use a WPS (welding procedure specification) qualified in conformance with Section 6.

1. ASTM A 82/A 82M
2. ASTM A 496/A 496M
3. ASTM A 615/A 615M
4. ASTM A 706/A 706M
5. ASTM A 767/A 767M
6. ASTM A 775/A 775M
7. ASTM A 934/A 934M

Manufacturing and testing requirements for mats and fabric are covered by the respective ASTM specification. For joining the ASTM A 82/A 82M and A 496/A 496M to other reinforcing wires, reinforcing bars, or structural steels, the Engineer shall specify filler metal and the provisions of this code shall apply.

1.3.2 When a reinforcing steel not listed in 1.3.1 is approved under the provisions of the general building code or by the Engineer, its chemical composition and carbon equivalent shall be provided and its weldability established by qualification in accordance with the requirements of 6.2 and all other requirements prescribed by the Engineer.

1.3.3 Base metal, other than those previously listed, shall be one of the structural steels listed in the latest edition of AWS D1.1, *Structural Welding Code—Steel*, or any steel stipulated in the contract documents or approved by the Engineer.

1.3.4 The carbon equivalent of reinforcing steel bars shall be calculated as shown in 1.3.4.1 or 1.3.4.2, as applicable.

1.3.4.1 For all steel bars, except those designated as ASTM A 706, the carbon equivalent shall be calculated using the chemical composition, as shown in the mill test report, by the following formula:

$$C.E. = \%C + \%Mn/6 \quad (Eq. 1)$$

1.3.4.2 For steel bars designated ASTM A 706/A 706M, the carbon equivalent shall be calculated using the chemical composition, as shown in the mill test report, by the following formula:

$$\text{C.E.} = \%C + \%Mn/6 + \%Cu/40 + \%Ni/20 + \%Cr/10 - \%Mo/50 - \%V/10 \quad (\text{Eq. 2})$$

The carbon equivalent shall not exceed 0.55%.

1.3.4.3 If mill test reports are not available, chemical analysis may be made on bars representative of the bars to be welded. If the chemical composition is not known or obtained:

1. For bars number 6 [19] or less, use a minimum preheat of 300°F [150°C].
2. For bars number 7 [22] or larger, use a minimum preheat of 500°F [260°C].
3. For all ASTM A 706/A 706M bar sizes, use Table 5.2 C.E. values of “over 0.45% to 0.55% inclusive.”

1.4 Welding Processes

1.4.1 Welding shall be performed with shielded metal arc welding (SMAW), gas metal arc welding (GMAW), or flux cored arc welding (FCAW).

1.4.2 Other welding processes may be used when approved by the Engineer, provided that any special qualification test requirements not covered here are met to ensure that welds satisfactory for the intended application will be obtained.

1.5 Definitions

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

1.6 Welding Symbols

Welding symbols shall be those designated to the latest edition of AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*. Special conditions shall be fully explained by additional notes or details.

1.7 Safety Precautions

This technical document does not address all welding and health hazards. However, pertinent information can be found in the following documents:

1. ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*
2. Manufacturer’s safety literature on equipment and materials
3. Other pertinent documents as appropriate.

These documents shall be referred to and followed as required (also see Annex D, Safe Practices).

Note: This code may involve hazardous materials, operations, and equipment. The code does not purport to address all of the safety problems 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.

1.8 Standard Units of Measurement

This standard makes use of both U.S. Customary Units and the International System of Units (SI). The measurements may not be exact equivalents; therefore, each system shall be used independently of the other without combining in any way. The standard with the designation D1.4:2005 uses U.S. Customary Units. The standard designation D1.4M:2005 uses SI Units. The latter are shown within brackets [].

1.9 Reference Documents

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For undated references, the latest edition of the referenced standard in use at the date of the contract bid submission shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

ASNT Standards¹

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

¹ ASNT standards are published by the American Society for Nondestructive Testing, 1711 Arlingate Lane, Columbus, OH 43228-0518.

ASME Standards²

1. ASME B46.1, Surface Texture
2. ASME Boiler and Pressure Vessel Code

ASTM Standards³

1. ASTM A 82/A 82M, Specification for Steel Wire, Plain, for Concrete Reinforcement
2. ASTM A 496/A 496M, Specification for Steel Wire, Deformed, for Concrete Reinforcement
3. ASTM A 615/A 615M, Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
4. ASTM A 706/A 706M, Specification for Low-Alloy Steel Deformed and Plain Bars for Concrete Reinforcement
5. ASTM A 767/A 767M, Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement
6. ASTM A 775/A 775M, Specification for Epoxy-Coated Steel Reinforcing Bars
7. ASTM A 934/A 934M, Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars
8. ASTM E 94, Standard Guide for Radiographic Examination
9. ASTM E 165, Standard Test Method for Liquid Penetrant Examination
10. ASTM E 709, Standard Guide for Magnetic Particle Examination
11. ASTM E 1032, Standard Test Method for Radiographic Examination of Weldments

² ASME standards are published by the American Society of Mechanical Engineers, 3 Park Avenue, New York, NY 10017.

³ ASTM standards are published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

AWS Standards⁴

1. ANSI Z49.1:1999, Safety in Welding, Cutting, and Allied Processes
2. AWS A2.4-98, Standard Symbols for Welding, Brazing, and Nondestructive Examination
3. AWS A3.0:2001, Standard Welding Terms and Definitions
4. AWS A5.1:2004, Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding Electrodes
5. AWS A5.5-96, Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding Electrodes
6. AWS A5.18:2001, Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding
7. AWS A5.20:2005, Specification for Carbon Steel Electrodes for Flux Cored Arc Welding
8. AWS A5.28-96, Specification for Low Alloy Steel Filler Metals for Gas Shielded Arc Welding
9. AWS A5.29:1998, Specification for Low Alloy Steel Electrodes for Flux Cored Arc Welding
10. AWS D1.1:2004, Structural Welding Code—Steel
11. AWS D12.1-75, Reinforcing Steel Welding Code (obsolete, superseded by D1.4-79)
12. AWS QC1-96, Standard for AWS Certification of Welding Inspectors

CSA Standards⁵

1. CSA Standard W178.2, Certification of Welding Inspectors

⁴ AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

⁵ CSA standards are published by the Canadian Standards Association, 178 Rexdale Boulevard, Toronto, Ontario, Canada, M9W 1R3.

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2. Allowable Stresses

2.1 Base-Metal Stresses

The allowable base-metal stresses shall be those specified in the applicable code or general specification for reinforced concrete construction.

2.2 Allowable Stresses in Welds

2.2.1 Except as modified by Table 2.1, the allowable stresses for complete joint penetration bevel and V-groove welds in direct butt joints subject to tension or compression shall be the same as the corresponding allowable stresses for the reinforcing steel base metal, provided the filler metal used has a strength classification at least equal to the tensile strength of the base metal being welded.

2.2.2 The allowable stresses for fillet welds, flare-bevel-, and flare-V-groove welds shall be in accordance with Table 2.1.

2.3 Effective Weld Areas, Lengths, Throats, and Sizes

2.3.1 Complete Joint Penetration Groove Welds in Direct Butt Joints. The effective weld area shall be the nominal cross-sectional area of the bar being welded (see Figure 3.2). If different size bars are being welded, the weld area shall be based on the smaller bar.

2.3.2 Flare-Bevel- and Flare-V-Groove Welds. The effective weld area shall be the effective weld length multiplied by the effective weld size (see Figure 2.1).

2.3.2.1 The effective weld length shall be the weld length of the specified weld size.

2.3.2.2 The minimum effective weld length shall not be less than two times the bar diameter for equal size bars or two times the smaller bar diameter for two unequal size bars.

2.3.2.3 The effective weld size, when filled flush to the solid section of the reinforcing steel bar, shall be 0.4 of the bar radius for flare-bevel-groove welds and 0.6 of the bar radius for flare-V-groove welds. Larger effective weld sizes may be used to determine allowable stresses provided, the WPS qualifies the larger weld size. When bars of unequal diameter are being joined, the effective weld size shall be based on the radius of the smaller bar. See 6.2.6.2 for macroetch test requirements for determining weld size.

2.3.3 Fillet Welds. The effective weld area shall be the effective weld length multiplied by the effective throat. (Stress in a fillet weld shall be considered as applied to this effective weld area, for any direction of applied load.)

2.3.3.1 The effective weld length of a curved fillet weld shall be measured along the weld axis.

2.3.3.2 The effective throat shall be calculated as the minimum distance from the weld root to the face of the fillet weld, minus convexity.

Table 2.1
Allowable Stresses in Welds (see 2.2.1)

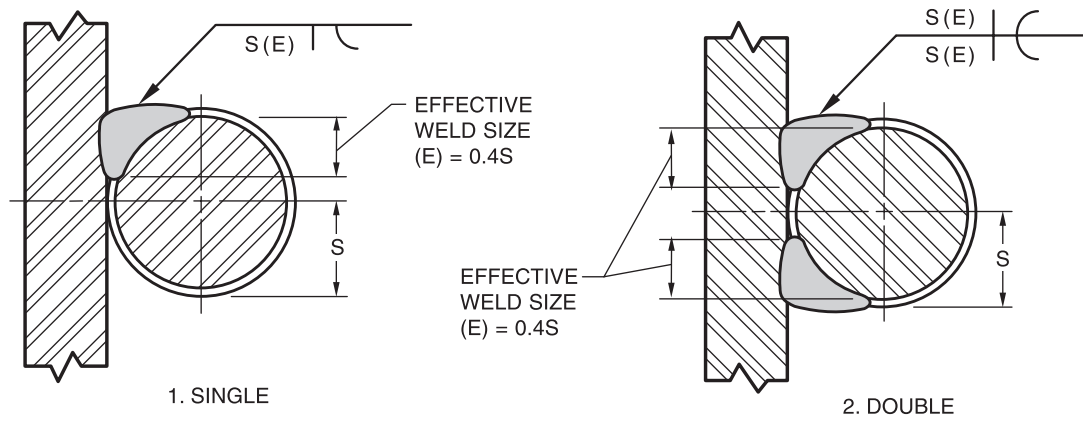
Type of Weld	Stress in Weld ^a		Allowable Stress ^{b,c}	Required Filler Metal Strength Level ^d
Complete joint penetration groove welds	Tension normal to the effective area		Same as base metal	Matching filler metal shall be used. See Table 5.1
	Compression normal to the effective area		Same as base metal	Filler metal with a strength level equal to or one classification (10 ksi [70 MPa]) less than matching filler metal may be used
	Shear on the effective areas		$0.30 \times$ nominal tensile strength of filler metal, except shear stress on base metal shall not exceed $0.40 \times$ yield strength of base metal	Filler metal with a strength level equal to or less than matching filler metal may be used
Flare-bevel and flare-V-groove welds	Compression normal to effective area	Joint not designed to bear	$0.50 \times$ nominal tensile strength of filler metal, except stress on base metal shall not exceed $0.60 \times$ yield strength of base metal	Filler metal with a strength level equal to or less than matching filler metal may be used
		Joint designed to bear	Same as base metal	
	Shear on the effective area		$0.30 \times$ nominal tensile strength of filler metal, except shear stress on base metal shall not exceed $0.40 \times$ yield strength of base metal	
	Tension normal to the effective area		$0.30 \times$ nominal tensile strength of filler metal, except tensile stress on base metal shall not exceed $0.60 \times$ yield strength of base metal	
Fillet welds	Shear on the effective area		$0.30 \times$ nominal tensile strength of filler metal	Filler metal with a strength level equal to or less than matching filler metal may be used

^a For definition of effective area, see 2.3.1, 2.3.2, and 2.3.3.

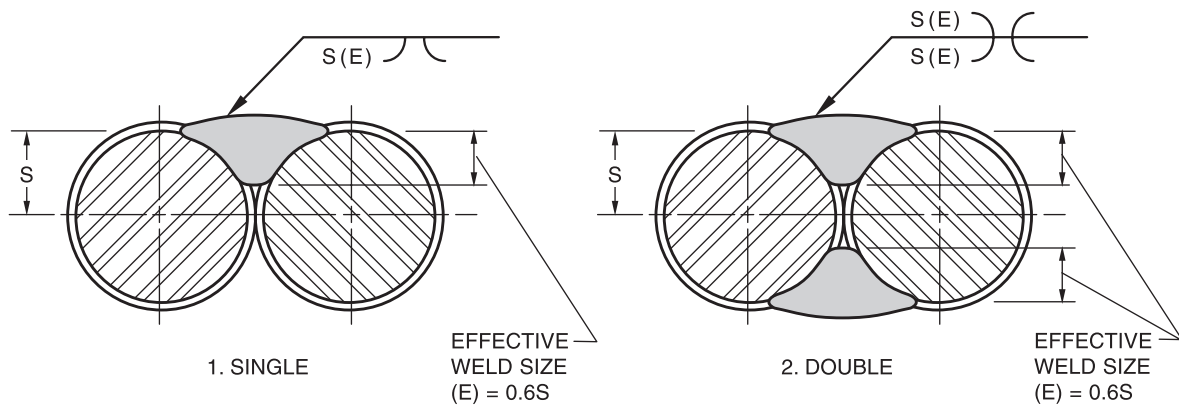
^b For fatigue or dynamic loading refer to the applicable construction code or specification for allowable stress values.

^c The Engineer should be aware that the strength of cold drawn wire may be reduced when welded.

^d For matching filler metal, see Table 5.1.



(A) FLARE-BEVEL-GROOVE WELD



(B) FLARE-V-GROOVE WELD

Notes:

1. Radius of reinforcing bar = S .
2. These are sectional views. Bar deformations are shown only for illustrative purposes.

Figure 2.1—Effective Weld Sizes for Flare-Groove Welds (see 2.3.2)

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3. Structural Details

3.1 Transition in Bar Size

Direct butt joints in tension in axially aligned bars of different size shall be made as shown in Figure 3.1 (see Annex B for bar sizes).

3.2 Eccentricity

3.2.1 Where welded lap or indirect butt joints are used (Figures 3.3 and 3.4, respectively), the concrete surrounding the joint in the finished structure shall be sufficiently strengthened with transverse reinforcement (splice plate) to prevent splitting of the concrete caused by the tendency of the joint to flex during eccentric loading.

3.2.2 Welded lap joints shall be limited to bar size No. 6 [19] and smaller.

3.3 Joint Types

Reinforcing bars may be welded with direct or indirect butt joints, lap joints, or T-joints (Figures 3.2, 3.3, 3.4, and 3.5); however, direct butt joints are preferable for bars greater than No. 6 [19].

3.4 Direct Butt Joints

Direct butt joints shall be welded with complete joint penetration groove welds. Table 3.1 and Figure 3.2 describe the type of welded joints required.

3.5 Indirect Butt Joints

An indirect butt joint shall be made with either single- or double-flare-groove welds between the bars and the splice member. See Figure 3.3.

3.6 Lap Joints

3.6.1 A lap joint shall be made with double-flare-V-groove welds [see Figure 3.4(A)], except that single-flare-V-groove welds may be used when the joint is accessible from only one side, and approved by the Engineer.

3.6.2 An indirect lap joint shall be made with single-flare-bevel groove welds between the bars and the splice plate, with the bars being separated [see Figure 3.4(B)].

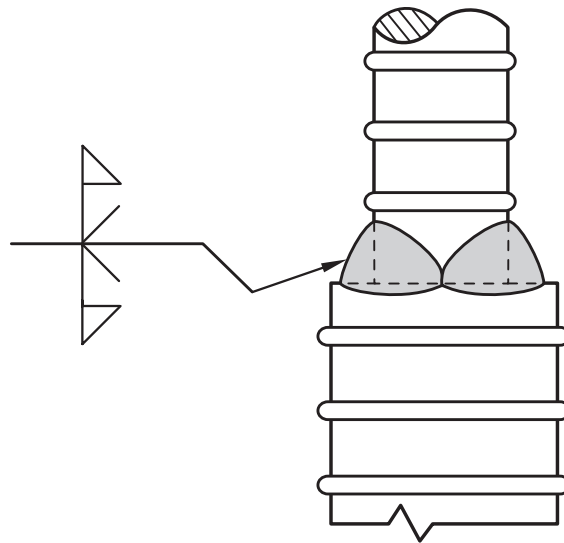
3.7 Interconnection of Precast Members

Precast members may be interconnected by welding reinforcing bars that project through the ends of the precast members or by welding together insert plates which have been cast into the precast members. The welding of reinforcing steel for precast concrete structures shall conform to the requirements of this code.

Table 3.1
CJP Groove Weld Requirements for Direct Butt Joints (see 3.4)

Bar Axis Orientation	Optional Types of CJP Groove Weld	Optional Figure 3.2 Detail
Horizontal	Single-V	A
	Double-V	B
	Single-V with Split Pipe Backing	C ^a
Vertical	Single-Bevel	D
	Double-Bevel	E
	Single-Bevel with Split Pipe Backing	C ^a

^a Bars shall be of equal diameter.



