

**Specification for
Welding Earthmoving and Construction
Equipment**



American Welding Society

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construction equipment

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Specification for Welding Earthmoving and Construction Equipment

Prepared by
AWS Committee on Machinery and Equipment

Approved by
AWS Board of Directors

Abstract

This specification provides standards for producing structural welds used in the manufacture of earthmoving and construction equipment. Such equipment is defined as self propelled, on and off highway machinery. Manufacturer's responsibilities are presented as they relate to the welding practices that have been proven successful within the industry in the production of weldments on this equipment. Basic dimensional weld details are defined and interpreted for application throughout the document. Provisions are made to identify base metals used in these weldments.

Procedures to assure they are welded with compatible, identifiable welding processes and consumables are included with consideration given to factors that affect weldability.



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This standard is subject to revision at any time by the AWS Machinery and Equipment 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 It must be reviewed every five years and if not revised, it must be either reapproved or withdrawn.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 Machinery and Equipment 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 Machinery and Equipment 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, Florida 33126.

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Foreword

(This Foreword is not a part of ANSI/AWS D14.3–94, *Specification for Welding Earthmoving and Construction Equipment*, but is included for information purposes only.)

AWS first published the Specification for Welding Earthmoving and Construction Equipment in 1977 to provide a welding specification where none previously existed. By definition, the types of equipment covered by the specification are numerous and varied. Every effort was made to reflect the best welding practices employed by manufacturers within the industry, and to incorporate all the various methods which have been proven successful by individual manufacturers. No restrictions are placed on the use of any welding process or procedure, provided the weld produced by the process meets the qualification requirements of the specification. Similarly, no limitation is intended on the use of any base metal, weld joint preparation, or welding consumable capable of being qualified.

In preparation of this issue, various parts of the specification have been reworded to eliminate misunderstanding concerning some of the provisions and to clarify their intent. Other revisions or additions to the specification include reorganizing various sections to provide smoother flow. The “Welding Personnel Qualification” section, for example, is structured so those testing variables that are particular to that method are located in that section.

Comments or inquiries pertaining to this specification are welcome. They should be addressed to the Secretary, Machinery and Equipment Committee, 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

	Page No.
<i>Personnel</i>	iii
<i>Foreword</i>	iv
<i>List of Tables</i>	vii
<i>List of Figures</i>	vii
 1. General Provisions	 1
1.1 Scope	1
1.2 Definitions	1
1.3 Symbols	1
1.4 References	1
 2. Basic Weld Detail	 2
2.1 General Requirements	2
2.2 Groove Welds	2
2.3 Fillet Welds	2
2.4 Intermittent Welds	2
 3. Base Metals	 5
3.1 Structural Steels and Nonferrous Metals	5
3.2 Properties	5
3.3 Weldability and Procedure Qualification	5
 4. Welding Processes and Consumables	 5
4.1 Processes	5
4.2 Consumables	5
 5. Welding Procedure Qualification	 5
5.1 Scope	5
5.2 General Requirements	5
5.3 Method I — Prototype Testing	6
5.4 Method II — Procedure Qualification Tests	9
5.5 Method III — Prequalified Joint Procedure	14
 6. Welding Personnel Qualification	 47
6.1 Scope	47
6.2 General	47
6.3 Welder Qualification	48
6.4 Welding Operator Qualification	57
6.5 Operators of Automatic Welding Equipment	57
6.6 Qualification of Tack Welders	57

7. Workmanship and Welding Quality Requirements	58
7.1 Scope	58
7.2 General Requirements	58
7.3 Preparation of Materials	59
7.4 Assembly	59
7.5 Quality of Welds	59
7.6 Repair of Weld Defects	61
7.7 Cleaning	61
7.8 Dimensional Tolerance	61
8. Inspection	61
9. Field Repair	63
Annex A: Sample of Welding Procedure Specification and Qualification Test Record	65
Annex B: Recommended Practices for Treatment of Shielded Metal Arc Electrodes	67
Annex C: Commonly Used Metric Conversions	68
Annex D: Conversions for Fahrenheit – Celsius Temperature Scales	70
Annex E: Guided-Bend Test Jigs	73
Annex F: Safety Considerations	77
List of AWS Documents	(Inside of back cover)

List of Tables

Table		Page No.
1	Procedure Qualification Tests for Complete Joint Penetration	
	Groove Welds	11
2	Weldability Classification—Typical Steel Products	42
3	Weldability Classification	43
4	Minimum Preheat and Interpass Temperature for Prequalified Procedures	44
5	Filler Metal Requirements for Prequalified Complete Joint Penetration	
	Groove Welds	45
6	Maximum Amperages for Submerged Arc Welding	46
7	Electrode Classification Groups—Welder Qualification	48
8	Welding Personnel Qualification Type and Position Limitations	49
9	Welder Qualification Tests	49
10	Electrode Classification Groups—Tack Welder Qualification	58
11	Workmanship Tolerances for Groove Welds	60

List of Figures

Figure		Page No.
1	Skewed Groove Weld	2
2	Concave Fillet Weld Profiles	3
3	Convex Fillet Weld Profiles	3
4	Skewed T-Joint	4
5	Combination of Bevel-Groove and Fillet Weld Profile	4
6	Positions of Groove Welds	7
7	Positions of Fillet Welds	8
8	Positions of Test Plates for Groove Welds	9
9	Positions of Test Plates for Fillet Welds	10
10	Order of Removal of Test Specimens from Welded Test Plate Over 3/4 in. (19 mm) Thick—Procedure Qualification	11
11	Order of Removal of Test Specimens from Welded Test Plate 3/8 in. (9.5 mm) Thick—Procedure Qualification	11

12	Order of Removal of Test Specimens from Welded Test Plate Over 3/4 in. (1.9 mm) Thick—Electroslag and Electrogas – Welding Procedure Qualification	12
13	Reduced Section Tension Specimen	12
14	All Weld Metal or Reduced Section Tension Specimen	13
15	Fillet Weld Soundness Test for Procedure Qualification	14
16	Complete Joint Penetration Prequalified Shielded Metal Arc Welded Joints	15
17	Partial Joint Penetration Prequalified Shielded Metal Arc Welded Joints	23
18	Complete Joint Penetration Prequalified Submerged Arc Welded Joints	26
19	Partial Joint Penetration Prequalified Submerged Arc Welded Joints	30
20	Complete Joint Penetration Prequalified Gas Metal and Flux Cored Arc Welded Joints	32
21	Partial Joint Penetration Prequalified Gas Metal and Flux Cored Arc Welded Joints	38
22	Details for Prequalified Fillet Welds of Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (GMAW), Submerged Arc Welding (SAW), and Flux Cored Arc Welding (FCAW)	41
23	Test Plate for Unlimited Thickness—All Position—Welder Qualification	50
24	Optional Test Plate for Unlimited Thickness—Horizontal Position—Welder Qualification	50
25	Test Plate for Limited Thickness—All Positions—Welder Qualification	51
26	Optional Test Plate for Limited Thickness—Horizontal Position—Welder Qualification	51
27	Face and Root Bend Specimens	52
28	Side-Bend Specimen	52
29	Fillet Weld Break & Macroetch Test Plate—Welder Qualification—Option 1	53
30	Fillet Weld Soundness (Guided Root Bend) Test Plate—Welder Qualification— Option 2	54
31	Example of Workmanship Sample	56
32	Example of Workmanship Sample	56
33	Example of Workmanship Sample	56
34	Fillet Weld Break Specimen – Tack Welder Qualification	58
35	Method of Rupturing Specimen – Tack Welder Qualification	58
36	Acceptable and Unacceptable Weld Profiles	62
E1	Guided-Bend Test Jigs	74
E2	Alternative Roller-Equipped Guided-Bend Test Jig for Bottom Ejection of Test Specimen	75
E3	Alternative Wraparound Guided-bend Test Jig	75
E4	Method of Applying Load on Fillet Weld Break Test Specimen	76

Specification for Welding Earthmoving and Construction Equipment

1. General Provisions

1.1 Scope

1.1.1 This specification applies to all structural welds¹ used in the manufacture of earthmoving and construction equipment.² It reflects the welding practices employed by manufacturers within the industry and incorporates various methods which have been proven successful by individual manufacturers.³ No restrictions are placed on the use of any welding process or procedure, provided the weld produced meets the qualification requirements of this specification. No attempt is made to limit or restrict technological progress in the welding of earthmoving and construction equipment, nor should any such limitation be inferred.

1.1.2 The manufacturer's adherence to this specification shall include responsibility for

- (1) Welding, as defined in 1.1.1, in accordance with this specification
- (2) Producing welds as designated on drawings by appropriate symbols and notes, with sufficient detail

1. *Structural welds* are defined as welds which carry the primary working loads during normal operations.

2. For purposes of this specification, earthmoving and construction equipment is described as self-propelled, on and off-highway machinery. Such products as crawlers, tractors, graders, loaders, off-highway trucks, power shovels, backhoes, truck and crawler cranes, draglines, and similar equipment are considered to be included in this specification.

3. Manufacturer means the organization responsible for the performance of the work covered by this specification.

to show joint preparation compatible with applied processes

- (3) Providing written welding procedures
- (4) Recording results of all welder and procedure qualification tests
- (5) Controlling use of designated base metals and consumables
- (6) Inspecting the welds to the requirements of this specification
- (7) Ensuring a safe welding environment and safe welding practice (see Annex F)

1.2 Definitions. Welding terms used in this specification shall be in accordance with ANSI/AWS A3.0, *Standard Welding Terms and Definitions*, except as defined herein.

1.3 Symbols. Welding symbols shown on drawings shall be compatible with those shown in ANSI/AWS A2.4, *Standard Symbols for Welding, Brazing and Nondestructive Examination*. Special conditions or deviations shall be fully explained by added notes, details, or definitions.

1.4 References. The following standards have either been cited in this specification, or are deemed to contain information which would be useful in meeting the requirements of this specification:

- (1) ANSI/ASC Z49.1, *Safety in Welding and Cutting*
- (2) ANSI/AWS A2.4, *Standard Symbols for Welding Brazing and Nondestructive Examination*
- (3) ANSI/AWS A3.0, *Standard Welding Terms and Definitions*
- (4) Applicable AWS Filler Metal Specifications

(5) ANSI/AWS D1.1, *Structural Welding Code – Steel*

(6) AWS D14.4, *Classification and Application of Welded Joints for Machinery and Equipment*

(7) ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*

(8) SAE-J1116 *Categories of Off-Road Self-Propelled Work Machines*

(9) Section IX ASME *Boiler and Pressure Vessel Code*

(10) Annex C, Commonly Used Metric Conversions

(11) Annex D, Conversion for Fahrenheit – Celsius Temperature Scales

2. Basic Weld Detail

2.1 General Requirements. Final weld sizes considerably less than plate thickness may result in the following from lack of adequate heat input: cracking, loss of toughness, and lack of fusion. When weld sizes smaller than 30 percent of plate thickness are to be used, it is recommended that testing be performed to determine that the resulting welded joint properties are consistent with design and quality requirements.

2.2 Groove Welds

2.2.1 A *complete joint penetration groove weld* is defined as one in which the weld metal fills the groove

and is fused with the base metal throughout its total thickness.

The size of a complete joint penetration groove weld shall be the thickness of the thinner part joined.

2.2.2 A *partial joint penetration groove weld* is defined as one welded from one or both sides and having joint penetration that is less than complete.

The size of a partial joint penetration groove weld shall be the joint penetration obtained.

2.2.3 The effective length for any groove weld, square or skewed (see Figure 1), shall be the width of the part joined.

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

2.3 Fillet Welds

2.3.1 The *effective throat* for a fillet weld is defined as the minimum distance from the root of a weld to its face, less any reinforcement (see Figures 2, 3, and 4).

2.3.1.1 Design values based on depth of penetration or effective throat, or both, which are beyond the root of the joint shall only be used when the values have been determined from a significant number of cross-sectioned samples which reflect the range of materials, material thicknesses, and welding conditions.

2.3.2 The effective throat for a combination of bevel-groove and fillet weld shall be the shortest distance from the root of weld to the face of the fillet, less any reinforcement (see Figure 5).

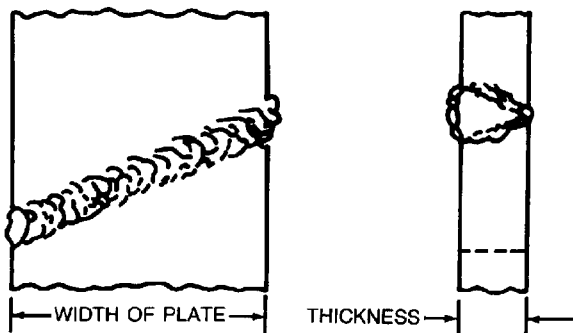
2.3.3 The length of a fillet weld shall be the overall length of the full-size fillet, including boxing.

2.3.4 The effective area shall be the effective weld length multiplied by the effective throat. Stress in a fillet weld shall be considered as applied to this effective area for any direction of applied load.

2.3.5 Fillet welds may be used in skewed T-Joints (Tee Joints) having a dihedral angle of not less than 60 degrees nor more than 135 degrees (see Figure 4). Angles less than 60 degrees may be used, however, welds are considered to be partial penetration groove welds.

2.4 Intermittent Welds

2.4.1 The length of any segment of an intermittent fillet weld shall not be less than four times the weld size. Welds less than 1/4 in. (6.4 mm) size shall not be less than 1 in. (25.4 mm) in length.



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

Figure 1—Skewed Groove Weld

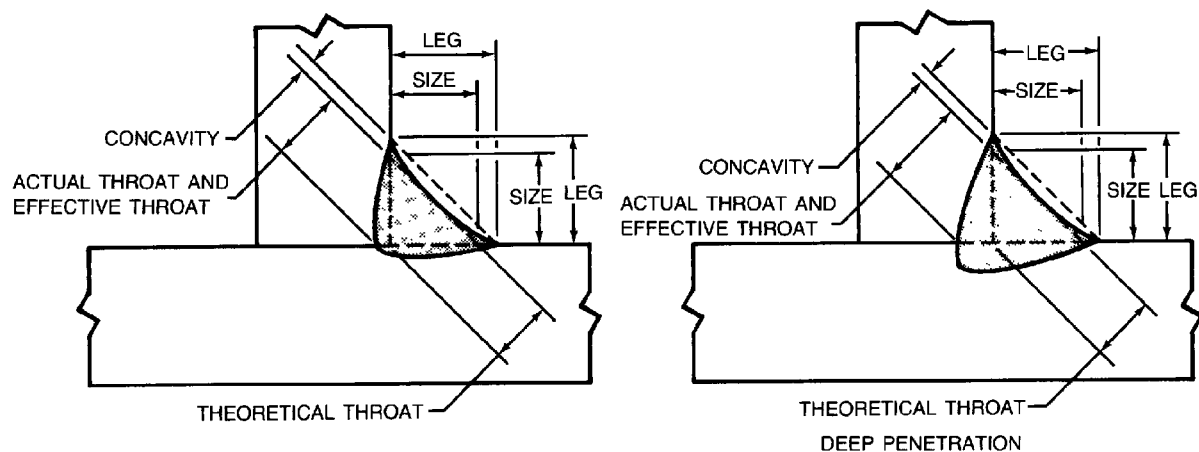


Figure 2—Concave Fillet Weld Profiles

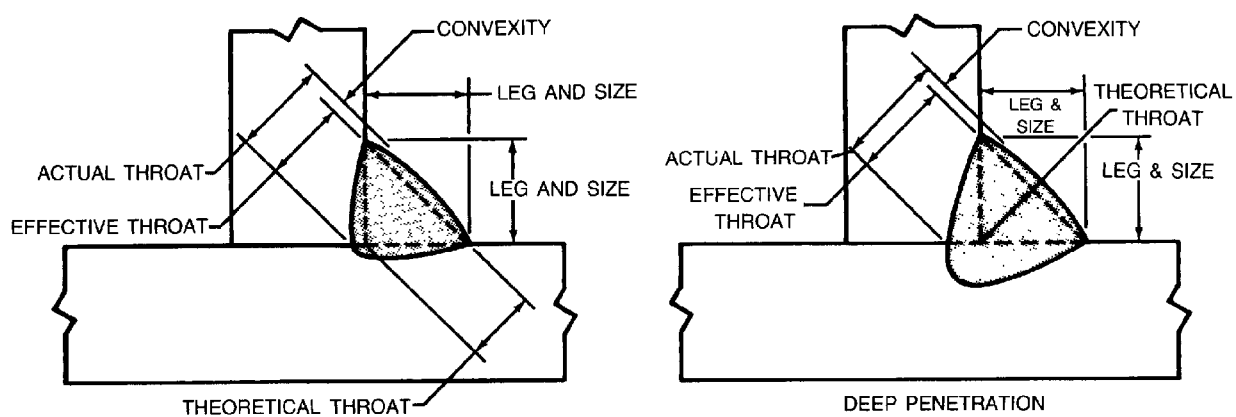


Figure 3—Convex Fillet Weld Profiles

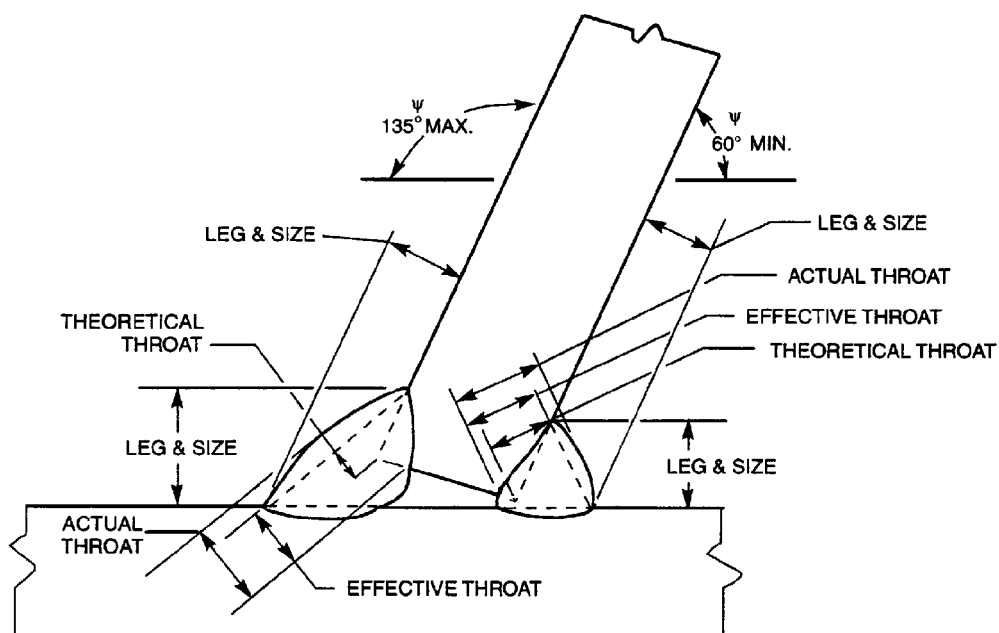


Figure 4—Skewed T-Joint

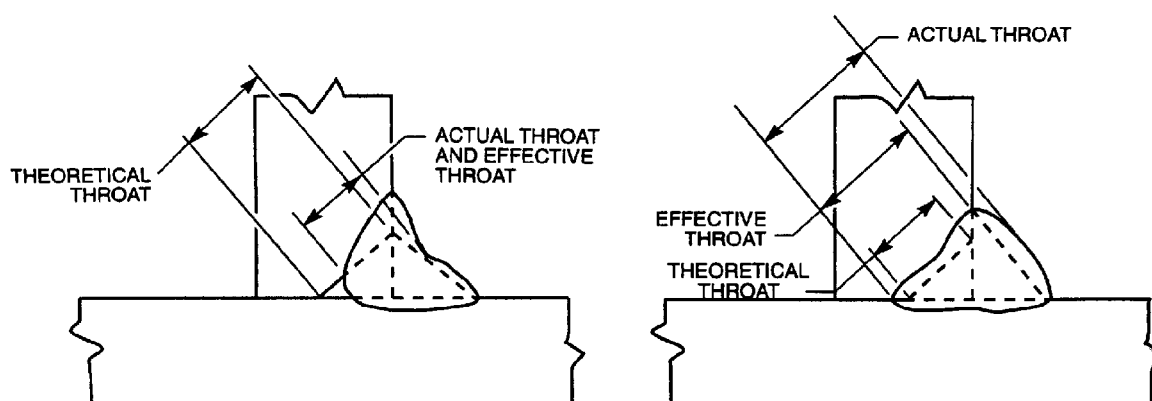


Figure 5—Combination of Bevel-Groove and Fillet Weld Profile

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

3. Base Metals

3.1 Structural Steels and Nonferrous Metals.

Structural steel, steel castings and forgings (see Tables 2 and 3), and nonferrous metals used in the weldments of earthmoving and construction equipment must be identified by a specification. Specifications developed by the manufacturer or commonly used industry-wide specifications such as American Society for Testing and Materials (ASTM), American Iron and Steel Institute (AISI), Society of Automotive Engineers (SAE), and American Foundrymen's Society (AFS) may be used.

3.2 Properties. Base metal specifications shall designate the mechanical properties and composition of the material to be used. These base metals are expected to be compatible with the welding process and consumables recommended in this specification. This is not intended to restrict base metal selection, but rather to assure that weldability factors have been considered.

