ANSI/AWS D1.4-98
An American National Standard

Structural Welding Code— Reinforcing Steel

American Welding Society

STD.AWS D1.4-ENGL 1998 ■ 0784265 0508941 777 ■

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

ANSI/AWS D1.4-98
An American National Standard

Approved by
American National Standards Institute
November 6, 1997

Structural Welding Code— Reinforcing Steel

Including
Metal Inserts and Connections
in Reinforced Concrete
Construction

Fifth Edition

Supersedes ANSI/AWS D1.4-92

Prepared by
AWS Structural Welding Committee

Under the Direction of
AWS Technical Activities Committee

Approved by
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
550 N.W. LeJeune Road, Miami, Florida 33126

Statement on Use of AWS Standards

All standards (codes, specifications, recommended practices, methods, classifications, and guides) of the American Welding Society are voluntary consensus standards that have been developed in accordance with the rules of the American National Standards Institute. When AWS standards are either incorporated in, or made part of, documents that are included in federal or state laws and regulations, or the regulations of other governmental bodies, their provisions carry the full legal authority of the statute. In such cases, any changes in those AWS standards must be approved by the governmental body having statutory jurisdiction before they can become a part of those laws and regulations. In all cases, these standards carry the full legal authority of the contract or other document that invokes the AWS standards. Where this contractual relationship exists, changes in or deviations from requirements of an AWS standard must be by agreement between the contracting parties.

International Standard Book Number: 0-87171-538-4

American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126

Note: The primary purpose of AWS is to serve and benefit its members. To this end, AWS provides a forum for the exchange, consideration, and discussion of ideas and proposals that are relevant to the welding industry and the consensus of which forms the basis for these standards. By providing such a forum, AWS does not assume any duties to which a user of these standards may be required to adhere. By publishing this standard, the American Welding Society does not insure anyone using the information it contains against any liability arising from that use. Publication of a standard by the American Welding Society does not carry with it any right to make, use, or sell any patented items. Users of the information in this standard should make an independent, substantiating investigation of the validity of that information for their particular use and the patent status of any item referred to herein.

With regard to technical inquiries made concerning AWS standards, oral opinions on AWS standards may be rendered. However, such opinions represent only the personal opinions of the particular individuals giving them. These individuals do not speak on behalf of AWS, nor do these oral opinions constitute official or unofficial opinions or interpretations of AWS. In addition, oral opinions are informal and should not be used as a substitute for an official interpretation.

This standard is subject to revision at any time by the AWS Structural Welding Committee. It must be reviewed every five years and if not revised, it must be either reapproved or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are requested and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the AWS Structural Welding Committee and the author of the comments will be informed of the Committee's response to the comments. Guests are invited to attend all meetings of the AWS Structural Welding Committee to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Photocopy Rights

Personnel

AWS D1 Main Committee

D. L. McQuaid, Chairman	D and L Incorporated
D. D. Rager, 1st Vice Chairman	Reynolds Metals Company
D. K. Miller, 2nd Vice Chairman	The Lincoln Electric Company
A. W. Sindel, 3rd Vice Chairman	Sindel and Associates
H. H. Campbell III, Secretary	American Welding Society
**W. G. Alexander*	Consultant
E. M. Beck	Law Engineering and Environmental Services
F. R. Beckmann	AISC
R. D. Block	Diamond Power Specialty Company
**O. W. Blodgett*	The Lincoln Electric Company
F. C. Breismeister	Bechtel Corporation
L. E. Collins	Team Industries, Incorporated
R. B. Corbit	GPU Nuclear Corporation, TMI
E. G. Costello	Boeing Defense and Space Group
W. F. Crozier	Department of Transportation Engineering Service Center
M. V. Davis	Consultant
**J. D. Duncan*	Fluor Daniel
G. L. Fox	Federal Medical Center Carswell
A. R. Fronduti, PE	Rex Fronduti and Associates
**G. A. Gix*	Consultant
M. A. Grieco	Massachusetts Highway Department
C. R. Hess	High Steel Structures Incorporated
G. J. Hill	G. J. Hill and Associates
M. L. Hoitomt	Thomas and Betts-Meyer Industries
C. W. Holmes	West Virginia Department of Transportation
A. J. Julicher, PE	Consultant
R. M. Kotan	Omaha Public Power District
P. W. Marshall	Moonshire Hill Proprietary MHP Systems Engineering
W. A. Milek, Jr.	Consultant
J. L. Munnerlyn	PSI
J. E. Myers	SMI Owen Steel Company
M. L. Peterson	Consultant
J. W. Post	J. W. Post and Associates, Incorporated
D. E. H. Reynolds	Canadian Welding Bureau
J. E. Roth	James E. Roth Incorporated
W. W. Sanders, Jr.	Iowa State University
R. E. Shaw, Jr.	Steel Structures Technical Center Incorporated
J. L. Skiles	Omaha Public Power District
D. L. Sprow	McDermott Incorporated
R. W. Stieve	Greenman-Pedersen Incorporated
P. J. Sullivan	Massachusetts Highway Department
**J. D. Theisen*	Exxon Research and Engineering Company
K. K. Verma	Federal Highway Administration (DOT)
B. D. Wright	Consultant

*Advisor

AWS Subcommittee on Reinforcing Steel

J. E. Myers, Chairman	SMI Owen Steel Company
M. J. Mayes, Vice Chairman	Mayes Testing Engineers, Incorporated
D. P. Gustafson, Sr.	Concrete Reinforcing Steel Institute
R. M. Kotan	Omaha Public Power District
D. R. Scott	Professional Service Industries

Foreword

(This Foreword is not a part of ANSI/AWS D1.4-98, *Structural Welding Code—Reinforcing Steel,* but is included for information 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 edition reflected many of these changes, and subsequently more revisions have been required. This edition, ANSI/AWS D1.4-98, addresses these changes.

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.

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

Official interpretations of any of the technical requirements of this standard may be obtained by sending a request, in writing, to the Managing Director, Technical Services Division, American Welding Society. A formal reply will be issued after it has been reviewed by the appropriate personnel following established procedures.

Table of Contents

Annexes

List of Tables

List of Figures

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 specifications and is appli-

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.[1] 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 A82, *Specification for Plain Steel Wire for Concrete Reinforcement*

(2) ASTM A184/A184M, *Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement*

(3) ASTM A185, *Specification for Welded Plain Steel Wire Fabric for Concrete Reinforcement*

(4) ASTM A496, *Specification for Deformed Steel Wire for Concrete Reinforcement*

(5) ASTM A497, *Specification for Welded Deformed Steel Wire Fabric for Concrete Reinforcement*

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 specifications 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. When reinforcing steel is welded to structural steel, the provisions of the latest edition of ANSI/AWS D1.1, *Structural Welding Code—Steel* shall apply to the structural steel component.

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 *Building Commissioner,* defined as the Building Commissioner or the Engineer. Hereinafter the term *Engineer* will be used, and is to be construed to mean the *Building Commissioner* or 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.[1] 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 A82, *Specification for Plain Steel Wire for Concrete Reinforcement*

(2) ASTM A184/A184M, *Specification for Fabricated Deformed Steel Bar Mats for Concrete Reinforcement*

(3) ASTM A185, *Specification for Welded Plain Steel Wire Fabric for Concrete Reinforcement*

(4) ASTM A496, *Specification for Deformed Steel Wire for Concrete Reinforcement*

(5) ASTM A497, *Specification for Welded Deformed Steel Wire Fabric for Concrete Reinforcement*

(6) ASTM A615/A615M, *Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement*

(7) ASTM A616/A616M, *Specification for Rail-Steel Deformed and Plain Bars for Concrete Reinforcement*

(8) ASTM A617/A617M, *Specification for Axle-Steel Deformed and Plain Bars for Concrete Reinforcement*

(9) ASTM A706/A706M, *Specification for Low Alloy Steel Deformed Bars for Concrete Reinforcement*

(10) ASTM A767/A767M, *Specification for Zinc-Coated (Galvanized) Steel Bars for Concrete Reinforcement*

(11) ASTM A775/A775M, *Specification for Epoxy-Coated Reinforcing Steel Bars*

(12) ASTM A934/A934M, *Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars*

1. Available from American Society for Testing and Materials, 100 Barr Harbor Drive, W. Conshohocken, PA 19428.

Manufacturing and testing requirements for mats and fabric are covered by the respective ASTM specification. For joining the mats and fabric to other reinforcing bars or structural steels, 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 ANSI/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 A706, the carbon equivalent shall be calculated using the chemical composition, as shown in the mill test report, by the following formula:

$$C.E = \%C + \%Mn/6 \qquad \text{(Eq. 1)}$$

1.3.4.2 For steel bars designated ASTM A706, the carbon equivalent shall be calculated using the chemical composition, as shown in the mill test report, by the following formula:

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

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 A706 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 ANSI/AWS A3.0, *Standard Welding Terms and Definitions.*

1.6 Welding Symbols

Welding symbols shall be those designated to the latest edition of ANSI/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

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

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

Note: Fabrication performed in conformance with 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

The numerical values in this code are in U.S. customary units, with the corresponding SI units in parentheses. Both units are to be regarded as code standards. These unit systems shall be used independently of the other, since the values stated in each system are not necessarily exact equivalents. Combining values from the two systems may result in nonconformance with this specification. Nominal dimensions of standard reinforcing bars are given in Annex B.

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.)