**Figure 3.1—Direct Butt Joint Showing
Transition Between Bars of Different Sizes
(see 3.1)**

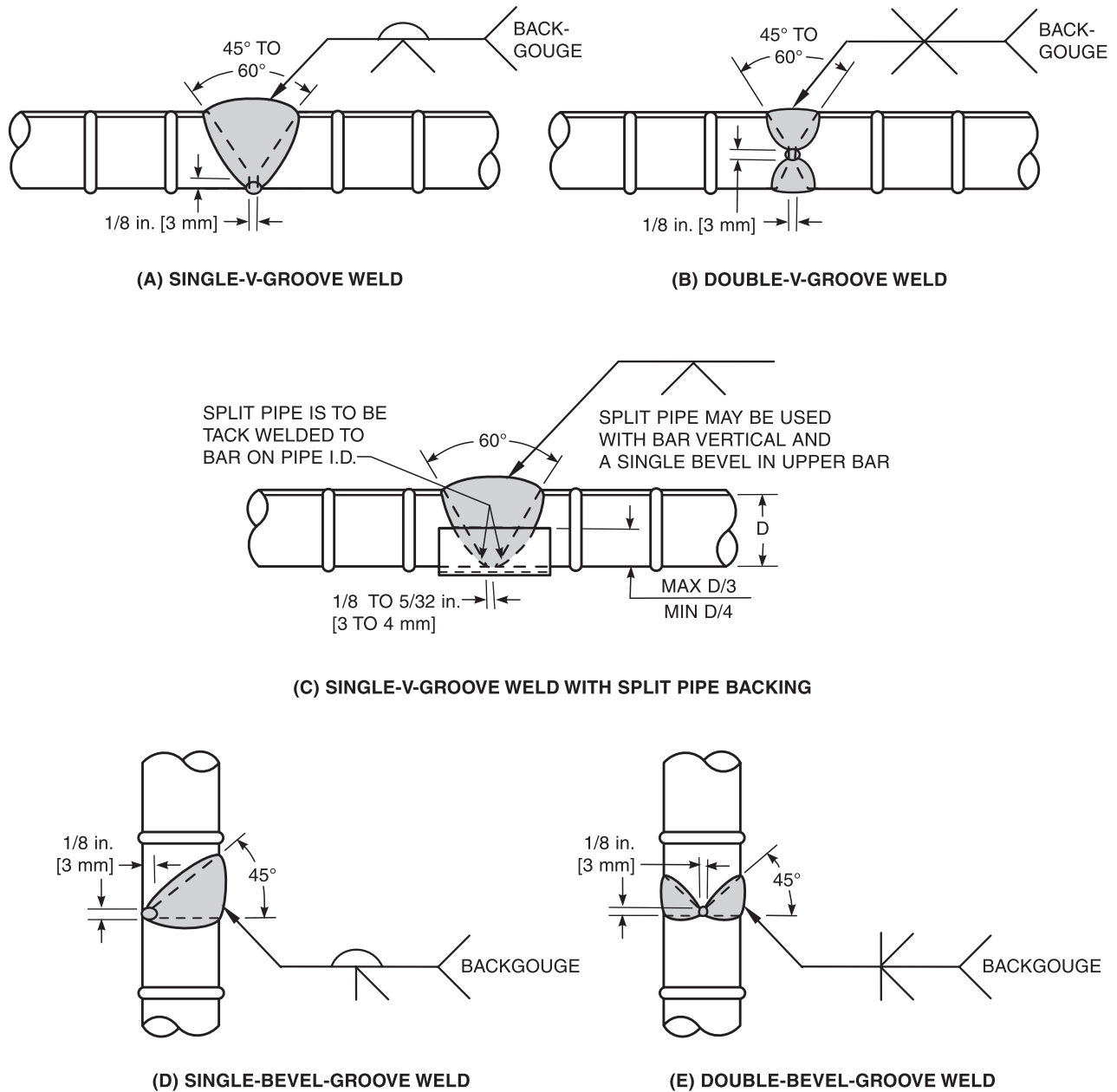
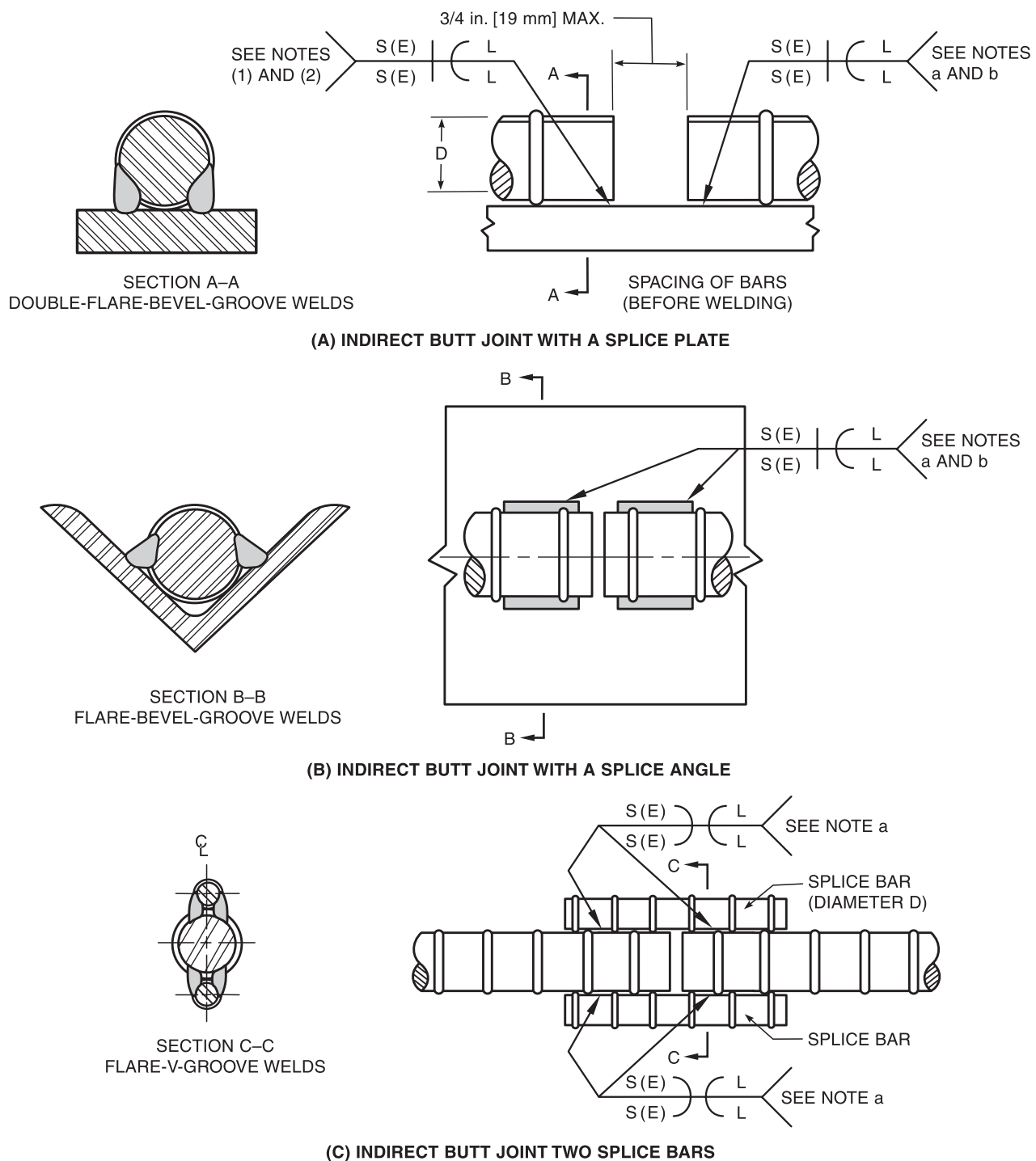


Figure 3.2—Direct Butt Joints (see Table 3.1)



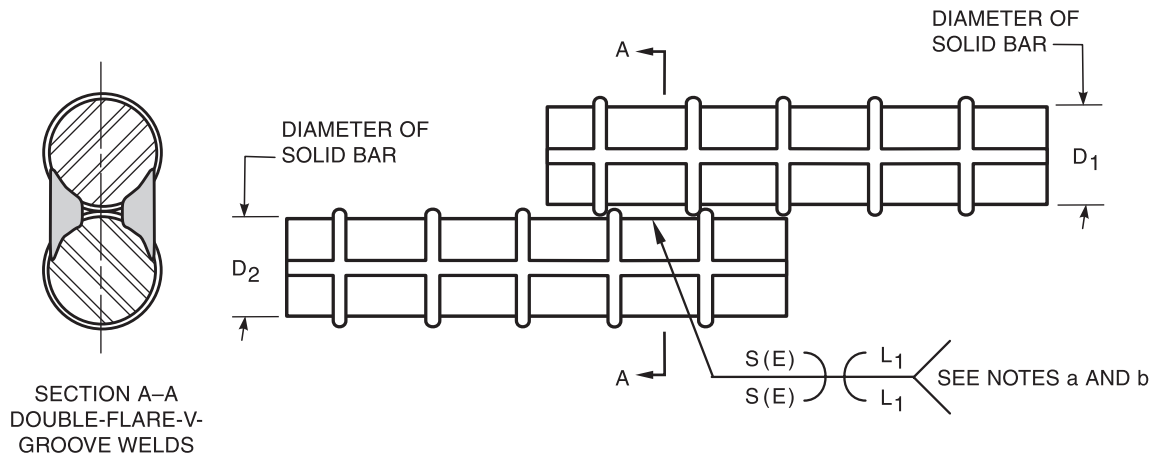
^a $L = 2D$ (min.)

^b Variation of this weld using single flare-V welds is permitted provided eccentricity is considered or restraint provided in the design of the joint.

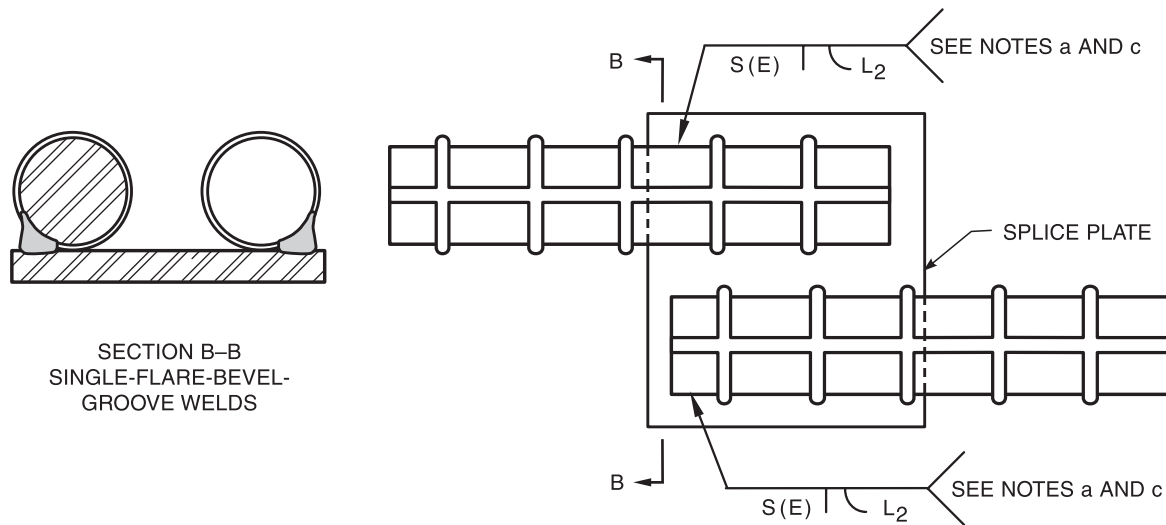
Notes:

1. Gaps between bars and plate will vary depending on height of deformations.
2. Deformations shown on sectional views are for illustrative purposes only.

Figure 3.3—Indirect Butt Joints (see 3.5)



(A) DIRECT LAP JOINT WITH BARS IN CONTACT



(B) INDIRECT LAP JOINTS WITH BARS SEPARATED

^a The effects of eccentricity shall be considered or restraint provided in the design of the joint.

^b $L_1 = 2 D_1$ (min); $D_1 \leq D_2$.

^c $L_2 = 2 \times$ diameter of bar (min.).

Note: Gaps between bars and plate will vary depending on height of deformations.

Figure 3.4—Lap Joints (see 3.2.1)

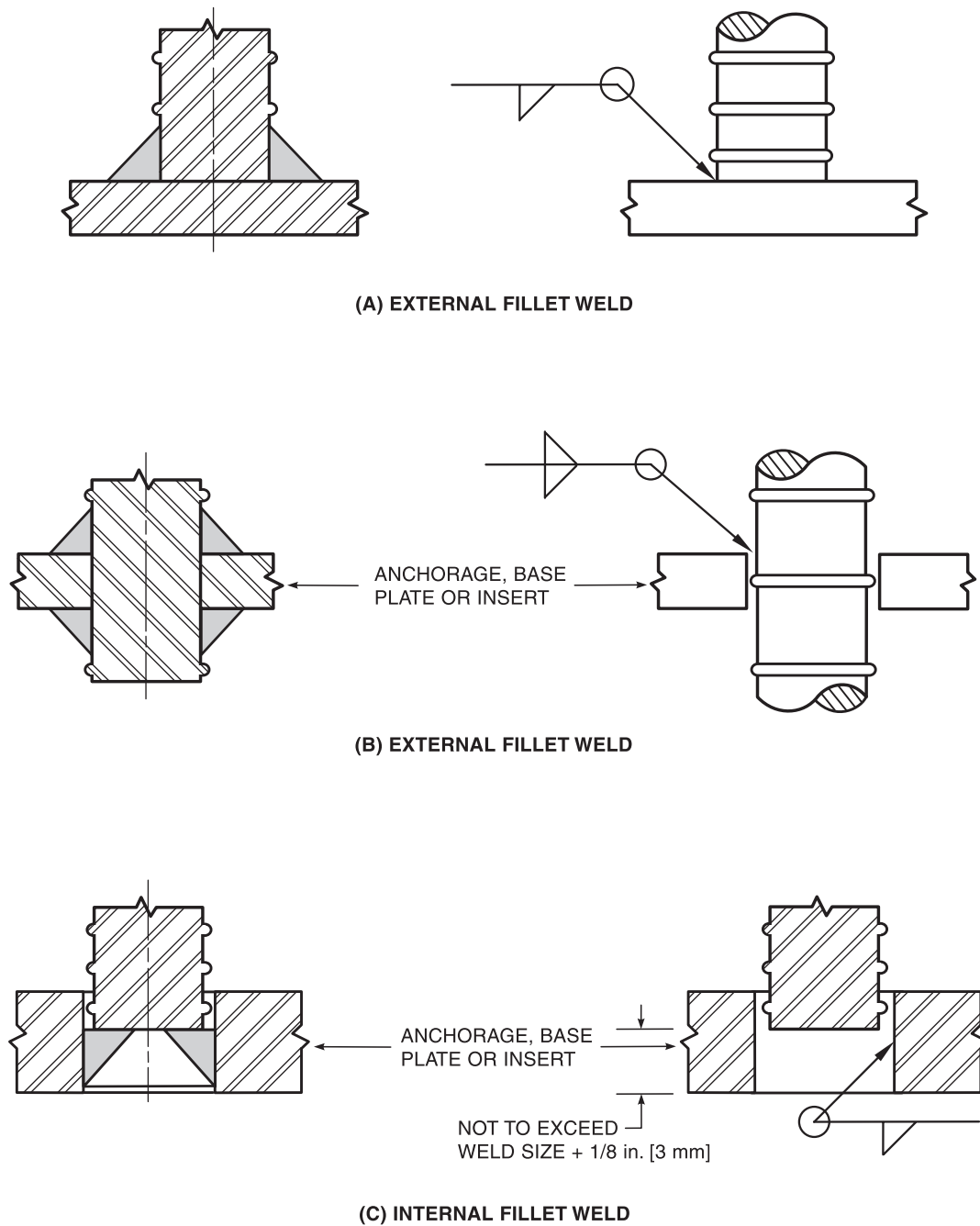
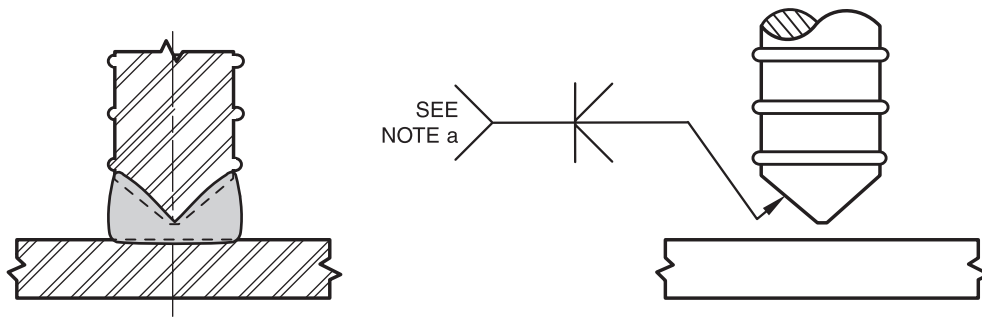
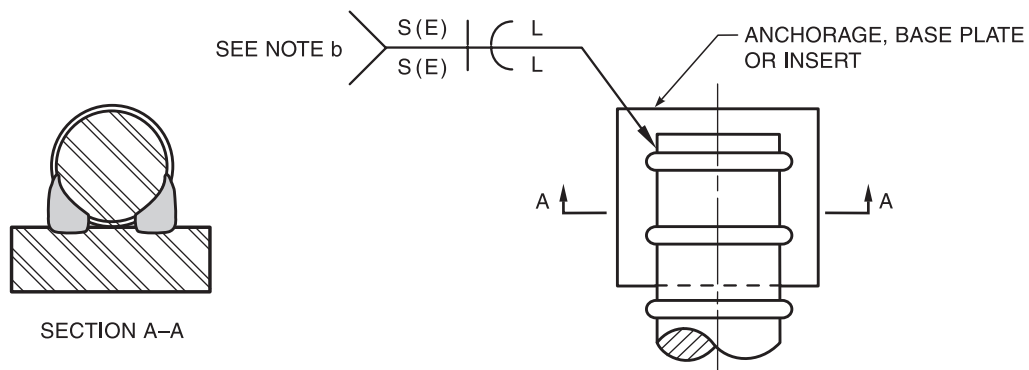


Figure 3.5—Details of Joints of Anchorages, Base Plates, and Inserts (see 3.3)



**(D) COMPLETE JOINT PENETRATION
GROOVE WELD — T-JOINT**



**(E) LAP JOINTS IN AN ANCHORAGE
USING FLARE-BEVEL-GROOVE WELDS**

^a Backgouge to sound metal before welding other side. For bar sizes 8 [25] or smaller, the single-bevel weld with backgouging and back welding is recommended.

^b $L = 2 \times \text{bar diameter (min.)}$.

Figure 3.5 (Continued)—Details of Joints of Anchorages, Base Plates, and Inserts (see 3.3)

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4. Workmanship

4.1 Preparation of Base Metal

4.1.1 Surfaces to be welded shall be free from fins, tears, cracks, or other defects that would adversely affect the quality or strength of weld. Surfaces to be welded, and surfaces adjacent to a weld, shall also be free from loose or thick scale, slag, rust, moisture, grease, epoxy coating, 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, or antispatter compound may remain.

4.1.2 The ends of reinforcing bars in direct butt joints shall be shaped to form the weld groove by oxygen cutting, air carbon arc cutting, sawing, or other mechanical means. Roughness of oxygen cut surfaces shall be no greater than the 2000 μin . [50 μm] limit defined in ANSI/ASME B46.1, *Surface Texture*. Roughness exceeding this value and occasional notches or gouges not more than 3/16 in. [5 mm] deep, on otherwise satisfactory surfaces, shall be removed by machining or grinding. Bars for direct butt joints that have sheared ends shall be trimmed back beyond the area deformed by shearing.

4.2 Assembly

4.2.1 The joint members shall be aligned so as to minimize eccentricities. Welded direct butt joints shall not be offset at the joint by more than the following:

Bar sizes No. 10 [32] or smaller	1/8 in. [3 mm]
Bar sizes No. 11 [36] and No. 14 [43].....	3/16 in. [5 mm]
Bar size No. 18 [57]	1/4 in. [6 mm]

4.2.2 For indirect butt joints with splice plates, the maximum joint clearance between the bars shall not be more than 3/4 in. [19 mm]. See Figure 3.3(A).

4.2.3 For direct lap joints, if the bar deviates by more than one-half of the bar diameter, or by no more than 1/4 in. [6 mm] from each other while the bars remain in approximately the same plane, the joint shall be made

through a splice bar or plate, and the requirements for an indirect lap joint shall apply (see 3.6.2).

4.2.4 For indirect lap joints [see Figure 3.4(B)], the maximum separation between the bar and the splice plate shall be no more than one-quarter of the bar diameter, but not more than 3/16 in. [5 mm].