3.3 Weldability and Procedure Qualification. The weldability and procedure for welding base metal shall be established by qualification in accordance with the requirements of 5, Welding Procedure Qualification.

4. Welding Processes and Consumables

4.1 Processes

4.1.1 All welding processes and methods recognized by ANSI/AWS A3.0 may be used in the construction and fabrication of component parts of earthmoving and construction equipment.

4.1.2 Processes which are not classified or recognized by AWS may be used, provided the manufacturer can show evidence that the process used produces welds which meet the requirements of 5, Welding Procedure Qualification.

4.2 Consumables

4.2.1 Consumables⁴ purchased to the requirements of AWS filler metal specifications need not be tested by the user.

4. The term *consumables* refers to filler metals and fluxes used in the welding process.

4.2.2 Consumables which are not classified or recognized by AWS may be used, provided the manufacturer can show evidence that the consumables used produce welds which meet the requirements of 5, Welding Procedure Qualification.

4.2.3 Consumables shall be protected and stored so that their characteristics or welding properties are not adversely affected. Consumable manufacturer's specific recommendations shall be applied. Annex B contains general practices that are commonly employed for application within the scope of this specification.

4.2.4 When a gas or gas mixture is used for shielding in gas metal arc or flux cored arc welding, it shall be a welding grade having a dew point of -40°F (-40°C) or lower.

5. Welding Procedure Qualification

5.1 Scope. The welding procedure qualification shall be performed to establish the weldability with any particular combination of the following essential variables:

- (1) Base metal
- (2) Welding process
- (3) Filler metal
- (4) Joint design
- (5) Welding conditions

Each of the above five variables, as established by procedure qualification, shall be part of the welding procedure. All procedures to be used shall be prepared by the manufacturer as written procedure specifications and shall include the range of essential variables (see Annex A for suggested form).

Any changes in the values of the five variables, once qualified, are subject to review for possible requalification. Such a review may involve tests and the judgement of those responsible for the written welding procedure. The manufacturer shall be responsible for assuring such changes are consistent with the weld quality requirements of 7, Workmanship and Welding Quality Requirements. Any changes shall be reflected in the written procedure specifications.

5.2 General Requirements

5.2.1 Qualification of Welding Procedures. Welding procedure qualification may be achieved in the following manner:

- Method I —Prototype Testing
- Method II —Procedure Qualification Tests
- Method III—Prequalified Joint Procedure

The manufacturer shall be responsible for the choice of qualifying method and for recording of all tests demonstrating satisfactory welding procedures by Methods I, II, or III. Records of the test results shall be kept by the manufacturer, and shall be available for review, for a length of time as required by contract. Welding procedures, once qualified by any of the methods, are considered qualified whenever the same set of five variables are encountered. This permits the development of standard procedures by a manufacturer.

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

5.2.3 Position of Test Welds. All welds that will be encountered in actual construction shall be classified as being (1) flat, (2) horizontal, (3) vertical, or (4) overhead, in accordance with the definitions of welding positions given in Figures 6 and 7. Each method of qualification (Methods I and II) shall be tested in the manner stated for each position for which it is to be qualified.

5.2.3.1 Groove Welds

(1) Position 1G (flat) – The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the upper side as illustrated in Figure 8(A).

(2) Position 2G (horizontal) – The test plates shall be placed in an approximately vertical plane with the welding groove approximately horizontal as illustrated in Figure 8(B).

(3) Position 3G (vertical) – The test plates shall be placed in an approximately vertical plane with the welding groove as illustrated in Figure 8(C).

(4) Position 4G (overhead) – The test plates shall be placed in an approximately horizontal plane and the weld metal deposited from the under side as illustrated in Figure 8(D).

5.2.3.2 Fillet Welds

(1) Position 1F (flat) – The test plates shall be so placed that each fillet weld is deposited with its axis approximately horizontal and its throat approximately vertical, as illustrated in Figure 9(A).

(2) Position 2F (horizontal) – The test plates shall be so placed that each fillet weld is deposited on the upper side of the horizontal surface and against the vertical surface, as illustrated in Figure 9(B).

(3) Position 3F (vertical) – Each fillet weld shall be made vertically, as illustrated in Figure 9(C).

(4) Position 4F (overhead) – The test plates shall be so placed that each fillet weld is deposited on the under side of the horizontal surface and against the vertical surface, as illustrated in Figure 9(D).

5.2.4 Welding shall comply in all respects to the Welding Procedure Specification (WPS).

5.3 Method I—Prototype Testing

5.3.1 Welding procedures may be qualified under Method I by utilizing prototype structures or components that comply with the minimum performance criteria as follows:

5.3.1.1 Simulated service tests of a welded assembly or a mockup of the welded joint. These tests may include required specification performance tests such as SAE criteria for rollover protection structures (ROPS) and falling object protection structures (FOPS), lift arm safety devices, steering frame locks, industrial power mower housings, etc. The simulated service test may include impact loading, loading in bending, static loading or fatigue testing to duplicate the type of loading the joint will be subjected to in service.

5.3.1.2 A field test of the welded assembly on a machine loaded and performing the work for which it was designed.

5.3.2 For simulated service or field tests, the following shall be documented and recorded:

5.3.2.1 The weldment drawing to which the test part or assembly was made.

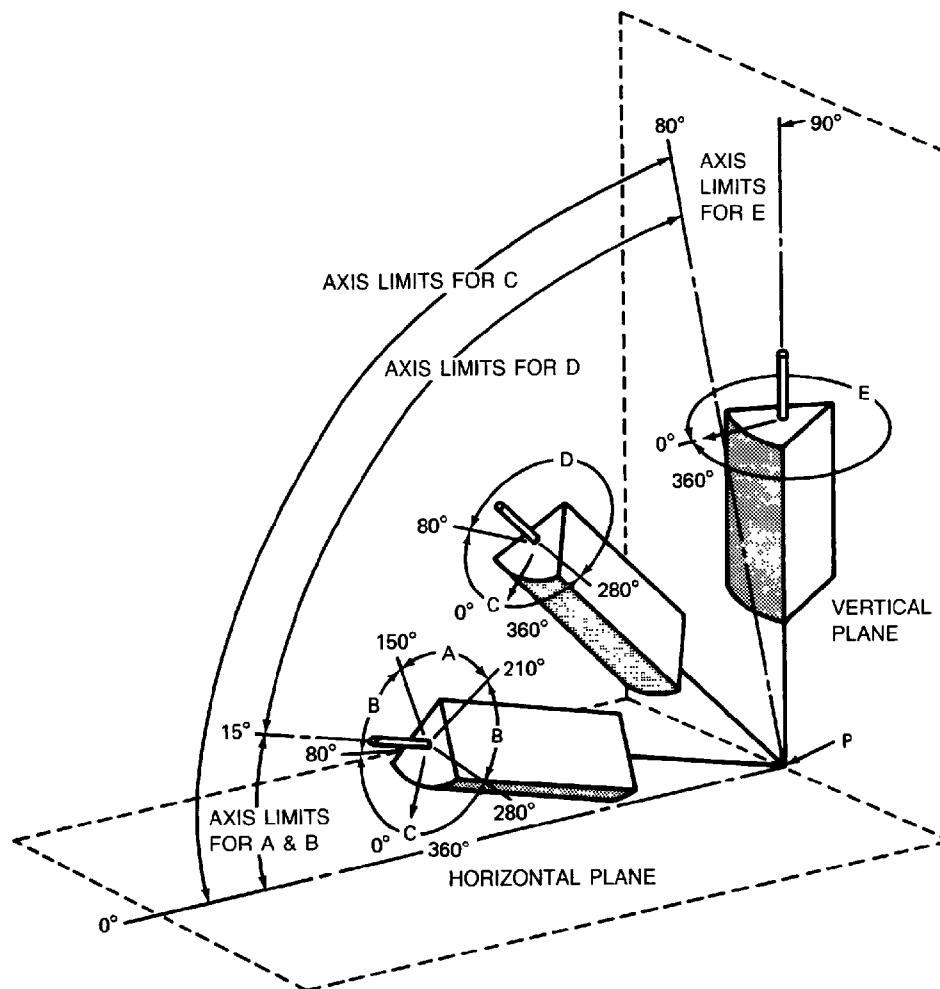
5.3.2.2 The material specifications of all items included in the assembly.

5.3.2.3 The detailed welding procedure employed including welding process, filler metal, joint preparation, preheat, welding conditions and sequence of weld passes. (See example in Annex A.)

5.3.2.4 The type of loading applied, direction and magnitude of forces (by calculation or instrumentation), frequency and total number of applications or specific duration of the test.

5.3.2.5 The results of visual examination and nondestructive testing of all welds subjected to loading in the test.

5.3.2.6 The results of destructive tests of weldments.

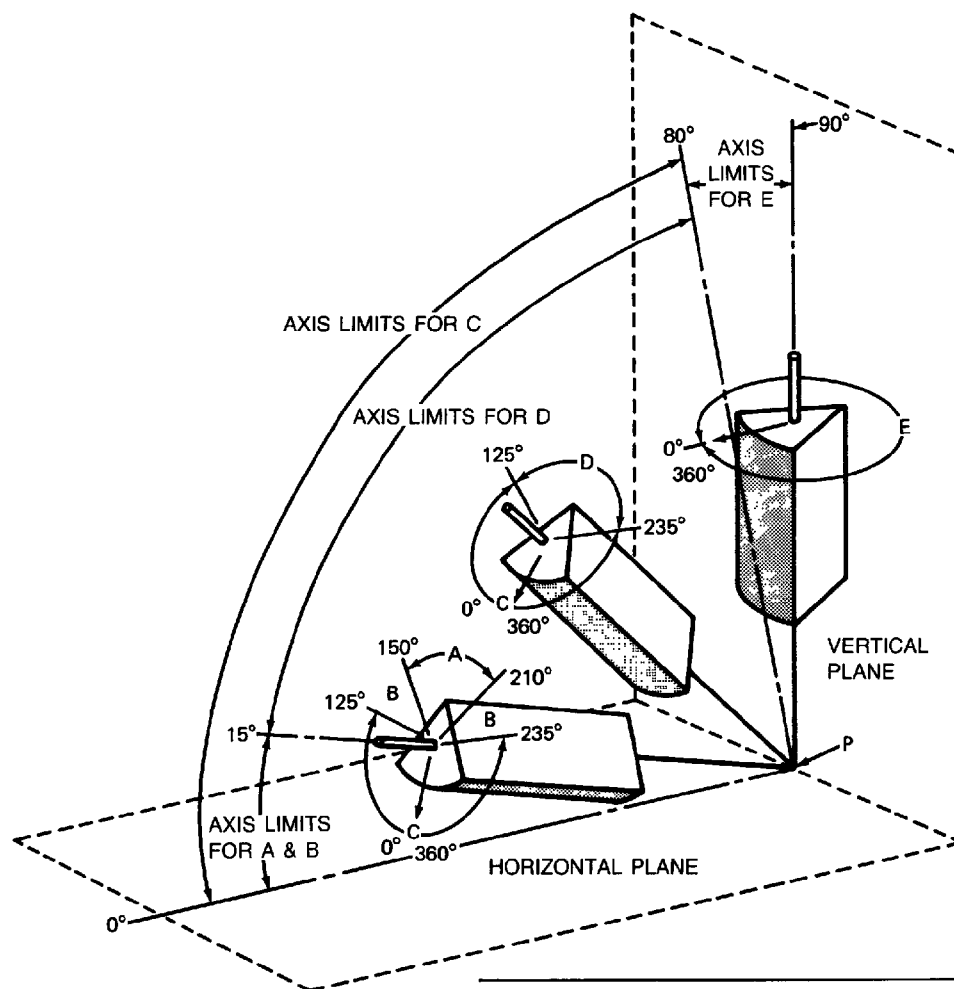


Notes:

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°).

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°

Figure 6—Positions of Groove Welds



TABULATION OF POSITIONS OF FILLET WELDS			
POSITION	DIAGRAM REFERENCE	INCLINATION OF AXIS	ROTATION OF FACE
FLAT	A	0° to 15°	150° to 210°
HORIZONTAL	B	0° to 15°	125° to 150°
			210° to 235°
OVERHEAD	C	0° to 80°	0° to 125°
			235° to 360°
VERTICAL	D	15° to 80°	125° to 235°
		80° to 90°	0° to 360°

Figure 7—Positions of Fillet Welds

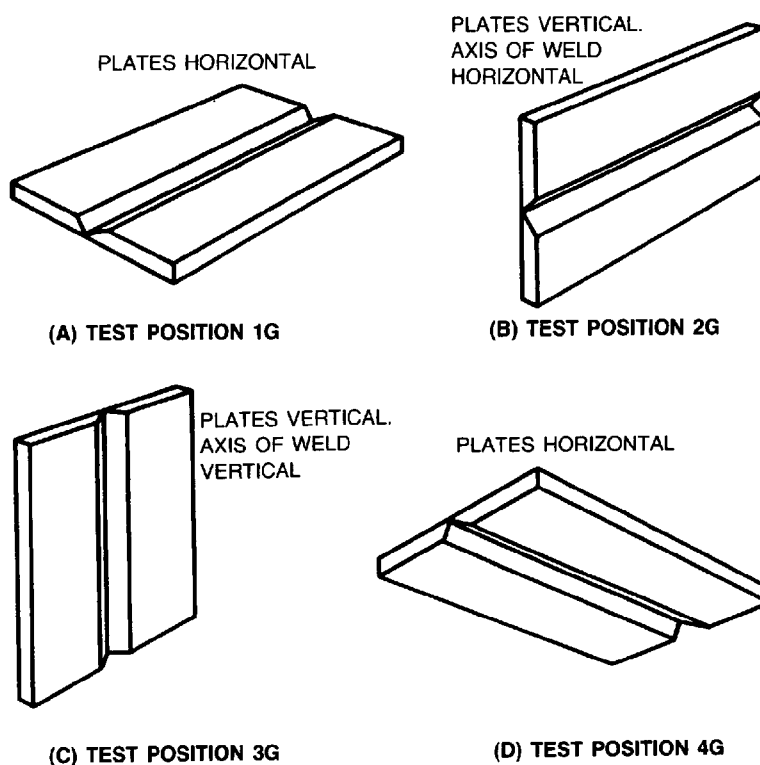


Figure 8—Positions of Test Plates for Groove Welds

5.3.3 The welding procedure employed for the test assembly shall be considered qualified provided:

5.3.3.1 Visual and any required nondestructive examinations, prior to test, meet the requirements of 7, Workmanship and Welding Quality Requirements.

5.3.3.2 Specified examinations conducted after test assure performance criteria are met.

5.4 Method II—Procedure Qualification Tests. Welding procedures qualified by Method II utilize standard laboratory-type weld samples. This method may also be used to supplement the application of prequalified welding procedures and prototype qualification.

5.4.1 Welding Procedures. Welding shall comply in all respects with the Welding Procedure Specification (WPS).

5.4.2 Complete Joint Penetration Groove Welds

5.4.2.1 For groove welds in material up to and including 3/4 in. (19.1 mm) thick, one test weld shall be made in base metal 3/8 in. (9.5 mm) thick for each process and position to be used in construction.

5.4.2.2 When construction involves welding of base metal over 3/4 in. (19.1 mm) thick, a test weld shall be made in base metal of the maximum thickness to be used in construction for each process and position. However, the maximum test thickness need not exceed 1 in. (25.4 mm).

5.4.2.3 No test need be repeated in the 3/8 in. (9.5 mm) thickness if a test is made in the maximum, or 1 in. (25.4 mm) thickness.

5.4.2.4 The test piece shall be sectioned to determine whether the procedure provides the specified minimum penetration, fusion and weld profile (see 7.5.6). Reduced-section tension tests and bend tests of the joint shall be used where specified mechanical properties of groove welds are required as indicated in Table 1.

5.4.2.5 Reference shall be made to AWS D14.4, *Classification and Application of Welded Joints for Machinery and Equipment* for complete joint penetration groove welds in pipe or tubing.

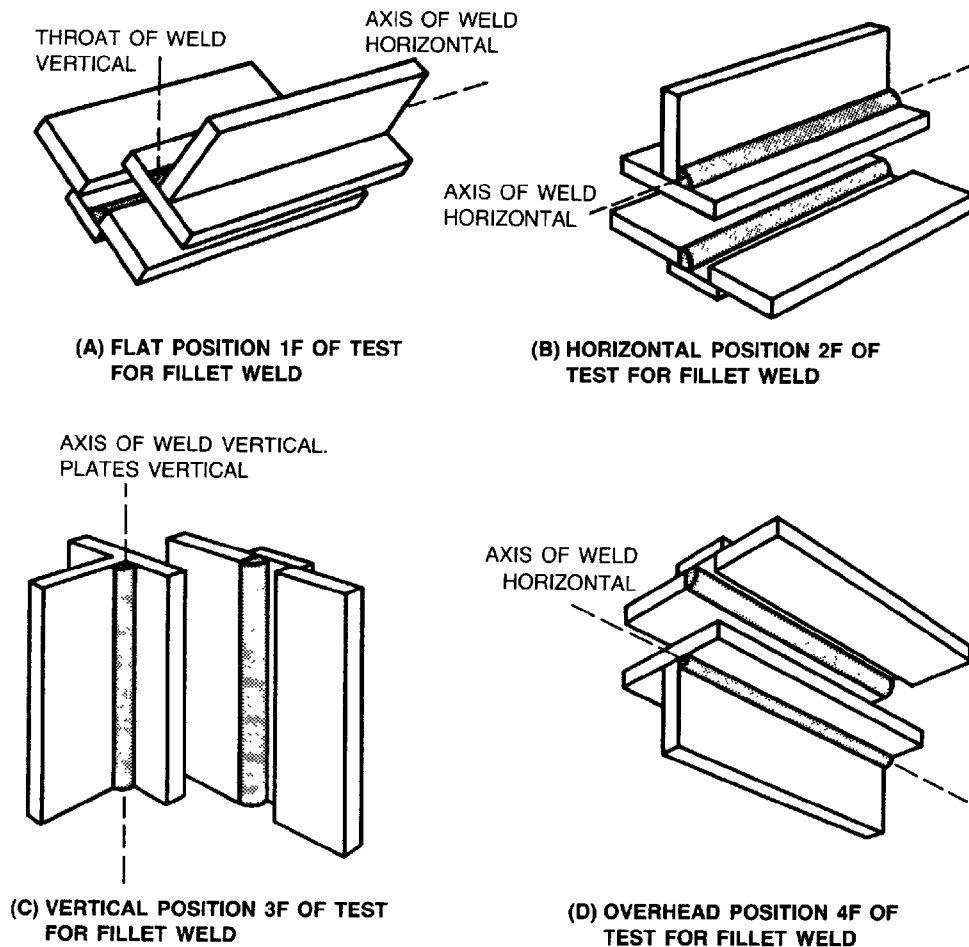


Figure 9—Positions of Test Plates for Fillet Welds

5.4.3 Test Specimens—Number, Type and Preparation

5.4.3.1 Complete Joint Penetration Groove Welds. The method of preparing the specimens of groove welds and the number of tests required shall be in accordance with the figures referred to in Table 1. The test specimens shall be removed in the order given in Figures 10, 11, and 12, as appropriate. In addition to these tests, the test plate for electroslag and electrogas welding shall be nondestructively tested (see 7.5.2).

5.4.3.2 Partial Joint Penetration Groove Welds. A welded sample of the groove design to be used in construction shall be cross-sectioned and macroetched to demonstrate that the designed weld size is obtained in accordance with requirements of 7.5.1. The depth of the groove need not exceed 1 in. (25.4 mm).

5.4.4 Method of Testing Specimens

5.4.4.1 Reduced-Section Tension Specimens. See Figures 13 or 14. The least width and corresponding thickness of the reduced section shall be measured before testing. The specimen shall be ruptured under tensile load, and the maximum load shall be determined. The cross-sectional area shall be obtained as follows: Initial cross-sectional area of the gauge section area = width x thickness. The tensile strength shall be obtained by dividing the maximum load by the initial cross-sectional area of the gauge section.