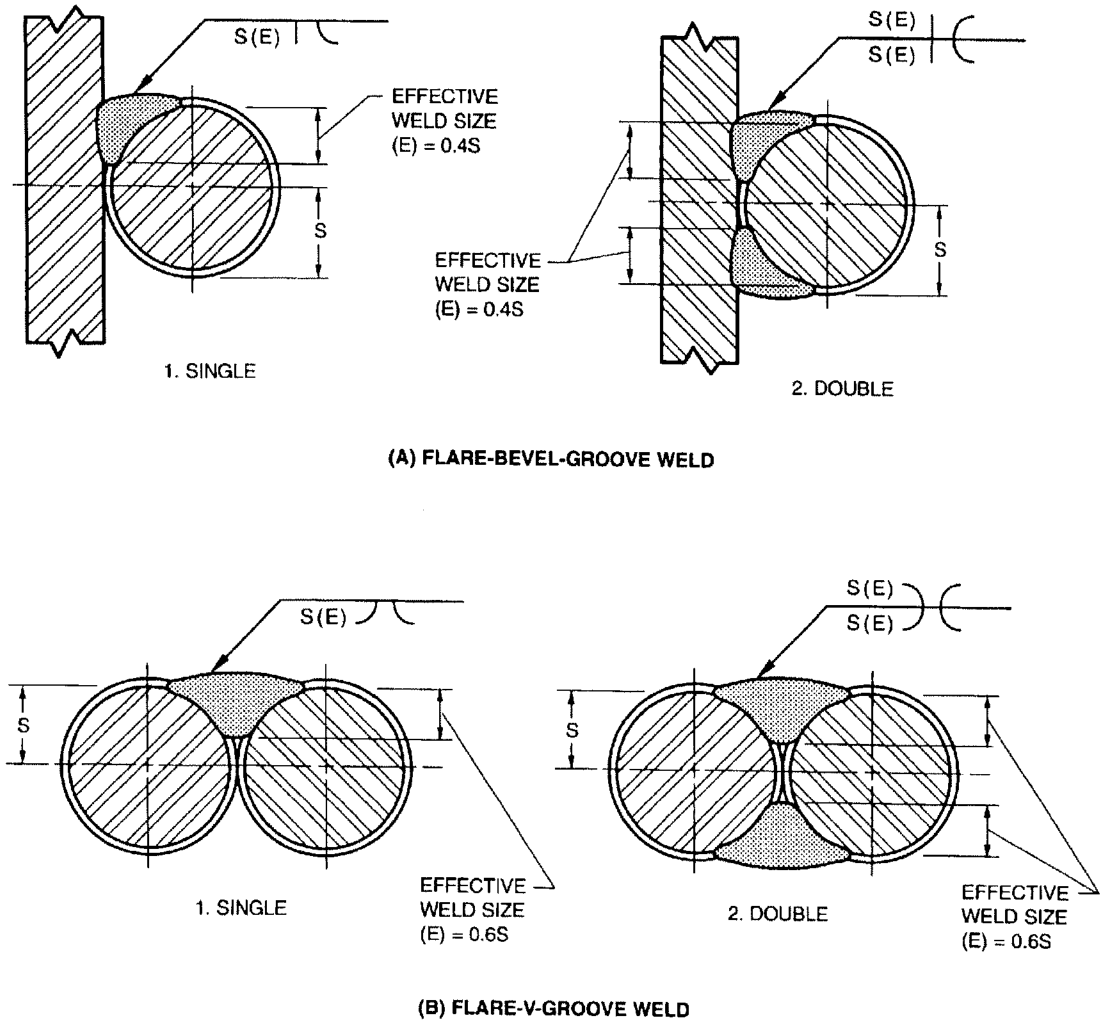
2.3.3.1 The effective weld length of a curved fillet weld shall be measured along the weld axis.

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)

<table>
<tr><th>Type of Weld</th><th colspan="2">Stress in Weld[1]</th><th>Allowable Stress[3,4]</th><th>Required Filler Metal Strength Level[2]</th></tr>
<tr><td rowspan="3">Complete joint penetration groove welds</td><td colspan="2">Tension normal to the effective area</td><td>Same as base metal</td><td>Matching filler metal shall be used. See Table 5.1</td></tr>
<tr><td colspan="2">Compression normal to the effective area</td><td>Same as base metal</td><td>Filler metal with a strength level equal to or one classification (10 ksi [70 MPa]) less than matching filler metal may be used</td></tr>
<tr><td colspan="2">Shear on the effective areas</td><td>0.30 × nominal tensile strength of filler metal, except shear stress on base metal shall not exceed 0.40 × yield strength of base metal</td><td>Filler metal with a strength level equal to or less than matching filler metal may be used</td></tr>
<tr><td rowspan="4">Flare-bevel and flare-V-groove welds</td><td rowspan="2">Compression normal to effective area</td><td>Joint not designed to bear</td><td>0.50 × nominal tensile strength of filler metal, except stress on base metal shall not exceed 0.60 × yield strength of base metal</td><td rowspan="4">Filler metal with a strength level equal to or less than matching filler metal may be used</td></tr>
<tr><td>Joint designed to bear</td><td>Same as base metal</td></tr>
<tr><td colspan="2">Shear on the effective area</td><td>0.30 × nominal tensile strength of filler metal, except shear stress on base metal shall not exceed 0.40 × yield strength of base metal</td></tr>
<tr><td colspan="2">Tension normal to the effective area</td><td>0.30 × nominal tensile strength of filler metal, except tensile stress on base metal shall not exceed 0.60 × yield strength of base metal</td></tr>
<tr><td>Fillet welds</td><td colspan="2">Shear on the effective area</td><td>0.30 × nominal tensile strength of filler metal</td><td>Filler metal with a strength level equal to or less than matching filler metal may be used</td></tr>
</table>

Notes:
1. For definition of effective area, see 2.3.1, 2.3.2, and 2.3.3.
2. For matching filler metal, see Table 5.1.
3. For fatigue or dynamic loading refer to the applicable construction code or specification for allowable stress values.
4. The Engineer should be aware that the strength of cold drawn wire may be reduced when welded.



GENERAL 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)

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 3.4 and 3.3, 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.

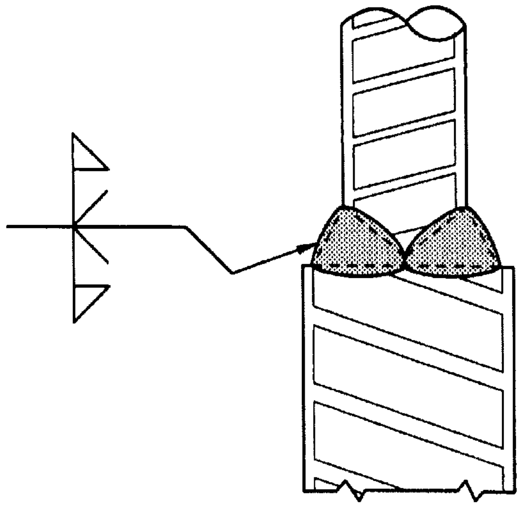


Figure 3.1—Direct Butt Joint Showing Transition Between Bars of Different Sizes (see 3.1)

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[1]
Vertical	Single-Bevel	D
	Double-Bevel	E
	Single-Bevel with Split Pipe Backing	C[1]

Note 1. Bars shall be of equal diameter.

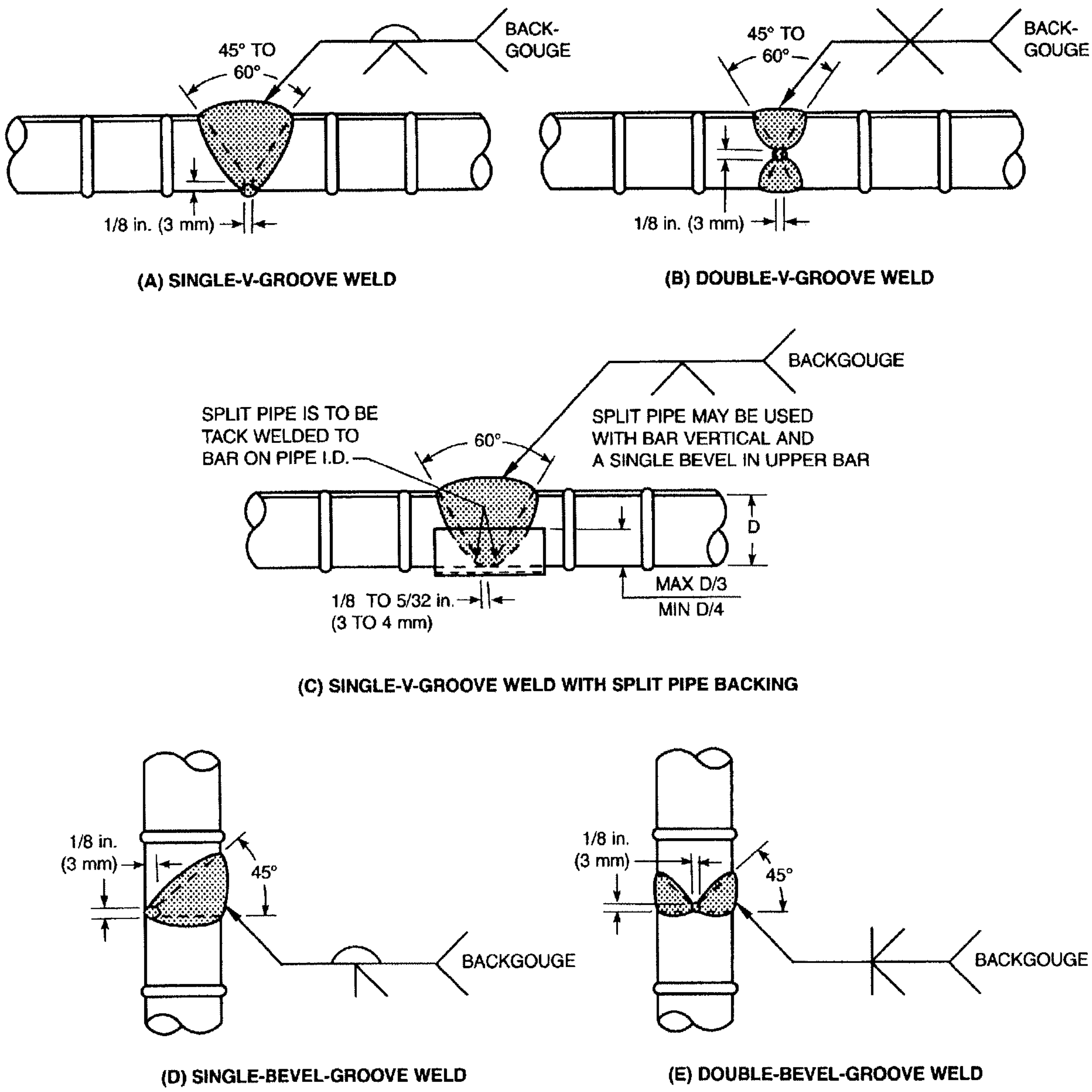
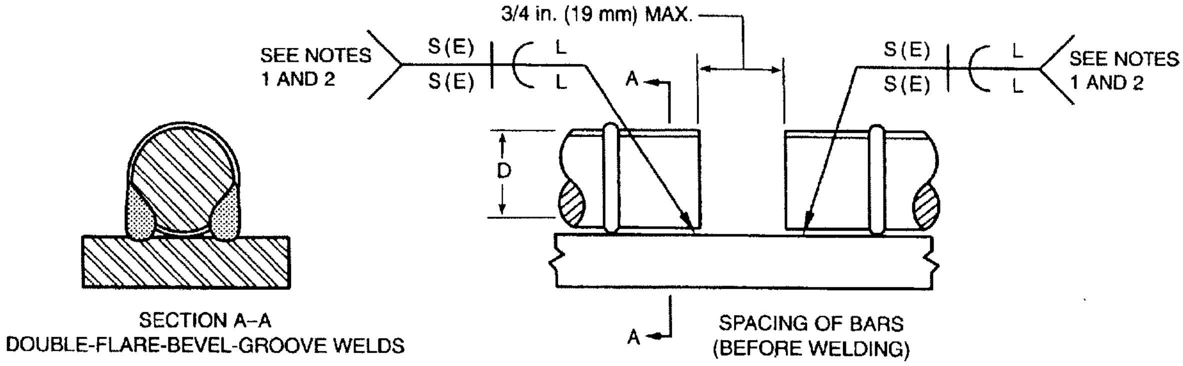
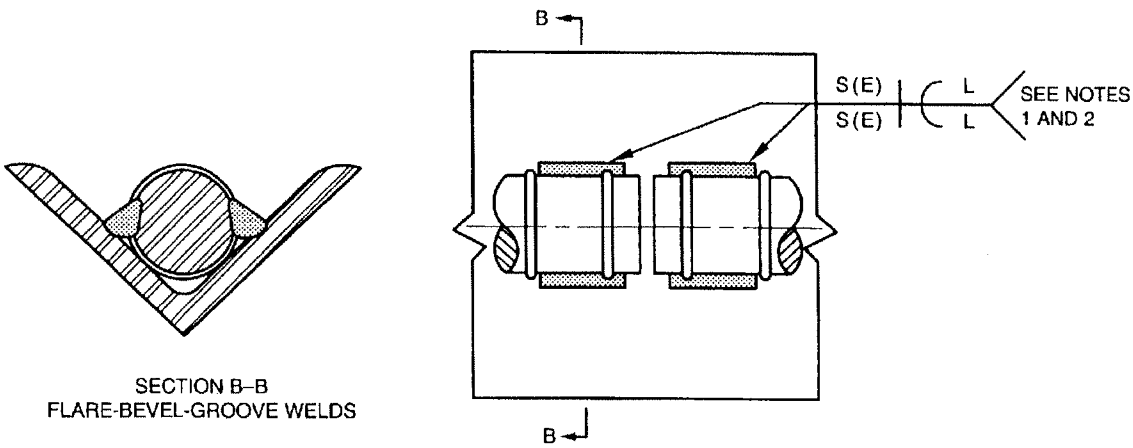