4.2.5 Welding of bars which cross shall not be permitted unless authorized by the Engineer.

4.2.6 Welds made on the unbent portion of cold bent reinforcing steel shall be terminated or initiated at a minimum distance of two bar diameters from the points of tangency for the radius created by cold bending. See Figure 4.2.

4.3 Control of Distortion, Shrinkage, and Heat

4.3.1 In assembling and joining parts of a structure or precast member, the procedure and sequence followed shall minimize distortion and shrinkage.

4.3.2 When welding is performed on bars or other structural components that are already embedded in concrete, allowance shall be made for thermal expansion of the steel to prevent spalling or cracking of the concrete or significant destruction of the bond between the concrete and the steel. The heat of welding may cause localized damage to the concrete.

4.4 Quality of Welds

Welds that do not meet the quality requirements of 4.4.1 through 4.4.8, inclusive, shall be repaired by removal of unacceptable portions or by rewelding, whichever is applicable.

4.4.1 The fillet weld faces shall be slightly convex or slightly concave as shown in Figures 4.1(A) and 4.1(B) or flat, and with none of the unacceptable profiles exhibited in Figure 4.1(C). Groove weld profiles shall conform to Figure 4.1(D).

4.4.2 Welds shall have no cracks in either the weld metal or heat-affected zone (HAZ).

4.4.3 There shall be complete fusion between weld metal and base metal and between successive passes in the weld.

4.4.4 All weld craters shall be filled to a cross section that meets the minimum specified weld size.

4.4.5 Welds shall be free from overlap.

4.4.6 Undercut depth greater than 1/32 in. [1 mm] in the solid section of the bar or structural member shall not be allowed.

4.4.7 The sum of diameters of piping porosity in flare-groove welds and fillet welds shall not exceed 3/8 in. [10 mm] in any linear inch [25 mm] of weld and shall not exceed 9/16 in. [14 mm] in any 6 in. [150 mm] length of weld.

4.4.8 When radiographic inspection of direct butt joints is required, the maximum dimension of any single porosity or fusion-type discontinuity, or the sum of the maximum dimensions of all porosity or fusion-type discontinuities, shall not exceed the limits given in Table 4.1. For radiographic inspection, see 7.7.3.

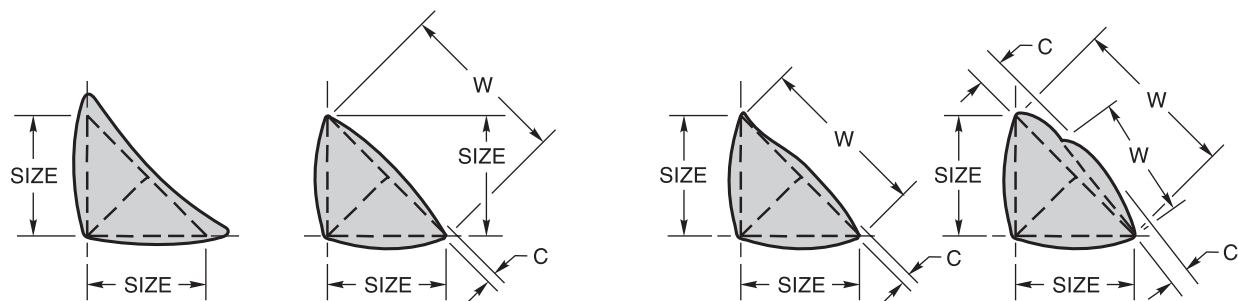
4.4.9 Repairs to welds made with the shielded metal arc welding (SMAW), gas metal arc welding (GMAW), or flux cored arc welding (FCAW) processes shall be made in accordance with a qualified WPS approved by the Engineer applicable to these processes.

4.4.10 The weld size shall be equal to or greater than the weld size specified. The length of weld containing this weld size shall be equal to or greater than the weld length specified. Any portion of the length, including starts or stops, that contain a smaller weld size shall not be measured in the weld length.

Table 4.1
Radiographic Acceptance Criteria^a (see 4.4.8)

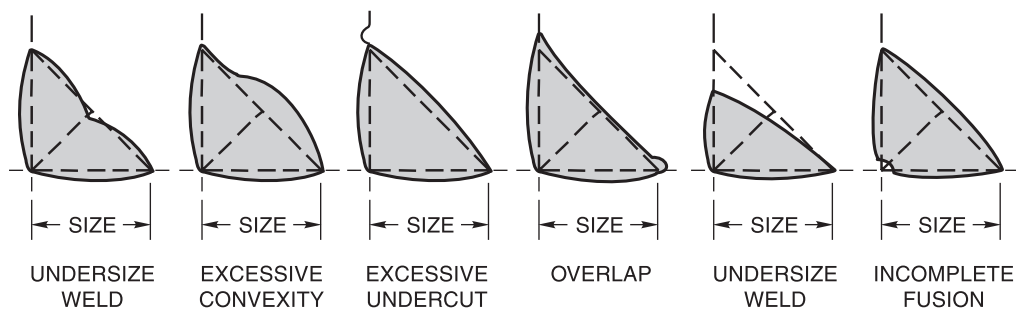
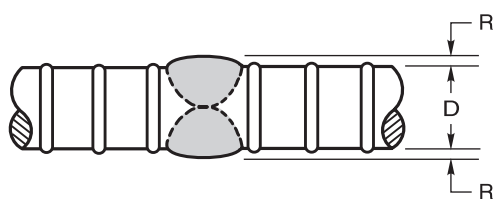
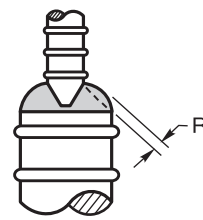
Bar Size	Sum of Discontinuity Dimensions		Single Discontinuity Dimension	
	in.	mm	in.	mm
8 [25]	3/16	5	1/8	3
9 [29]	3/16	5	1/8	3
10 [32]	1/4	6	1/8	3
11 [36]	1/4	6	3/16	5
14 [43]	5/16	8	3/16	5
18 [57]	7/16	11	1/4	6

^a Acceptance criteria for bar sizes less than No. 8 [25] shall be established by the Engineer.

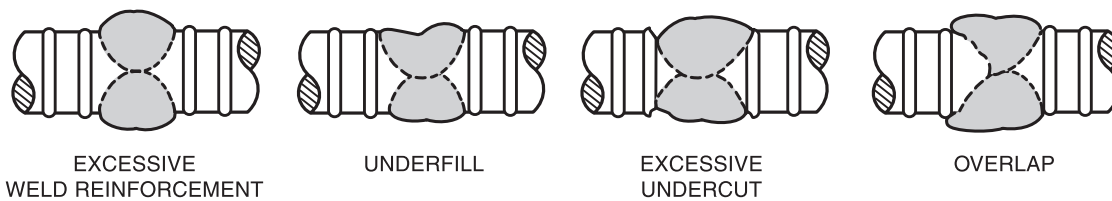
**(A) DESIRABLE FILLET WELD PROFILES****(B) ACCEPTABLE FILLET WELD PROFILES**

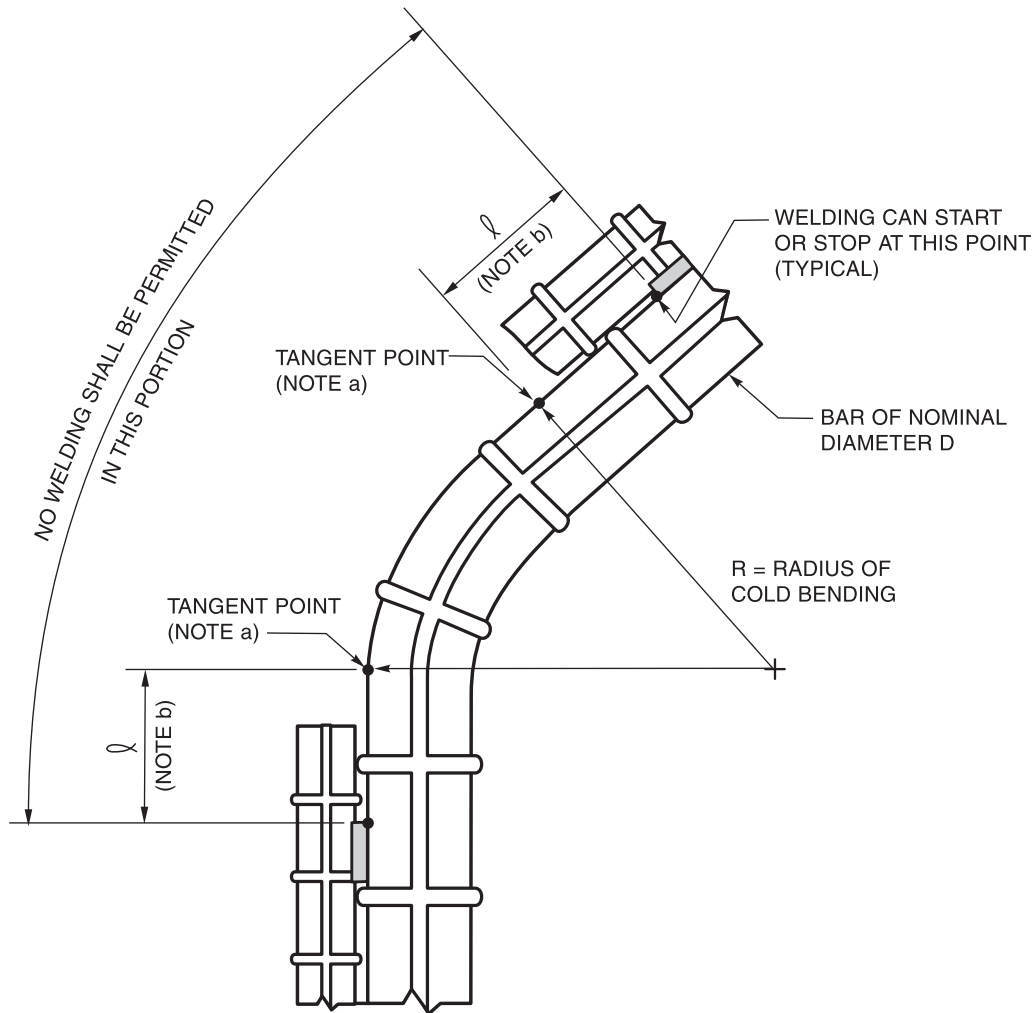
Note: Convexity, C, of a weld or individual surface bead with dimension W shall not exceed the value of the following table:

WIDTH OF WELD FACE OR INDIVIDUAL SURFACE BEAD, W	MAX CONVEXITY, C
$W \leq 5/16$ in. [8 mm]	1/16 in. [2 mm]
$W > 5/16$ in. [8 mm] TO $W < 1$ in. [25 mm]	1/8 in. [3 mm]
$W \geq 1$ in. [25 mm]	3/16 in. [5 mm]

**(C) UNACCEPTABLE FILLET WELD PROFILES****BUTT JOINT—
EQUAL DIAMETER****JOINT (TRANSITION)—
UNEQUAL DIAMETER**

Note: Reinforcement R shall not exceed 1/8 in. [3 mm].

(D) ACCEPTABLE GROOVE WELD PROFILE IN BUTT JOINT**(E) UNACCEPTABLE GROOVE WELD PROFILES IN BUTT JOINTS****Figure 4.1—Acceptable and Unacceptable Weld Profiles (see 4.4.1)**



^a For welding on inside radius, use tangent points on inside radius.

^b $\ell \geq 2D$.

Note: This figure is for illustration only.

Figure 4.2—Minimum Distance to Cold Bending Radius Tangent Points¹ (see 4.2.6)

5. Technique

5.1 Filler Metal Requirements

5.1.1 For any connections welded to this code, the base metal–filler metal strength relationship below shall be used in conjunction with Table 5.1 to determine whether matching or undermatching filler metals are required.

Relationship	Base Metal	Filler Metal Strength Required
Matching	Any reinforcing steel to itself or any reinforcing steel to any other steel with a comparable minimum tensile strength.	Any filler metal listed in the same Table 5.1 strength group.
	Any reinforcing steel in one group to any reinforcing steel or other steel with a lower minimum tensile strength.	Any filler metal listed for the same Table 5.1 strength group as the steel with the lower minimum tensile strength.
Under-matching	Any reinforcing steel to a reinforcing steel or other steel with a comparable minimum tensile strength.	Any filler metal listed for the next lower Table 5.1 strength group.

Note: See Table 2.1 to determine the filler metal strength requirements to match or undermatch base metal strength.

5.1.2 When joining different grades of steels, the filler metal shall be selected for the lower tensile strength base metal.

5.2 Minimum Preheat and Interpass Temperature Requirements

5.2.1 Minimum preheat and interpass temperatures shall be in accordance with Table 5.2 using the highest carbon equivalent number of the base metal as determined in accordance with 1.3.4.

5.2.2 Welding shall not be done when ambient temperature is lower than 0°F [–18°C], or when surfaces to be welded are exposed to rain or snow. For the GMAW and FCAW-G processes, welding shall not be performed when wind velocities exceed 5 mph [8 km/h].

5.3 Arc Strikes

Arc strikes outside the area of permanent welds shall be avoided, especially on reinforcing bars.

5.4 Weld Cleaning

5.4.1 In-Process Cleaning. Before welding over previously deposited metal, all slag shall be removed and the weld and adjacent base metal shall be brushed clean. This requirement shall apply not only to successive layers but also to successive beads and to the crater area when welding is resumed after any interruption.

5.4.2 Cleaning of Completed Welds. Slag shall be removed from all completed welds, and the weld and adjacent base metal shall be cleaned by brushing or other suitable means. Tightly adherent spatter remaining after the cleaning operation is acceptable, unless its removal is required for the purpose of NDT. Welded joints shall not be painted until after welding has been completed and the weld accepted.

5.5 Tack Welds

Tack welds that do not become a part of permanent welds shall be prohibited unless authorized by the Engineer. Tack welds shall be subject to the welding requirements of the code, including preheat, electrode selection, and discontinuity acceptance criteria.

5.6 Progression of Welding

Welds made in the vertical position [Figure 6.1(C), Position 3G or Figure 6.2(C), Position 3G], shall use uphill progression.

5.7 Welding of Coated Base Metal

5.7.1 Preparation for welding on coated base metal shall preferably be made after coating. After welding to a qualified WPS, suitable coating protection shall be applied to the finished joint to restore the corrosion-resistant properties of the coated bars.

5.7.2 When welding galvanized base metal, one of the following options shall be met:

5.7.2.1 Option 1. Welding of galvanized base metal, without prior removal of the coating, shall be performed in accordance with a WPS qualified to the requirements of this code. Note that the WPS will normally involve larger root openings in joints, electrodes with lower silicon content, and slower welding speeds.

5.7.2.2 Option 2. Welding of galvanized base metal may be done after removing all coating from within 2 in. [50 mm] of the weld joint. In this option, the welding shall be performed using a WPS for uncoated reinforcing bar qualified in accordance with this code. The galvanized coating may be removed with oxyfuel gas flame, abrasive shot blasting, or other suitable means.

5.7.3 When welding galvanized surfaces, suitable ventilation shall be provided to prevent the concentration of fumes. See ANSI Z49.1 and Annex D.

5.7.4 When welding or preheating epoxy coated base metal, the epoxy coating shall be removed from the surfaces to be heated.

5.8 SMAW Electrodes

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

5.8.1 Low-Hydrogen Electrode Storage Conditions. All electrodes having low-hydrogen coverings conforming to AWS A5.1 and AWS A5.5 shall be purchased in hermetically sealed containers or shall be rebaked prior to use. Immediately after opening the hermetically sealed container, electrodes shall be stored in ovens held at a temperature of at least 250°F [120°C].

5.8.2 Approved Atmospheric Time Periods. After hermetically sealed containers are opened or after electrodes are removed from baking or storage ovens, the electrode exposure to the atmosphere shall not exceed the values shown in column A, Table 5.3, for the specific electrode classification with optional supplemental designators, where applicable. Electrodes exposed to the atmosphere for periods less than those permitted by column A, Table 5.3 may be returned to a holding oven maintained at 250°F [120°C] min; after a minimum hold period of four hours at 250°F [120°C] min., the electrodes may be reissued. Electrodes that have been wet shall not be used.

5.8.3 Alternative Atmospheric Exposure Time Periods Established by Tests. The alternative exposure time values shown in column B in Table 5.3 may be used, provided testing establishes the maximum allowable time. The testing shall be performed in conformance with AWS A5.5, subsection 3.10, for each electrode classification and each electrode manufacturer. Such tests shall establish that the maximum moisture-content values of AWS A5.5 (Table 9) are not exceeded. Additionally, E70XX or E70XX-X (AWS A5.1 or A5.5) low-hydrogen electrode coverings shall be limited to a maximum moisture content not exceeding 0.4% by weight. These electrodes shall not be used at relative humidity-temperature combinations that exceed either the relative humidity or moisture content in the air that prevailed during the testing program.

For proper application to this provision, see Annex E for the temperature-moisture content chart and its examples. The chart shown in Annex E, or any standard psychrometric chart, shall be used in the determination of temperature-relative humidity limits.

5.8.4 Rebaking Electrodes. Electrodes exposed to the atmosphere for periods greater than those permitted in Table 5.3 shall be rebaked as follows:

1. All electrodes having low-hydrogen coverings conforming to AWS A5.1 shall be baked for at least two hours between 500°F [260°C] and 800°F [430°C], or
2. All electrodes having low-hydrogen coverings conforming to AWS A5.5 shall be baked for at least one hour at temperatures between 700°F [370°C] and 800°F [430°C].

Electrode shall be rebaked no more than once.

5.8.5 Electrode Restrictions for ASTM A 514 or A 517 Steels. When used for welding ASTM A 514 or A 517 steels, electrodes of any classification lower than E100XX-X, except for E7018M and E70XXH4R, shall be baked at least one hour at temperatures between 700 and 800°F [370 and 430°C] before being used, whether furnished in hermetically sealed containers or otherwise.

5.9 Electrodes and Shielding Gas for Gas Metal Arc Welding (GMAW) and Flux Cored Arc Welding (FCAW)

The electrodes and shielding for gas metal arc welding (GMAW) or flux cored arc welding (FCAW) for producing weld metal with minimum specified yield strengths of 60 000 psi [420 MPa] or less, shall conform to the requirements of the latest edition of AWS A5.18, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*, or AWS A5.20, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*, as applicable.

5.9.1 Low-Alloy Electrodes for GMAW. The electrodes and shielding for GMAW for producing weld

metal with a minimum specified yield strength greater than 60 000 psi [420 MPa] shall conform with the latest edition of AWS A5.28, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*.

5.9.2 Low-Alloy Electrodes for FCAW. The electrodes and shielding gas for FCAW for producing weld metal with a minimum specified yield strength greater than 60 000 psi [415 MPa] shall conform to the latest edition of AWS A5.29, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*.

5.9.3 Shielding Gas. When a gas or gas mixture is used for shielding in GMAW or FCAW, it 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 will meet the dew point requirement.