5.4.4.2 Macroetch Test. Specimens shall be etched with a suitable solution to give a clear definition of the weld.

5.4.4.3 Root-, Face- and Side-Bend Specimens. Each specimen shall be bent to the contour shown in Annex E. Any convenient means may be used for

Table 1
Procedure Qualification Tests¹ for Complete Joint Penetration Groove Welds

Maximum Thickness to be Welded in Construction	Test Plate Thickness	Visual Examination	Reduced ⁴ Section Tension	Root ⁵ Bend	Face ⁵ Bend	Side ⁶ Bend	All Weld ⁷ Metal Tension
Up to and including 3/4 in. ⁵	3/8 in.	Yes	2	2	2	—	—
Over 3/4 in. ⁶	Maximum to be welded but need not exceed 1 in.	Yes	2			4	
All	Electroslag or electrogas welding ² Maximum thickness to be welded or 0.91 ³	Yes	2			4	1

Notes:

- Impact tests may be required if specified.
- Radiographic or ultrasonic testing is required (7.5.2).
- T is the plate thickness to be used in construction.
- See Figure 13 and 14
- See Figure 11
- See Figure 10 and 12
- See Figure 12 and 14

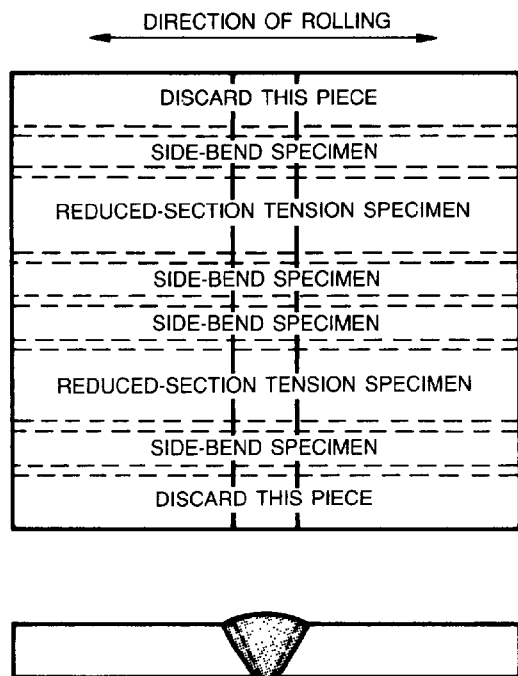
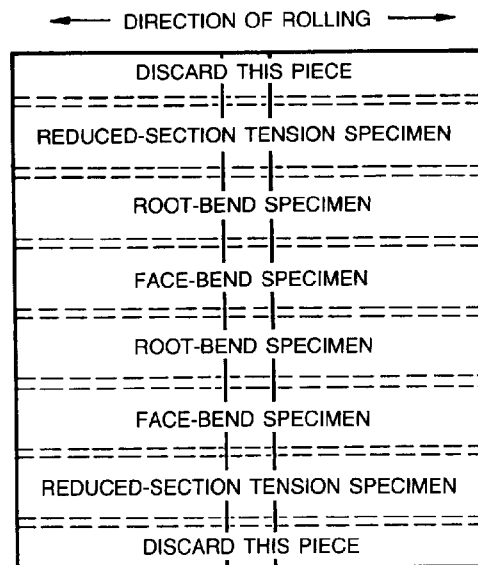


Figure 10—Order of Removal of Test Specimens from Welded Test Plate over 3/4 in. Thick – Procedure Qualification



GROOVE CONFIGURATION SHOWN IS FOR ILLUSTRATION ONLY. THE GROOVE SHAPE USED SHALL CONFORM TO THAT BEING QUALIFIED.

Figure 11—Order of Removal of Test Specimens from Welded Test Plate 3/8 in. Thick – Procedure Qualification

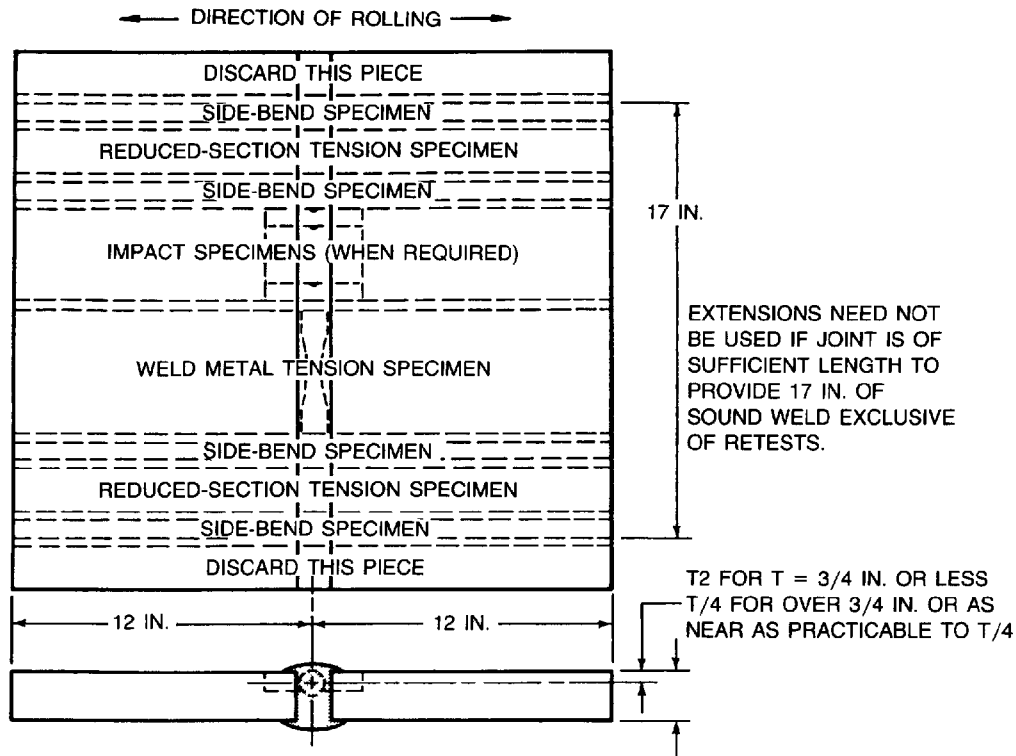
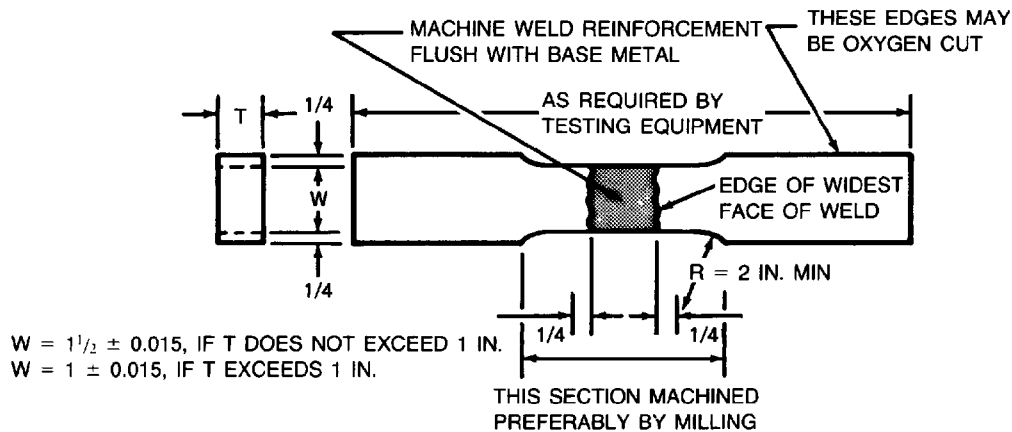
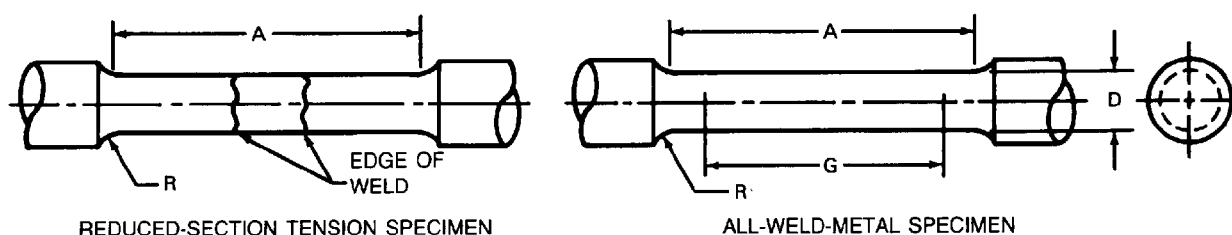


Figure 12—Order of Removal of Test Specimens from Welded Test Plate over 3/4 in. Thick—Electroslag and Electrogas—Welding Procedure Qualification



Note: For plates over 1-1/2 in. thick, specimens may be cut into the minimum number of approximately equal strips not exceeding 1-1/2 in. in thickness. Test each strip and average the results.

Figure 13—Reduced Section Tension Specimen



	DIMENSIONS		
	STANDARD SPECIMEN	SMALL SIZE SPECIMENS PROPORTIONAL TO STANDARD	
		0.350 round	0.250 round
G - GAGE LENGTH	2.0 ± 0.005	1.4 ± 0.005	1 ± 0.005
D - DIAMETER (NOTE 1)	0.500 ± 0.010	0.350 ± 0.007	0.250 ± 0.005
R - RADIUS OF FILLET, MIN	3/8	3/8	1/4
A - LENGTH OF REDUCED SECTION (NOTE 2), MIN	2-1/4	1-3/4	1-1/4

Notes:

1. The reduced section may have a gradual taper from the center toward the ends with the ends not more than 0.005 in. larger in diameter than the center (controlling dimension) on the standard specimen and not more than 0.003 in. larger than the center on the small size specimens.
2. If desired, on the small size specimens, the length of the reduced section may be increased to accommodate an extensometer. However, reference marks for the measurement of elongation should nevertheless be spaced at the indicated gage length.
3. The gage length and fillets shall be as shown, but the ends may be of any form to fit the holders of the testing machine in such a way that the load shall be axial.

*Applies to All-Weld-Metal specimen only.

Figure 14—All-Weld-Metal or Reduced Section Tension Specimen

moving the plunger member with relation to the die member. The specimen shall be placed on the die with the weld at midspan. Face-bend specimens shall be placed with the face of the weld directed toward the gap. Root-bend specimens shall be placed with the root of the weld directed toward the gap. Side-bend specimens shall be placed with the side showing the most significant discontinuities, if any, directed toward the gap. The specimen shall be bent through an angle of 180 degrees.

5.4.4.4 All-Weld-Metal Tension Test (see Figure 14) The test specimen shall be tested in accordance with ANSI/AWS B4.0 *Standard Methods for Mechanical Testing of Welds*.

5.4.5 Test Results Required. The requirements for the test results shall be as follows:

- (1) Visual examination shall meet the visual quality requirements of 7.5.1.
- (2) Nondestructive testing required for electroslog and electrogas welds shall meet the requirements of 7.5.2.
- (3) Reduced-Section Tension Test. The tensile strength shall be not less than that required by design.

(4) Root-, Face-, and Side-Bend Tests. For acceptance, the convex surface of the bend test specimen shall be visually examined for surface discontinuities. For acceptance, the surface shall contain no discontinuities exceeding the following dimensions:

- (a) 1/8 in. (3.2 mm) measured in any direction on the surface
- (b) 3/8 in. (9.5 mm)—the sum of the greatest dimensions of all discontinuities exceeding 1/32 in. (0.8 mm), but less than or equal to 1/8 in. (3.2 mm)
- (c) 1/4 in. (6.4 mm)—the maximum corner crack, except when that corner crack resulted from visible slag inclusion or other fusion-type discontinuities, then the 1/8 in. (3.2 mm) maximum shall apply.

Specimens with corner cracks exceeding 1/4 in. (6.4 mm) with no evidence of slag inclusions or other fusion type discontinuities shall be disregarded and a replacement test specimen from the original weldment shall be tested.

(5) Macroetch Tests. The specimens shall be examined for defects and any which have defects prohibited by requirements of 7.5 shall be considered as having failed.

(6) All-Weld-Metal Tension (electroslag and electrogas) Test. The mechanical properties shall not be less than those required by design.

5.4.6 Fillet Welds. Two test welds shall be made for each fillet weld procedure and position to be used in construction. One test shall be made with the maximum size single-pass fillet weld and one with the minimum size multiple-pass fillet weld that will be used in construction. Three macroetch surfaces from two specimens shall be prepared as shown in Figure 15. Each surface of the macroetch specimen shall be suitably prepared before etching. The specimens shall be etched with a suitable solution to give a clear definition of the welds.

5.4.7 Test Results Required. The requirements for the test results shall be as follows:

The macroetch specimens shall be examined for defects, and any welds which have defects prohibited by 7.5 shall be considered as having failed. Fillet welds shall show fusion to the root but not necessarily beyond.

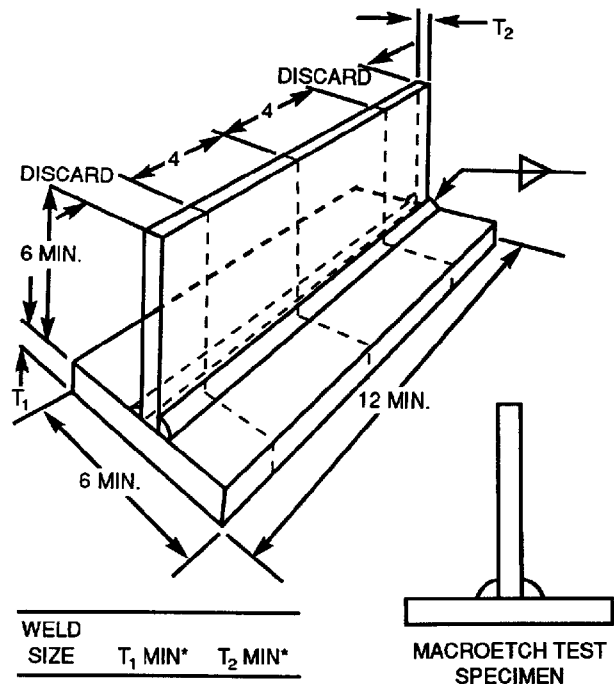
5.4.8 Other Weld Configurations. Where the welding process does not lend itself to making basic groove or fillet welds, or both, because of the process (such as resistance welding, solid state welding and other processes) or because of the configuration (such as in plug or slot welds), test pieces conforming to the actual production joint in size, mass, and material shall be made and sectioned to determine whether the procedure provides the specified minimum penetration, fusion, and weld profile. In addition, suitable mechanical tests of the welded joint shall be performed (tensile tests where applicable) when specified mechanical properties are required.

5.5 Method III—Prequalified Joint Procedure. Certain fundamental groove welded joints meeting all the requirements listed in 2.2 are designated as prequalified within the limitations shown in Figure 16 through 21. Fillet welds meeting all the requirements listed for a specified joint in 2.3 and shown in Figure 22 are also designated as prequalified. Both prequalified groove welds and fillet welds may be used without performing welding procedure qualification tests, provided the requirements of 5.5.1 through 5.5.4 are met.

Legend for Figures 16 through 22

Symbols for Base Metal Thickness and Penetration

- L – limited thickness – complete joint penetration
- U – unlimited thickness – complete joint penetration
- P – partial joint penetration



WELD SIZE	T ₁ MIN*	T ₂ MIN*
3/16	1/2	3/16
1/4	3/4	1/4
5/16	1	5/16
3/8	1	3/8
1/2	1	1/2
5/8	1	5/8
3/4	1	3/4
> 3/4	1	1

*Note: Where the maximum plate thickness used in production is less than the value shown in the table, the maximum thickness of the production pieces may be substituted for T₁ and T₂.

Figure 15—Fillet Weld Soundness Test for Procedure Qualification

Symbols for Welding Processes if not shielded metal arc

- S – submerged arc welding
- G – gas metal arc welding
- F – flux cored arc welding

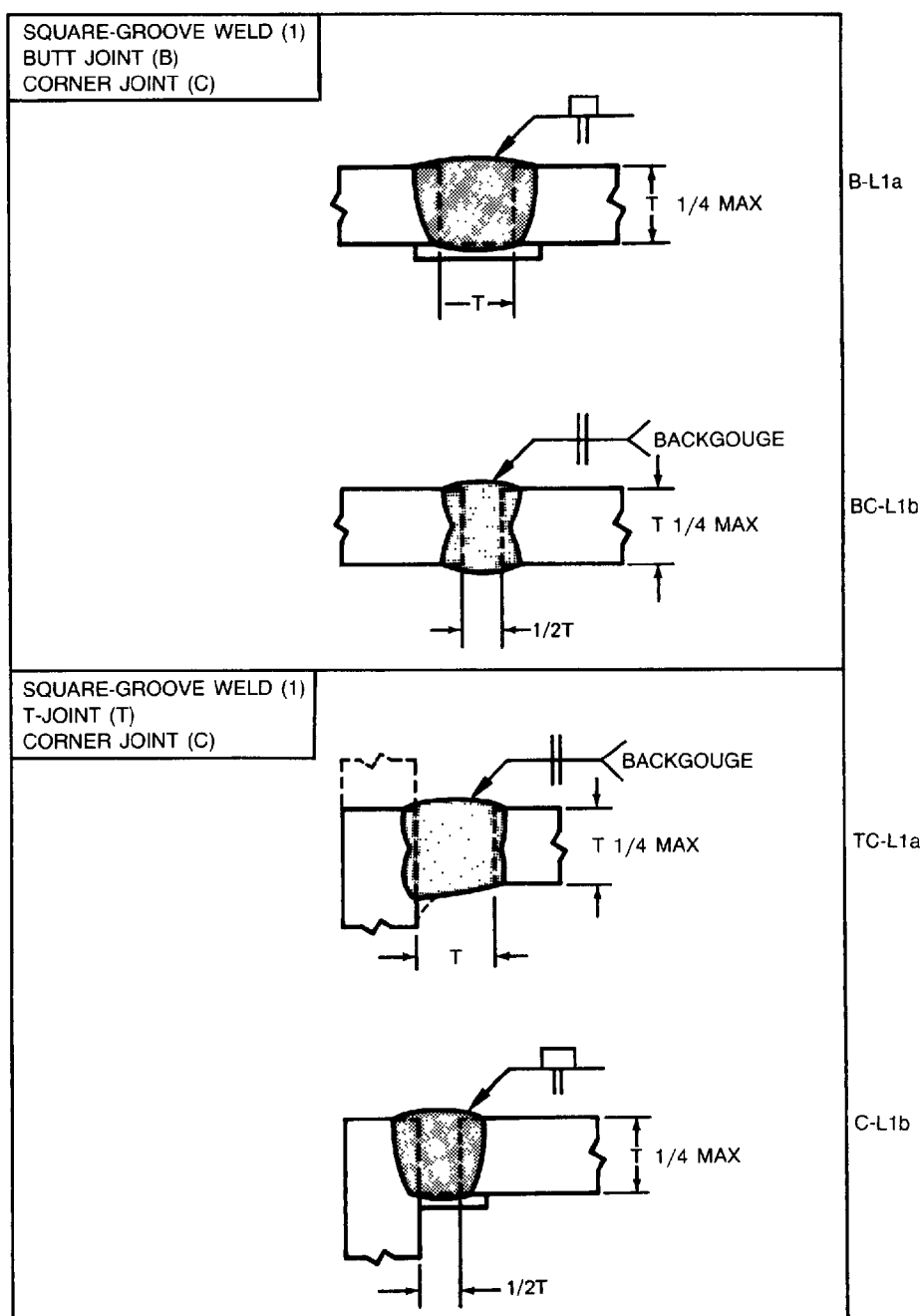
Symbols for Joint Types

- B – butt joint
- C – corner joint
- T – T-joint
- BC – butt or corner
- TC – T- or corner joint
- BTC – butt, T-, or corner joint

Symbols for Weld Types

- 1 – square-groove
- 2 – single-V-groove
- 3 – double-V-groove
- 4 – single-bevel-groove
- 5 – double-bevel-groove
- 6 – single-U-groove
- 7 – double-U-groove
- 8 – single-J-groove
- 9 – double-J-groove

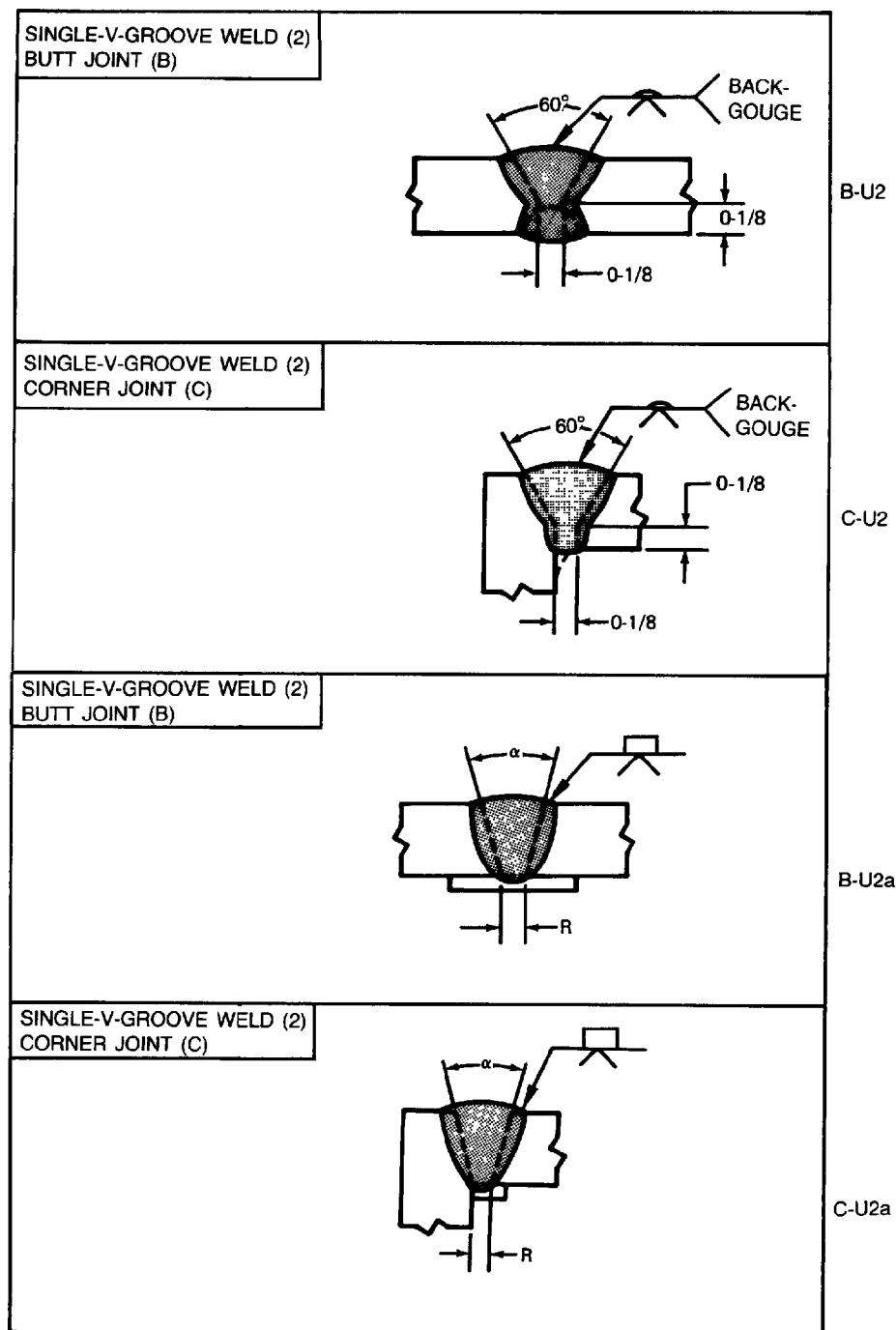
Small or lower case letters, i.e., a, b, c, etc., are used as symbols to differentiate between variations from a basic joint geometry with root opening closing to zero for joints that are designated by the same weld symbol. Alphabetical progression is confined within each joint penetration category, complete (L&U) and partial (P), for each welding process.