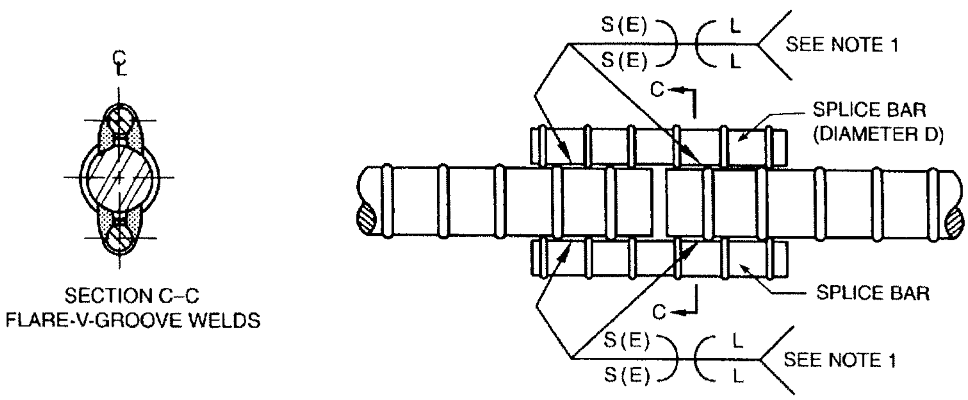
Figure 3.2—Direct Butt Joints (see Table 3.1)



(A) INDIRECT BUTT JOINT WITH A SPLICE PLATE



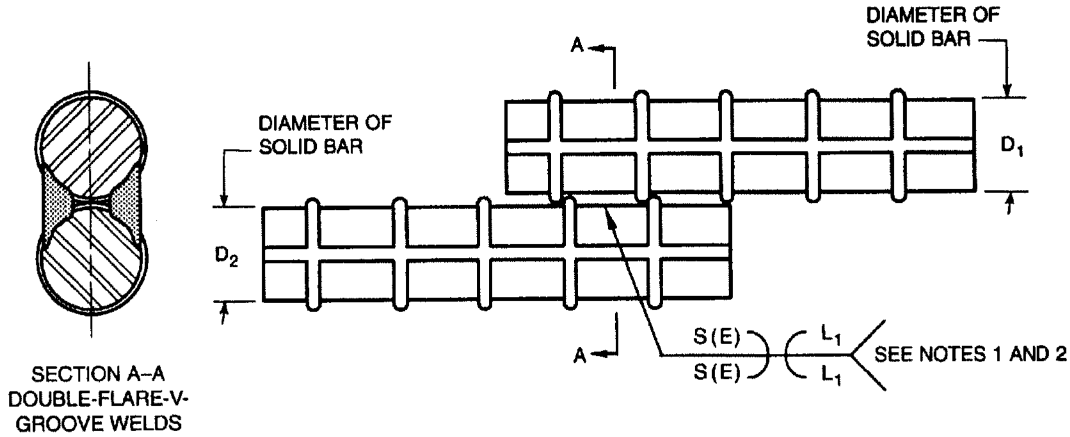
(B) INDIRECT BUTT JOINT WITH A SPLICE ANGLE



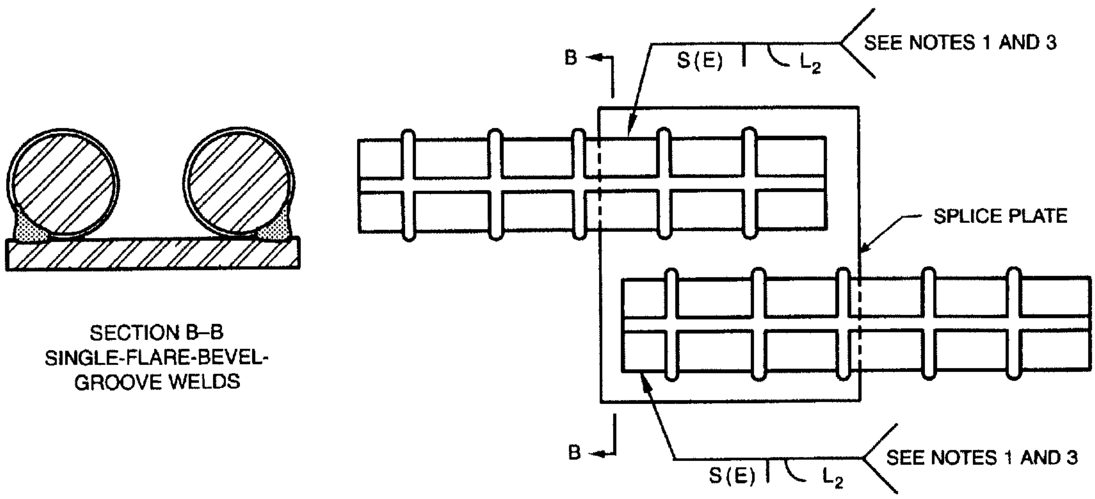
(C) INDIRECT BUTT JOINT TWO SPLICE BARS

NOTES:
1. L = 2D (MIN)
2. VARIATION OF THIS WELD USING SINGLE FLARE-V WELDS IS PERMITTED PROVIDED ECCENTRICITY IS CONSIDERED OR RESTRAINT PROVIDED IN THE DESIGN OF THE JOINT.
3. GAPS BETWEEN BARS AND PLATE WILL VARY DEPENDING ON HEIGHT OF DEFORMATIONS.
4. DEFORMATIONS SHOWN ON SECTIONAL VIEWS ARE FOR ILLUSTRATIVE PURPOSES ONLY.

Figure 3.3—Indirect Butt Joints (see 3.5)



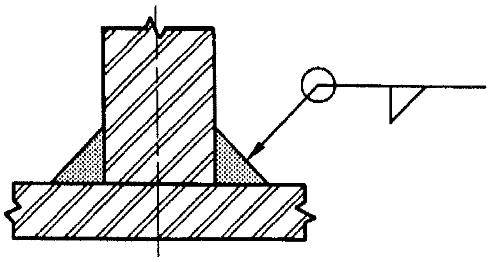
(A) DIRECT LAP JOINT WITH BARS IN CONTACT



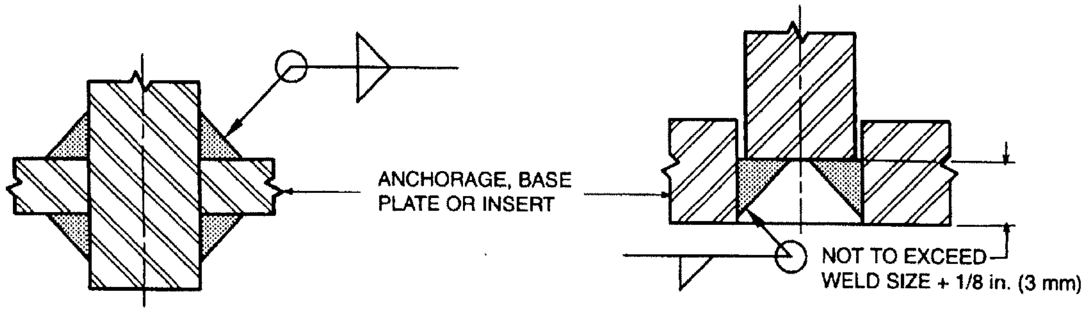
(B) INDIRECT LAP JOINTS WITH BARS SEPARATED

NOTES:
1. THE EFFECTS OF ECCENTRICITY SHALL BE CONSIDERED OR RESTRAINT PROVIDED IN THE DESIGN OF THE JOINT.
2. $L_1 = 2\ D_1$ (MIN) : $D_1 \leq D_2$
3. $L_2 = 2$ X DIAMETER OF BAR (MIN)
4. GAPS BETWEEN BARS AND PLATES WILL VARY BASED ON HEIGHT OF DEFORMATIONS.

Figure 3.4—Lap Joints (see 3.2.1)

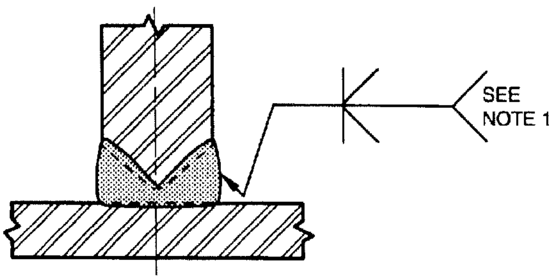


(A) EXTERNAL FILLET WELD

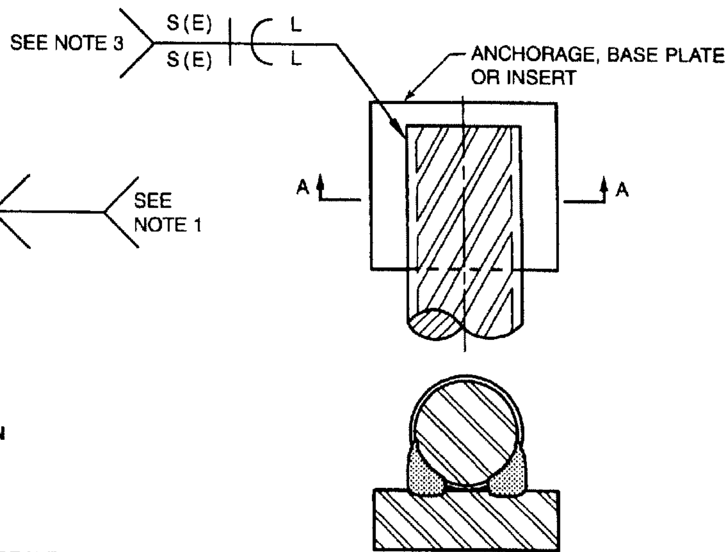


(B) EXTERNAL FILLET WELD

(C) INTERNAL FILLET WELD



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



SECTION A–A

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

NOTES:
1. BACKGOUGE TO SOUND METAL BEFORE WELDING OTHER SIDE.
2. FOR BAR SIZES 8 (25) OR SMALLER, THE SINGLE-BEVEL WELD WITH BACKGOUGING AND BACK WELDING IS RECOMMENDED.
3. L = 2 X BAR DIAMETER (MIN)

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

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. (6.4 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

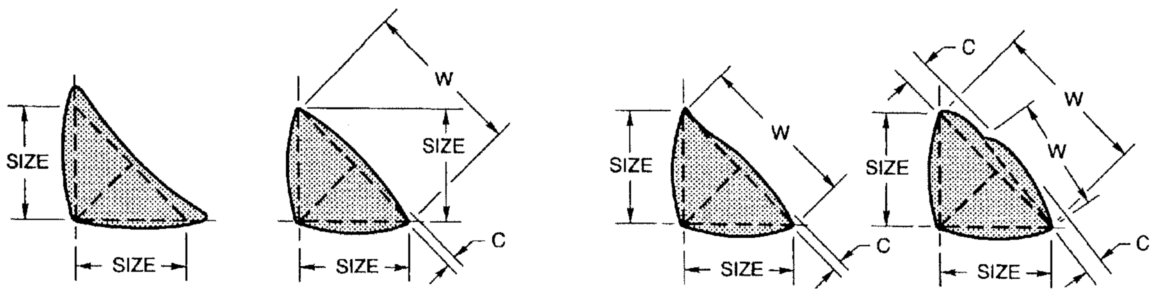
4.3.1 In assembling and joining parts of a structure or precast member, the procedure and sequence followed shall minimize distortion and shrinkage.