Table 5.1
Matching Filler Metal Requirements (see 5.1)

Group	Steel Specification Requirements						Filler Metal Requirements					
	Steel Specification		Minimum Yield Point/Strength		Minimum Tensile Strength		Electrode Specification ^a	Yield Point/Strength ^b		Tensile Strength ^b		
			ksi	MPa	ksi	MPa		ksi	MPa	ksi	MPa	
I	ASTM A615 ASTM A615M	Grade 40 Grade 300	40 —	— 300	70 —	— 500	SMAW AWS A5.1 and A5.5					
							E7015, E7016, E7018, E7028		53–72	365–496	70	482
							E7015-X, E7016-X, E7018-X		57–60	390–415	70–75	480–520
							GMAW AWS A5.18					
							ER70S-X, E70C-3, E70C-6		58	400	70	480
							FCAW AWS A5.20 and A5.29					
							E7XT-X		58	400	70	480
II	ASTM A706 ASTM A706M	Grade 60 Grade 420	60 —	— 420	80 —	— 550	SMAW AWS A5.5					
							E8015-X, E8016-X, E8018-X		67	460	80	550
							GMAW AWS A5.28					
							ER80S-X, E80C-X, E90C-X		68	470	80	550
							FCAW AWS A5.29					
							E8XTX-X		68	470	80–100	550–690
							III	ASTM A615 ASTM A615M	Grade 60 Grade 420	60 —	— 420	90 —
E9015-X, E9016-X, E9018-X		77	530	90	620							
GMAW AWS A5.28												
ER90S-X		78	540	90	620							
FCAW AWS A5.29												
E9XTX-X		78	540	90–110	620–760							

(continued)

Table 5.1 (Continued)
Matching Filler Metal Requirements (see 5.1)

G r o u p	Steel Specification Requirements						Filler Metal Requirements				
	Steel Specification		Minimum Yield Point/Strength		Minimum Tensile Strength		Electrode Specification ^a	Yield Point/Strength ^b		Tensile Strength ^b	
			ksi	MPa	ksi	MPa		ksi	MPa	ksi	MPa
IV	ASTM A615 ASTM A615M	Grade 75 ^c Grade 520 ^d	75	—	100	—	SMAW AWS A5.5				
							E10015-X, E10016-X, E10018-X	87	600	100	690
							E10018-M	88–100	610–690	100	690
							GMAW AWS A5.28				
							ER100S-X, E100C-X	88	610	100	690
							FCAW AWS A5.29				
						E10XTX-X	88	610	100–120	690–830	

^a Filler metals of alloy group B3, B3L, B4L, B5, B5L, B6, B6L, B7, B7L, B8, B8L, or B9 in AWS A5.5, A5.28, or A5.29 may be used when given prior approval by the Engineer. Consideration shall be made of the differences in tensile strength, ductility, and hardness between the PWHT versus as-welded conditions.

^b This table is based on filler metal as-welded properties. Single values are minimums. Hyphenated values indicate minima and maxima.

^c Applicable to bar sizes Nos. 6 through 18.

^d Applicable to bar sizes Nos. 19 through 57.

Table 5.2
Minimum Preheat and Interpass Temperatures^{a, b} (see 5.2.1)

Carbon Equivalent (C.E.) Range, % ^{c, d}	Size of Reinforcing Bar	SMAW with Low-Hydrogen Electrodes, GMAW, or FCAW	
		Minimum Temperature	
		°F	°C
Up to 0.40	Up to 11 [36] inclusive	none ^e	none ^e
	14 and 18 [43 and 57]	50	10
Over 0.40 to 0.45 inclusive	Up to 11 [36] inclusive	none ^e	none ^e
	14 and 18 [43 and 57]	50	10
Over 0.45 to 0.55 inclusive	Up to 6 [19] inclusive	none ^e	none ^e
	7 to 11 [22 to 36]	50	10
	14 to 18 [43 to 57]	200	90
Over 0.55 to 0.65 inclusive	Up to 6 [19] inclusive	100	40
	7 to 11 [22 to 36]	200	90
	14 to 18 [43 to 57]	300	150
Over 0.65 to 0.75	Up to 6 [19] inclusive	300	150
	7 to 18 [22 to 57] inclusive	400	200
Over 0.75	Up to 6 [19] inclusive	300	150
	7 to 18 [22 to 57] inclusive	500	260

^a When reinforcing steel is to be welded to main carbon steel, the preheat requirements of the structural steel shall also be considered (see AWS D1.1, table titled “Prequalified Minimum Preheat and Interpass Temperature.”) The minimum preheat requirement to apply in this situation shall be the higher requirement of the two tables. However, extreme caution shall be exercised in the case of welding reinforcing steel to quenched and tempered steels, and such measures shall be taken as to satisfy the preheat requirements for both. If not possible, welding shall not be used to join the two base metals.

^b Welding shall not be done when the ambient temperature is lower than 0°F [–18°C]. When the base metal is below the temperature listed for the welding process being used and the size and carbon equivalent range of the bar being welded, it shall be preheated (except as otherwise provided) in such a manner that the cross section of the bar for not less than 6 in. [150 mm] on each side of the joint shall be at or above the specified minimum temperature. Preheat and interpass temperatures shall be sufficient to prevent crack formation.

^c After welding is complete, bars shall be allowed to cool naturally to ambient temperature. Accelerated cooling is prohibited.

^d Where it is impractical to obtain chemical analysis, the carbon equivalent shall be assumed to be above 0.75%. See also 1.3.4.3.

^e When the base metal is below 32°F [0°C], the base metal shall be preheated to at least 70°F [20°C], or above, and maintained at this minimum temperature during welding.

Table 5.3
Permissible Atmospheric Exposure of Low-Hydrogen Electrodes (see 5.7.2 and 5.7.3)

Electrode	Column A (hours)	Column B (hours)
A5.1		
E70XX	4 max	
E70XXR	9 max	Over 4 to 10 max
E70XXHZR	9 max	
E7018M	9 max	
A5.5		
E70XX-X	4 max	Over 4 to 10 max
E80XX-X	2 max	Over 2 to 10 max
E90XX-X	1 max	Over 1 to 5 max
E100XX-X	1/2 max	Over 1/2 to 4 max
E110XX-X	1/2 max	Over 1/2 to 4 max

Notes:

1. Column A: Electrodes exposed to atmosphere for longer periods than shown shall be redried before use.
2. Column B: Electrodes exposed to atmosphere for longer periods than those established by testing shall be redried before use.
3. Entire table: Electrodes shall be issued and held in quivers, or other small open containers. Heated containers are not mandatory.
4. The optional supplemental designator, R, designates a low-hydrogen electrode, which has been tested for covering moisture content after exposure to a moist environment for 9 hours and has met the maximum level permitted in AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*.

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6. Qualification

6.1 General

6.1.1 Responsibility

6.1.1.1 All welding performed to contracts involving AWS D1.4 shall utilize written WPSs that meet the requirements of this code.

6.1.1.2 Each contractor shall conduct the test required by Section 6 to qualify the WPSs and the welders who will apply these WPSs.

6.1.1.3 At the Engineer's discretion, evidence of previous qualification of the WPSs and welders to be employed may be accepted.

6.1.2 Welding Procedures

6.1.2.1 WPS qualification by testing in conformance with 6.2 shall be required for all joint types (see 3.3), except that WPSs for fillet welds shall be considered prequalified and exempt from testing.

6.1.2.2 Subject to the approval of the Engineer, WPSs meeting the requirements of this code may be used for work being performed under the provisions of previous editions of this code and AWS D12.1.

6.1.2.3 Each WPS shall be prepared by the contractor. This written WPS shall include, as a minimum, the applicable essential variables of 6.2 and shall be available to those authorized to examine them. A suggested form showing the information required in the WPS specification is given in Annex A.

6.1.2.4 WPS qualifications performed prior to publication of this edition of the code may be updated to the requirements of this code, provided the variables required by this edition of the code were previously recorded.

6.1.3 Welders

6.1.3.1 Welders who perform code work shall be qualified in conformance with 6.3 prior to production welding.

6.1.3.2 Welders who successfully complete a WPS qualification for either complete joint penetration groove

welds or flare-groove welds shall be considered qualified for welding the type of weld joint used in the WPS qualification and other joint types as permitted in 6.3.3.1. The position of welding may be changed to the extent permitted by 6.3.4.

6.1.3.3 Subject to the approval of the Engineer, welders who qualify to the requirements of this edition of the code may be used for work being performed under provisions of previous editions of this code.

6.2 WPS Qualification

6.2.1 Limitation of Variables

6.2.1.1 The largest bar size to be production welded shall be used for qualification. Qualification for each specification and grade of reinforcing bar is not required.

6.2.1.2 WPS qualification shall be performed using a steel that has a carbon equivalent (C.E.) at least equal to the highest C.E. to be encountered in production. The WPS is then qualified for the highest C.E. value qualified and all lower values.

6.2.1.3 A change from uncoated bars or steel to coated bars or steel where the coating lies within 2 in. [50 mm] of weld joint preparation, or any greater distance required to prevent coating from melting and contaminating the weld metal shall require requalification. (The 2 in. limit should keep any coating from melting and contaminating the weld where the bars are in the vertical plane.)

6.2.1.4 Any changes beyond the essential variable limitations of Table 6.1 shall require WPS requalification.

6.2.2 Types of Tests and Their Purposes. The following tests are to determine the tensile strength and degree of soundness of welded joints made under a given WPS specification:

1. Full section tension test (for tensile strength)
2. Macroetch test (for soundness)

6.2.3 Position of Test Welds

The position of production welds may be determined from Figure 6.3 (groove) and Figure 6.4 (fillet.) The test positions are defined in Figures 6.1 and 6.2. A WPS shall be required for each production welding position.

6.2.4 Test Assemblies Number, Type, and Preparation

6.2.4.1 Number and Type of Test Assemblies. The number and type of assemblies that shall be tested to qualify a WPS are shown in Table 6.2.

6.2.4.2 Test assemblies for groove welds in T-joints may be either direct butt joints having the same groove configuration as the T-joint to be used in construction, or the T-joint assembly shown in Figure 6.5(B).

6.2.4.3 Tension Test Assemblies. The size and length of tension test assemblies shall be as follows:

1. *Direct Butt Joint and T-Joint.* Unless a greater length is required for testing, welded test assemblies for direct butt joints shall have a minimum length of at least 16 times the diameter of the bar, with the weld located centrally [see Figures 6.5(A) and 6.5(B), as appropriate].

2. *Indirect Butt Joint.* For indirect butt joint welded test assemblies, the minimum length in No. 1 above shall be increased by the length of the joint [see Figures 6.5(C) and 6.5 (D)]. The length of the connecting welds shall be such that the total shear capacity is equal to 0.6 times the minimum specified tensile strength times the nominal area of the solid bar. Note that for two bars of unequal tensile strengths, the lesser of the two values shall be used.

6.2.4.4 Macroetch Specimens. Macroetch test specimens shall be prepared as follows:

1. *Direct Butt Joints and T-Joints.* The test assembly shall be mechanically cut at one location transverse to the direction of welding. The test specimen shall show the full longitudinal cross section of the weld, the root of the weld, and any reinforcement. [See Figures 6.5(A) or 6.5(B).]

2. *Indirect Butt Joints.* Each test assembly shall be mechanically cut at one location to provide a transverse cross section of each welded assembly. [See Figures 6.5(C) and 6.5(D).]

6.2.5 Method of Testing Specimens

6.2.5.1 Full Section Tension Test. The minimum distance between the jaws of the testing machine shall be equal to the following:

1. At least eight times the diameter of the bars for direct butt joints
2. At least eight times the diameter of the bar, plus the length of the joint, for indirect butt joints

The test specimen shall be ruptured under tension load, and the maximum load shall be determined. The

tensile strength shall be obtained by dividing the maximum load by the nominal cross-sectional area of the bar.

6.2.5.2 Macroetch Test. All cross sections shall be polished and etched with a suitable solution to give a clear definition of the weld.

6.2.6 Test Results Required

6.2.6.1 Full Section Tension Test. The tensile strength shall be no less than 125% of the minimum specified yield strength of the type and grade of bars to be joined, unless otherwise stipulated by the general specification.

6.2.6.2 Macroetch Test. The specimen shall be examined for discontinuities, and any that have discontinuities prohibited by 4.4 shall be considered as failed. The etched cross sections shall have complete penetration with the base metal for single-V- or double-V-groove welds. For flare-bevel- and flare-V-groove welds, the designated weld size shall be obtained.

6.3 Welder Qualification

6.3.1 The qualification test described here are especially devised to determine the welder's ability to produce sound welds. It is not intended that the qualification tests be used as a guide for welding during actual construction. The latter shall be performed in accordance with the requirements of the WPS.

6.3.2 Limitation of Variables

6.3.2.1 Qualification with a particular process and with any of the steels permitted by this code shall be considered as qualification to weld any of the other approved steels with that process except that qualification for galvanized steel shall be performed using galvanized steel.

6.3.2.2 Qualified Bar Sizes. The smallest bar size used in qualification shall qualify the welder for welding that bar size and any larger size.

6.3.2.3 Base Metal. The base metal used shall comply with 1.3.1 or the WPS. The base metal may be uncoated or galvanized, as required by 6.3.2.1.

6.3.2.4 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 (see Table 5.1) for the process used in the qualification test.

6.3.2.5 A change in the position of welding to one for which the welder is not qualified requires qualification in that position.

6.3.3 Qualification Tests Required

6.3.3.1 Qualification tests for welders shall be as follows:

1. Direct butt joint groove weld test made using SMAW, GMAW, or FCAW processes qualifies for complete joint penetration groove welds and for fillet welds.

2. Indirect butt joint flare-groove weld test made using SMAW, GMAW, or FCAW processes. This test qualifies welders for welding indirect butt joints, lap joints, and for fillet welds.

3. Complete joint penetration groove weld T-joint made using SMAW, GMAW, or FCAW processes qualifies welders for welding complete joint penetration groove welds (both direct butt joints and T-joints) and fillet welds.

4. Fillet weld tests made using SMAW, GMAW, or FCAW processes qualifies for external fillet welds as shown in Figure 3.5(A) and Figure 3.5(B).

6.3.3.2 The qualification test assembly shall have joint details as follows:

1. The direct butt joint groove weld test assembly shall be a complete joint penetration groove weld made by SMAW, GMAW, or FCAW processes. See Figure 6.6(A). The smallest bar size to be fabricated shall be used.

2. The indirect butt joint flare-groove weld test shall be an indirect butt joint made by SMAW, GMAW, or FCAW processes using a double-flare-bevel-groove and flat bar, as shown in Figure 6.6(B).

3. The complete joint penetration T-joint made by SMAW, GMAW, or FCAW processes shall be as shown in Figure 6.6(C).

4. The fillet weld bend test shall be a bar welded to a plate, see Figure 6.6(D). The welder shall be qualified with the smallest bar size to be used in construction. The bar shall be welded to a plate with the minimum size single pass fillet weld to be used in construction.

6.3.4 Position of Test Welds and Related Validity of Qualification

6.3.4.1 Direct Butt Joint Groove Weld Test

1. Qualification in the 1G (flat) position qualifies for direct butt joints in the 1G flat position, and for fillet welds in the 1F (flat) and 2F (horizontal) positions (see Figure 6.1).

2. Qualification in the 2G (horizontal) position qualifies for direct butt joints in the 1G (flat) and 2G (horizontal) positions and for fillet welds in 1F (flat) and 2F (horizontal) positions (see Figure 6.1).

3. Qualification in the 3G (vertical) position qualifies for direct butt joints in the 1G (flat), 2G (horizontal), and 3G (vertical) positions; and for fillet welds in the 1F (flat), 2F (horizontal), and 3F (vertical) positions (see Figure 6.1).

4. Qualification in the 4G (overhead) position qualifies for direct butt joints in the 1G (flat) and 4G (over-

head) positions and for fillet welds in 1F (flat), 2F (horizontal), and 4F (overhead) positions (see Figure 6.1).

6.3.4.2 Indirect Butt Joint Flare-Groove Weld Test

1. Qualification in the 1G (flat) position qualifies for indirect butt joints and lap joints in the 1G (flat) position, and for fillet welds in 1F (flat), and 2F (horizontal) positions (see Figure 6.2).

2. Qualification in the 2G (horizontal) position qualifies for indirect butt joints and lap joints in the 1G (flat) and 2G (horizontal) positions and for fillet welds in 1F (flat), and 2F (horizontal) positions (see Figure 6.2).

3. Qualification in the 3G (vertical) position qualifies for indirect butt joints and lap joints in the 1G (flat), 2G (horizontal), and 3G (vertical) positions and for fillet welds in the 1F (flat), 2F (horizontal), and 3F (vertical) positions (see Figure 6.2).

4. Qualification in the 4G (overhead) position qualifies for indirect butt joints and lap joints in the 1G (flat) and 4G (overhead) positions and for fillet welds in 1F (flat), 2F (horizontal), and 4F (overhead) positions (see Figure 6.2).

6.3.4.3 T-Joint Groove Weld Test. The position requirements for groove welds shall govern the weld position qualified by the welder (see Figure 6.1).

6.3.4.4 Fillet Weld Test. The welder shall be qualified for the position tested (see Figure 6.4).

6.3.5 Test Specimens—Number, Type, and Preparation

6.3.5.1 The number and type of test assemblies that shall be tested to qualify a welder are shown in Table 6.3. Two test assemblies welded in accordance with 6.3.3.3 are required to qualify welders.

6.3.5.2 Direct Butt Joints. Direct butt joint welded test assemblies made by GMAW (except short circuiting transfer), SMAW, or FCAW, shall be tested by radiography, or one test assembly shall be subjected to the full section tension test and the other test assembly to the macroetch test. Radiography shall not be used on joints where split pipe backing is used.

6.3.5.3 Direct Butt Joints By GMAW-S. Direct butt joint welded test assemblies made by GMAW using short circuiting transfer shall have one test assembly subjected to the full section tension test and the other to the macroetch test.

6.3.5.4 Indirect Butt Joints. Both indirect butt joint welded test assemblies shall be subjected to the macroetch test.

6.3.5.5 T-Joint Test Assembly. The two welded T-joint test assemblies shall both be subjected to the macroetch test.

6.3.5.6 Tension Test Specimens. Unless a greater length is required for testing, the full section tension test specimen for direct butt joints shall have a minimum length of at least 16 times the diameter for the bar with the weld centrally located [see Figure 6.6(A)].

6.3.5.7 Tension Test Specimen With Split Pipe Backing. The split pipe backing need not be removed for tension testing.

6.3.5.8 Macroetch Test Specimens. Macroetch test specimens shall be prepared as follows (see Figure 6.6):

1. *Direct Butt and T-Joints.* The test assembly shall be mechanically cut at one location transverse to the direction of welding. The test specimen shall show the full longitudinal cross section of the weld, the root of the weld, and any reinforcement [see Figures 6.6(A) and 6.6(B)].