Notes:

1. Gouge the roots of joints without backing before welding other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to $T/4$ but need not exceed $3/8$ in.

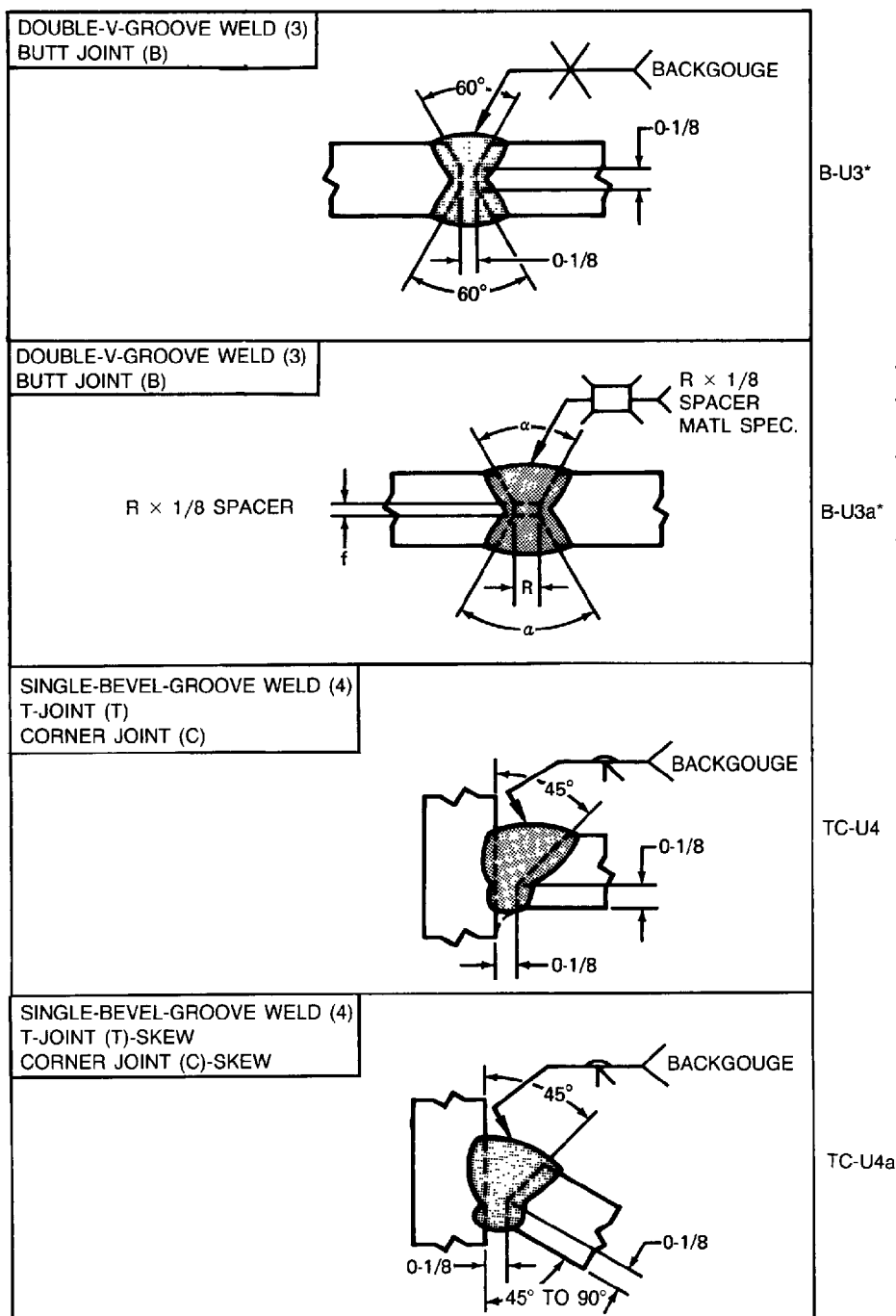
Figure 16—Complete Joint Penetration Prequalified Shielded Metal Arc Welded Joints

**Notes:**

1. Gouge roots of joints without backing before welding other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to $T/4$ but need not exceed $3/8$ in.

LIMITATIONS FOR JOINTS		
B-U2a AND C-U2a		
α	R	PERMITTED POSITIONS
45°	1/4	ALL POSITIONS
30°	3/8	FLAT & OVERHEAD
20°	1/2	FLAT & OVERHEAD

**Figure 16 (Cont'd)—Complete Joint Penetration Prequalified
Shielded Metal Arc Welded Joints**



LIMITATIONS FOR JOINTS

B-U3a

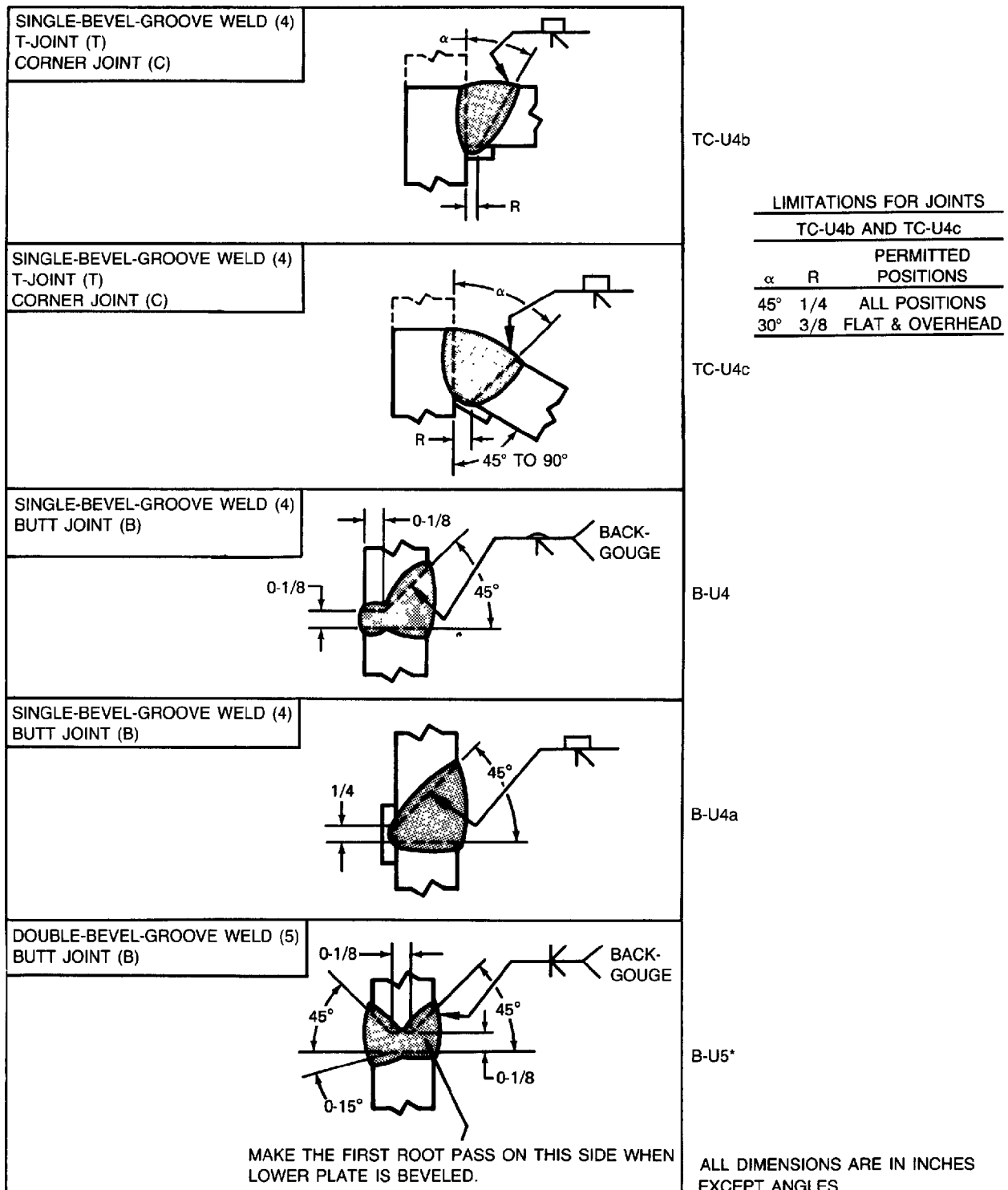
		PERMITTED POSITIONS
α	R	
45°	1/4	ALL POSITIONS
30°	3/8	FLAT & OVERHEAD
20°	1/2	FLAT & OVERHEAD

Notes:

1. Gouge roots of joints without backing before welding other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not exceed 3/8 in.

*The use of these welds shall preferably be limited to a base metal thickness of 5/8 in. or larger.

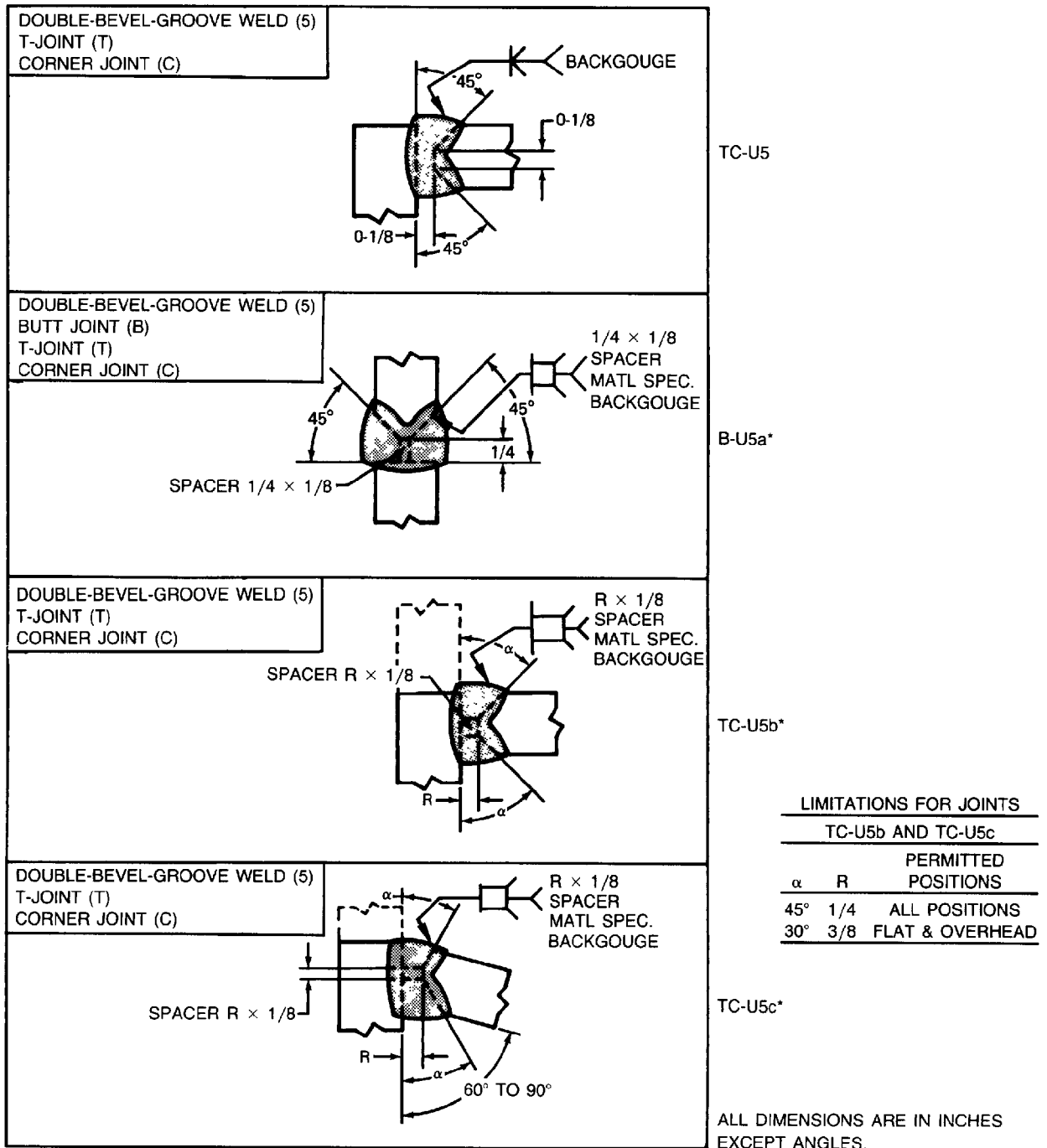
Figure 16 (Cont'd)—Complete Joint Penetration Prequalified Shielded Metal Arc Welded Joints

**Notes:**

1. Gouge roots of joints without backing before welding other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not exceed 3/8 in.

*The use of these welds shall preferably be limited to a base metal thickness of 5/8 in. or larger.

**Figure 16 (Cont'd) – Complete Joint Penetration Prequalified
Shielded Metal Arc Welded Joints**

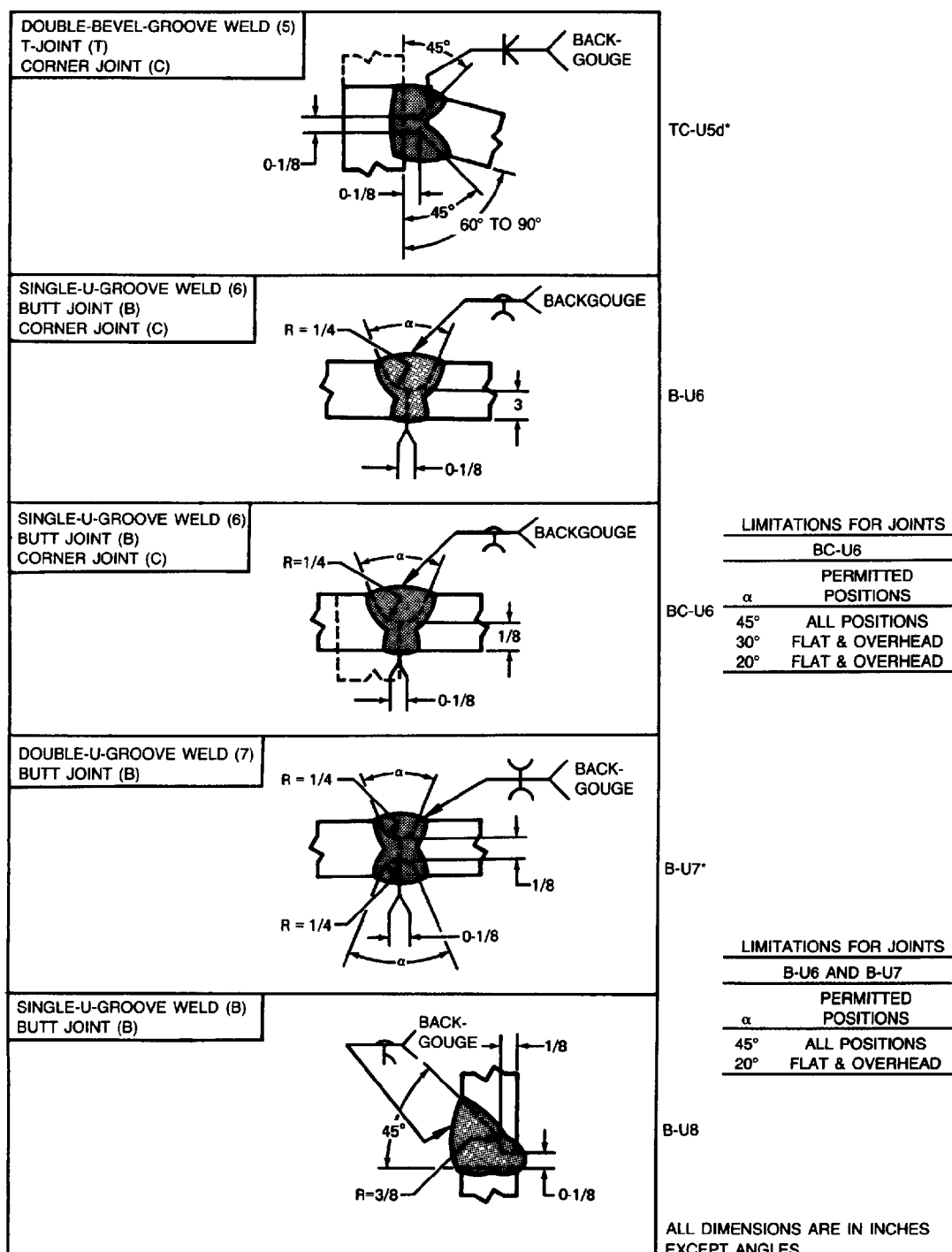


Notes:

1. Gouge roots of joints without backing before welding other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not exceed 3/8 in.

*The use of these welds shall preferably be limited to a base metal thickness of 5/8 in. or larger.

**Figure 16 (Cont'd)—Complete Joint Penetration Prequalified
Shielded Metal Arc Welded Joints**

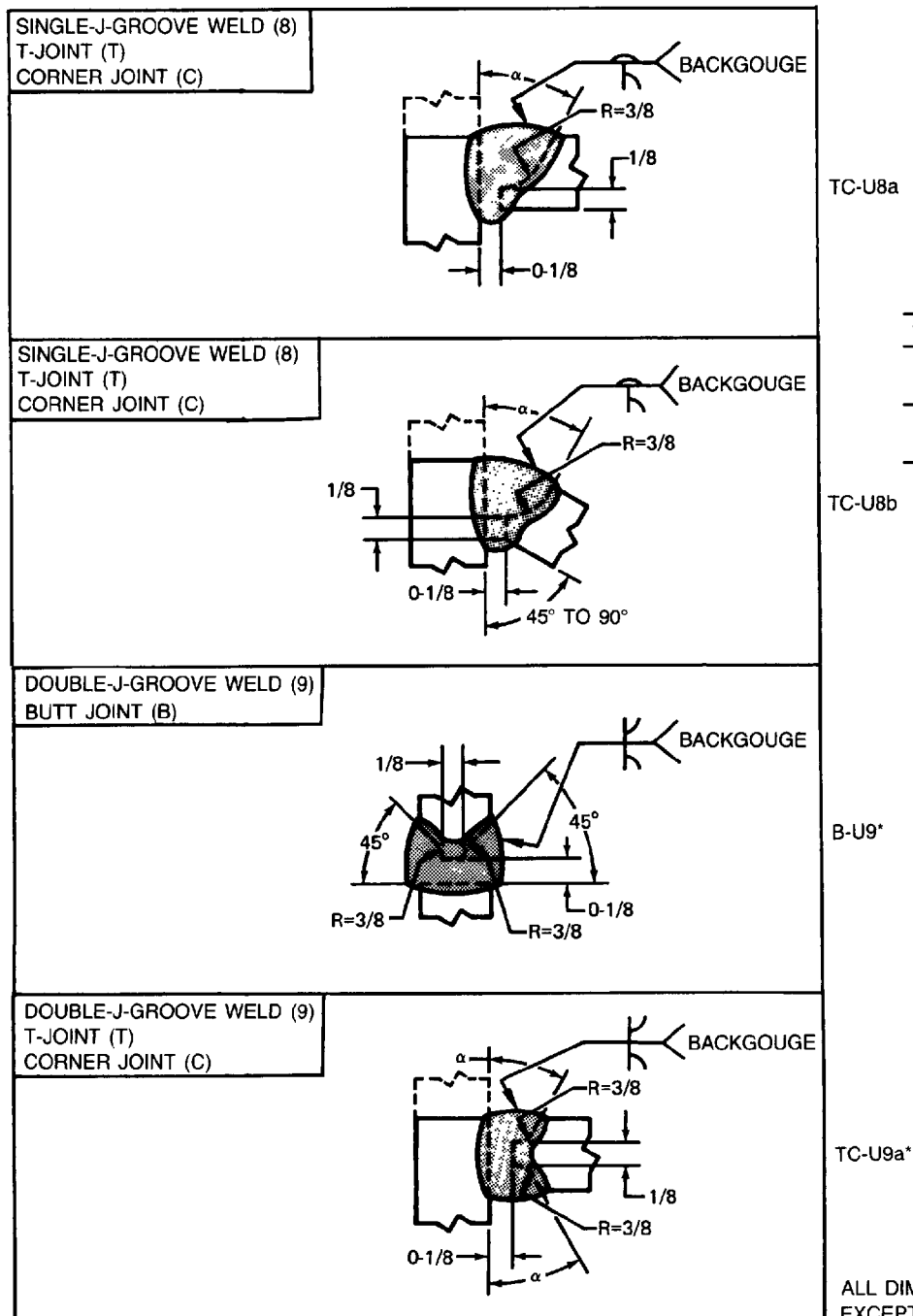


Notes:

1. Gouge roots of joints without backing before welding other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not exceed 3/8 in.