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).

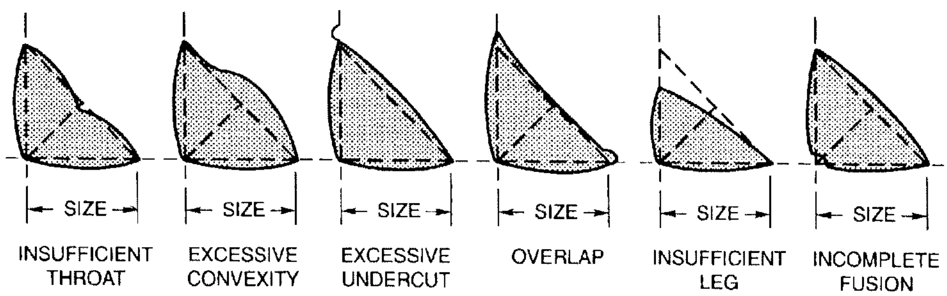


(A) DESIRABLE FILLET WELD PROFILES

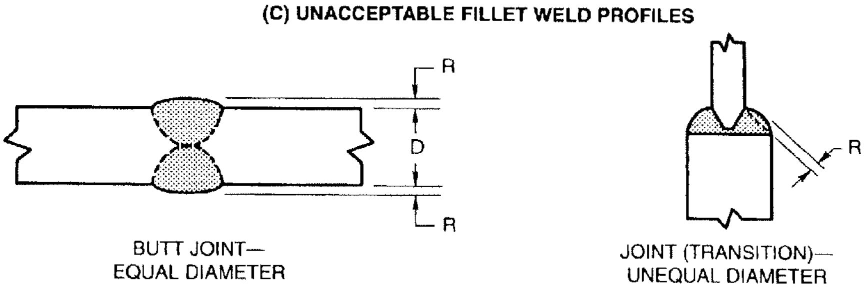
(B) ACCEPTABLE FILLET WELD PROFILES

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 ≤ 5/16 in. (8 mm)	1/16 in. (1.6 mm)
W > 5/16 in. TO W < 1 in. (25 mm)	1/8 in. (3 mm)
W ≥ 1 in.	3/16 in. (5 mm)

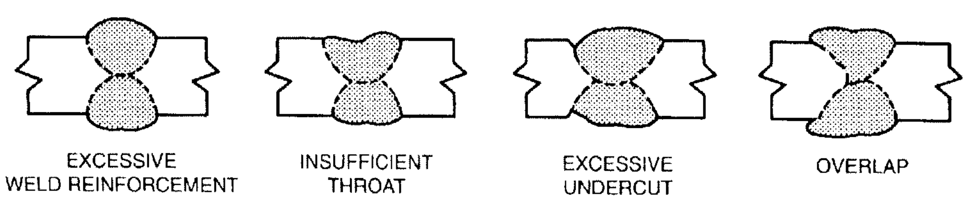


(C) UNACCEPTABLE FILLET WELD PROFILES



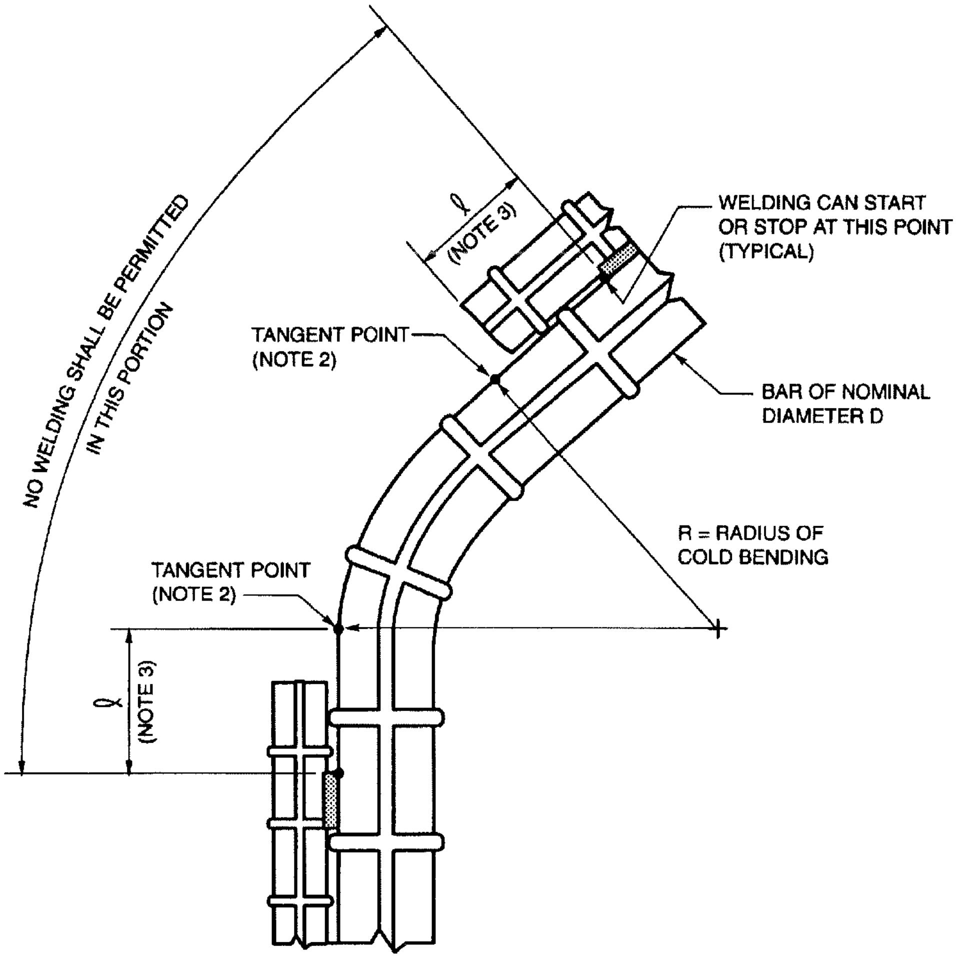
NOTE: REINFORCEMENT R SHALL NOT EXCEED 1/8 in. (3 mm).

(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)



NOTES:
1. THIS FIGURE IS FOR ILLUSTRATION ONLY.
2. FOR WELDING ON INSIDE RADIUS, USE TANGENT POINTS ON INSIDE RADIUS.
3. $\ell \geq 2D$

Figure 4.2—Minimum Distance to Cold Bending Radius Tangent Points[1] (see 4.2.6)

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

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 craters shall be filled to the full cross section of the weld.

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[1] (see 4.4.8)

	Sum of Discontinuity Dimensions		Single Discontinuity Dimension	
Bar Size	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

Note:
1. Acceptance criteria for bar sizes less than No. 8 (25) shall be established by the Engineer.

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 kph).

5.3 Arc Strikes

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

5.4 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.

5.5 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.

5.6 Welding of Coated Base Metal

5.6.1 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.

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

5.6.2.1 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

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[4]	Yield Point/Strength[1]		Tensile Strength[1]	
			ksi	MPa	ksi	MPa		ksi	MPa	ksi	MPa
I	ASTM A615	Grade 40	40	—	70	—	SMAW AWS A5.1 and A5.5				
	ASTM A615M	Grade 300	—	300	—	500	E7015, E7016, E7018, E7028	53–72	365–496	70	482
	ASTM A617	Grade 40	40	—	70	—	E7015-X, E7016-X, E7018-X	57–60	390–415	70–75	480–520
	ASTM A617M	Grades300	—	300	—	500	GMAW AWS A5.18				
							ER70S-X	58	400	70	480
							FCAW AWS A5.20				
							E7XT-X	58	400	70	480
							(Except -2, -3, -10, -13, -14, -GS)				
II	ASTM A616	Grade 50	50	—	80	—	SMAW AWS A5.5				
	ASTM A616M	Grade 350	—	350	—	550	E8015-X, E8016-X,	67	460	80	550
	ASTM A706	Grade 60	60	—	80	—	E8018-X				
	ASTM A706M	Grade 420	—	420	—	550	GMAW AWS A5.28				
							ER80S-X	68	470	80	550
							FCAW AWS A5.29				
							E8XTX-X	68	470	80–100	550–690
III	ASTM A615	Grade 60	60	—	90	—	SMAW AWS A5.5				
	ASTM A615M	Grade 420	—	420	—	600	E9015-X, E9016-X,	77	530	90	620
	ASTM616	Grade 60	60	—	90	—	E9018-X				
	ASTM 616M	Grade 420	—	420	—	600	GMAW AWS A5.28				
	ASTM 617	Grade 60	60	—	90	—	ER90S-X	78	540	90	620
	ASTM 617M	Grade 420	—	420	—	600	FCAW AWS A5.29				
							E9XTX-X	78	540	90–110	620–760

(continued)

Table 5.1 (Continued)

Group	Steel Specification Requirements						Filler Metal Requirements				
			Minimum Yield Point/Strength		Minimum Tensile Strength			Yield Point/Strength[1]		Tensile Strength[1]	
	Steel Specification		ksi	MPa	ksi	MPa	Electrode Specification[4]	ksi	MPa	ksi	MPa
IV	ASTM A615	Grade 75[2]	75	—	100	—	SMAW AWS A5.5				
	ASTM A615M	Grade 520[3]	—	520	—	700	E10015-X, E10016-X, E10018-X	87	600	100	690
							E10018-M	88–100	610–690	100	690
							GMAW AWS A5.28				
							ER100S-X	88–102	610–700	100	690
							FCAW AWS A5.29				
							E10XTX-X	88	610	100–120	690–830

Notes:
1. This table is based on filler metal as-welded properties. Single values are minimums. Hyphenated values indicate minima and maxima.
2. Applicable to bar sizes Nos. 6 through 18.
3. Applicable to bar sizes Nos. 19 through 57.
4. Filler metals of alloy group B3, B3L, B4L, B5, B5L, B6, B6L, B7, B7L, B8, B8L, or B9 in ANSI/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.