2. *Indirect Butt Joint.* Each test assembly shall be cut mechanically at one location to provide a transverse cross section of each welded assembly [see Figures 6.6(C) and 6.6(D)].

6.3.5.9 Fillet Weld Test. Test welds shall meet the visual quality requirements of 4.4.1 through 4.4.7. Two welded assemblies shall be subjected to bend testing, see 6.3.6.3.

6.3.6 Method of Testing Specimens

6.3.6.1 Full-Section Tension Test. The minimum distance between jaws of the testing machine shall be equal to at least eight times the diameter of the bar for direct butt joints. The test specimen shall be ruptured under tensile load, and the maximum load shall be determined. The tensile strength shall be obtained by dividing the maximum load by the nominal cross-sectional area of the bar.

6.3.6.2 Macroetch Test. All cross sections shall be polished and etched with a suitable solution to give a clear definition of the weld.

6.3.6.3 Fillet Weld Test. Testing shall be performed after the bar is allowed to cool to ambient temperature. It shall be bent to an angle not less than 30° from its original axis. Bending may be accomplished by striking the bar with a hammer on the unwelded end or by placing a pipe or other suitable hollow device over the bar and manually or mechanically bending the bar.

6.3.7 Test Results Required

6.3.7.1 Radiographic Test. For acceptable qualification, the weld as revealed by the radiograph shall conform to the requirements of 4.4.2 and 4.4.8.

6.3.7.2 Full-Section Tension Test. The tensile strength shall not be less than 125% of the minimum specified yield strength of the type and grade of bars joined, unless otherwise stipulated by the general specification.

6.3.7.3 Macroetch Test. The specimen shall be examined for discontinuities and if any are found that are prohibited by 4.4, it shall be considered as failed. The etched cross section shall show complete fusion for the direct butt joints or the designated effective weld size for the flare groove test assemblies.

6.3.7.4 Fillet Weld Bend Test. The bar shall be bent without any separation:

1. Between individual weld passes,
2. At the fusion line between the bar and weld,
3. At the fusion line between the plate and weld,
4. In the heat-affected zone (HAZ).

Separation shall be defined as any length or width that can be seen without magnification. If a separation occurs in either of the fillet welds or heat affected zones of the bar, the test fails. In the event that the failure occurs within the bar, the welder shall be considered qualified.

6.4 Retests

In case a welder fails to meet the requirements of one or more test welds, a retest may be allowed under the following conditions:

6.4.1 Immediate Retest. An immediate retest may be made consisting of two welds of each type and position that the welder failed. All retest specimens shall meet all of the specified requirements.

6.4.2 Retest After Further Training or Practice. A retest may be made, provided there is evidence that the welder has had further training or practice. A complete retest of the types and positions failed shall be made.

6.5 Period of Effectiveness

The welder's qualification as specified in this code 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 unless (2) there is some specific reason to question a welder's ability.

6.6 Records

Records of the test results shall be kept by the manufacturer or contractor and shall be available to those authorized to examine them.

Table 6.1
PQR Essential Variable Changes Requiring WPS Requalification
for SMAW, GMAW, and FCAW (see 6.2.1.4)

Essential Variable Changes to PQR Requiring Requalification	Process ^a		
	SMAW	GMAW	FCAW
Electrode			
(1) Increase in filler metal classification strength, e.g., a change from E70XX to E80XX-X, but not vice versa	X	X	X
(2) A change to an electrode or method of shielding not covered in:	AWS A5.1 or A5.5	AWS A5.18 or A5.28	AWS A5.20 or A5.29
(3) A change in electrode diameter by:	Any increase	Any increase or decrease	Any increase
Electrical Parameters			
(4) A change in the amperage for each electrode diameter by:	To a value not recommended by manufacturer	>10% increase or decrease	>10% increase or decrease
(5) A change in the voltage for each electrode diameter by:	To a value not recommended by manufacturer	>7% increase or decrease	>7% increase or decrease
(6) A change in type of current (ac or dc), polarity or mode of transfer (GMAW only)		X	X
(7) A change in the travel speed by:		>10% increase or decrease	>10% increase or decrease
Shielding Gas			
(8) An increase in shielding gas flow rate by 25% or more or a decrease of 25% or more		X	X
(9) A change in shielding gas from a single gas to any other single gas or mixture of gas, or a change of more than 25% in any minor elements of the mixture, or change from a gas mixture to a single gas, or change from external shielding gas to self-shielding (i.e., no external shielding gas)		X	X
General			
(10) A change in position not qualified per 6.2.4	X	X	X
(11) A change in groove type (e.g., flare-V to flare-bevel groove)	X	X	X
(12) A change in the shape or any one type of groove involving: (a) A decrease in the groove angle exceeding 5° (b) A decrease in the root opening exceeding 1/16 in. [1.6 mm] (c) An increase in the root face exceeding 1/16 in. [1.6 mm]	X	X	X
(13) The omission, but not inclusion, of backing material	X	X	X

^a An "X" indicates applicability for the process; a shaded area indicates non-applicability.

Table 6.2
Number and Type of Tests for WPS Qualification (see 6.2.4.1)

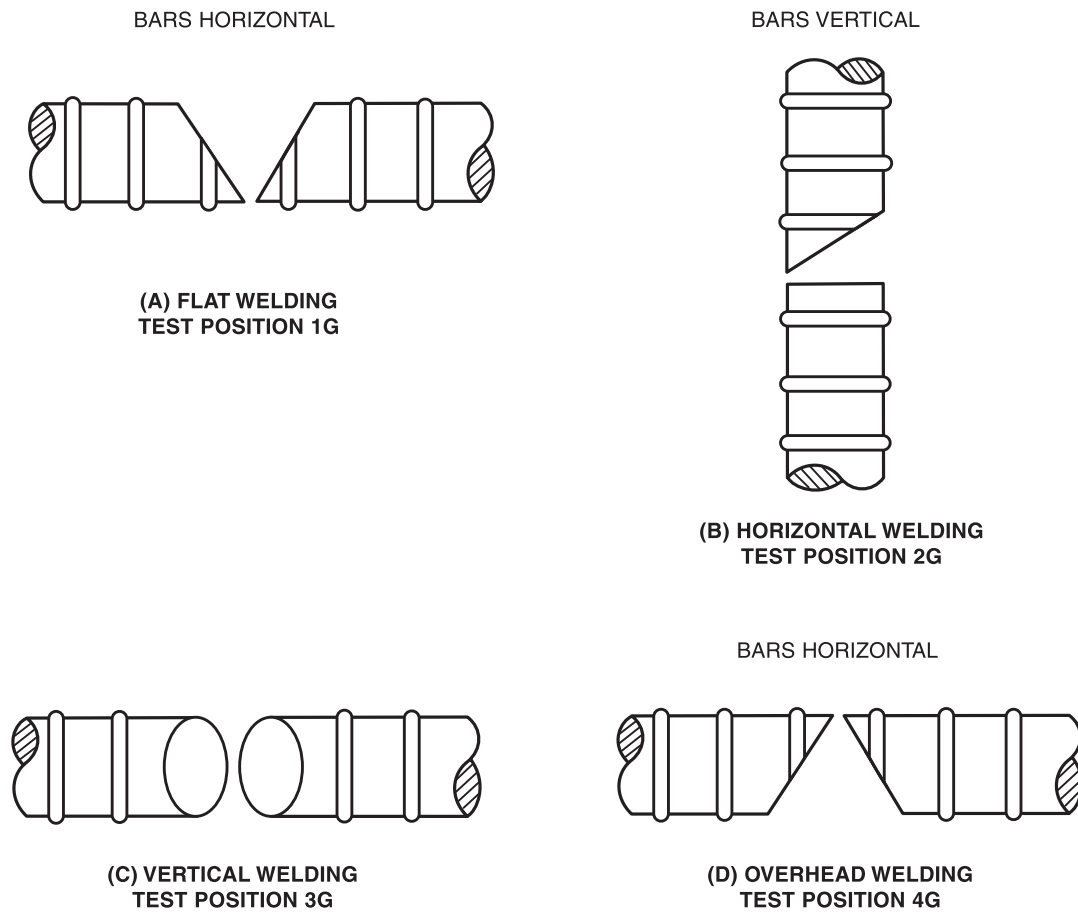
Production Type of Joint [Figure]	Minimum Number of Test Assemblies	Tension Tests (6.2.4.3)	Macroetch Tests (6.2.4.4)	Joints Qualified per Figure:
Direct butt [6.5(A)]	2	2	2	3.1, 3.2, 3.5(D)
T-Joint [6.5(B)]	2	2	2	3.1, 3.5(D)
Indirect butt [6.5(C)]	2	2	2	3.3(A), (B), 3.4, 3.5(E)
Indirect butt [6.5(D)]	2	2	2	3.3(C)

Table 6.3
Welder Qualification—Number, Types of Test, Production Welds, and Positions Qualified (see 6.3)

Qualification Test			Number and Type of Tests Required					Production Welding Joint and Position Qualified			
Test Type	Test Assembly	Number of Test Assemblies Required	Radiography (6.3.5.2)	Tension (6.3.5.3.)	Macroetch (6.3.5.4)	Bend Test (6.3.5.9)	Test Position	Direct Butt and T-Joint [Figure 3.1, 3.2, 3.5(D)]	Fillet Joint [Figure 3.5(A), (B), and (C)]	Indirect Butt Joint (Figure 3.3)	Lap Joint (Figure 3.4)
Direct Butt	Figure 6.6(A)	2	2 ^a	1 ^b	1 ^b	—	1G	F	F, H	—	—
							2G	F, H	F, H		
							3G	F, H, V	F, H, V		
							4G	F, OH	F, H, OH		
Indirect Butt	Figure 6.6(B)	2	—	—	2	—	1G	—	F, H	F, H	F, H
							2G		F, H	F, H	F, H
							3G		F, H, V	F, H, V	F, H, V
							4G		F, H, OH	F, OH	F, OH
T-Joint Complete Penetration	Figure 6.6(C)	2	—	—	2	—	1G	F	F, H	—	—
							2G	F, H	F, H		
							3G	F, H, V	F, H, V		
							4G	F, OH	F, H, OH		
Fillet Weld	Figure 6.6(D)	2	—	—	—	2	1F (Rotated)	—	F	—	—
							2F		F, H		
							2F (Rotated)		F, H		
							4F		F, H, OH		
							5F		All		

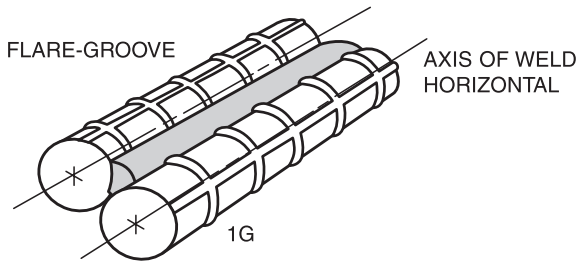
^a Radiography not permitted for welds made by GMAW short circuiting transfer.

^b Required for welds made by GMAW using short circuiting transfer. Tension and macroetch tests may be used in lieu of radiography for all other welding processes, at the Contractor's option.

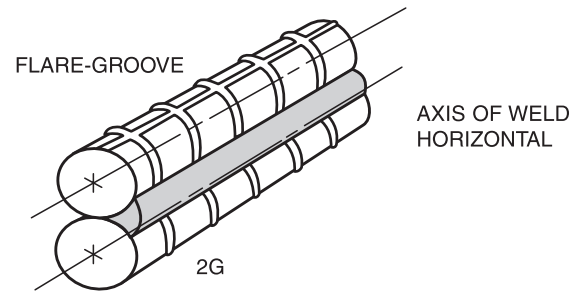


Note: See Figure 6.3 for definition of positions for groove welds.

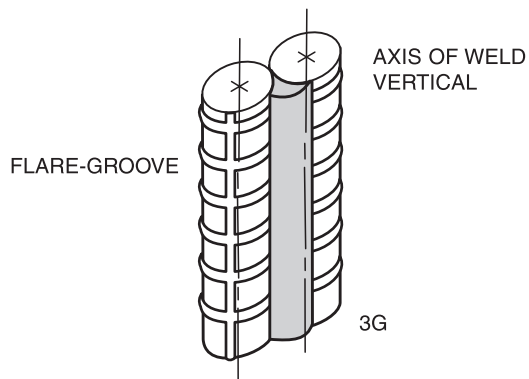
Figure 6.1—Direct Butt Joint Test Positions for Groove Welds (see 6.2.3)



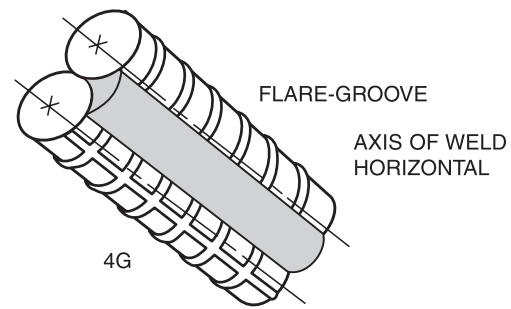
(A) TEST POSITION : FLAT



(B) TEST POSITION : HORIZONTAL



(C) TEST POSITION : VERTICAL

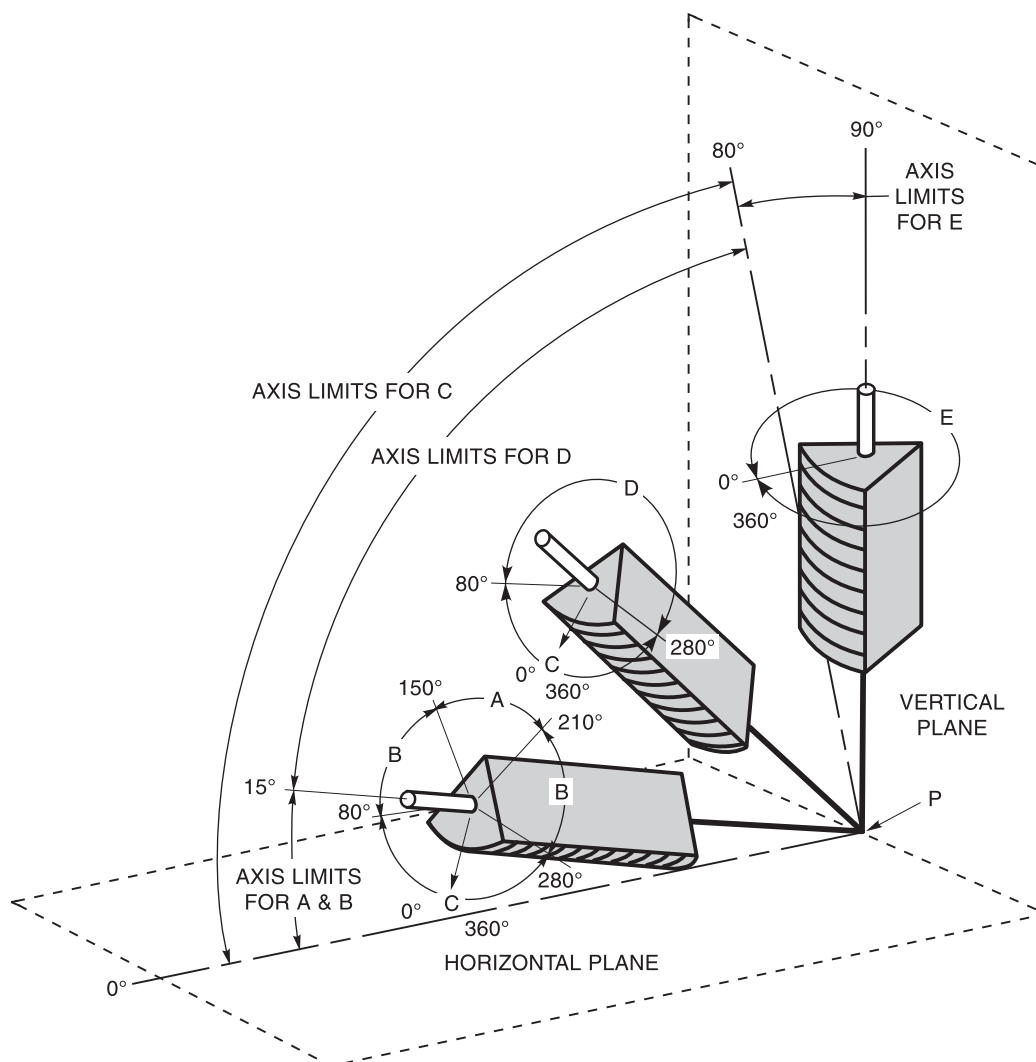


(D) TEST POSITION : OVERHEAD

Note: See Figures 6.3 and 6.4 for definitions of positions for flare-groove and fillet welds.