*The use of these welds shall preferably be limited to a base metal thickness of 5/8 in. or larger.

**Figure 16 (Cont'd)—Complete Joint Penetration Prequalified
Shielded Metal Arc Welded Joints**



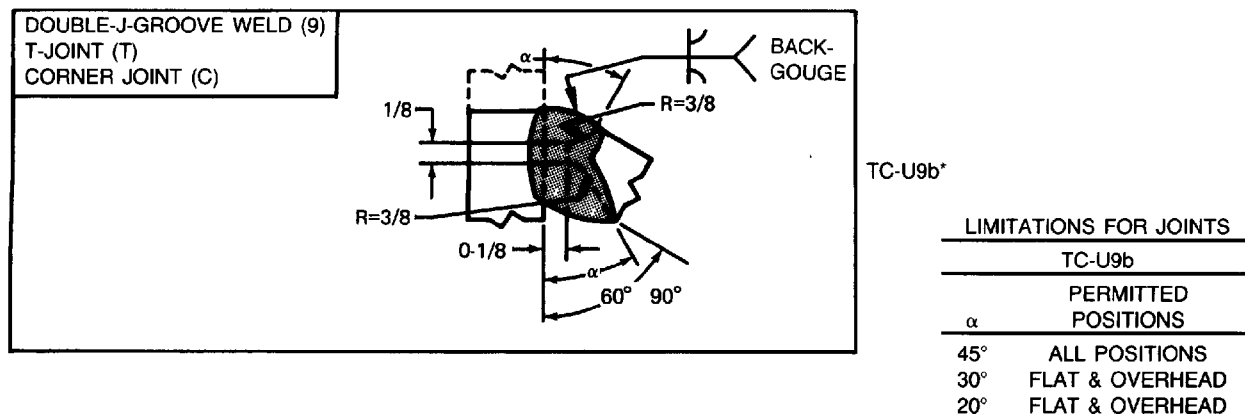
LIMITATIONS FOR JOINTS	
TC-U8a, TC-U8b AND TC-U9a	
α	PERMITTED POSITIONS
45°	ALL POSITIONS
30°	FLAT AND OVERHEAD

Notes:

1. Gouge roots of joints without backing before welding other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not exceed 3/8 in.

*The use of these welds shall preferably be limited to a base metal thickness of 5/8 in. or larger.

**Figure 16 (Cont'd)—Complete Joint Penetration Prequalified
Shielded Metal Arc Welded Joints**



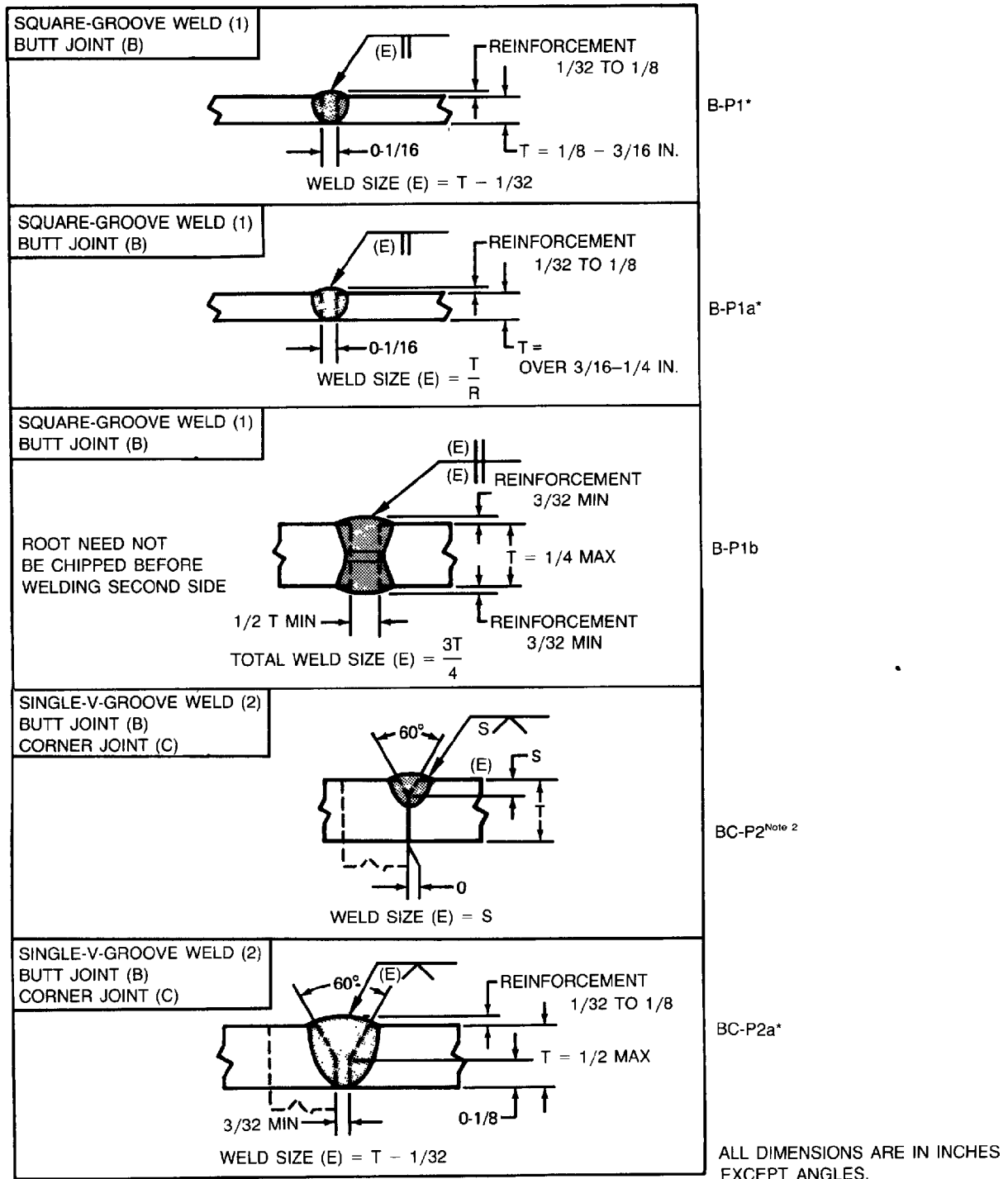
ALL DIMENSIONS ARE IN INCHES EXCEPT ANGLES.

Notes:

1. Gouge roots of joints without backing before welding other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not exceed 3/8 in.

*The use of these welds shall preferably be limited to a base metal thickness of 5/8 in. or larger.

**Figure 16 (Cont'd)—Complete Joint Penetration Prequalified
Shielded Metal Arc Welded Joints**

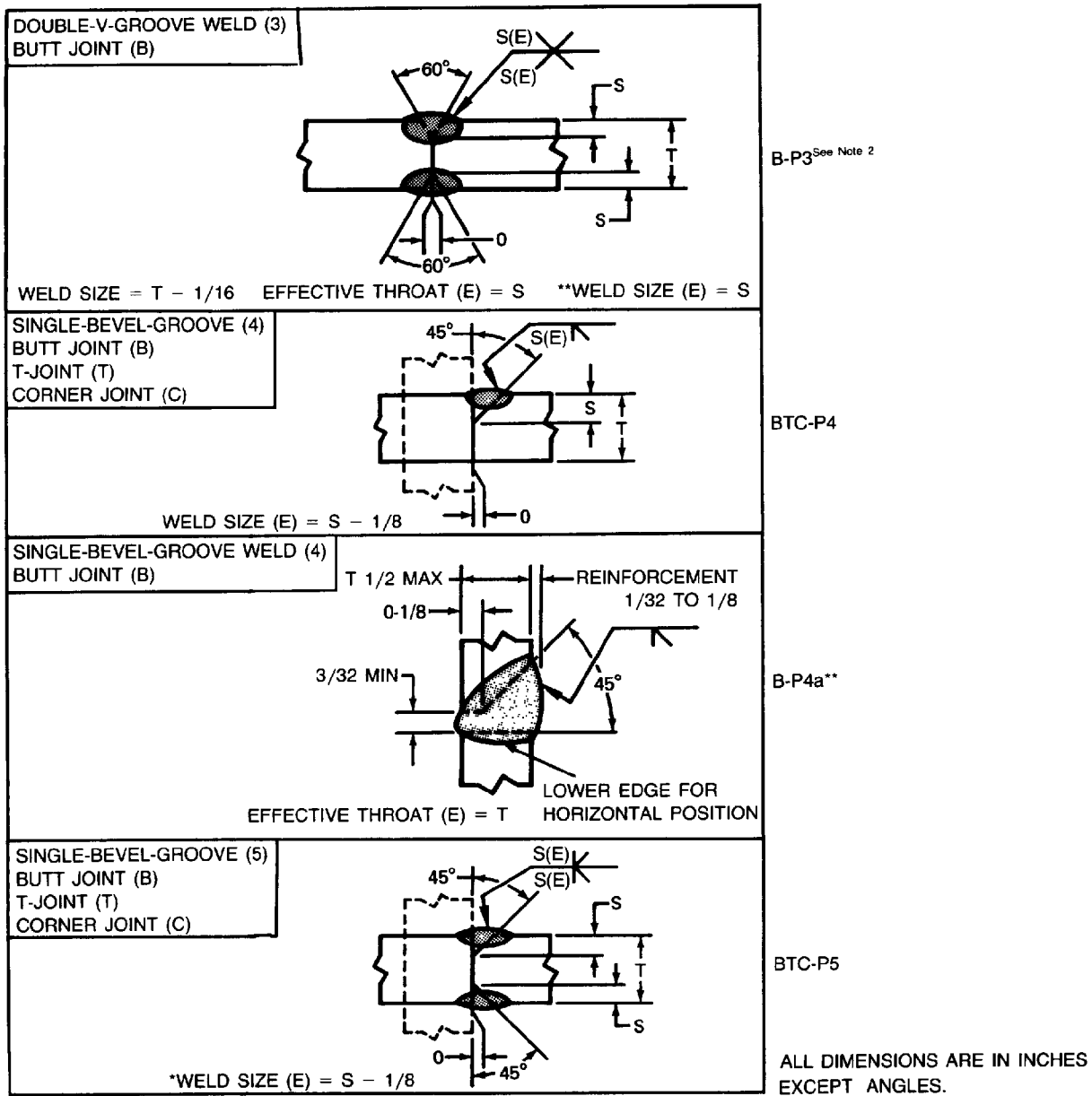


Notes:

1. See Table 11 for workmanship tolerances.
2. Minimum root face shall be 1/8 in.

*Joints welded from one side.

**Figure 17—Partial Joint Penetration Prequalified
Shielded Metal Arc Welded Joints**



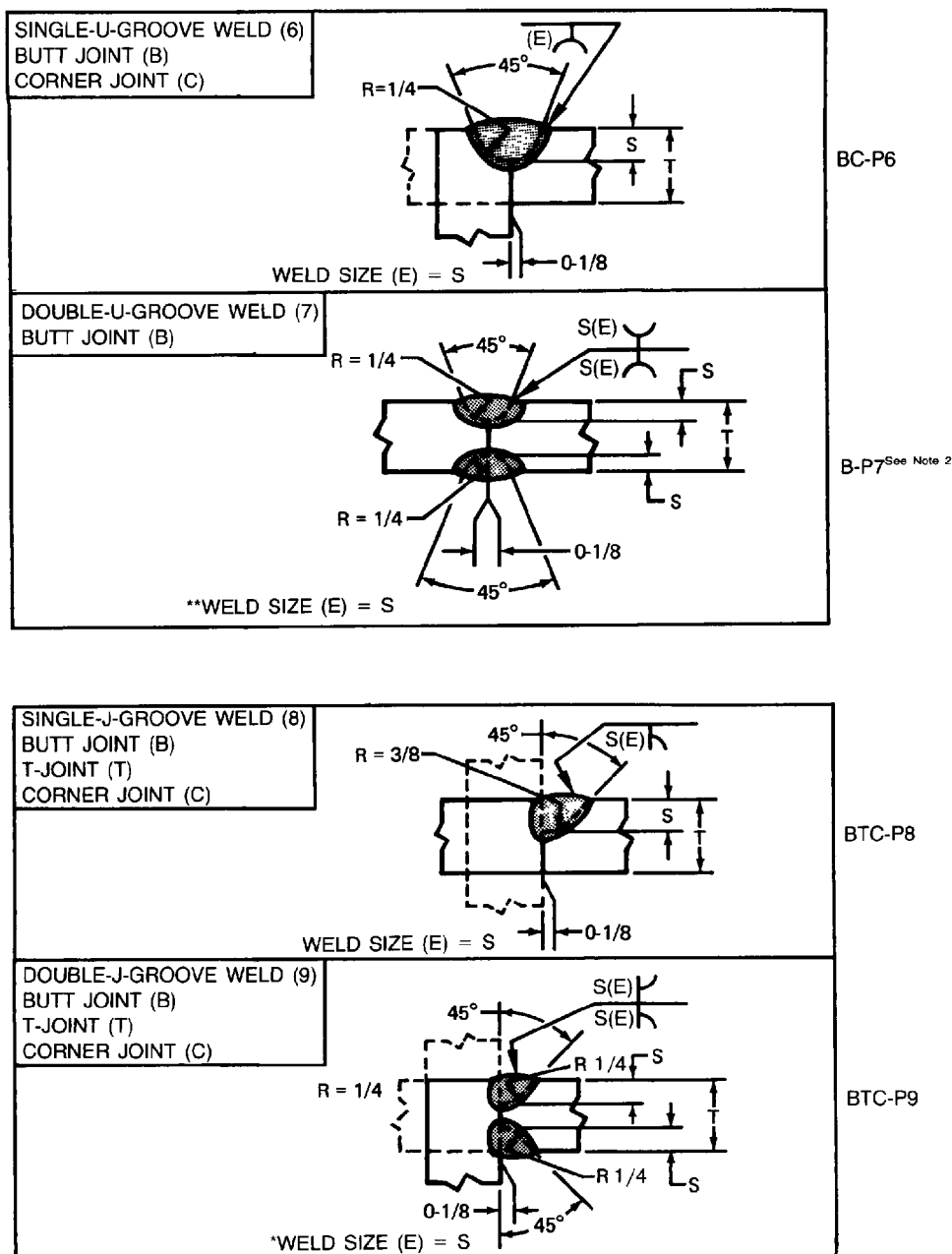
Notes:

1. See Table 11 for workmanship tolerances.
2. Minimum root face shall be 1/8 in.

* Total weld size (E) = (E) Side 1 plus (E) of Side 2.

**Joint welded from one side.

Figure 17 (Cont'd)—Partial Joint Penetration Prequalified Shielded Metal Arc Welded Joints



ALL DIMENSIONS ARE IN INCHES EXCEPT ANGLES.

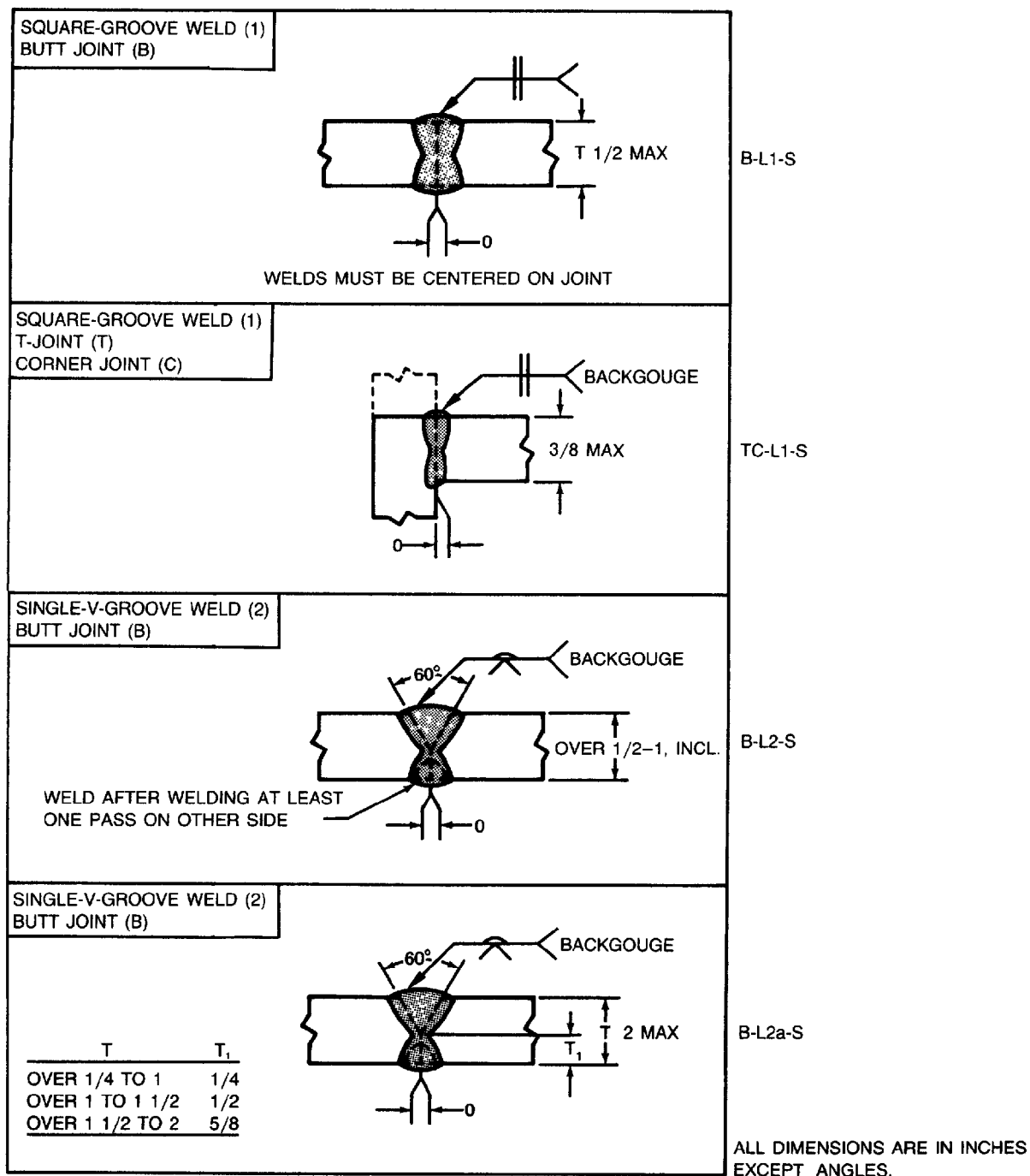
Notes:

1. See Table 11 for workmanship tolerances.
2. Minimum root face shall be 1/8 in.

*Total weld size (E) = (E) Side 1 plus (E) of Side 2.