Table 5.2
Minimum Preheat and Interpass Temperatures[1,2] (see 5.2.1)

Carbon Equivalent (C.E.) Range, %[3,4]	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[5]	none[5]
	14 and 18 (43 and 57)	50	10
Over 0.40 to 0.45 inclusive	Up to 11 (36) inclusive	none[5]	none[5]
	14 and 18 (43 and 57)	50	40
Over 0.45 to 0.55 inclusive	Up to 6 (19) inclusive	none[5]	none[5]
	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	7 to 18 (22 to 57) inclusive	500	260

Notes:
1. When reinforcing steel is to be welded to main structural steel, the preheat requirements of the structural steel shall also be considered (see ANSI/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.
2. 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.
3. After welding is complete, bars shall be allowed to cool naturally to ambient temperature. Accelerated cooling is prohibited.
4. 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.
5. 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.

larger root openings in joints, electrodes with lower silicon content, and slower welding speeds.

5.6.2.2 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.

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

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

5.7 SMAW Electrodes

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

5.7.1 Low-Hydrogen Electrode Storage Conditions. All electrodes having low-hydrogen coverings conforming to ANSI/AWS A5.1 and ANSI/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).

5.7.2 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 5.1 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 min., the electrodes may be reissued. Electrodes that have been wet shall not be used.

5.7.3 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 ANSI/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 ANSI/AWS A5.5 (Table 9) are not exceeded. Additionally, E70XX or E70XX-X (ANSI/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 psychometric chart, shall be used in the determination of temperature-relative humidity limits.

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

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 ANSI/AWS A5.1-91, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*.

(1) All electrodes having low-hydrogen coverings conforming to ANSI/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 ANSI/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.

5.7.5 Electrode Restrictions for ASTM A514 or A517 Steels. When used for welding ASTM A514 or A517 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.

5.8 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 (415 MPa) or less, shall conform to the requirements of the latest edition of ANSI/AWS A5.18, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*, or ANSI/AWS A5.20, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*, as applicable.

5.8.1 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 (415 MPa) shall conform with the latest edition of ANSI/AWS A5.28, *Specification for Low Alloy Steel Filler Metals for Gas Shielded Arc Welding.*

5.8.2 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 ANSI/AWS A5.29, *Specification for Low Alloy Steel Electrodes for Flux Cored Arc Welding.*

5.8.3 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.

6. Qualification

6.1 General

6.1.1 Responsibility

6.1.1.1 All welding performed to contracts involving ANSI/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 procedures.

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 6.3.3.2. 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:

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[1]		
	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:	ANSI/AWS A5.1 or A5.5	ANSI/AWS A5.18 or A5.28	ANSI/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

Note 1: An "X" indicates applicability for the process; a shaded area indicates non-applicability.

(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

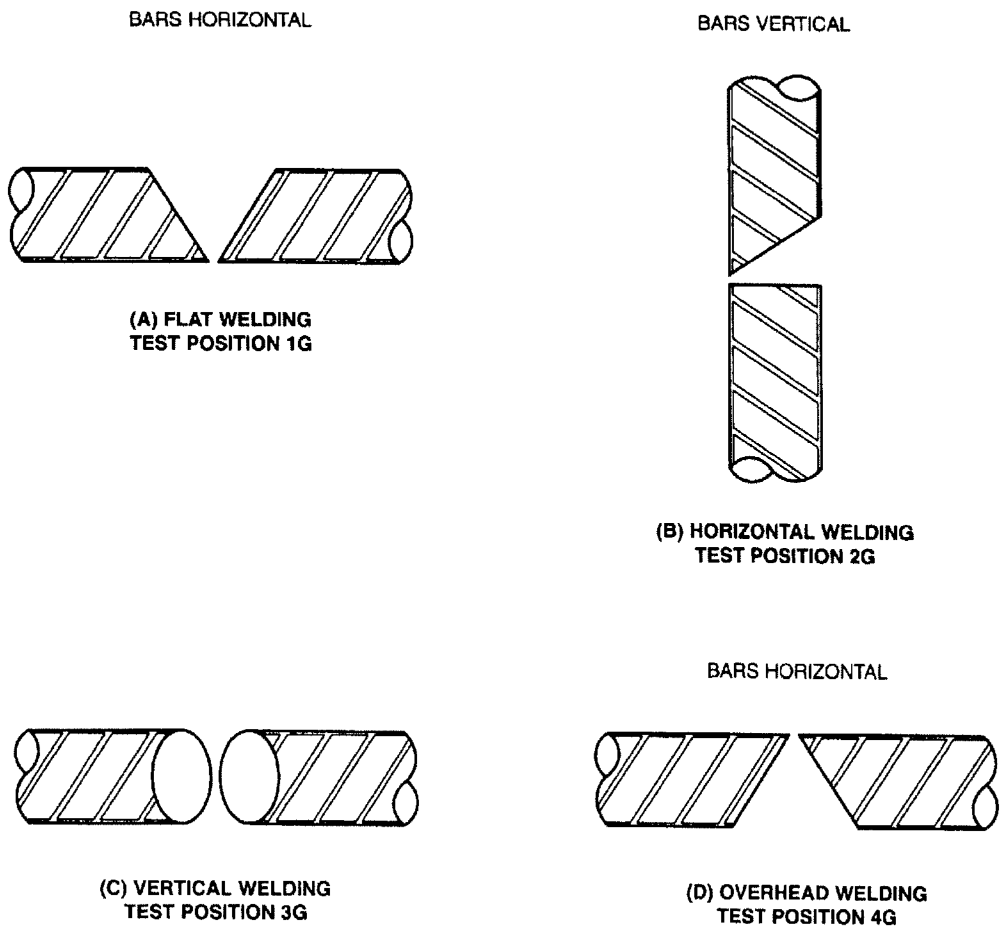
6.2.4.1 Number and Type of Test Assemblies. The number and type of assemblies that shall be tested to qualify a WPS are shown in Table 6.2.

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:

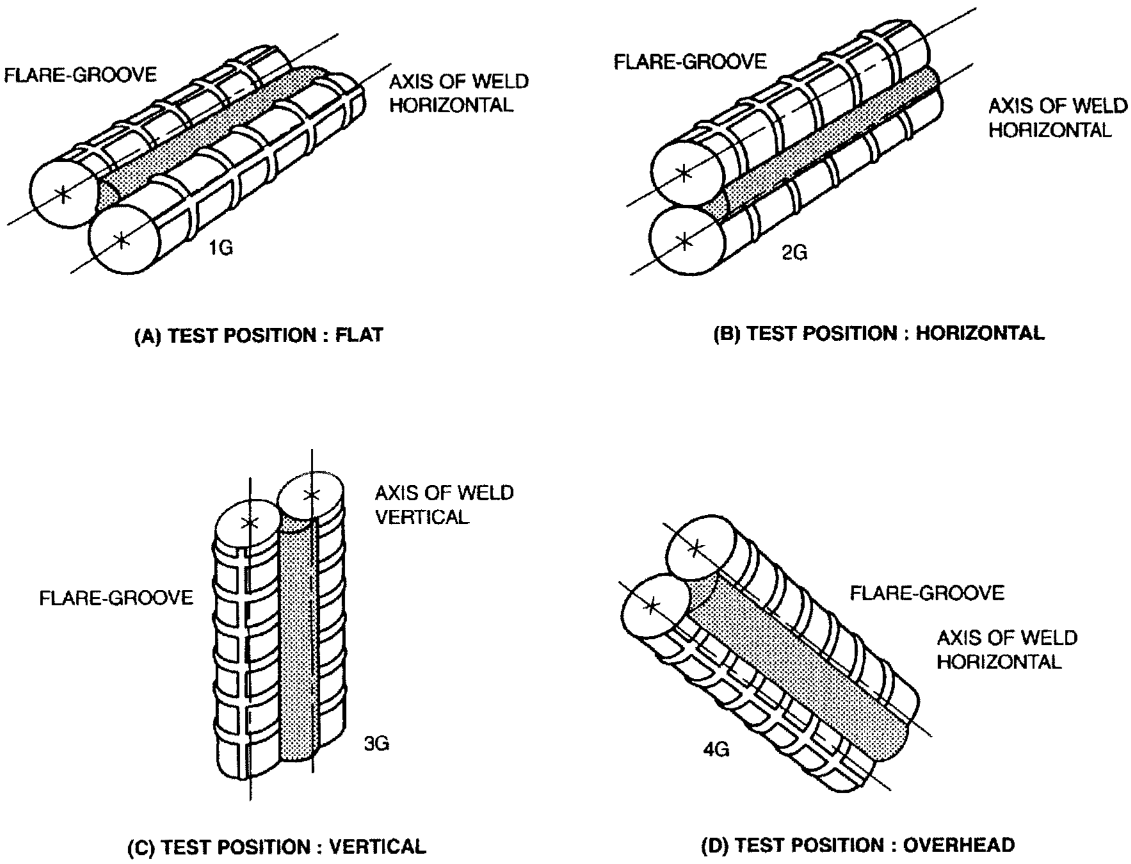
(1) Direct Butt Joint and T-Joint. Unless a greater length is required for testing, welded test assemblies for direct butt joints shall have a minimum length of a least 16 times the diameter of the bar, with the weld located centrally [see Figures 6.5(A) and 6.5(B), as appropriate].

(2) Indirect Butt Joint. For indirect butt joint welded test assemblies, the minimum length in (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



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)



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)

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:

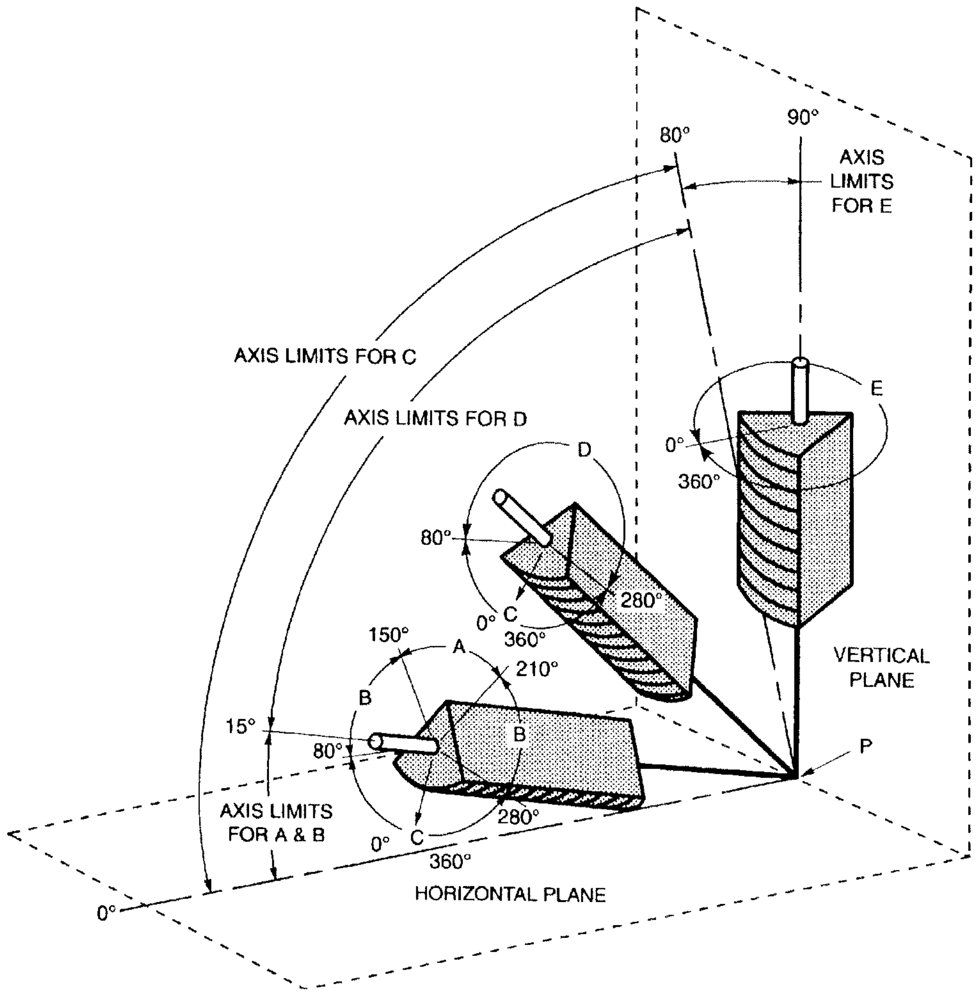
(1) At least eight times the diameter of the bars for direct butt joints

(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.