**Figure 6.2—Indirect Butt Joint Test Positions for
Flare-Groove Welds or Fillet Welds (see 6.2.3)**

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



Notes:

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

Figure 6.3—Positions of Groove Welds (see 6.2.3)

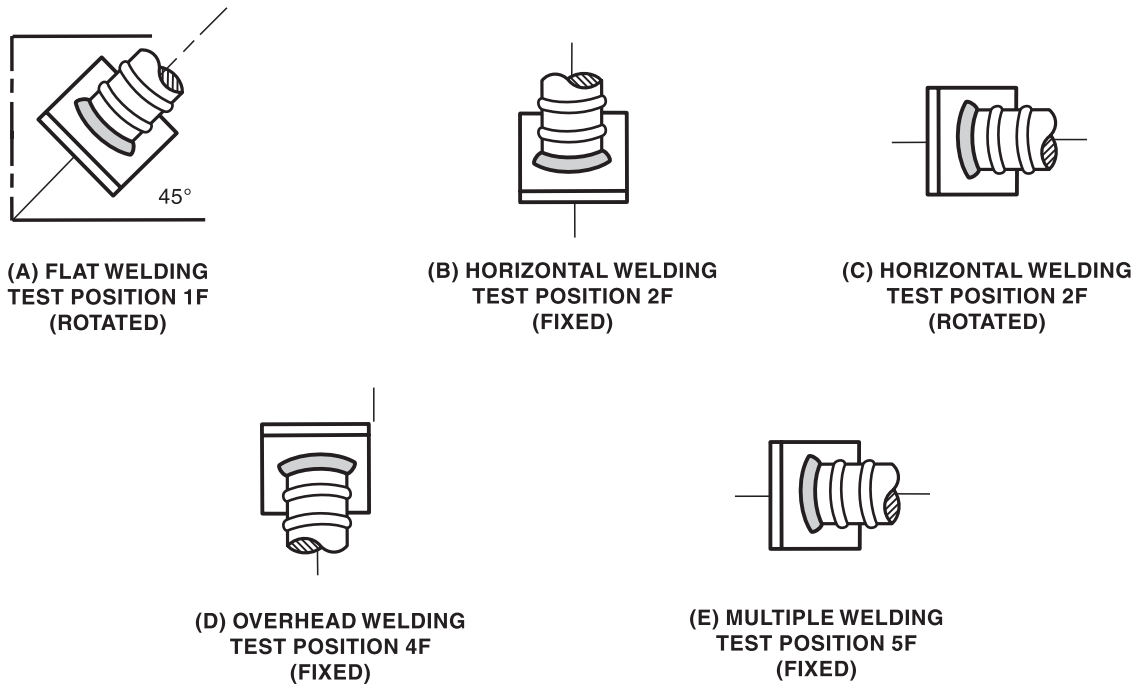
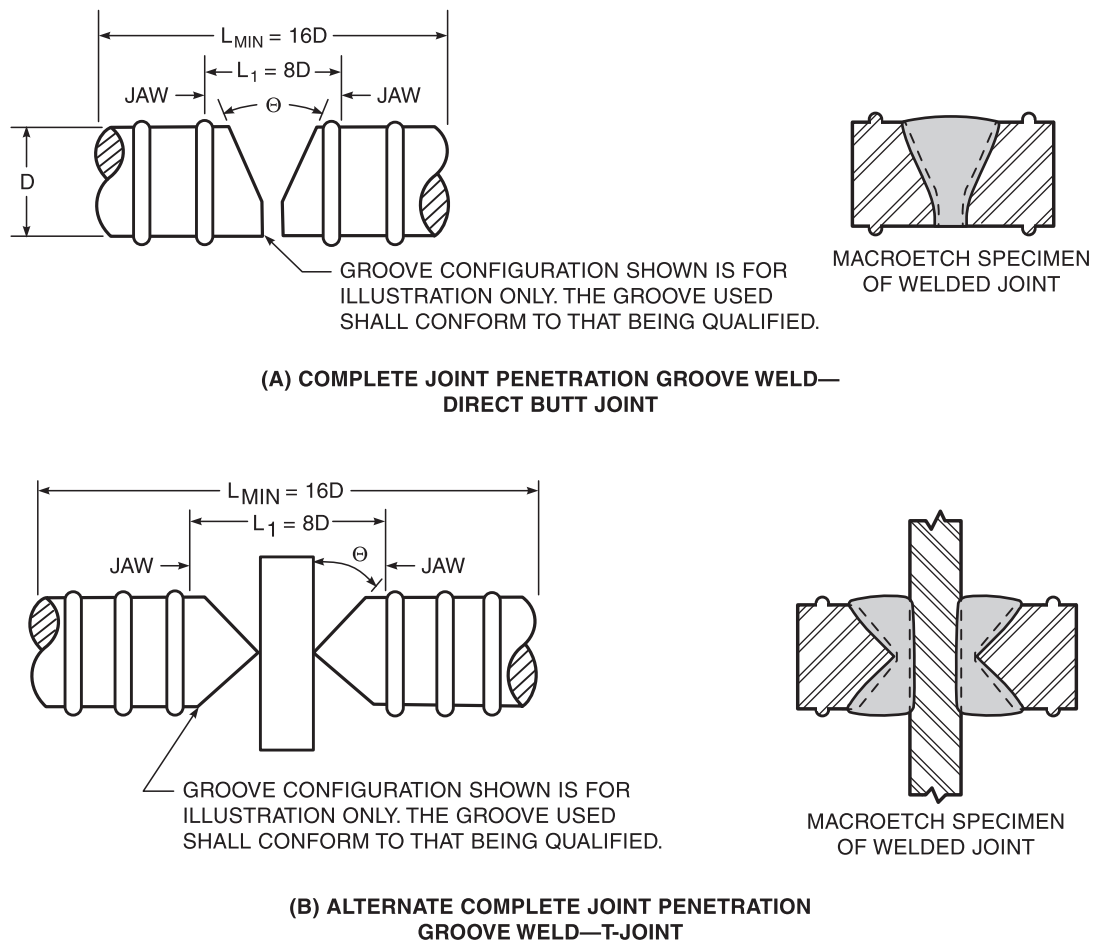
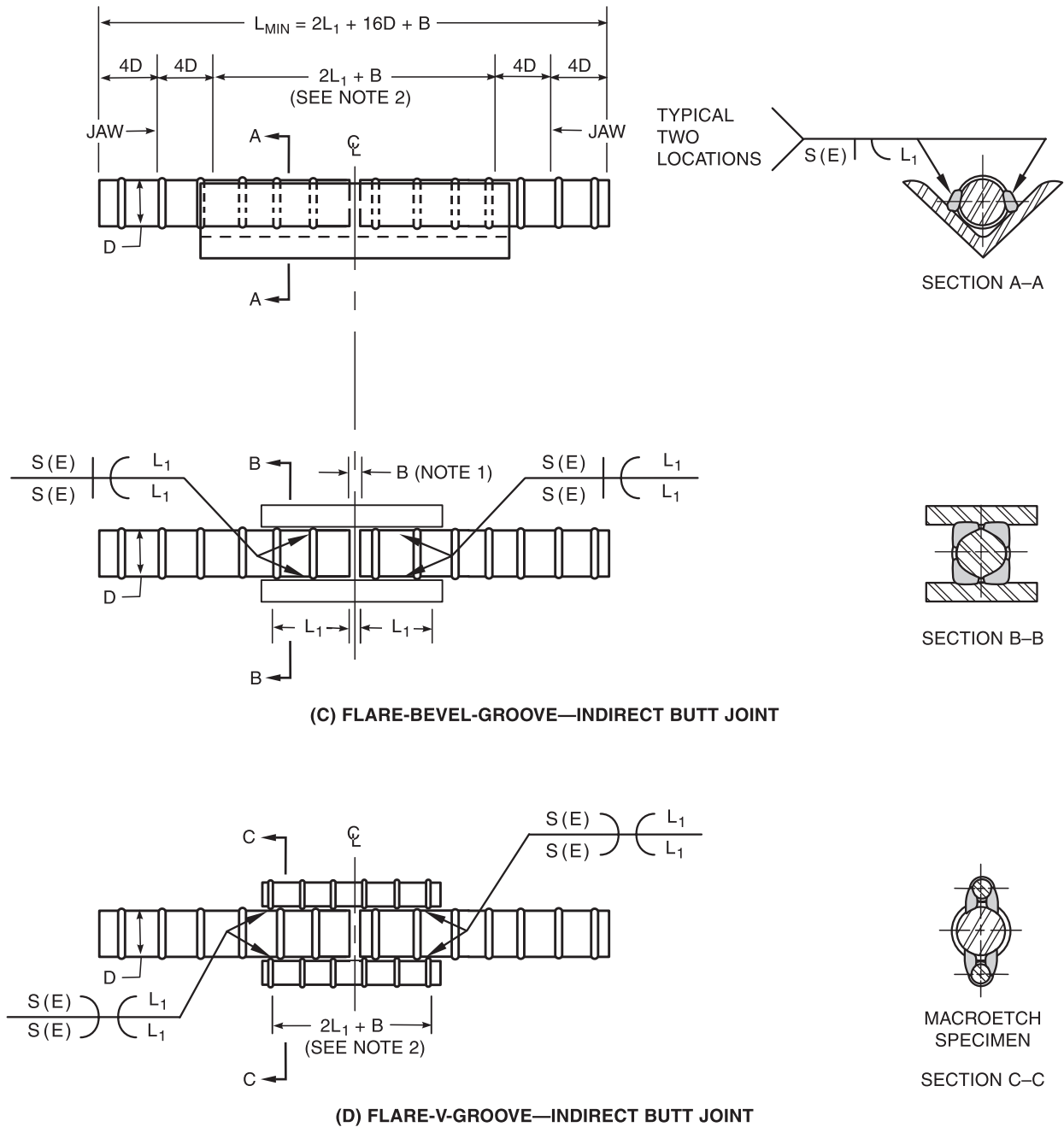


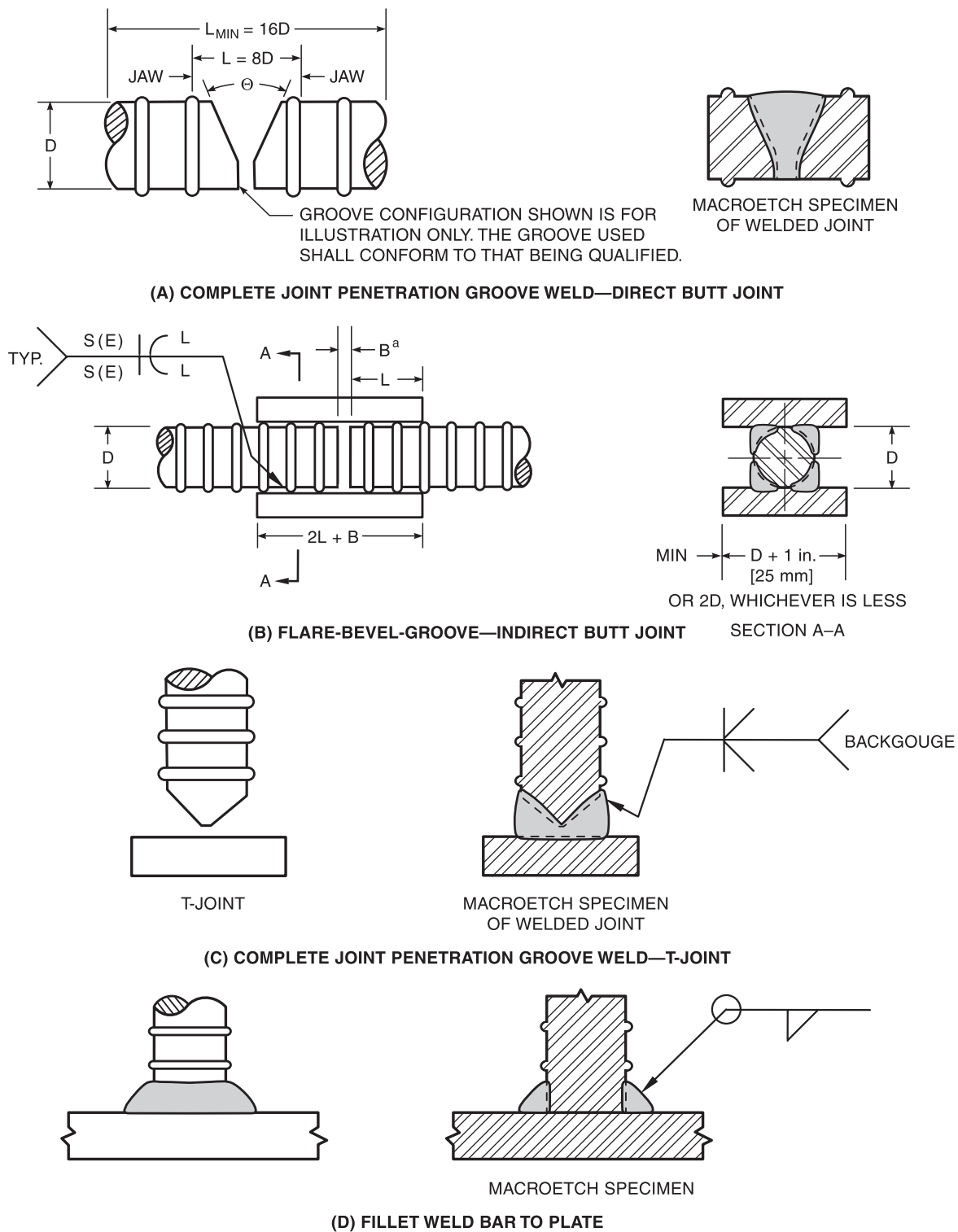
Figure 6.4—Positions of Fillet Welds (see 6.2.3)



**Figure 6.5—Full Section Tension Test Specimens
for WPS Qualification Tests (see 6.2.4.2)**



**Figure 6.5 (Continued)—Full Section Tension Test Specimens
for WPS Qualification Tests (see 6.2.4.2)**



^aB = Separation between ends of bars. Maximum: B = 3/4 in. [19 mm].

Notes:

1. For Bars No. 9 [29] or larger, use single-V or single-bevel-groove welds ($\Theta = 45^\circ$).
2. For Bars No. 8 [25] or smaller, use single-V with split pipe backing, [$\Theta = 60^\circ$, as in Figure 3.2(C)].

Figure 6.6—Full Section Tension Test and Macroetch Test Specimens for Welder Qualification Tests (see 6.3.3.3)

7. Inspection

7.1 General Requirements

7.1.1 The inspector shall ascertain that all fabrication by welding is performed in accordance with the requirements of this code.

7.1.2 Inspectors responsible for acceptance or rejection of material and workmanship shall be qualified. The basis of Inspector qualification shall be documented. If the Engineer elects to specify the basis of inspector qualification, it shall be so stated in contract documents.

The following are acceptable qualification bases:

1. Current or previous certification as an AWS Certified Welding Inspector (CWI) in accordance with the provisions of AWS QC1, *Standard for AWS Certification of Welding Inspectors*
2. Current or previous qualification by the Canadian Welding Bureau (CWB) to the requirements of the Canadian Standard Association (CSA) Standard W178.2, *Certification of Welding Inspectors*
3. An Engineer or technician who, by training, or experience, or both, in metals fabrication, inspection and testing, is competent to perform inspection of the work

7.1.3 The Inspector shall be furnished with complete detail drawings showing the size, length, type, and location of all welds to be made.

7.1.4 The Inspector shall be notified, in advance, of the start of any welding operations.

7.2 Inspection of Base Metals

The inspector shall make certain that only base metals are used that conform to the requirements of this code.

7.3 Inspection of WPS Qualification and Equipment

The Inspector shall verify the welding and subsequent testing of any WPS qualification specimens that are required. The Inspector shall inspect the welding equipment to be used for the work to make certain that it is in

such condition as to enable qualified welders to apply qualified WPSs and attain results prescribed elsewhere in this code.

7.4 Inspection of Welder Qualifications

7.4.1 The Inspector shall permit welding to be performed only by welders who are qualified in accordance with the requirements of this code. The Inspector shall witness the welding and testing of qualification specimens for each welder, or shall make certain that each welder has previously demonstrated those qualifications under other acceptable supervision.

7.4.2 When the quality of the welder's work appears to be below the requirements of this code, the Inspector may require testing of a welder's qualification by means of partial or complete requalification in accordance with 6.3.

7.5 Inspection of Work and Records

7.5.1 The Inspector shall verify that the size, length, and location of all welds conform to the requirements of this code and to the detail drawings, that no specified welds are omitted, and that no unspecified welds have been added without approval.

7.5.2 The Inspector shall verify that the WPSs used meet the provisions of this code.

7.5.3 The Inspector shall verify that welders have copies of, or access to, the WPSs, and that the welding is performed in conformance with the WPS and code requirements.

7.5.4 The Inspector shall, at suitable intervals, observe the technique and performance of each welder to verify that the applicable requirements of this code are met.

7.5.5 The Inspector shall examine the work to verify that it meets the requirements of this code. Size and length of welds shall be measured with suitable gages. Visual

inspection for cracks and other discontinuities in the welds and base metal should be aided by a strong light, magnifiers, or other helpful devices as necessary.

7.5.6 Inspectors shall identify with a distinguishing mark or other recording methods all parts or joints that they have inspected and accepted. Any recording method which is mutually agreeable may be used. Die stamping of dynamically loaded members is not permitted without the approval of the Engineer.

7.5.7 The Inspector shall keep a record of qualifications of all welders, all WPS qualifications or other tests that are made, and other such information as may be required.

7.6 Obligations of the Contractor

7.6.1 The contractor shall be responsible for visual inspection and necessary correction of all deficiencies in materials and workmanship in accordance with the requirements of Sections 3 and 4, and 4.4 or other parts of the code, as applicable.

7.6.2 The contractor shall comply with all requests of the Inspector(s) to correct deficiencies in materials and workmanship as provided in the contract documents.

7.6.3 In the event that faulty welding or its removal for rewelding damages the base metal so that in the judgment of the Engineer its retention is not in accordance with the intent of the contract documents, the contractor shall remove and replace the damaged base metal or shall compensate for the deficiency in a manner approved by the Engineer.

7.6.4 When nondestructive testing other than visual inspection is specified in the information furnished to bidders, it shall be the contractor's responsibility to ensure that all specified welds meet the quality requirement or 4.4.

7.6.5 If nondestructive testing other than visual inspection is not specified in the original contract agreement but is subsequently requested by the owner, the contractor shall perform any requested testing or shall permit any testing to be performed in accordance with 7.7. The owner shall be responsible for all associated costs including handling, surface preparation, nondestructive testing, and repair of discontinuities other than those listed in 4.4.1 to 4.4.7 inclusive, at rates mutually agreeable between owner and contractor. However, if such testing should disclose an attempt to defraud or gross nonconformance to this code, repair work shall be done at the contractor's expense.

7.7 Nondestructive Testing

7.7.1 When nondestructive testing other than visual is required, it shall be so stated in the information furnished to the bidders. This information shall designate the welds to be examined, the extent of the examination of each weld, and method of testing.

7.7.2 Welds tested nondestructively that do not meet the requirements of this code shall be repaired using the applicable provisions of this code.

7.7.3 When radiographic testing is used, the procedure and technique shall be in accordance with 7.9.

7.7.4 When magnetic particle testing is used, the procedure and technique shall be in accordance with ASTM E 709, *Standard Guide for Magnetic Particle Examination*, and the standard of acceptance shall be in accordance with 4.4 of this code.

7.7.5 For detecting discontinuities that are open to the surface, liquid penetrant inspection may be used. The standard methods set forth in ASTM E 165, *Standard Test Method for Liquid Penetrant Inspection*, shall be used for liquid penetrant inspection, and the standards of acceptance shall be in accordance with 4.4 of this code.

7.7.6 Ultrasonic inspection of direct butt joints in deformed reinforcing bars is not considered feasible except by highly specialized techniques and is not recommended.

7.8 Personnel Qualification

7.8.1 Personnel performing nondestructive testing other than visual shall be qualified in accordance with the current edition of the American Society for Nondestructive Testing's *Recommended Practice No. SNT-TC-1A*. Only individuals qualified for NDT Level I and working under the NDT Level II or individuals qualified for NDT Level II may perform nondestructive testing.

7.8.2 Certification of Level I and Level II individuals shall be performed by a Level III individual who has been certified by (1) The American Society for Nondestructive Testing, or (2) has the education, training, experience, and has successfully passed the written examination prescribed in SNT-TC-1A.

7.9 Radiographic Testing

7.9.1 Radiographic Testing of Direct Butt Joints

7.9.1.1 Procedures and Standards. The procedures and standards set forth in this code are to govern radiographic testing of welds when such inspection is required by the contract documents as provided in 7.6. The requirements listed herein are specifically for testing groove welds in direct butt joints in reinforcing steel bars by X-ray or gamma-ray sources. The methodology shall conform to ASTM E 94, *Standard Guide for Radiographic Testing*, and ASTM E 1032, *Standard Test Method for Radiographic Examination of Weldments*. *Note: Inspection of flare-V- and flare-bevel-groove welds or fillet welds by radiographic testing method is, in general, not considered feasible, except by highly specialized techniques, and is not recommended.*

7.9.1.2 Weld Quality. Prior to radiographic testing, welds shall meet the visual criteria described in 4.4. When radiographic testing of direct butt joints is required, the maximum dimension of any single porosity or fusion-type discontinuity, or the sum of the maximum dimensions of all porosity and fusion-type discontinuities, shall not exceed the limits given in Table 4.1. Welds tested nondestructively that do not meet the requirements of this code shall be repaired using the applicable provisions of this code.