**Joint welded from one side.

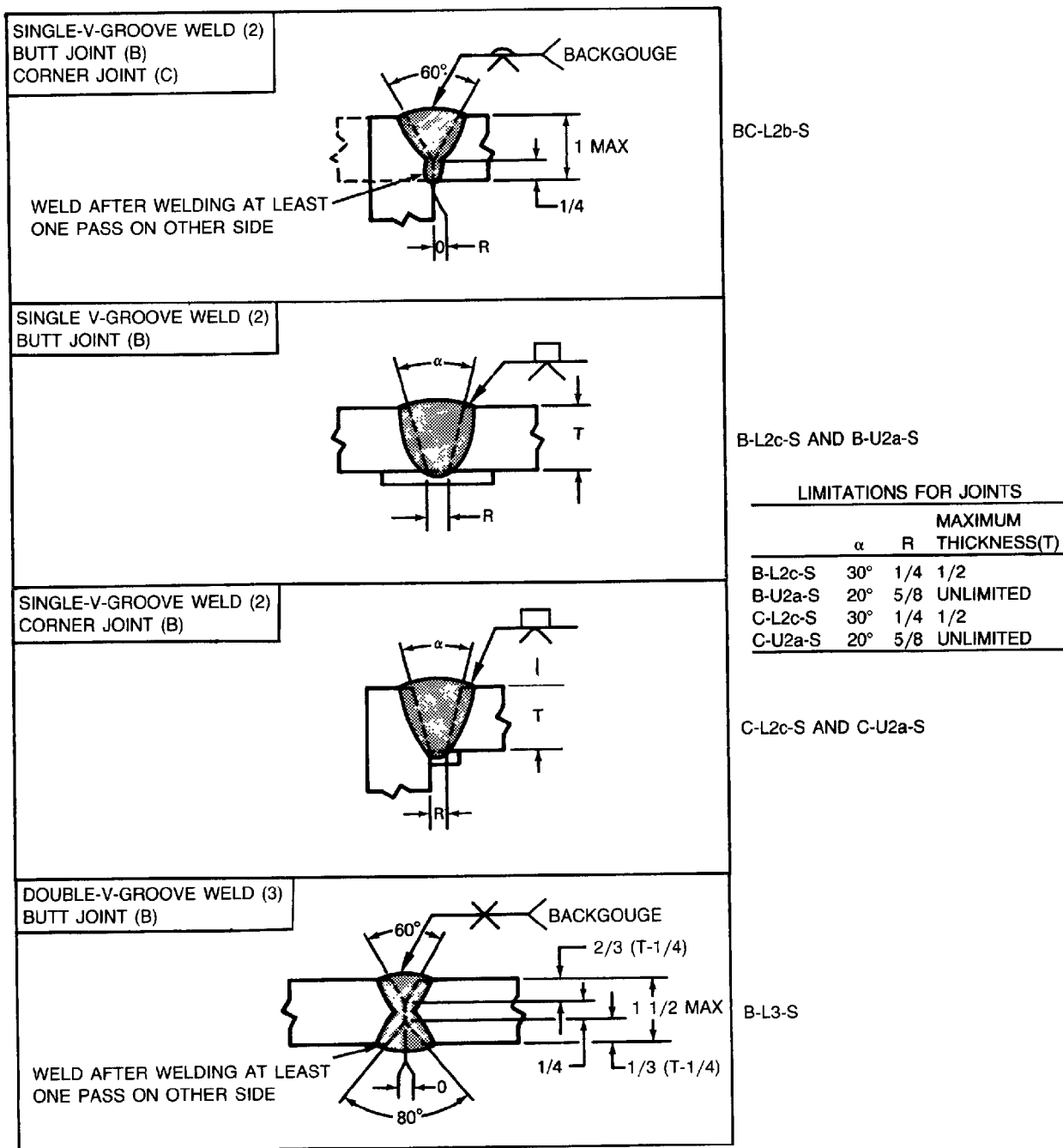
Figure 17 (Cont'd)—Partial Joint Penetration Prequalified Shielded Metal Arc Welded Joints



Notes:

1. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to $T/4$ but need not exceed $3/8$ in.
2. See Table 11 for workmanship tolerances.
3. Total weld size (E) = (E) Side 1 plus (E) of Side 2.
4. Gouge root of joints without backing before welding other side.

Figure 18—Complete Joint Penetration Prequalified Submerged Arc Welded Joints

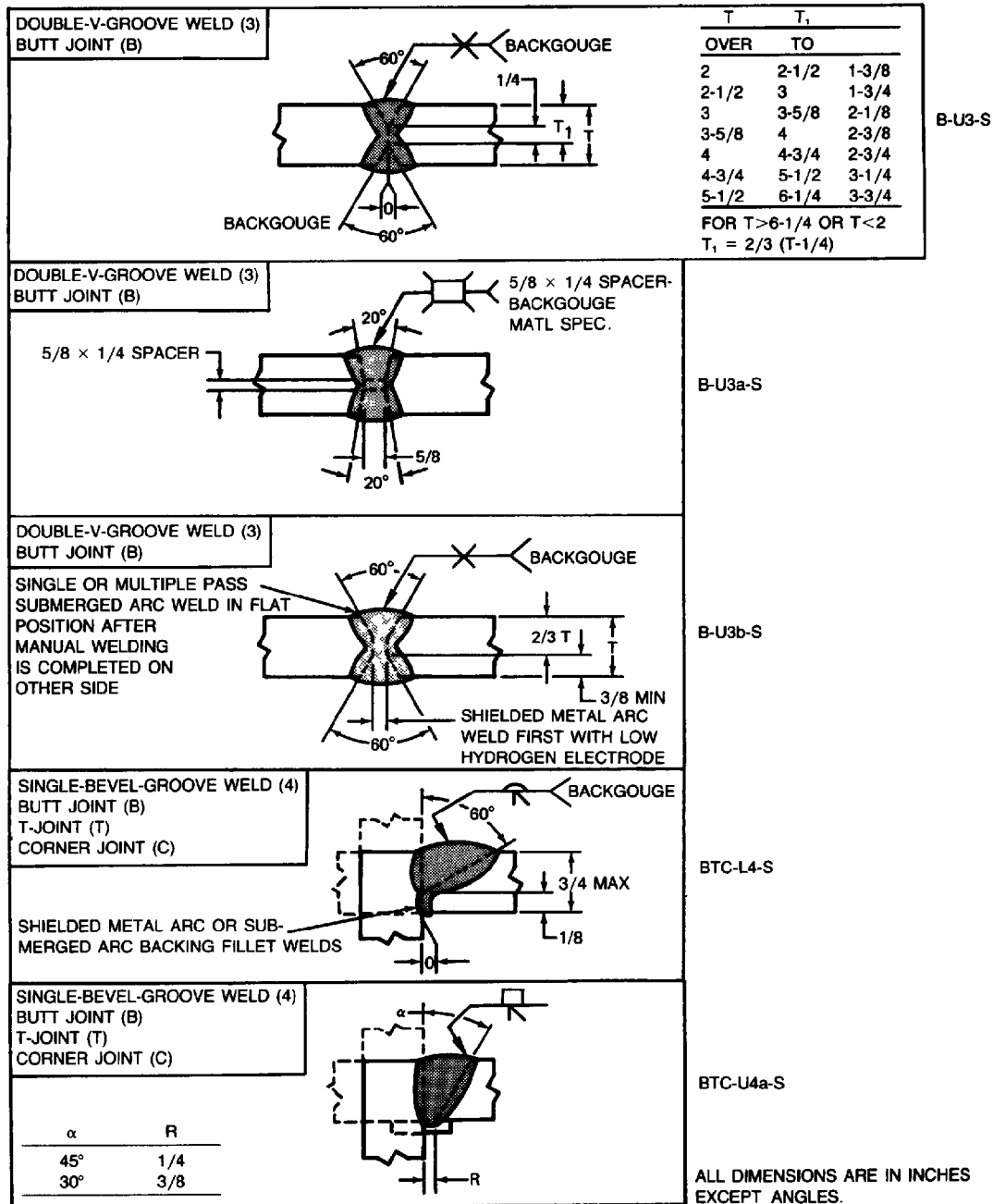


ALL DIMENSIONS ARE IN INCHES EXCEPT ANGLES.

Notes:

1. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to $T/4$ but need not exceed $3/8$ in.
2. See Table 11 for workmanship tolerances.
3. Total weld size (E) = (E) Side 1 plus (E) of Side 2.
4. Gouge root of joints without backing before welding other side.

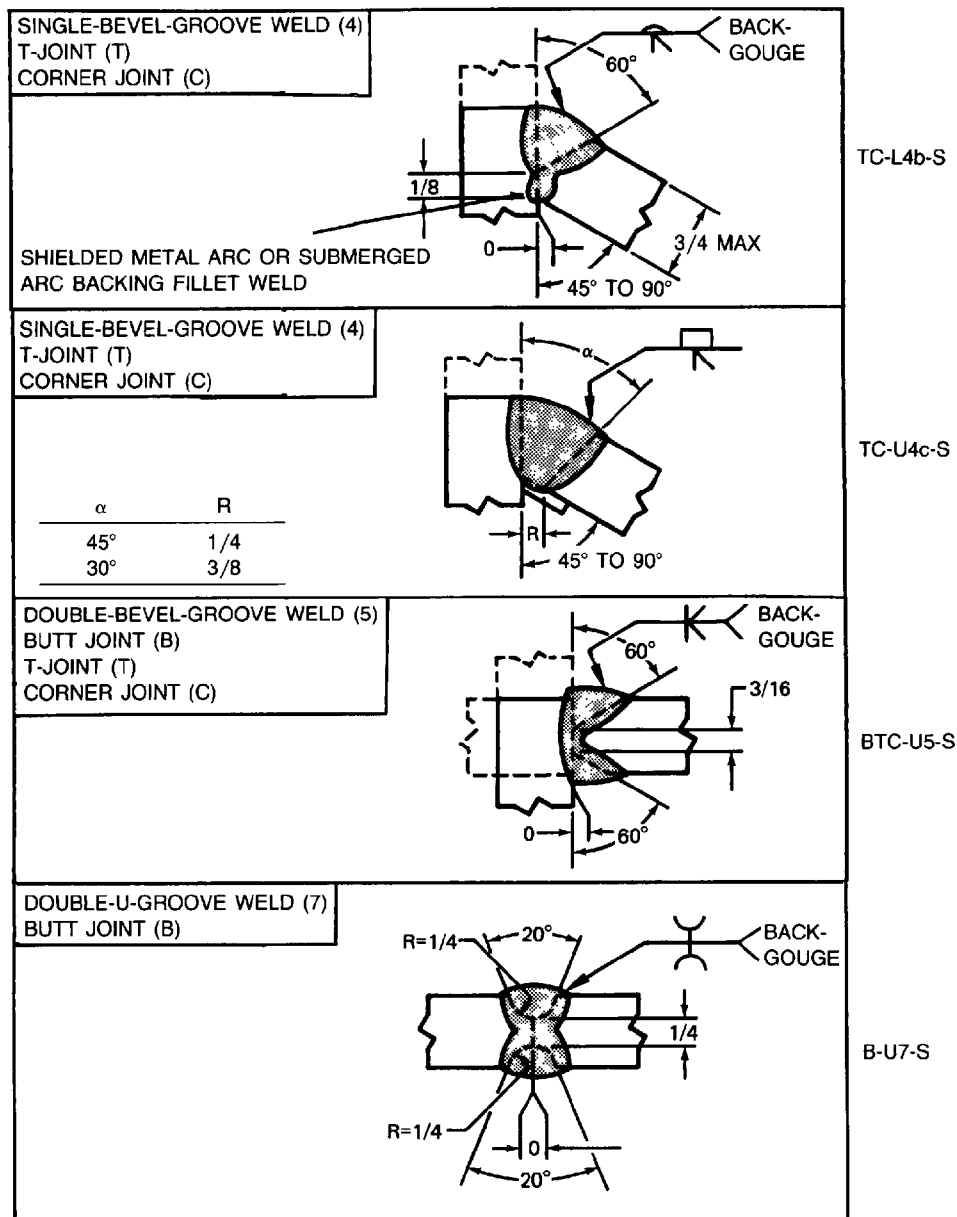
Figure 18 (Cont'd)—Complete Joint Penetration Prequalified Submerged Arc Welded Joints



Notes:

1. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not exceed 3/8 in.
2. See Table 11 for workmanship tolerances.
3. Total weld size (E) = (E) Side 1 plus (E) of Side 2.
4. Gouge root of joints without backing before welding other side.

**Figure 18 (Cont'd)—Complete Joint Penetration Prequalified
Submerged Arc Welded Joints**

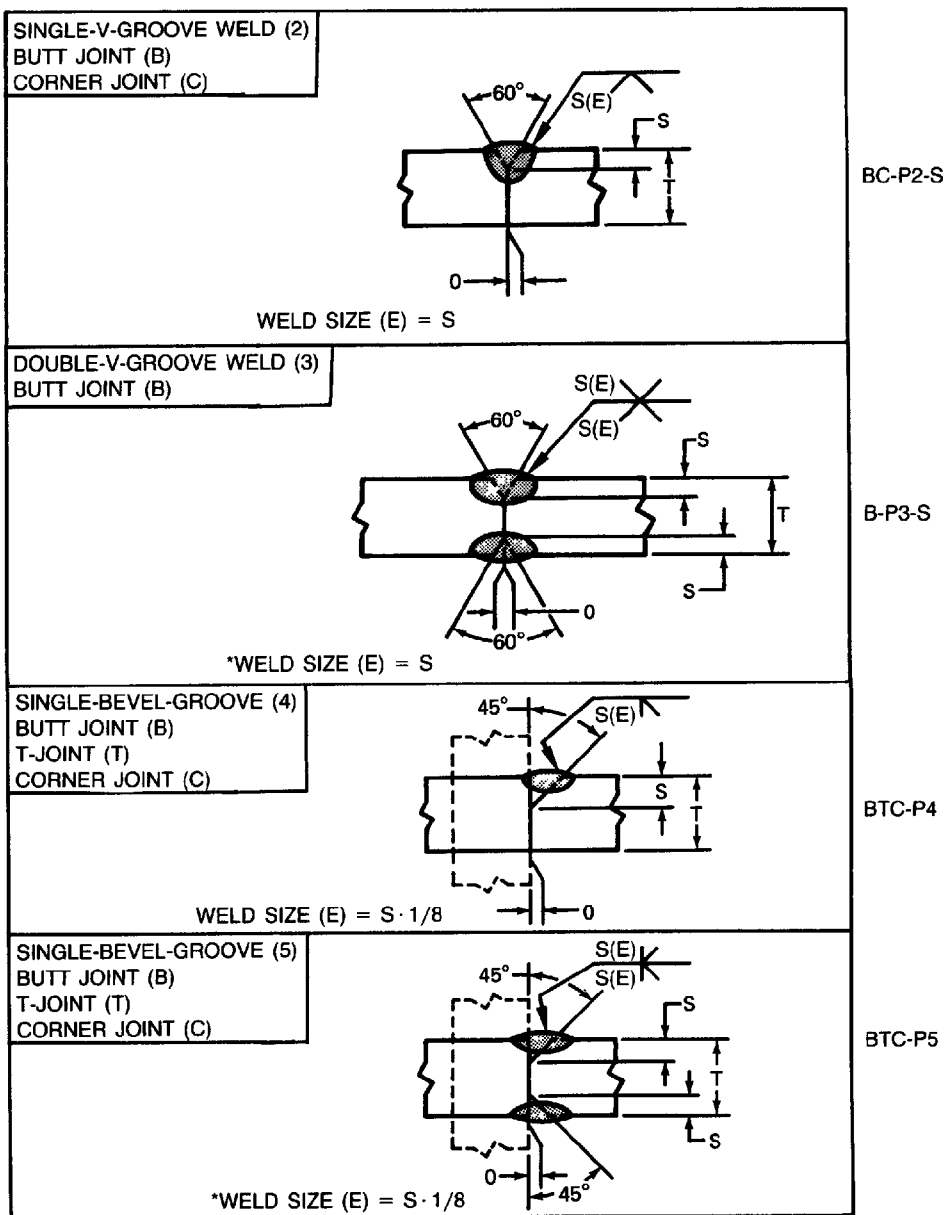


ALL DIMENSIONS ARE IN INCHES EXCEPT ANGLES.

Notes:

1. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not exceed 3/8 in.
2. See Table 11 for workmanship tolerances.
3. Total weld size (E) = (E) Side 1 plus (E) of Side 2.
4. Gouge root of joints without backing before welding other side.

Figure 18 (Cont'd)—Complete Joint Penetration Prequalified Submerged Arc Welded Joints



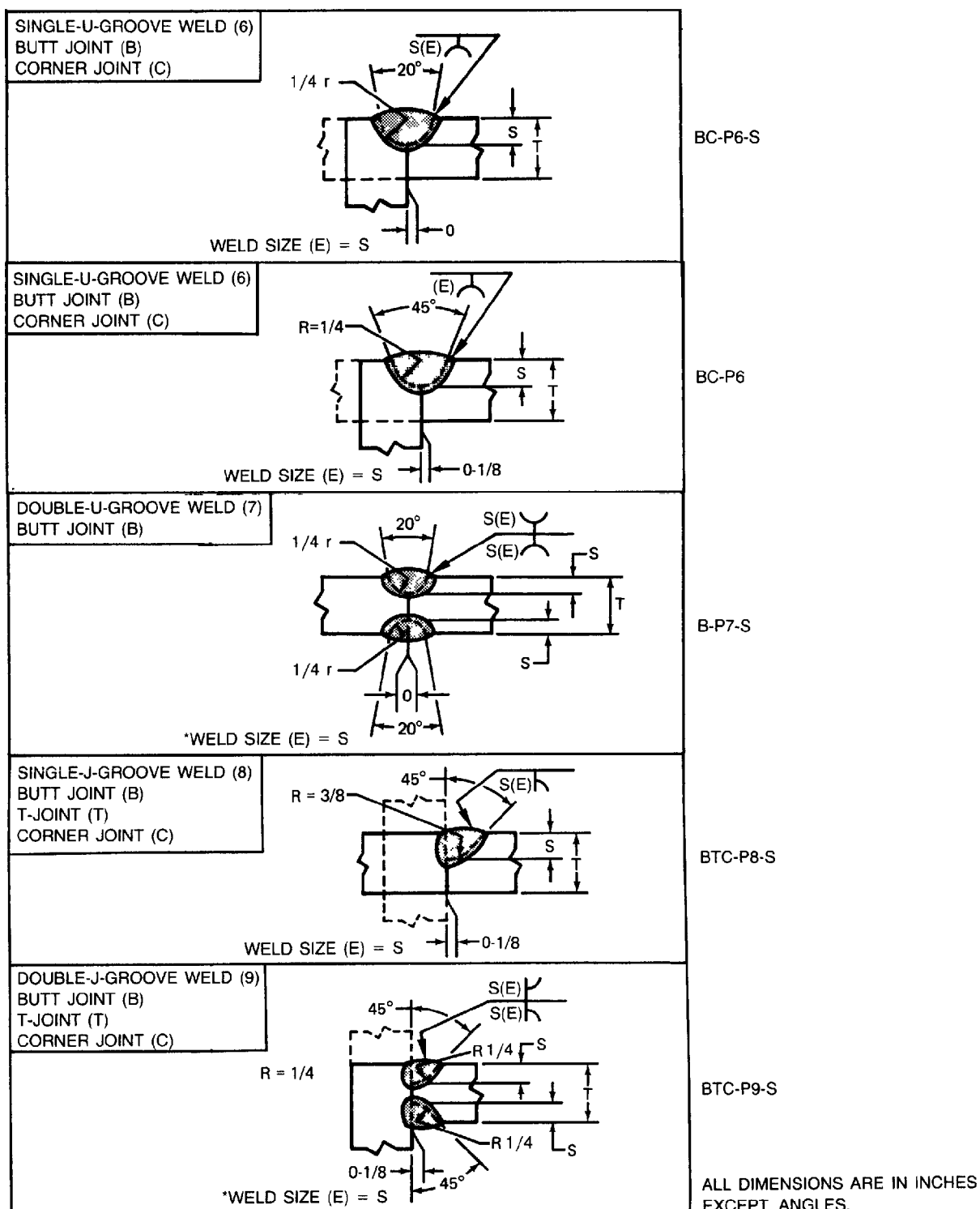
ALL DIMENSIONS ARE IN INCHES EXCEPT ANGLES

Notes:

1. See Table 11 for workmanship tolerances.
2. Minimum root face shall be 1/8 in.

* Total weld size (E) = (E) Side 1 plus (E) of Side 2.