Tabulation of positions of groove welds			
Position	Diagram reference	Inclination of axis	Rotation of face
Flat	A	0° to 15°	150° to 210°
Horizontal	B	0° to 15°	80° to 150° 210° to 280°
Overhead	C	0° to 80°	0° to 80° 280° to 360°
Vertical	D E	15° to 80° 80° to 90°	80° to 280° 0° to 360°



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

Figure 6.3—Positions of Groove Welds (see 6.2.3)

Tabulation of positions of fillet welds			
Position	Diagram reference	Inclination of axis	Rotation of face
Flat	A	0° to 15°	150° to 210°
Horizontal	B	0° to 15°	125° to 150° 210° to 235°
Overhead	C	0° to 80°	0° to 125° 235° to 360°
Vertical	D E	15° to 80° 80° to 90°	125° to 235° 0° to 360°

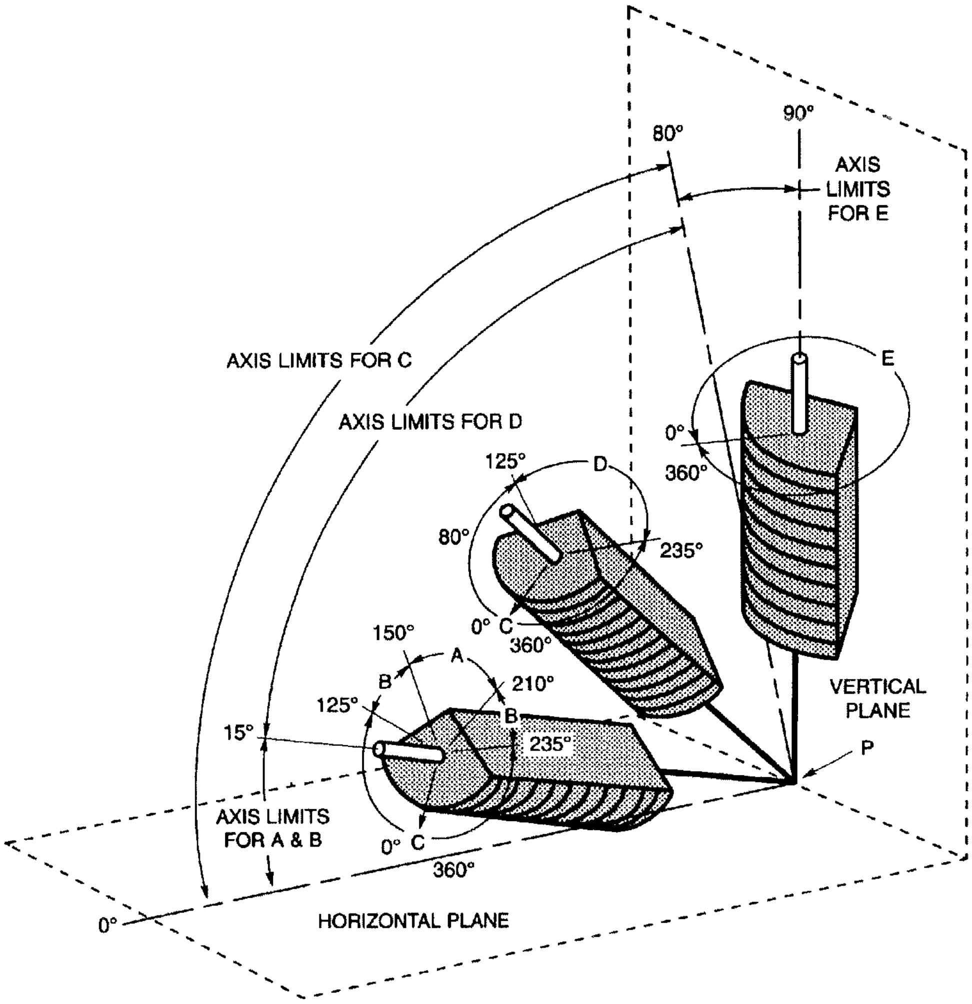
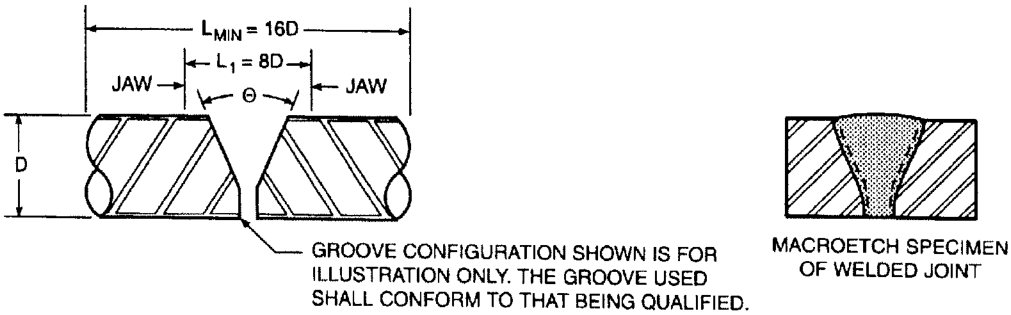


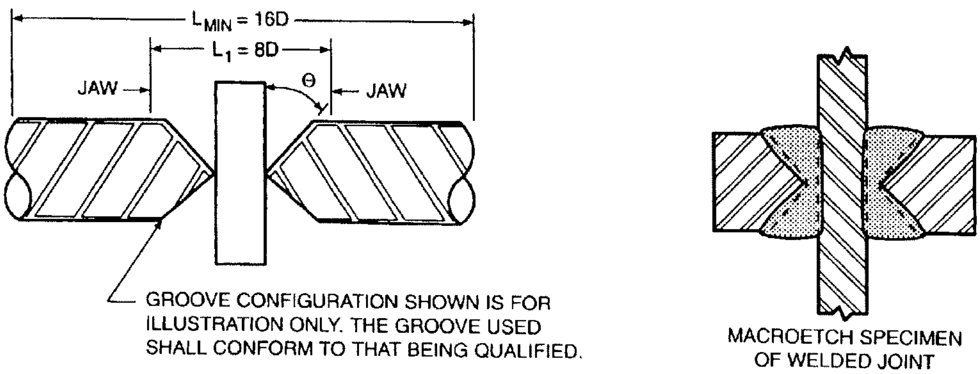
Figure 6.4—Positions of Fillet Welds (see 6.2.3)

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(C)]	2	2	2	3.3(C)

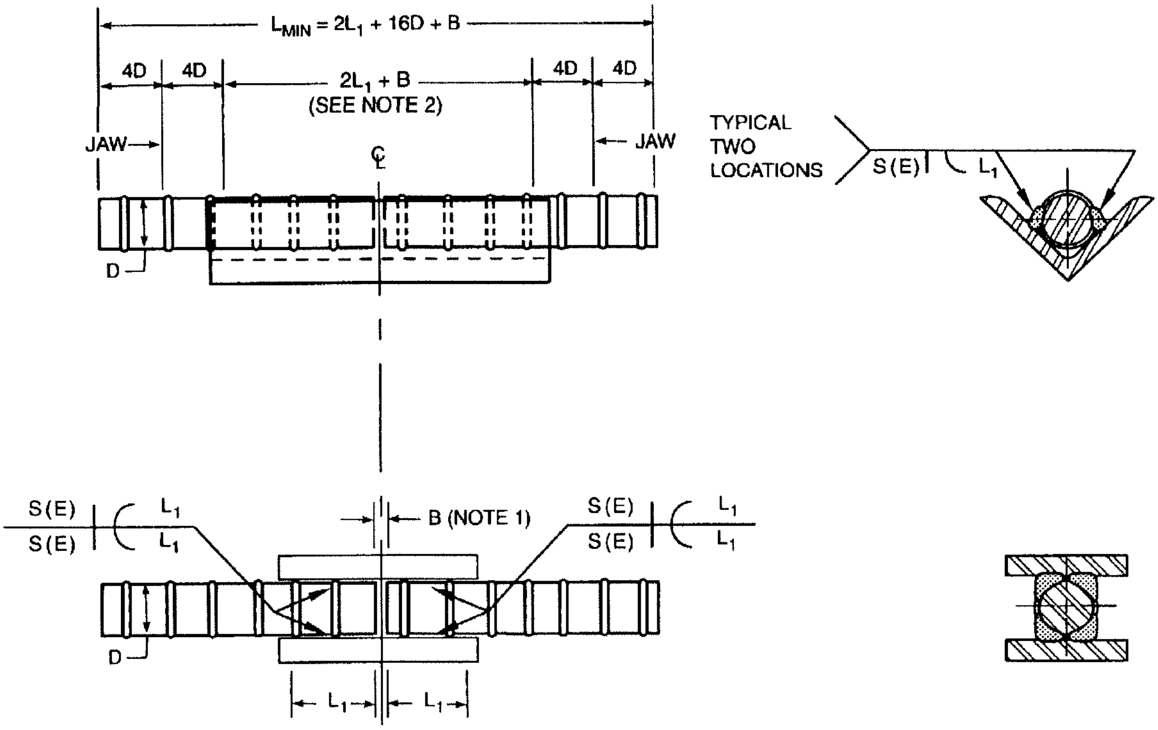


(A) COMPLETE JOINT PENETRATION GROOVE WELD—DIRECT BUTT JOINT

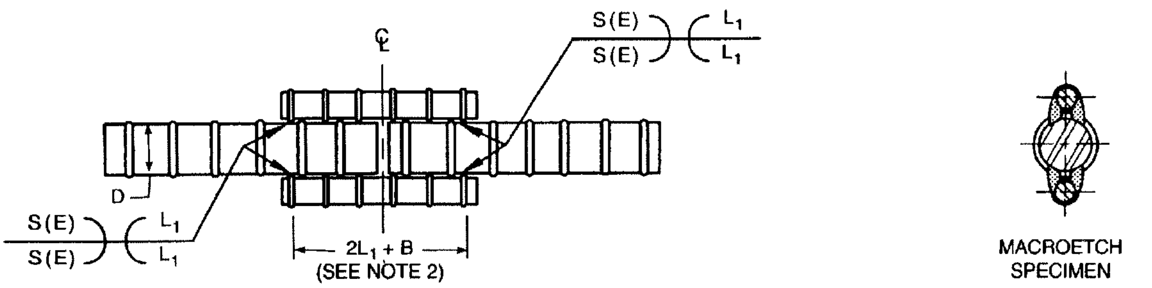


(B) ALTERNATE COMPLETE JOINT PENETRATION GROOVE WELD—T-JOINT

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



(C) FLARE-BEVEL-GROOVE—INDIRECT BUTT JOINT



(D) FLARE-V-GROOVE—INDIRECT BUTT JOINT

NOTES:

1. B = SEPARATION BETWEEN ENDS OF BARS, MAXIMUM B = 3/4 in. (19 mm)
2. $L_1 = \frac{5.23F_u(D)}{F_{xx}(n)}$ (SEE 6.2.4.3)
   WITH F_u = MINIMUM SPECIFIED TENSILE STRENGTH OF THE BAR (FOR BARS OF UNEQUAL F_u, USE LESSER OF THE TWO)
   F_{xx} = MINIMUM SPECIFIED TENSILE STRENGTH OF WELD METAL
   D = DIAMETER OF SOLID BAR
   n = NUMBER OF CONNECTING FLARE-BEVEL-GROOVE WELDS BETWEEN ONE BAR AND TWO PLATES (OR ONE ANGLE)

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

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 A welder may also be qualified for fillet welding of anchorage, base plate and insert plate connections (Figure 3.5) by welding a satisfactory test in accordance with the provisions of 6.3.3.3(2).

6.3.3.2 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.

6.3.3.3 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).

6.3.4 Position of Test Welds and Related Validity of Qualification

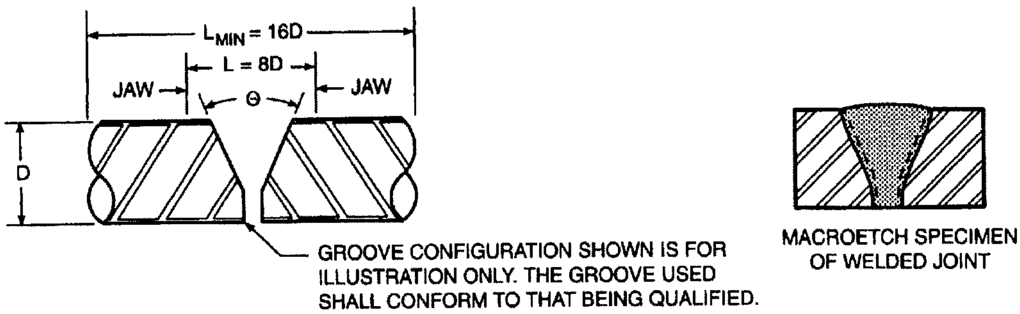
6.3.4.1 Direct Butt Joint Groove Weld Test

(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).

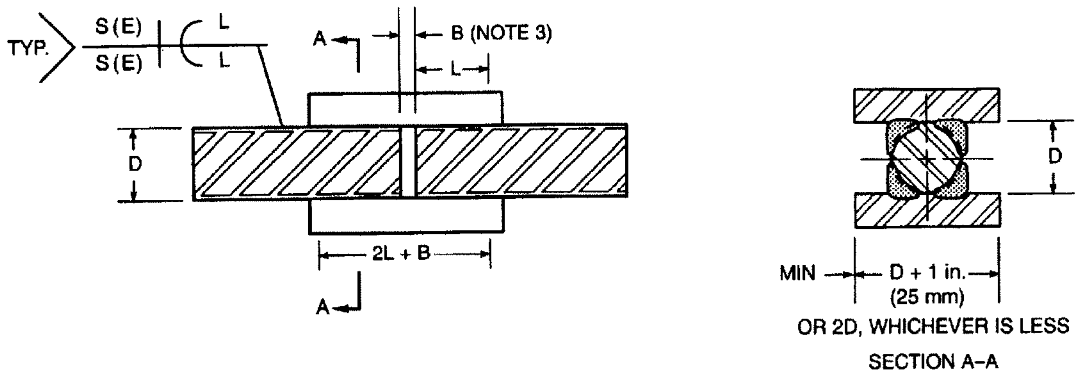
(3) Qualification in the 3G (vertical) position qualifies for direct butt joints in the 1G (flat), 2G (horizontal), and 3G (vertical) positions; and for fillet welds in the 1F (flat), 2F (horizontal), and 3F (vertical) positions (see Figure 6.1).

(4) Qualification in the 4G (overhead) position qualifies for direct butt joints in the 1G (flat) and 4G (overhead) positions and for fillet welds in 1F (flat), 2F (horizontal), and 4F (overhead) positions (see Figure 6.1).



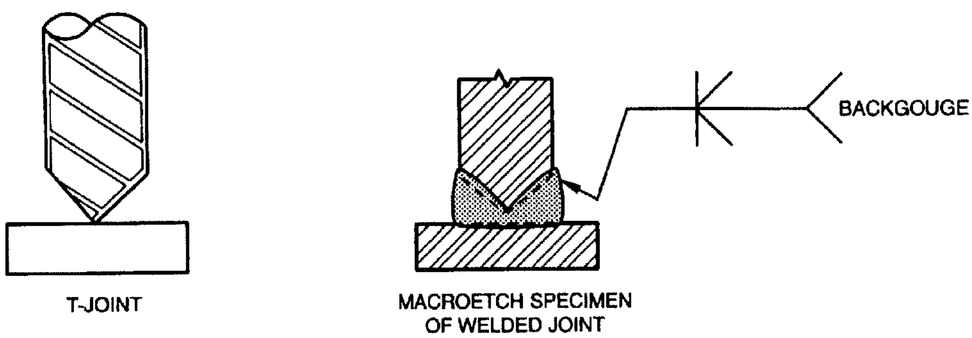
NOTES:
1. FOR BARS NO. 9 (29) OR LARGER, USE SINGLE-V OR SINGLE-BEVEL-GROOVE WELDS (Θ = 45°).
2. FOR BARS NO. 8 (25) OR SMALLER, USE SINGLE-V WITH SPLIT PIPE BACKING, [Θ = 60°, AS IN FIGURE 3.2(C)]

(A) COMPLETE JOINT PENETRATION GROOVE WELD— DIRECT BUTT JOINT



NOTE 3. B = SEPARATION BETWEEN ENDS OF BARS. MAXIMUM: B = 3/4 in. (19 mm).

(B) FLARE-BEVEL-GROOVE—INDIRECT BUTT JOINT



(C) COMPLETE JOINT PENETRATION GROOVE WELD—T-JOINT

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

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).

6.3.5 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 6.5):

(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 6.5(A) and 6.5(B)].

Table 6.3
Number and Type of Tests and Weld Qualified for WPS Qualification (see 6.3.5.1)

Qualification Test Assembly	Number of Test Assemblies Required	Welds Qualified for	Number and Type of Tests Required: Radiography (6.3.5.2)		Tension (6.3.6.1)		Macroetch (6.3.6.2)
Direct butt joint [Figure 6.6(A)]	2	Figures 3.1, 3.2, and 3.5(D)	2[a]	or	1[b]	+	1[b]
Indirect butt joint [Figure 6.6(B)]	2	Figures 3.3, 3.4, and 3.5(A), (B), (C), (E)	—		—		2
Complete joint penetration T-joint [Figure 6.6(C)]	2	Figure 3.1 or 3.5(D)	—		—		2

Notes:
a. Radiography not permitted for welds made by GMAW using 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 contractor's option.

(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 6.5(C) and 6.5(D)].

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.

6.3.7 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.

6.4 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.

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 section 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 standard industry practice. See the latest edition of ANSI/AWS D1.1, section 6, except for 6.17, radiographic procedure, for an example of such practice. The standards of acceptance shall be in accordance with 4.4.2 and 4.4.8 of this code. *Note: Inspection of flare-V- and flare-bevel-groove welds or fillet welds by the radiographic testing method is, in general, not considered feasible, except by highly specialized techniques, and is not recommended.*

7.7.4 When magnetic particle testing is used, the procedure and technique shall be in accordance with ASTM E709, *Standard Practice 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 E165, *Standard Practice 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.*[2] 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.

2. Available from the American Society for Nondestructive Testing, 4153 Arlingate Plaza, Columbus, OH 43228.

Annex A
Sample Welding Procedure Form
(Nonmandatory Information)

(This Annex is not a part of ANSI/AWS D1.4-98, *Structural Welding Code—Reinforcing Steel*, but is included for information purposes only.)

WELDING PROCEDURE SPECIFICATION, PROCEDURE QUALIFICATION RECORD, AND WELDER QUALIFICATION TEST RECORD

WELDING PROCEDURE SPECIFICATION

Material specification ____________
Bar size ____________
Bar coating type ____________
Backing material ____________
Backing size ____________
Welding process ____________
Carbon equivalent ____________
Manual or machine ____________
Position of welding ____________
Filler metal specification ____________
Filler metal classification ____________
Shielding gas ____________
Gas flow rate ____________
Single or multiple pass ____________
Single or multiple arc ____________
Welding current ____________
Polarity ____________
Root treatment ____________
Preheat and interpass temperature ____________

Specification No. ____________
Welder ____________

TEST RESULTS

Tensile strength, psi
1. ____________
2. ____________

Macroetch tests
1. ____________
2. ____________

Visual Inspection
Appearance ____________
Undercut ____________
Porosity ____________

NDT
Type ____________
Results ____________

WELDING PROCEDURE

Pass no.	Electrode size	Welding current		Joint detail
		Amperes	Voltage	

This procedure may vary due to fabrication sequence, fit-up, pass size, etc. within the Limitations of Variables given in Table 6.1. We the undersigned certify that the statements made in this record are correct and that the tests were prepared, welded, and tested in accordance with the requirements of 6.2 of ANSI/AWS D1.4, (_____) Structural Welding Code—Reinforcing Steel.
(year)

WPS no. ____________
Revision no. ____________

Manufacturer or contractor ____________
Authorized by ____________
Date ____________

Annex B
Nominal Dimensions of Standard Reinforcing Bars

(This Annex is not a part of ANSI/AWS D1.4-98, *Structural Welding Code—Reinforcing Steel*, but is included for information purposes only.)

Bar Size[1,2]		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

Notes:
1. 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.
2. The bar size number is based on the number of eights of an inch in the nominal diameter of the bar.

Annex C

Guidelines for Preparation of Technical Inquiries for the Structural Welding Committee

(Nonmandatory Information)

(This Annex is not a part of ANSI/AWS D1.4-98, *Structural Welding Code—Reinforcing Steel,* but is included for information purposes only.)

C1. Introduction

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

C2. Procedure

All inquiries must be directed to:

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

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

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 edition of the code that contains the provisions or that the Inquirer is addressing.