7.9.1.3 Variations. Variations in testing procedures, equipment, and acceptance standards may be used with approval of the Engineer. Such variations include, but are not limited to, the following. Changes in source-to-film distance; unusual application of film; unusual hole-type image quality indicators (IQI) applications (including film side IQI); film types, densities, and variations in exposure, development, and viewing techniques.

7.9.2 Radiographic Procedures

7.9.2.1 Procedure. Radiographs shall be made using a single source of either X-ray or gamma-ray radiation. The radiographic sensitivity shall be judged based on hole-type image quality indicators (IQI). Radiographic technique and equipment shall provide sufficient sensitivity to clearly delineate the required hole type IQIs and the essential holes as described in IQI Selection and Placement, Table 7.1 and Figure 7.1. Identifying letters and numbers shall show clearly in the radiograph.

7.9.2.2 Safety Requirements. Radiography shall be performed in accordance with all applicable safety requirements.

7.9.2.3 Weld Reinforcement. Weld reinforcement shall not exceed 1/8 in. [3 mm]. Weld surfaces need not be ground or otherwise smoothed for purposes of radio-

graphic testing unless surface irregularities or the junction between weld and base metal exist that may cause weld discontinuities to be obscured in the radiograph.

7.9.2.4 Tabs. Weld tabs shall be removed prior to radiographic inspection.

7.9.2.5 Steel Backing. When required by the contract documents, steel backing shall be removed, and the surface shall be finished flush by grinding prior to radiography.

7.9.2.6 Reinforcement. When weld reinforcement or backing, or both, is not removed, steel shims which extend at least 1/8 in. [3 mm] beyond three sides of the required IQI shall be placed under the hole type IQI. The total thickness of steel between the IQI and the film is approximately equal to the average thickness of the weld measured through its reinforcement and backing.

7.9.2.7 Radiographic Film. Radiographic film shall be as described in ASTM E 94. Lead foil screens shall be used as described in ASTM E 94. Fluorescent screens shall not be permitted.

7.9.2.8 Technique. Radiographs shall be made with a single source of radiation centered as near as practicable with respect to the centerline of the weld and width of the bar. The source shall be positioned so that the inspecting radiation passes through the plane of the weld at an angle normal to the long axis of the bar. No inspecting radiation shall penetrate any portion of the weld represented in the radiograph at an angle greater than $26\text{--}1/2^\circ$ from a line normal to the weld surface. See Figure 7.1 for source position.

7.9.2.9 Two Direction Radiography. Two exposures shall be made for each direct butt joint tested. The first exposure shall be made with the radiation source placed at zero degrees from the top of the weld and exactly perpendicular to the weld root or backing bar and identified with a lead station mark of "0." The second exposure shall be at 90 degrees to the "0" station mark and shall be identified with a lead station mark "90." When obstructions prevent an exact 90-degree placement of the radiation source, for the second exposure, the source may be rotated around the centerline of the reinforcing bar weld ± 35 degrees from 90° , and identified with a lead station mark appropriate to the location. Deviation from 0° and 90° positions shall require approval of the Engineer.

7.9.2.10 Backing Bar Width. The width of the backing bar shall not project beyond the diameter of the reinforcing bar in order to facilitate the perpendicular placement of the film in relation to the source of the 90-degree exposure.

7.9.2.11 Backing Bar Length. The length of the backing bar shall be sufficient to extend past the radiographic area of interest and allow for placement of the IQI within the radiographic image of the backing bar.

7.9.2.12 Film Placement. The radiographic film shall be placed perpendicular to the radiation source at all times and in contact with the bar. The film shall be placed at the root of the joint for the zero degree exposure. See Figure 7.2 for film placement.

7.9.2.13 Geometric Unsharpness. Gamma ray sources, regardless of size, shall be capable of meeting the geometric unsharpness limitation of ASME *Boiler and Pressure Vessel Code*, Section V, Article 2, regardless of the size of the reinforcing bar.

7.9.2.14 Source-to-Subject Distance. The source-to-subject distance shall be maintained so as to not violate the maximum geometric unsharpness criteria of 0.020, at all times, as specified in ASME *Boiler and Pressure Vessel Code*, Section V, Article 2. The source-to-subject distance shall not be less than seven times the thickness of weld plus reinforcement and backing, if any.

7.9.2.15 Sources. X-ray units, 600 kvp maximum, and iridium 192 may be used as a source for all radiographic inspection provided they have adequate penetrating ability. Other radiographic sources shall be subject to the approval of the Engineer.

7.9.2.16 IQI Selection and Placement. Hole type IQIs shall be selected and placed on the source side of the bar, perpendicular to the radiation source and nearest the area of interest being radiographed. One hole type IQI shall be placed in the center of each bar to be radiographed with the 2 T hole being closest to the weld and the IQI identification numbers being furthest from the weld. IQI image shall not appear in the radiographic image of the weld. When more than one bar is being radiographed each shall have an IQI placed as described above. Wire penetrameters or penetrometer blocks shall not be used. Penetrometer image density shall be maintained in accordance with the density limitations specified for the area of interest.

7.9.2.17 Technique Coverage. Welded joints shall be radiographed by methods that will provide complete inspection of the joint within the limits specified to be examined. Short film, short screens, excessive undercut by scattered radiation, or any other process that obscures portions of the total weld shall render the radiograph unacceptable.

7.9.2.18 Film Length. Film shall have sufficient length and shall be placed to provide at least 1/2 in. [12 mm] of film beyond the projected edge of the weld.

7.9.2.19 Film Width. Film widths shall be sufficient to depict all portions of the weld joint, including the heat-affected zones (HAZs), and shall provide sufficient additional space for the required hole type IQIs and film identification without infringing upon the areas of interest in the radiograph.

7.9.2.20 Backscatter. To check for backscatter radiation, a lead symbol "B," 1/2 in. [12 mm] high, 1/16 in. [2 mm] thick shall be attached to the back of each film cassette. If the "B" image appears on the radiograph, the radiograph shall be considered unacceptable. A dark image of the "B" on a lighter background is not cause for rejection.

7.9.2.21 Quality of Radiograph. All radiographs shall be free from mechanical, chemical, or other blemishes to the extent that they cannot mask or be confused with the image of any discontinuity in the area of interest in the radiograph. Such blemishes include, but are not limited to, the following:

1. fogging
2. processing defects such as streaks, water marks, or chemical stains.
3. scratches, finger marks, crimps, dirtiness, static marks, smudges, or tears.
4. loss of detail due to poor screen-to-film contact.
5. false indications due to defective screens or internal faults.

7.9.2.22 Density Limitations. The transmitted film density through the radiographic image of the body of the required hole type IQI(s) and the area of interest shall be 1.8 minimum for single film viewing for radiographs made with an X-ray source and 2.0 minimum for radiographs made with a gamma-ray source. For composite viewing of double film exposures, the minimum density shall be 2.6. Each radiograph of a composite set shall have a minimum density of 1.3. The maximum density shall be 4.0 for either single or composite viewing.

7.9.2.23 Transitions. When welds between bars with differing diameters are radiographed and the ratio of the thickness of the thicker section of the thickness of the thinner section is 3 or greater, radiographs should be exposed to produce single film densities of 3.0 to 4.0 in the thinner section. When this is done, the minimum density requirements stated above shall be waived unless otherwise provided in the contract documents.

7.9.2.24 Double Loaded Cassettes. Due to the geometric condition of reinforcing bars, the use of double loaded cassettes with film of differing speeds may be required in order to maintain proper density throughout the full cross-sectional area thickness of the bar. Variations in density between double loaded film shall be maintained by film speed and exposure time and not by

reducing or increasing the development time beyond the film manufacturer's recommended development duration. When utilizing double loaded cassettes the radiographic film density shall comply with the requirements for single film viewing in the area represented by the film. The middle portions or through thickness of the bar shall be represented by one film that has a faster exposure speed and the outer radius portion of the bar shall be represented by a second film that has a slower exposure speed. Each film is viewed separately and the evaluations are combined to determine the disposition of the weld in accordance with Table 4.1.

7.9.2.25 H & D Density. The density measured shall be H & D density (radiographic density), which is a measure of film blackening, expressed as:

$$D = \log I_0/I$$

where

D = H & D (radiographic) density

I_0 = light intensity on the film, and

I = light transmitted through the film.

7.9.2.26 Identification Marks. A radiograph identification mark and station identification marks shall be placed on the bar at each radiograph location. A corresponding radiograph identification mark and station identification marks, all of which shall show in the radiograph, shall be produced by placing lead numbers or letters, or both, over each of the identical identification and location marks made on the steel to provide a means for matching the developed radiograph to the weld. Additional identification information may be pre-printed no less than 3/4 in. [20 mm] from the edge of the weld or shall be produced on the radiograph by placing lead figures on the steel. Information required to show on the radiograph shall include the contract identification, initials of the radiographic inspection company, initials of the fabricator, the fabricator shop order number, the radiographic identification mark, the date, and the weld repair number, if applicable. Each piece of film identifi-

cation information shall be clearly legible. Film shall be identified by lead letters or numbers.

7.9.3 Examination, Report, and Disposition of Radiographs

7.9.3.1 Equipment Provided by Contractor. The contractor shall provide a suitable variable intensity illuminator (viewer) with spot review or masked spot review capability. The viewer shall incorporate a means for adjusting the size of the spot under examination. The viewer shall have sufficient capacity to properly illuminate radiographs with an H&D density of 4.0. Film review shall be done in an area of subdued light.

7.9.3.2 Reports. Before a weld subject to radiographic testing is accepted, all of its radiographs, including any that show unacceptable quality prior to repair, and a report interpreting them shall be submitted to the Engineer.

7.9.3.3 Record Retention. A full set of radiographs for welds subject to radiographic testing by the contractor for the owner, including any that show unacceptable quality prior to repair, shall be delivered to the owner upon completion of the work. The contractor's obligation to retain radiographs shall cease: (1) upon delivery of this full set to the owner, or (2) one full year after the completion of the contractor's work, provided the owner is given prior written notice.

7.9.3.4 Radiograph Interpretation. All radiographs shall be interpreted by an individual certified as a Level II in accordance with the latest edition of the American Society for Nondestructive Testing's Recommended Practice No. SNT-TC-1A. Interpretation of direct butt joints in steel reinforcing bars is considerably more difficult than interpreting groove welds in butt joints between plates. Individuals responsible for interpreting reinforcing bar weld radiographs shall be experienced in the radiographic techniques required to evaluate the complex geometric characteristics of cylindrical objects.

Table 7.1
Hole-Type Image Quality Indicator (IQI) Requirements (see 7.9.2.1)

Bar Size		Source Side (IQI)	
in.	mm	Designation	Essential Hole
3	10	12	4T
4	13	15	4T
5	16	15	4T
6	19	17	4T
7	22	20	4T
8	25	20	4T
9	29	25	4T
10	32	30	2T
11	36	30	2T
14	43	35	2T
18	57	40	2T

Notes:

1. Weld reinforcement has been accounted for in the above table.
2. No increase in IQI designation or change in essential hole is permitted to account for weld reinforcement or backing.
3. Film side IQIs are prohibited.

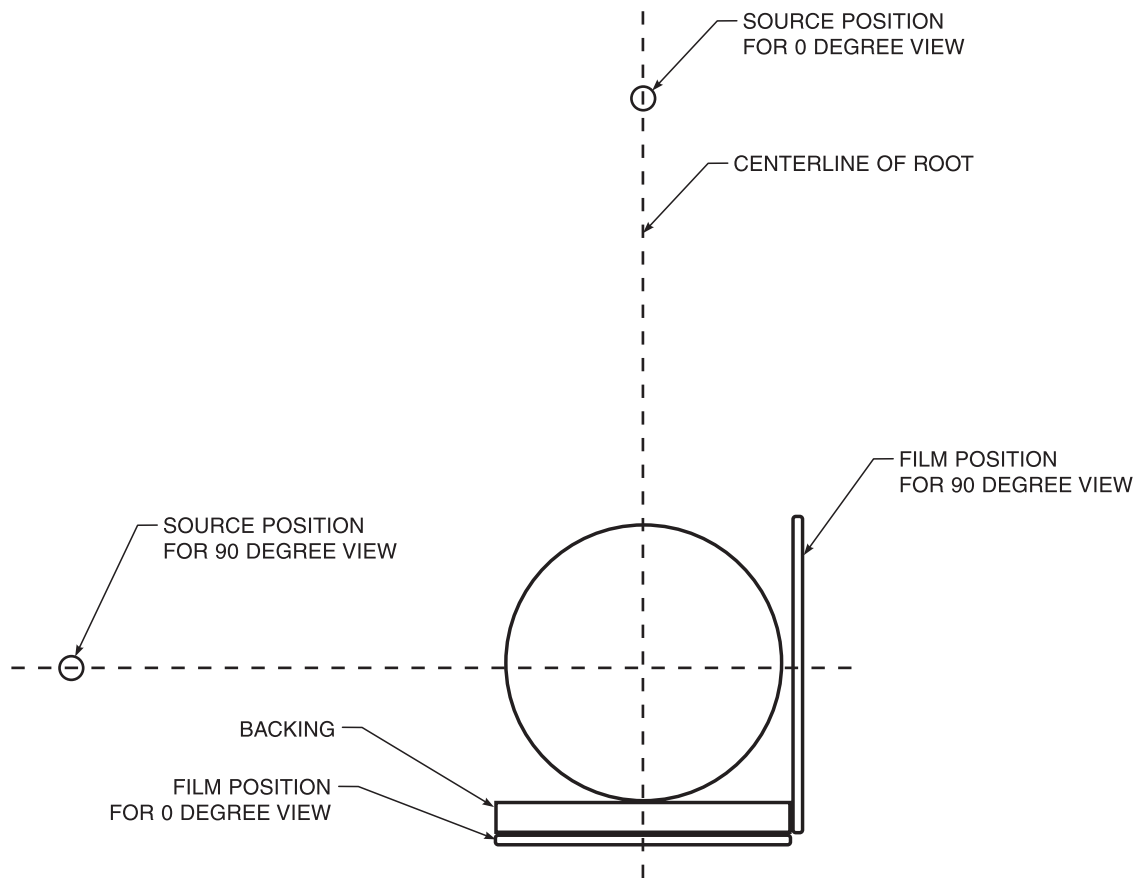


Figure 7.1—Source Position (see 7.9.2.1)

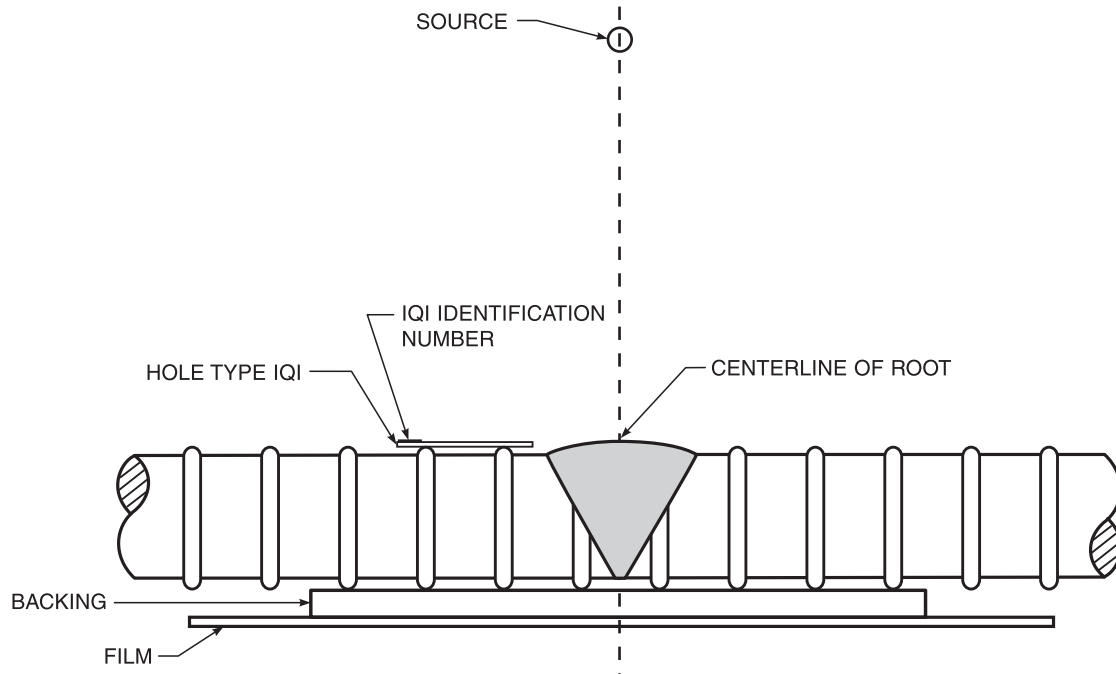


Figure 7.2—Film Placement (see 7.9.2.12)

Annex A (Informative)

Sample Welding Forms

This annex is not a part of AWS D1.4/D1.4M:2005, *Structural Welding Code—Reinforcing Steel*, but is included for informational purposes only.

This annex contains three sample forms.

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Sample Procedure Qualification Record (PQR) Form

Procedure Qualification Record (PQR) No. _____

Contractor _____

Authorized by _____

Revision No. _____

Welder _____

Test Date _____

Welding Process: ☐ FCAW-G ☐ FCAW-S ☐ GMAW ☐ SMAW

PQR JOINT TYPE

☐ Direct Butt ☐ Indirect Butt ☐ T-Joint

Test Assembly: ☐ Figure 6.5(A) ☐ Figure 6.5(B) ☐ Figure 6.5(C) ☐ Figure 6.5(D)

Position _____ Groove Type _____ ☐ Single Bevel ☐ Double Bevel

Root Opening _____ Root Face _____ Groove Angle _____

Backing: ☐ Yes ☐ No Backing Type _____

Backgouging: ☐ Yes ☐ No Backgouging Method _____

Technique: ☐ Stringers ☐ Weave

ELECTRICAL CHARACTERISTICS

Current: ☐ AC ☐ DCEP ☐ DCEN

Transfer Mode (GMAW): ☐ Short-circuiting ☐ Globular ☐ Spray

BASE METAL

Material Specification _____ Grade _____

welded to Material Specification _____ Grade _____

Carbon Equivalent (Bar) _____ Bar size _____

Coated Bar: ☐ Yes ☐ No Type of Coating _____

FILLER METAL

AWS Specification _____ AWS Classification _____

Describe filler metal (if not covered by AWS specification) _____

SHIELDING

Gas: ☐ Single ☐ Mixture Composition _____ Flow rate _____

PREHEAT/INTERPASS

Preheat/Interpass Temperature (Min) _____

Interpass Temperature (Max) _____

WELDING PARAMETERS

Pass Number	Electrode Diameter	Current				Travel Speed (ipm)	Joint Detail
		Type	Amperage	WFS (ipm)	Volts	Electrical Stickout	

Note: Attach additional sheets as required for detailing each pass.