Figure 19—Partial Joint Penetration Prequalified Submerged Arc Welded Joints

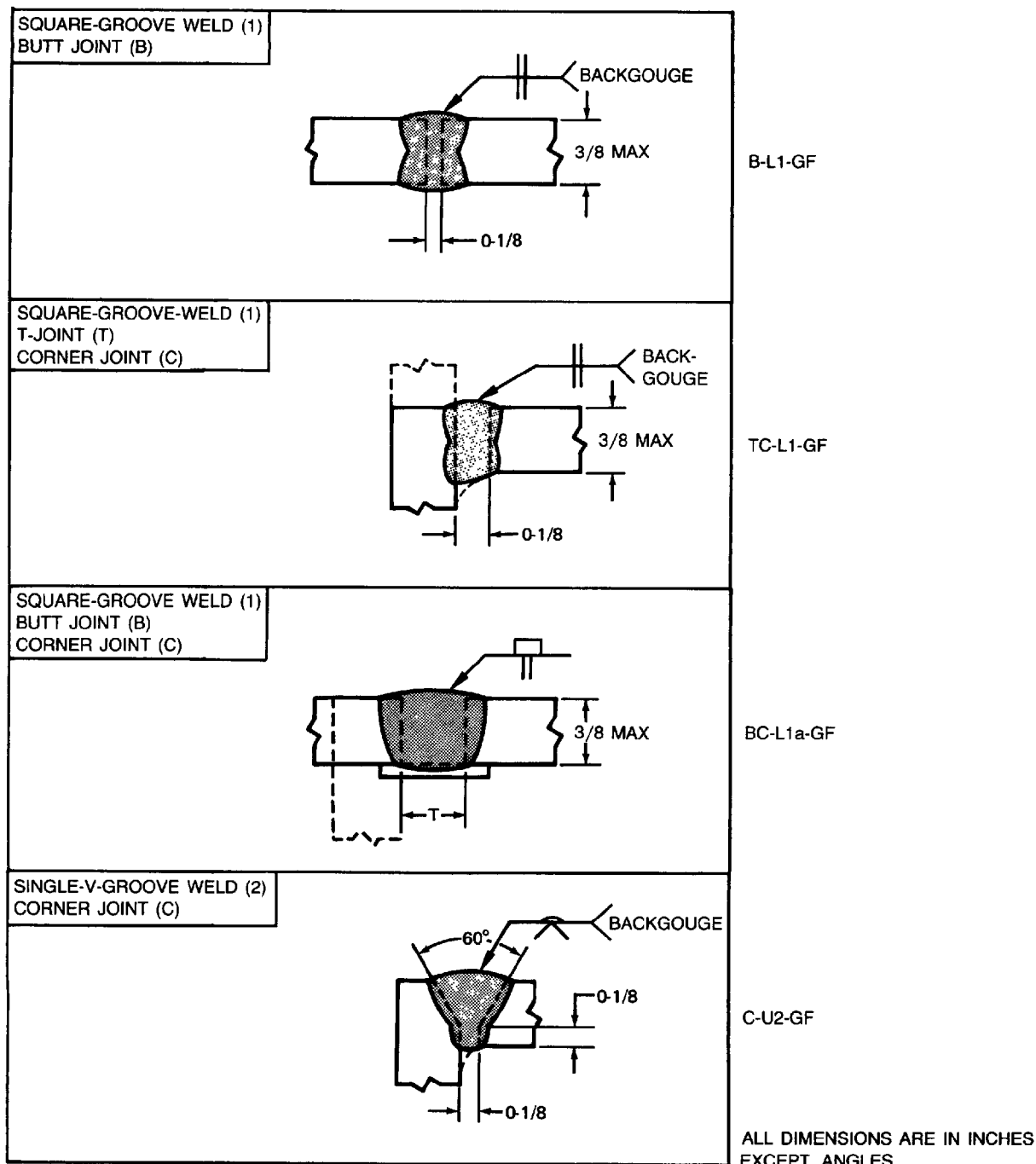


Notes:

1. See Table 11 for workmanship tolerances.
2. Minimum root of face of joint shall be 1/4 in.

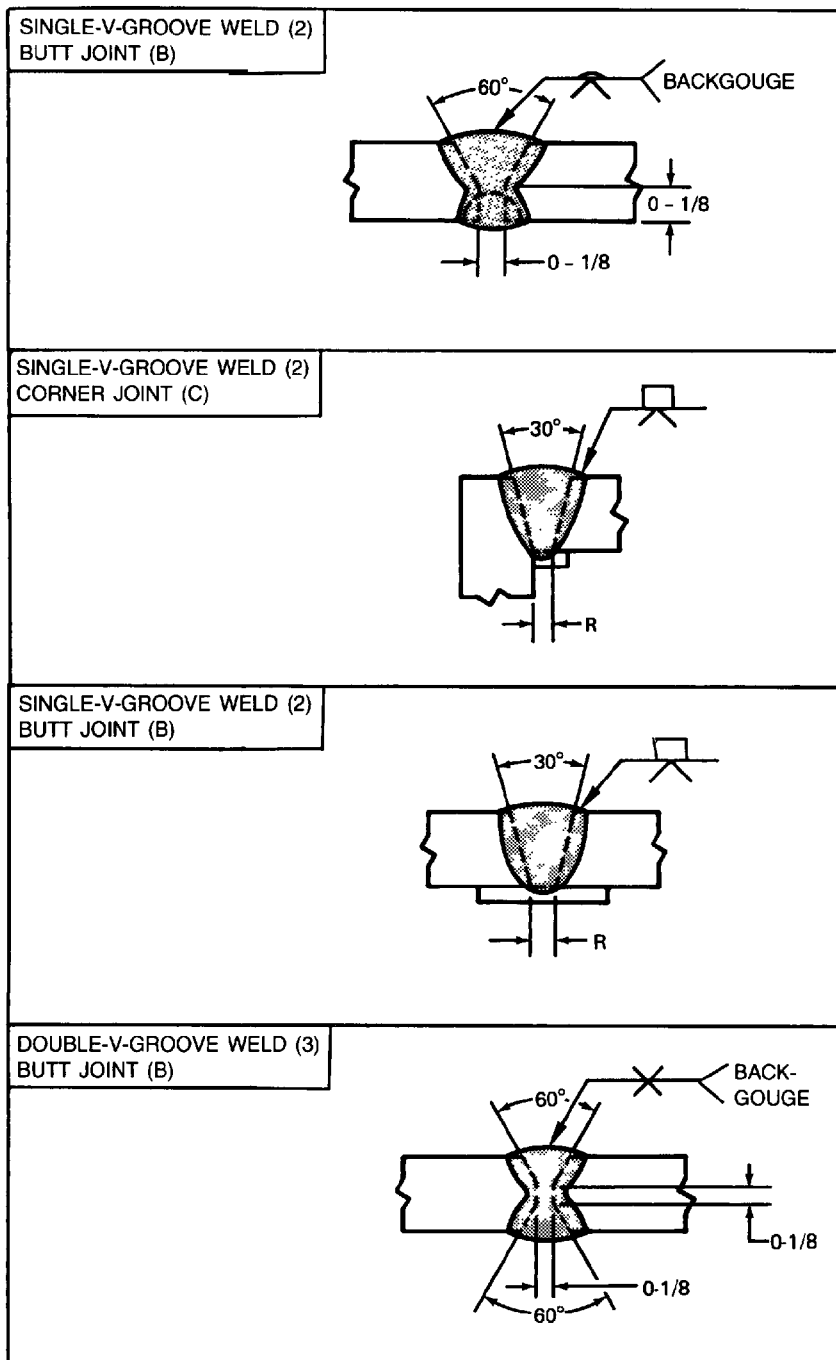
*Total weld size (E) = (E) Side 1 plus (E) of Side 2.

Figure 19 (Cont'd) – Partial Joint Penetration Prequalified Submerged Arc Welded Joints

**Notes:**

1. Gouge the roots of joints without backing before welding the other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to $T/4$ but need not exceed $3/8$ in.
4. Not prequalified for gas metal arc welding using short circuiting transfer or pulsed arc.

Figure 20—Complete Joint Penetration Prequalified Gas Metal and Flux Cored Arc Welded Joints



B-U2-GF

LIMITATIONS FOR JOINTS

C-U2a-GF		
SHIELDING	POSITIONS	R
GAS	F, V, & O	3/16
NO GAS	FLAT ONLY	3/8
	V & O ONLY	1/4

C-U2a-GF

LIMITATIONS FOR JOINTS

B-U2a-GF		
SHIELDING	POSITIONS	R
GAS	F, V, & O	3/16
NO GAS	FLAT ONLY	3/8
	V & O ONLY	1/4

B-U2a-GF

B-U3-GF*

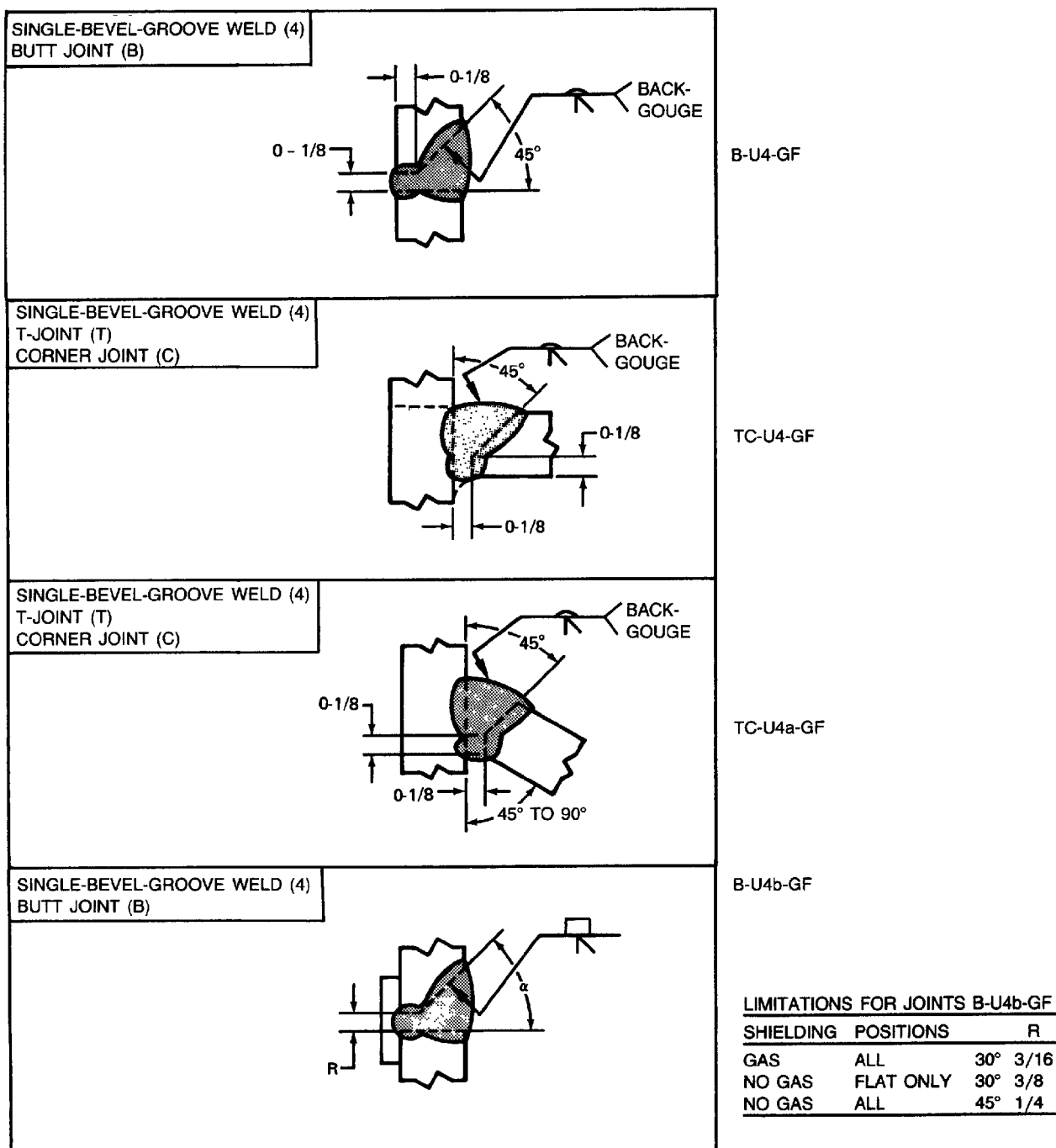
Notes:

1. Gouge the roots of joints without backing before welding the other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to $T/4$ but need not exceed $3/8$ in.
4. Not prequalified for gas metal arc welding using short-circuiting transfer or pulsed arc.

ALL DIMENSIONS ARE IN INCHES EXCEPT ANGLES.

* The use of these welds shall preferably be limited to base metal thickness of $5/8$ in. or larger.

**Figure 20 (Cont'd)—Complete Joint Penetration Prequalified
Gas Metal and Flux Cored Arc Welded Joints**

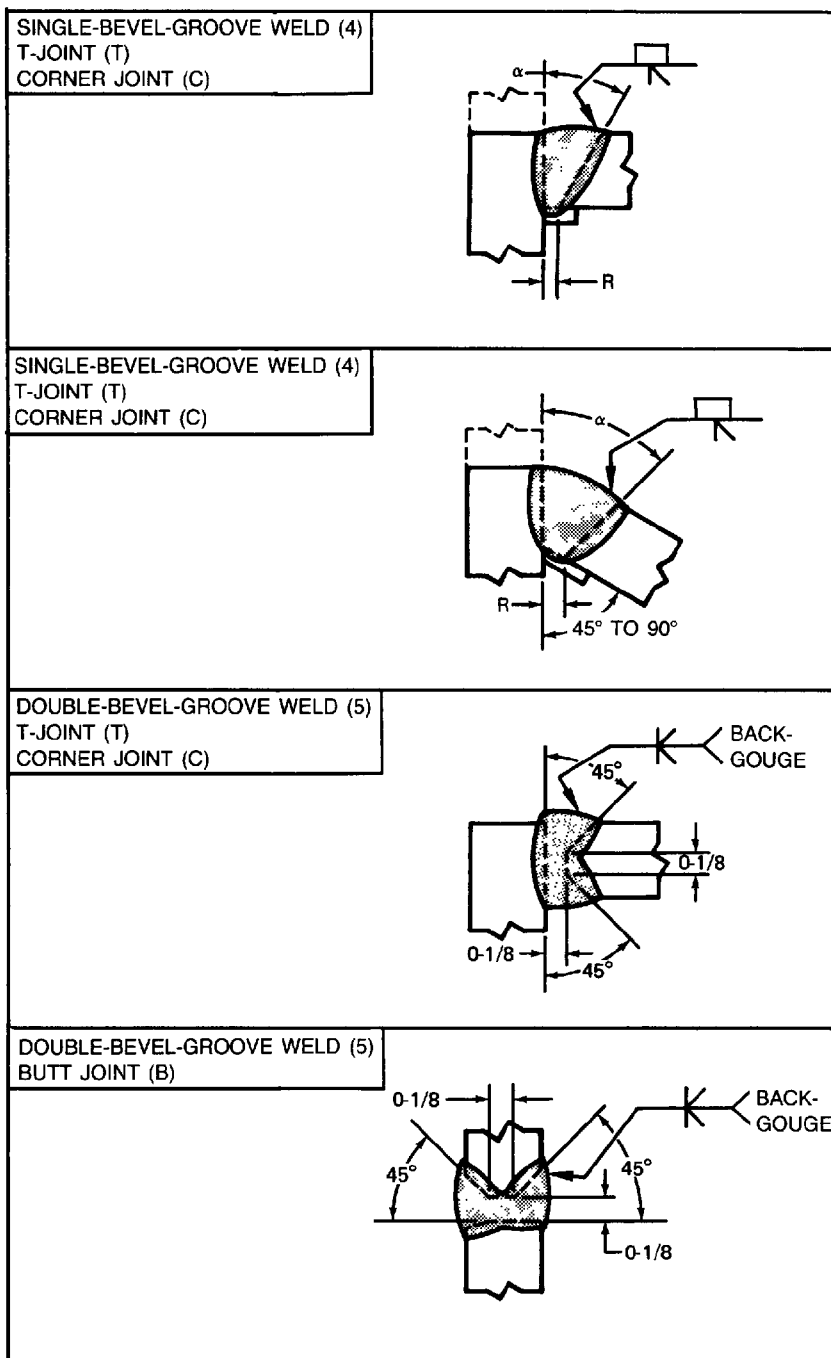
**Notes:**

1. Gouge the roots of joints without backing before welding the other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not exceed 3/8 in.
4. Not prequalified for gas metal arc welding using short circuiting transfer or pulsed arc.

ALL DIMENSIONS ARE IN INCHES EXCEPT ANGLES.

*The use of these welds shall preferably be limited to base metal thickness of 5/8 in or larger.

Figure 20 (Cont'd)—Complete Joint Penetration Prequalified Gas Metal and Flux Cored Arc Welded Joints



TC-U4c-GF

LIMITATIONS FOR JOINTS

TC-U4c-GF & TC-U4d-GF

SHIELDING	POSITIONS	R
GAS	ALL	30° 3/16
NO GAS	FLAT ONLY	30° 3/8
NO GAS	ALL	45° 1/4

TC-U4d-GF

TC-U5-GF*

B-U5-GF*

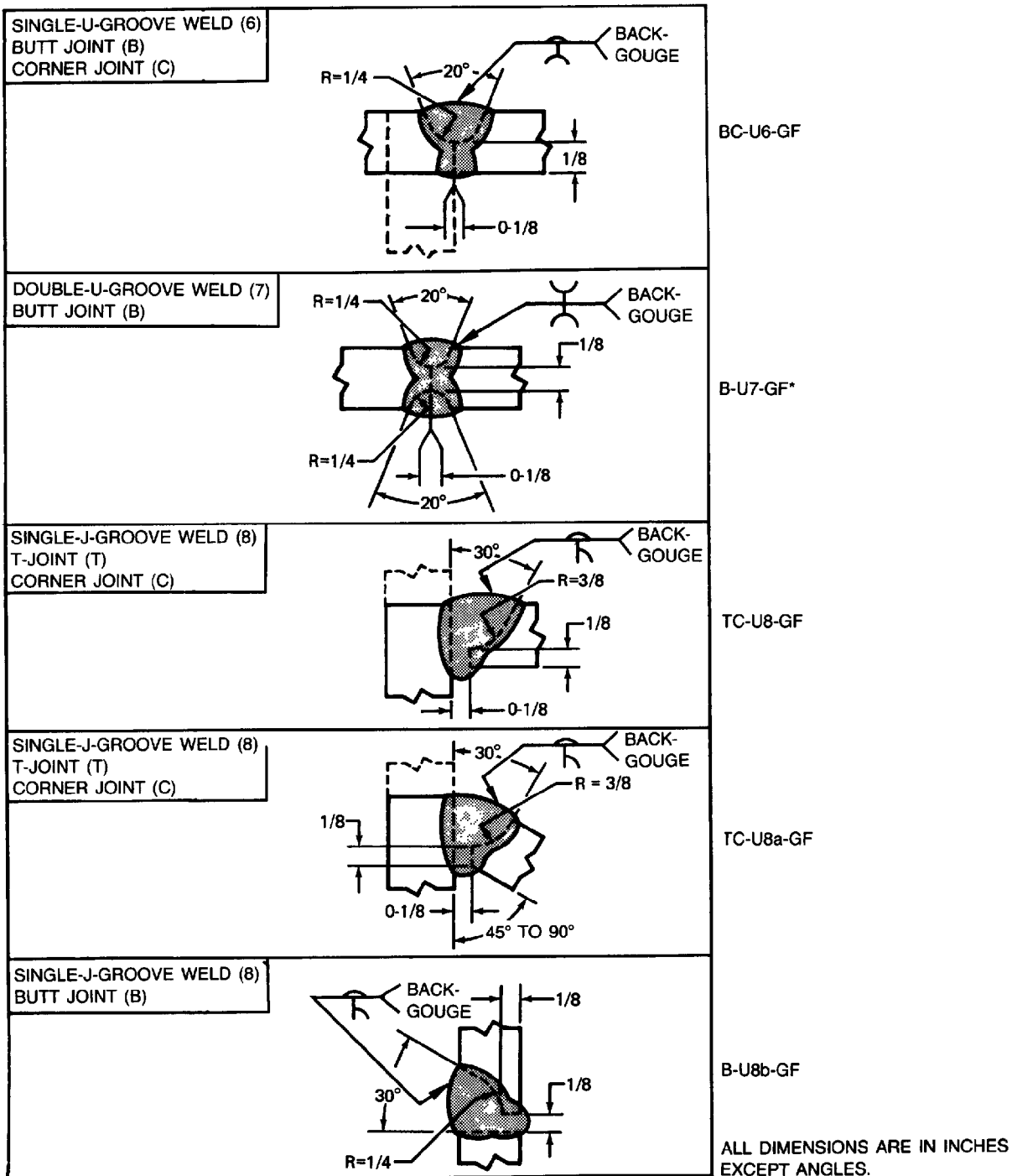
Notes:

1. Gouge the roots of joints without backing before welding the other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to T/4 but need not exceed 3/8 in.
4. Not prequalified for gas metal arc welding using short circuiting transfer or pulsed arc.

ALL DIMENSIONS ARE IN INCHES EXCEPT ANGLES

*The use of these welds shall preferably be limited to base metal thickness of 5/8 in or larger.

**Figure 20 (Cont'd)—Complete Joint Penetration Prequalified
Gas Metal and Flux Cored Arc Welded Joints**

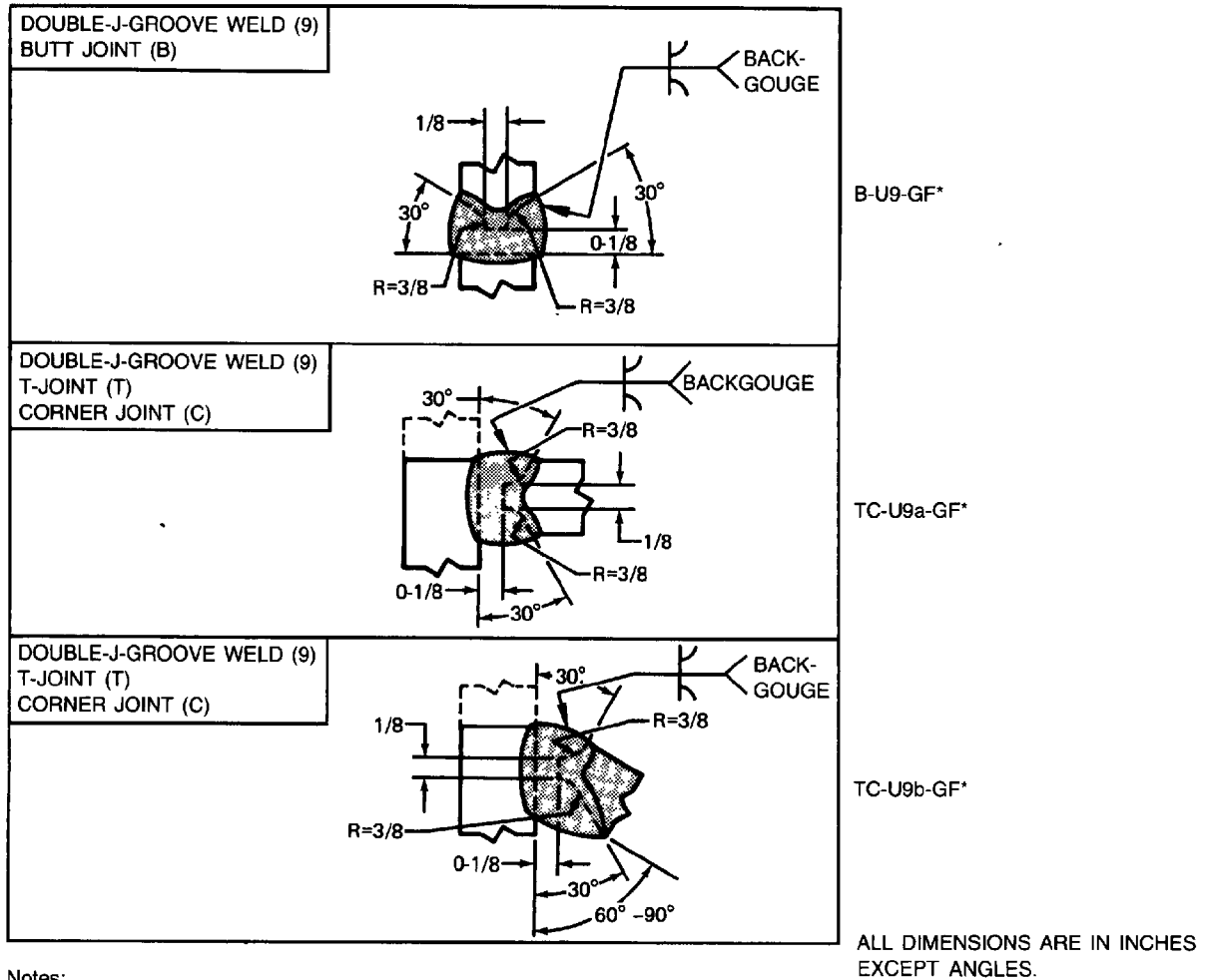


Notes:

1. Gouge the roots of joints without backing before welding the other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to $T/4$ but need not exceed $3/8$ in.
4. Not prequalified for gas metal arc welding using short circuiting transfer or pulsed arc.