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

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

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

C3. Interpretation of Code Provisions

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

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
Safe Practices

(This Annex is not a part of ANSI/AWS D1.4-98, *Structural Welding Code—Reinforcing Steel*, but is included for information 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 inquiry 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

1. American Conference of Governmental Industrial Hygienists. *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*. Cincinnati, OH: American Conference of Governmental Industrial Hygienists (ACGIH).

2. American National Standards Institute. *Practice for Occupational and Educational Eye and Face Protection*, ANSI/ASC Z87.1. New York: American National Standards Institute.

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

4. ASTM. "Definitions of terms relating to gamma and x-radiography," E586, *1988 Annual Book of ASTM Standards*, Section 3, Volume 03.03. Philadelphia, PA: ASTM, 1988.

5. American Welding Society. *Fumes and Gases in the Welding Environment*, AWS report. Miami, FL: American Welding Society.

6. ——. *Method for Sound Level Measurement of Manual Arc Welding and Cutting Processes*, ANSI/AWS F6.1. Miami, FL: American Welding Society.

7. ——. *Recommended Safe Practices for the Preparation for Welding and Cutting Containers and Piping*, ANSI/AWS F4.1. Miami, FL: American Welding Society.

8. ——. *Safety in Welding, Cutting, and Allied Processes*, ANSI/ASC Z49.1. Miami, FL: American Welding Society.

9. ——. *Safe Practices*, Reprint from Welding Handbook, Volume 1, Eighth Edition. Miami, FL: American Welding Society.

10. National Bureau of Standards. *General Safety Standard for Installation Using Non-medical X-ray and Sealed Gamma Ray Sources up to 10 MeV Equipment Design and Use*, NBS-HDBK-114. Gaithersburg, Maryland: National Bureau of Standards.

11. ——. *Safety Standard for Non-medical X-ray and Sealed Gamma-ray Sources*, NBS-HDBK-93. Gaithersburg, Maryland: National Bureau of Standards.

12 ——. *X-ray Protection*, NBS-HDBK-60. Gaithersburg, Maryland: National Bureau of Standards.

13. National Fire Protection Association. *Fire Prevention in Use of Cutting and Welding Processes*, NFPA Standard 51B. Quincy, Massachusetts: Fire Protection Association, latest edition.

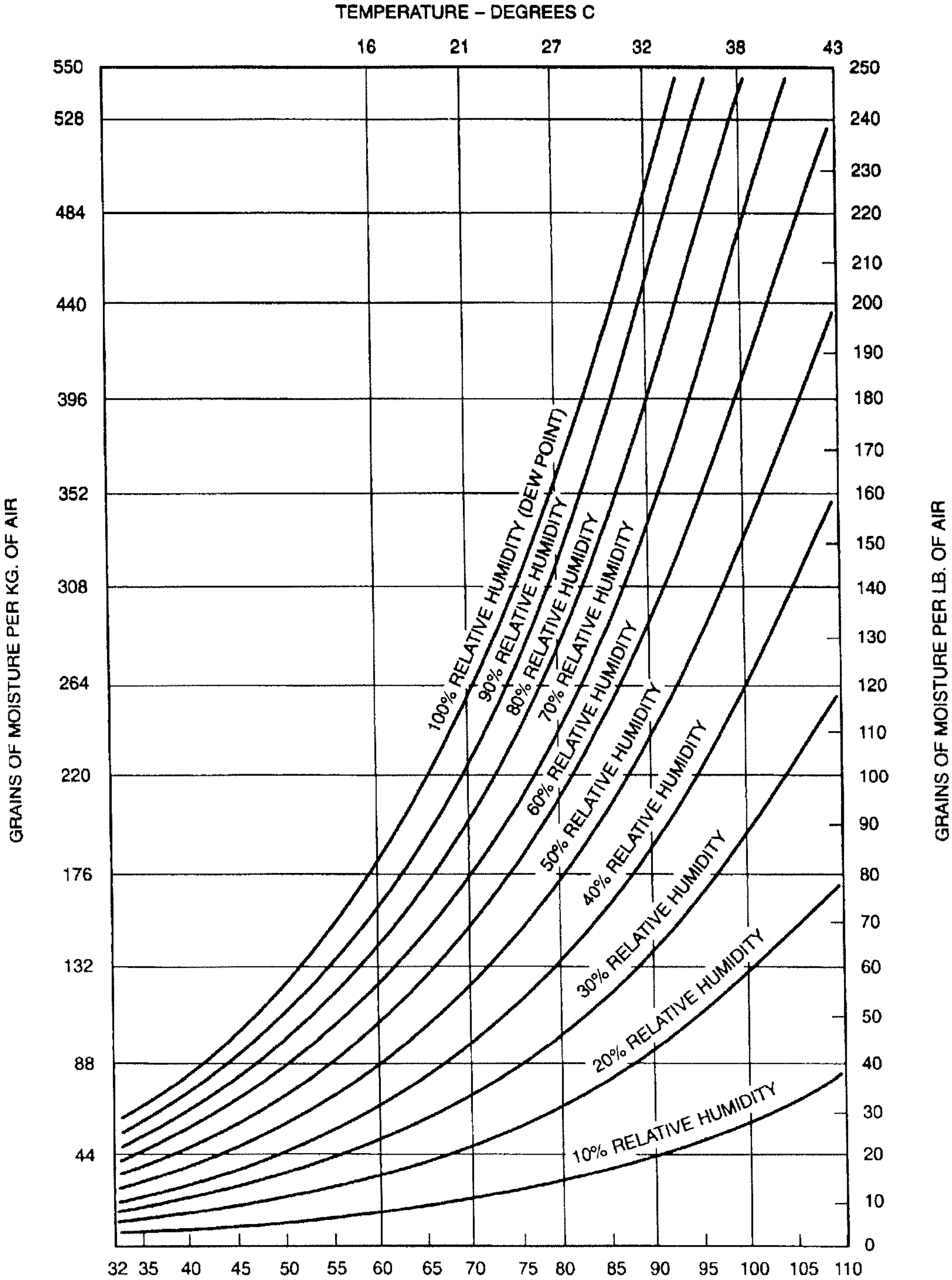
14. ——. *National Electrical Code*, NFPA No. 70. Quincy, Massachusetts: National Fire Protection Association.

15. U.S. Government Printing Office. *Code of Federal Regulations* (CFR), Title 29, Subtitle B Chapter XVII, Part 1910. Occupational Safety and Health Standards Washington, DC: U.S. Government Printing Office.

16. ——. "Safety requirements for cabinet x-ray," Federal Standard No. 21—*Code of Federal Regulations*. Washington, DC: U.S. Government Printing Office.

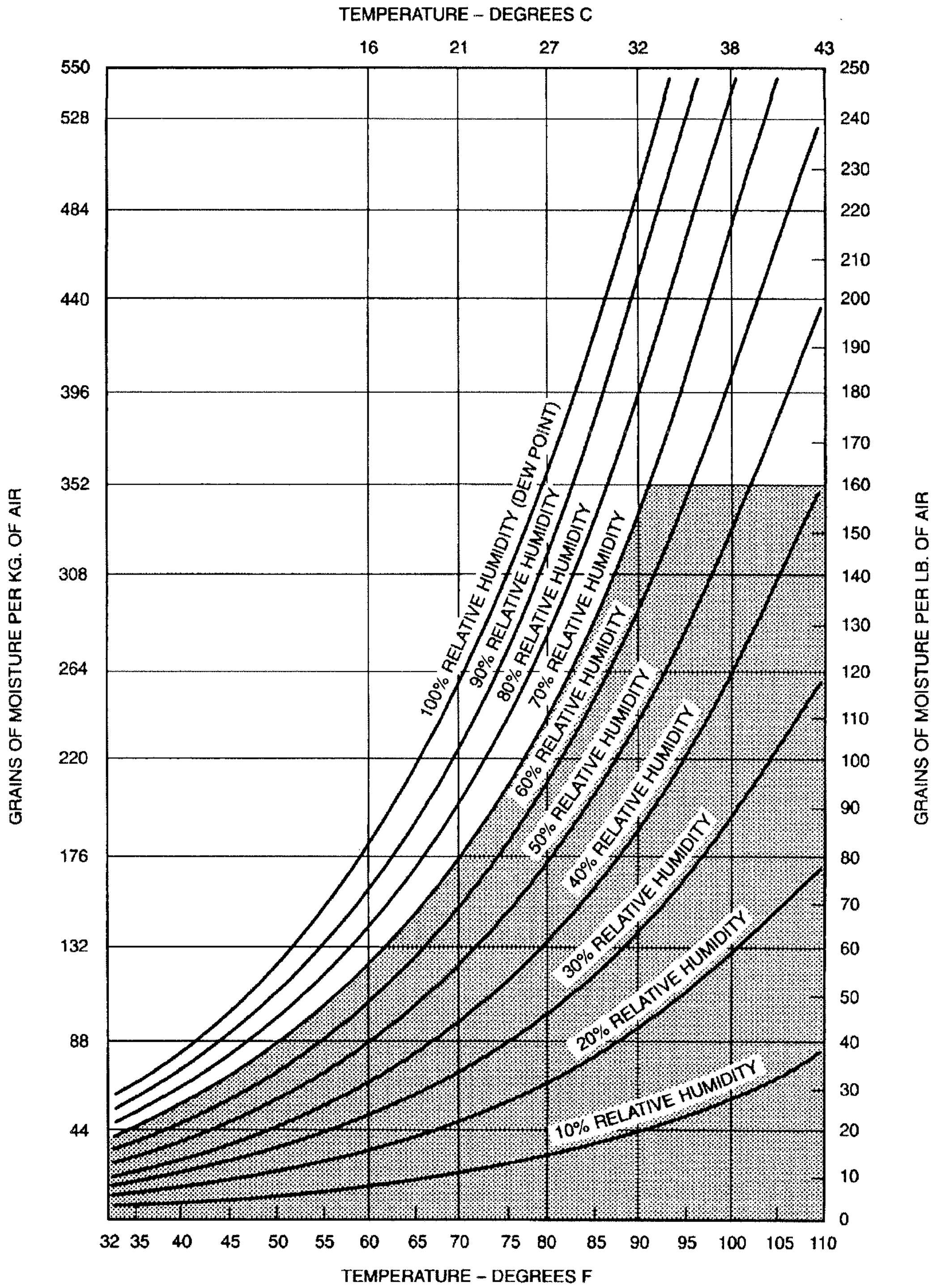
Annex E
Temperature-Moisture Content Charts
(Nonmandatory Information)

(This Annex is not a part of ANSI/AWS D1.4-98, *Structural Welding Code—Reinforcing Steel,* but is included for information purposes only.)



Notes:
1. Any standard psychrometric chart may be used in lieu of this chart.
2. 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)

AWS Structural Welding Code Document List

Code	Document
D1.1	Structural Welding Code—Steel
D1.2	Structural Welding Code—Aluminum
D1.3	Structural Welding Code—Sheet Steel
D1.4	Structural Welding Code—Reinforcing Steel
D1.5	Bridge Welding Code

For ordering information, contact the Order Department, American Welding Society, 550 N.W. LeJeune Road Miami, FL 33126. Phone: 1-800-334-9353.