Form A-1 (front)

Sample Procedure Qualification Record (PQR) Form

Continuation of Procedure Qualification Record (PQR) No. _____

TEST RESULTS

VISUAL EXAMINATION

Test Assembly Number One

☐ Pass ☐ Fail (AWS D1.4, Section 4.4)

Comments _____

Test Assembly Number Two

☐ Pass ☐ Fail (AWS D1.4, Section 4.4)

Comments _____

TENSILE TEST

Test Assembly Number One

☐ Pass ☐ Fail (AWS D1.4, Section 6.3.7.2)

Test Assembly Number Two

☐ Pass ☐ Fail (AWS D1.4, Section 6.3.7.2)

Specimen No.	Width	Thickness	Area	Ultimate Tensile Load (lbs)	Ultimate Unit Stress (psi)	Character of Failure and Location

MACROETCH TEST

Test Assembly Number One

☐ Pass ☐ Fail (AWS D1.4, Section 6.3.7.3)

Test Assembly Number Two

☐ Pass ☐ Fail (AWS D1.4, Section 6.3.7.3)

Specimen No.	Results	Remarks

Welder's Name _____

Clock No. _____ Stamp No. _____

Test conducted by _____ (Laboratory)

Test Number _____

Per _____

We, 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 AWS D1.4/D1.4M:2005, *Structural Welding Code—Reinforcing Steel*.

Manufacturer or Contractor _____

Authorized by _____ Date _____

Form A-1 (back)

Sample Welding Procedure Specification (WPS) Form

Welding Procedure Specification (WPS) No. _____

Contractor _____

Authorized by _____

Revision No. _____

Supporting PQR Identification _____

Test Date _____

WELDING PROCESS: ☐ FCAW-S ☐ FCAW-G ☐ GMAW ☐ SMAW

WELD TYPE: ☐ Groove ☐ Fillet

JOINT TYPE: ☐ Direct Butt ☐ Indirect Butt ☐ T-Joint

Joint(s) Qualified (see Table 6.2) _____

Position _____ Groove Type _____

Root Opening _____ Root Face _____ Groove Angle _____

Backing: ☐ Yes ☐ No Backing Type _____

Backgouging: ☐ Yes ☐ No Backgouging Method _____

TECHNIQUE: ☐ Stringers ☐ Weave

ELECTRICAL CHARACTERISTICS

Current: ☐ AC ☐ DCEP ☐ DCEN

Transfer Mode (GMAW): ☐ Short-circuiting ☐ Globular ☐ Spray

BASE METAL

Material Specification _____ Grade _____

Welded to: Material Specification _____ Grade _____

Maximum Carbon Equivalent _____ Bar size _____ Plate Thickness _____

Coated Bar: ☐ Yes ☐ No Type of Coating _____

FILLER METAL

AWS Specification _____ AWS Classification _____

Describe filler metal (if not covered by AWS specifications) _____

SHIELDING

Gas: ☐ Single ☐ Mixture Composition _____ Flow rate _____

PREHEAT/INTERPASS

Preheat/Interpass Temperature (Min) _____ Interpass Temperature (Max) _____

WELDING PARAMETERS

Pass Number(s)	Electrode Diameter	Current				Travel Speed (ipm)	Joint Detail
		Type	Amperage Range	Volts Range	Electrical Stickout		

Manufacturer or Contractor _____

Authorized by _____ Date _____

Form A-2

Sample Welder Qualification Test Record

Welder's Name & ID No. _____ Date _____

Welding Procedure Specification No. _____ Revision No. _____

Process: ☐ GMAW ☐ FCAW ☐ SMAW ☐ GMAW-S	Material Specification: Bar _____ Structural Steel _____	☐ T-Joint [Figure 6.5(B)] ☐ Direct Butt [Figure 6.5(A)] ☐ Indirect Butt [Figure 6.5(C) & (D)] ☐ Fillet [Figure 6.6(D)]
Backing: ☐ Yes ☐ No	Position: ☐ Vertical Up ☐ OH ☐ Horizontal ☐ Flat	Material Specification: Bar to Bar _____ Bar to Structural Steel _____

FILLER METAL

AWS Specification No. _____	AWS Classification _____
Electrode _____	Diameter/F No. _____
Shielding Gas _____	Trade Name _____

TEST RESULTS

Visual Weld Appearance: (Section 4.4) 1. ☐ Pass ☐ Fail 2. ☐ Pass ☐ Fail	Tensile Strength, psi: (Subsection 6.3.7.2) 1. _____ 2. _____
Macroetch Test Results: (Subsection 6.3.7.3) 1. ☐ Pass ☐ Fail 2. ☐ Pass ☐ Fail	Fillet Weld Test: (Subsection 6.3.7.4) 1. ☐ Pass ☐ Fail 2. ☐ Pass ☐ Fail
Interpreted by _____ Organization _____	Test No. _____ Date _____

RADIOGRAPHIC TEST RESULTS

Film Identification	Results	Remarks	Film Identification	Results	Remarks

Interpreted by _____	Test No. _____
Organization _____	Date _____

We, 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 AWS D1.4/D1.4M:2005, *Structural Welding Code—Reinforcing Steel*.

Manufacturer or Contractor _____

Authorized by _____ Date _____

QUALIFICATION RESULTS

The Welder/Operator identified above ☐ DOES ☐ DOES NOT meet the performance qualifications specified in the AWS D1.4/D1.4M:2005 code for the variables stated.
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Annex B (Informative)

Nominal Dimensions of ASTM Standard Reinforcing Bars

This annex is not a part of AWS D1.4/D1.4M:2005, *Structural Welding Code—Reinforcing Steel*, but is included for informational purposes only.

Bar Size ^{a, b}		Unit Weight		Diameter		Cross-Sectional Area	
in.	mm	lb/ft	kg/m	in.	mm	in. ²	mm ²
3	10	0.376	0.56	0.375	9.52	0.11	71.0
4	13	0.668	1.00	0.500	12.70	0.20	129.0
5	16	1.043	1.55	0.625	15.88	0.31	200.0
6	19	1.502	2.26	0.750	19.05	0.44	283.9
7	22	2.044	3.64	0.875	22.22	0.60	387.1
8	25	2.670	3.98	1.000	25.40	0.79	509.7
9	29	3.400	5.07	1.128	28.65	1.00	645.2
10	32	4.303	6.41	1.270	32.26	1.27	819.4
11	36	5.313	7.92	1.410	35.81	1.56	1006.5
14	43	7.65	11.40	1.693	43.00	2.25	1451.7
18	57	13.60	20.26	2.257	57.33	4.00	2580.8

^a The nominal dimensions of a deformed bar are equivalent to those of a plain round bar having the same weight per foot as the deformed bar.

^b The bar size number is based on the number of eighths of an inch in the nominal diameter of the bar.

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Guidelines for Preparation of Technical Inquiries for the Structural Welding Committee

C1. Introduction

C2. Procedure

C2.1 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

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

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

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

C4. Publication of Interpretations

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

C5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning the *Structural Welding Code* should be limited to questions of a general nature or to matters directly related to the use of the code. The 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. AWS Headquarters staff cannot provide consulting services. The staff can, however, refer a caller to any of those consultants whose names are on file at AWS Headquarters.

C6. 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.

Annex D (Informative)

Safe Practices

This annex is not a part of AWS D1.4/D1.4M:2005, *Structural Welding Code—Reinforcing Steel*, but is included for informational purposes only.

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

D1. 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 worklead should not be mistaken for a ground connection.

To prevent shock, the work area, equipment, and clothing should be kept dry 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 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 administered until breathing has been restored, or until a physician has arrived. See References 8, 9, and 14.

D2. Fumes and Gases

Many welding, cutting, and allied processes produce fumes and gases which may be harmful to one's health. Fumes originate from welding consumables, the base

metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Everyone associated with the welding operation should acquaint themselves with the effects of these fumes and gases.

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

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

For more detailed information on fumes and gases produced by the various welding processes, see References 1, 5, and 15.

D3. 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. For more information see References 1 and 15.

D4. 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-retardant 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-retardant 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-retardant 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 in contact with hot items or handling electrical equipment.

For more detailed information on personal protection, References 1, 6, 8 and 15 should be consulted.

D5. 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-retardant 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 an atmosphere 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 and 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 2, 8, and 15.

D6. Radiation

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

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

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

Protection from possible harmful radiation effects include the following:

1. Welding arcs should not be viewed except through welding filter plates (see Reference 3). 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 of welding operations should be protected by the use of screens, curtains, or adequate distance from aisles, walkway, etc.
4. Safety glasses with ultraviolet protective side shields have been shown to provide some beneficial protection from ultraviolet radiation produced by welding arcs.

D7. Radiographic Procedures

The problems of personnel protection against X-rays and gamma rays are not covered in this standard. Radiographic procedures should be carried out under protected conditions so that the radiographer will not receive a maximum whole-body radiation dosage exceeding that permitted by city, state, or national codes. Mandatory rules and regulations are published by governmental licensing agencies. Careful radiation surveys should be made in accordance with appropriate regulations and codes and should be conducted in the inspection area as well as adjacent areas under all possible operating conditions.

For more complete information, the user should refer to References 4, 10, 11, 12, and 16.

References Cited

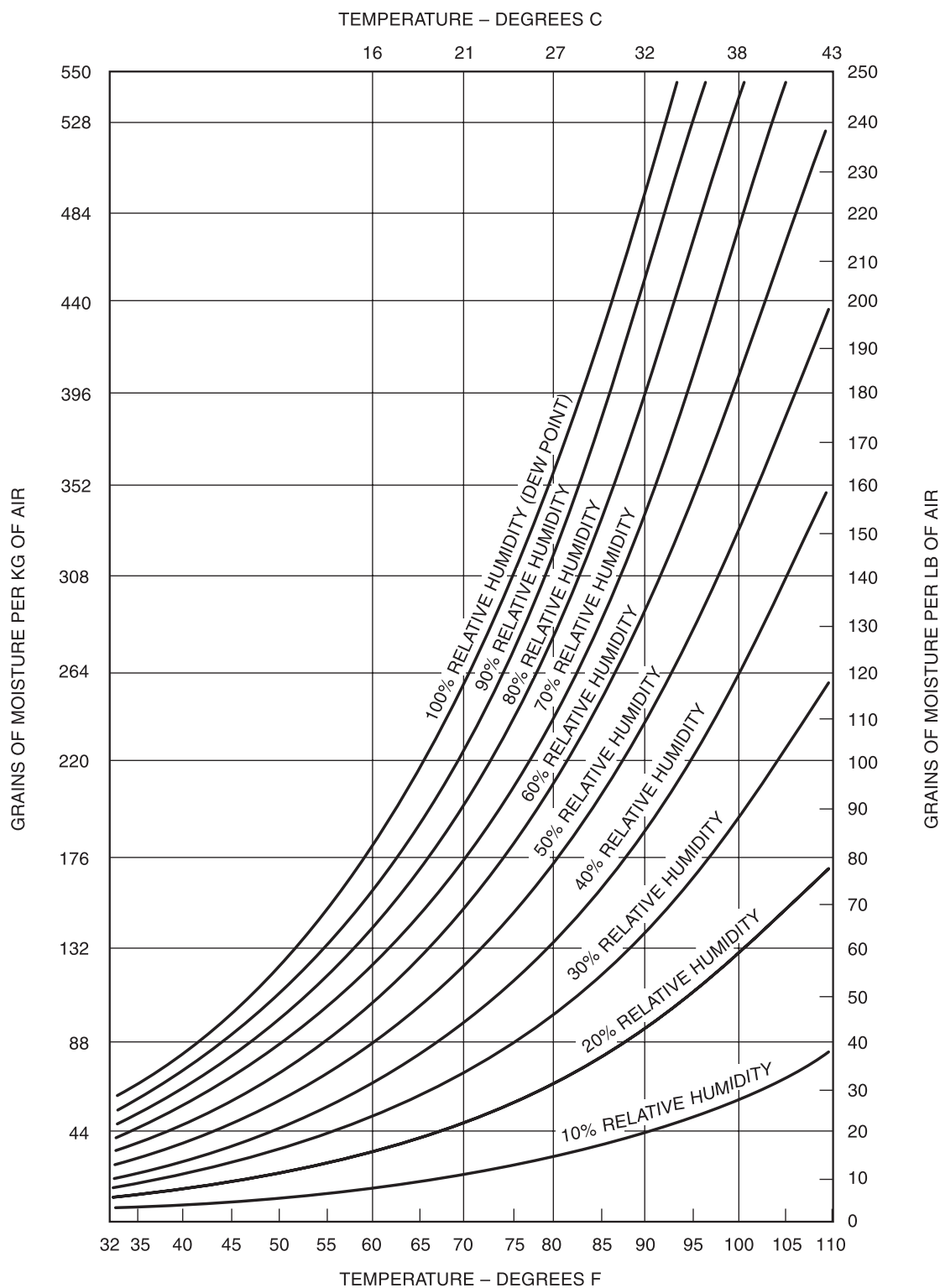
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Annex E (Informative)

Temperature-Moisture Content Charts

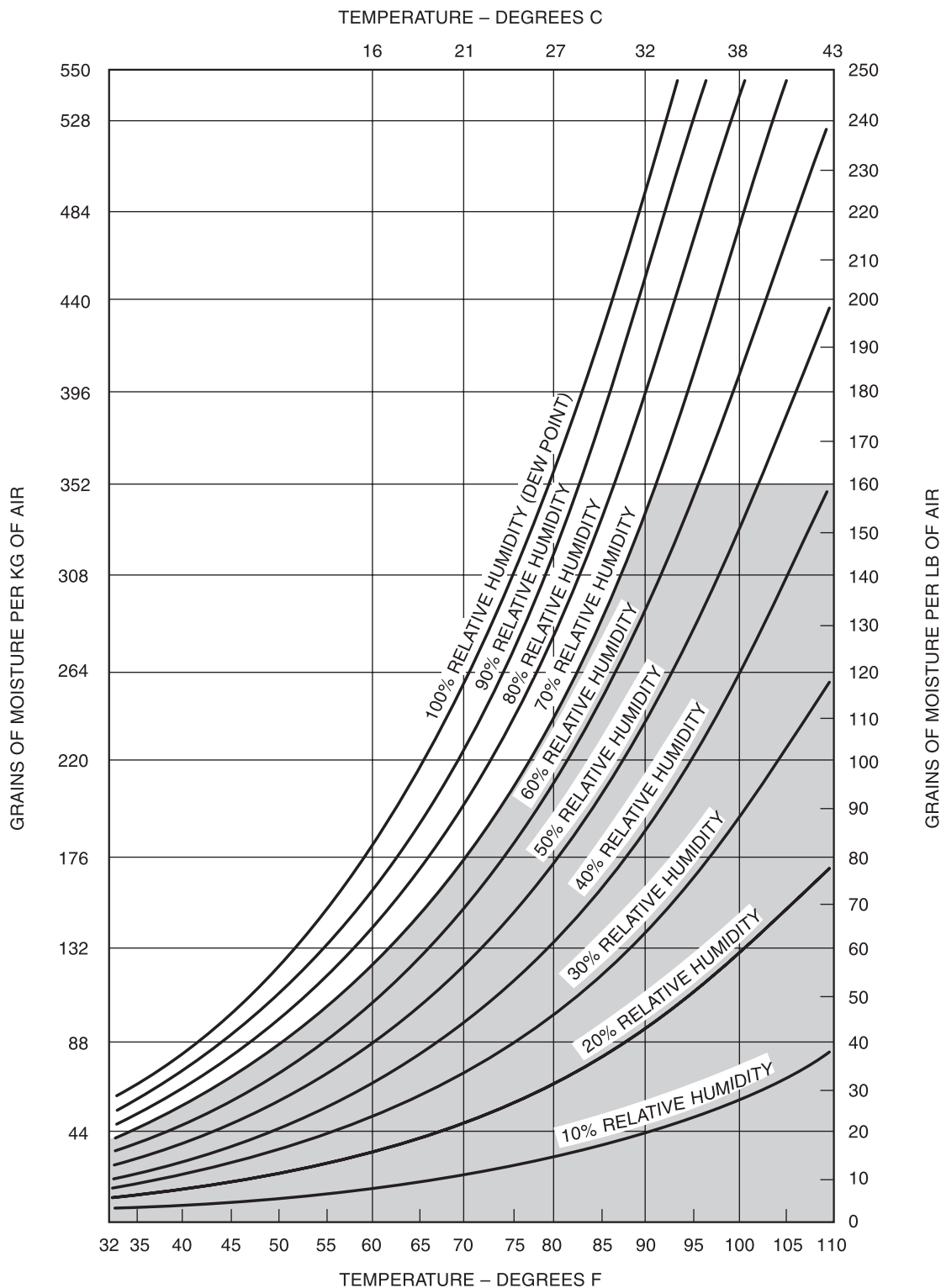
This annex is not a part of AWS D1.4/D1.4M:2005, *Structural Welding Code—Reinforcing Steel*, but is included for informational purposes only.



General Notes:

- (a) Any standard psychrometric chart may be used in lieu of this chart.
 (b) See Figure E-2 for an example of the application of this chart in establishing electrode exposure conditions.

Figure E.1—Temperature-Moisture Content Chart to be Used in Conjunction with Testing Program to Determine Extended Atmospheric Exposure Time of Low-Hydrogen Electrodes (see 5.7.3)



EXAMPLE: AN ELECTRODE TESTED AT 90°F [32°C] AND 70% RELATIVE HUMIDITY (RH) MAY BE USED UNDER THE CONDITIONS SHOWN BY THE SHADED AREAS. USE UNDER OTHER CONDITIONS REQUIRES ADDITIONAL TESTING.

Figure E.2—Application of Temperature-Moisture Content Chart in Determining Atmospheric Exposure Time of Low-Hydrogen Electrodes (see 5.7.3)

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List of AWS Documents on Structural Welding Code

Designation	Title
D1.1/D1.1M	<i>Structural Welding Code—Steel</i>
D1.2/D1.2M	<i>Structural Welding Code—Aluminum</i>
D1.3	<i>Structural Welding Code—Sheet Steel</i>
D1.4/D1.4M	<i>Structural Welding Code—Reinforcing Steel</i>
D1.5/D1.5M	<i>Bridge Welding Code</i>
D1.6	<i>Structural Welding Code—Stainless Steel</i>
D1.8/D1.8M	<i>Structural Welding Code—Seismic Supplement (publication pending)</i>
D1.9/D1.9M	<i>Structural Welding Code—Titanium (publication pending)</i>

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