*The use of these welds shall preferably be limited to base metal thickness of $5/8$ in or larger.

Figure 20 (Cont'd)—Complete Joint Penetration Prequalified Gas Metal and Flux Cored Arc Welded Joints

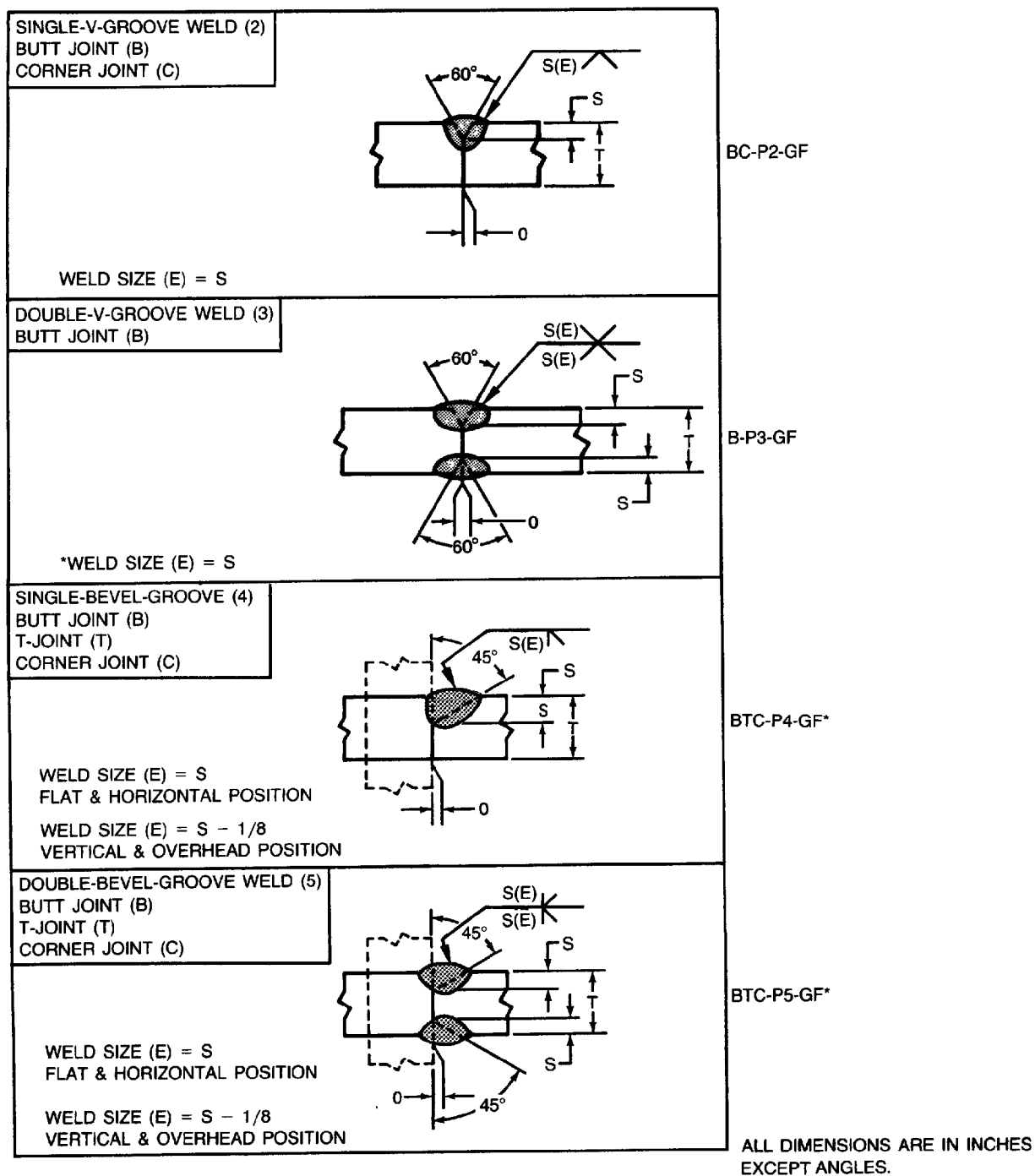


Notes:

1. Gouge the roots of joints without backing before welding the other side.
2. See Table 11 for workmanship tolerances.
3. If fillet welds are used to reinforce groove welds in T and corner joints, they shall be equal to $T/4$ but need not exceed $3/8$ in.
4. Not prequalified for gas metal arc welding using short circuiting transfer or pulsed arc.

*The use of these welds shall preferably be limited to base metal thickness of $5/8$ in. or larger.

**Figure 20 (Cont'd) – Complete Joint Penetration Prequalified
Gas Metal and Flux Cored Arc Welded Joints**

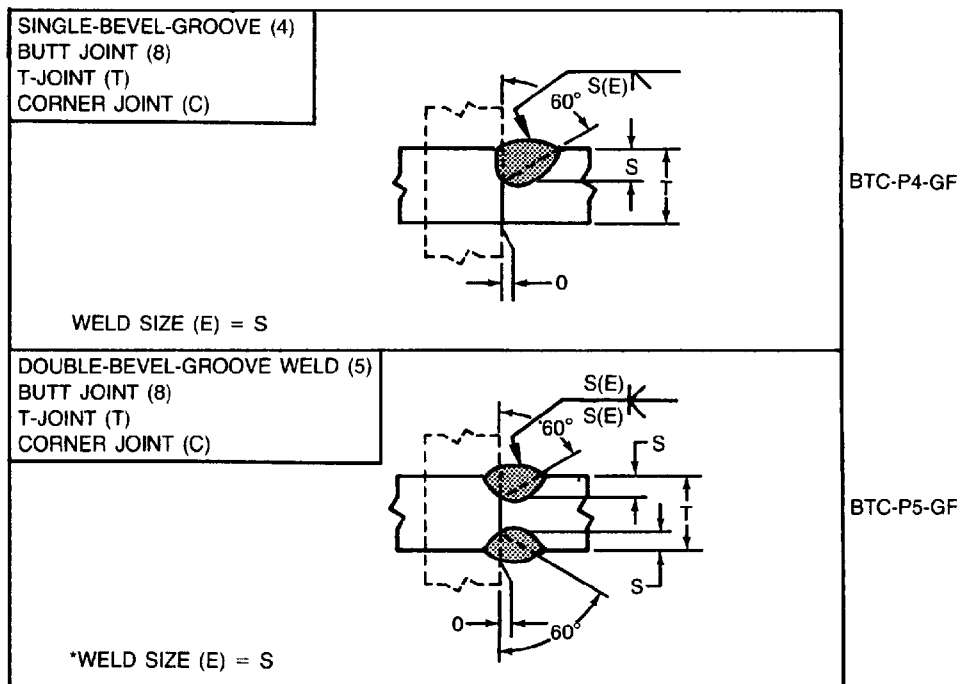


Notes:

1. See Table 11 for workmanship tolerances.
2. Minimum root face of joint shall be 1/4 in.
3. Not prequalified for gas metal arc welding using short circuiting transfer or pulsed arc.

*Total weld size (E) side 1 plus (E) of side 2.

Figure 21—Partial Joint Penetration Prequalified Gas Metal and Flux Cored Arc Welded Joints



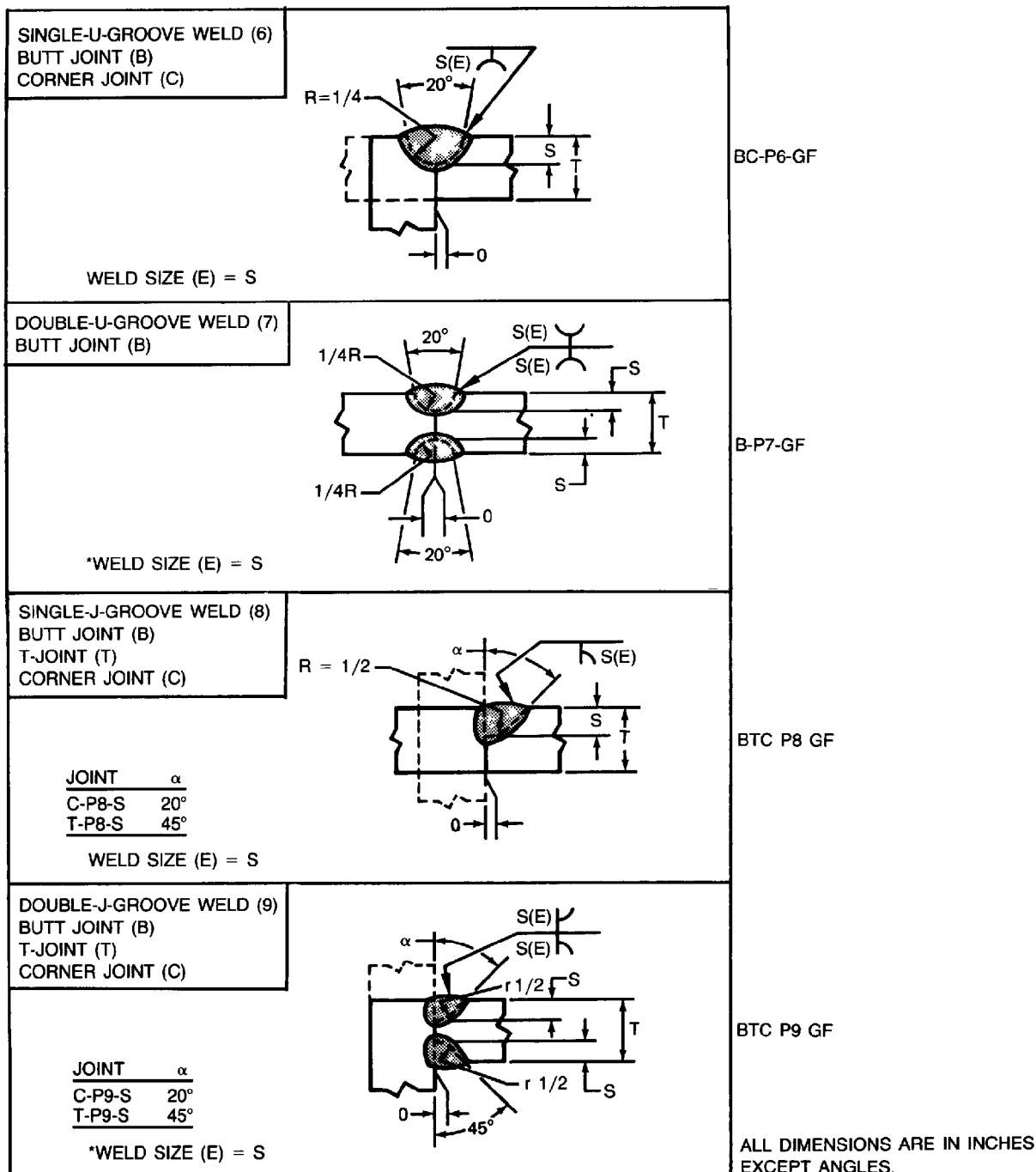
ALL DIMENSIONS ARE IN INCHES
EXCEPT ANGLES.

Notes:

1. See Table 11 for workmanship tolerances.
2. Minimum root face of joint shall be 1/4 in.
3. Not prequalified for gas metal arc welding using short circuiting transfer or pulsed arc.

*Total weld size (E) side 1 plus (E) of side 2.

**Figure 21—Partial Joint Penetration Prequalified Gas Metal
and Flux Cored Arc Welded Joints**

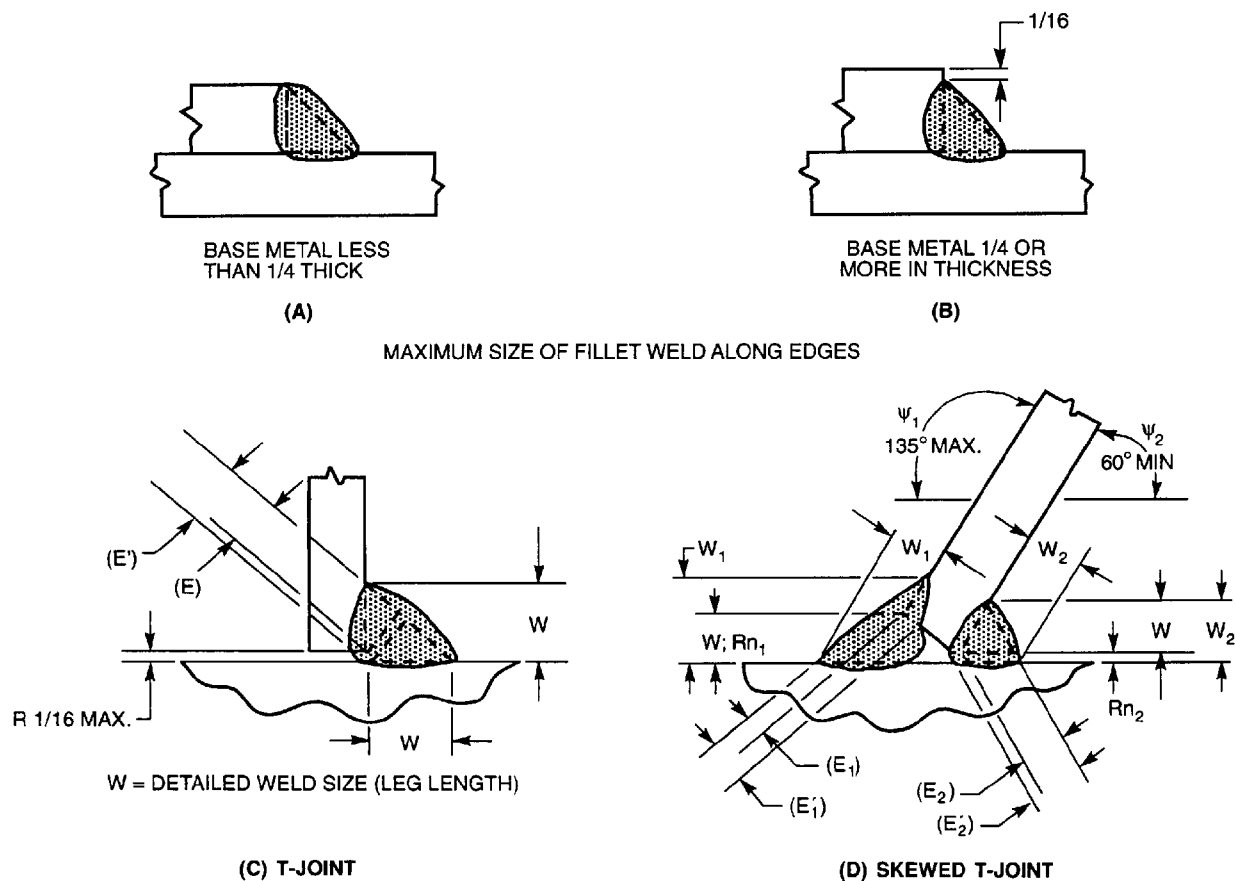


Notes:

1. See Table 11 for workmanship tolerances.
2. Not prequalified for gas metal arc welding using short-circuiting transfer or pulsed arc.
3. Minimum root face of joint shall be 1/8 in.

*Total weld size (E) Side 1 plus (E) of Side 2.

Figure 21 (Cont'd)—Partial Joint Penetration Prequalified Gas Metal and Flux Cored Arc Welded Joints



Notes:

1. Not prequalified for gas metal arc welding using short circuiting or pulsed arc.
2. Maximum detailed size along edges shall be base metal thickness when it is less than 1/4 in. (6.4 mm); see Sketch (A). For base metals 1/4 in. (6.4 mm) and over the maximum size specified shall be 1/16 in. (1.6 mm) less than the metal thickness; see sketch (B).
3. The minimum weld size that can be specified for the thinner member (T) joined shall be:
3/16 in. (4.8 mm) for T up to and including 1/2 in. (12.7), 1/4 in. (6.4 mm) for T over 1/2 in. (12.7 mm) and including 3/4 in. (19.1 mm).
4. The root opening R, Rn₂ shall not exceed 1/16 in. (1.6 mm).
5. (E), (E'), (E''), (E'n) = Effective throats are dependent on the magnitude of the root opening R, Rn₂. For qualification of joints with root openings exceeding 1/16 in. (1.6 mm) (see 7.4.1.3).

Figure 22—Details of Prequalified Fillet Welds of Shielded Metal Arc Welding (SMAW), Gas Metal Arc Welding (GMAW), Submerged Arc Welding (SAW), and Flux Cored Arc Welding (FCAW)

Table 2
Weldability Classification—Typical Steel Products*

Class I	AISI/SAE 1005, 1006, 1008, 1010, 1012, 1015, 1016, 1017, 1020, and 1021
Class II	ASTM A36; A53, Gr B; A106; A131; A139; A500, A501; A516; A524; A529; A570, Gr A, B, C, CS, D, E, and R
Class III	ASTM A242; A441; A537, Gr A and E; A572, Gr 42, and 50; A588; A618; A656, Gr 50; A715, Gr 50; API 5LX, Gr 42; ABS, Gr AH, DH, and EH
Class IV	ASTM A572, 60, 65, A656, Gr 60, 70 & 80; A715, Gr 60, 70 and 80
Class V	ASTM A514 and A517

* See 5.5.2

5.5.1 The welding process used shall be one of the following processes, or a combination of these processes:

- (1) Shielded metal arc welding (SMAW), see 5.5.5
- (2) Submerged arc welding (SAW), see 5.5.6 and 5.5.7
- (3) Gas metal arc welding (GMAW),⁵ see 5.5.8
- (4) Flux cored arc welding (FCAW), see 5.5.8

5.5.2 Base metal, filler metal, preheat, and interpass temperature shall meet the following requirements:

(1) Steels listed and defined in Table 2 are prequalified for welding, provided the preheat and interpass temperatures used are no lower than those listed in Table 4 and the steels meet the mechanical property requirements of this specification.

(2) Prequalified steels are divided into five weldability classes for the purpose of specifying the minimum preheat and interpass welding temperatures. Table 3 lists typical steel products which are in each of the classes.

(3) The weldability classification for steels not listed in Table 3 may be determined by comparison to the limitations within these classes as listed in Table 3. These limitations are

(a) Minimum yield strength

(b) Carbon equivalent

(c) Maximum limit for individual alloying element

(4) Table 5 lists prequalified filler metals for complete joint penetration groove welds when the design requires that the filler metal shall equal the tensile strength of the base steel. For welds which, by design, do not require filler metals with a tensile strength equal to the base metal, lower strength filler metal may be specified.

5.5.3 Welding procedures shall meet the applicable requirements given in 5.5.5, 5.5.6, 5.5.7 and 5.5.8. When prequalified procedures are to be used on certain components with required performance criteria tests 5.3.1.1, the test unit shall be welded using the intended procedures. Any subsequent change to these given procedures shall be requalified by Methods I or II.

5.5.4 Workmanship and Weld Quality Requirements. Applicable requirements of 7, Workmanship and Welding Quality Requirements, shall be met.

5.5.5 Prequalified Procedures for Manual Shielded Metal Arc Welding (SMAW)

5.5.5.1 The work shall be positioned for flat position welding whenever practicable.

5.5.5.2 The classification and size of electrode, arc voltage and amperage shall be suited to the thickness of the material, type of material, type of groove,

5. Applies only when utilizing the spray or globular transfer mode. Prequalification does not apply to the "low energy" modes of metal transfer, i.e., short circuiting and pulsed power welding.

Table 3
Weldability Classification

	Structural Carbon Steels		High Strength Low Alloy Steels		Quenched and Tempered Steels
	Class I	Class II	Class III ¹	Class IV ¹	Class V
Minimum Yield strength (Ksi) ²	30–46	35–55	40–55	50–80	90–100
Maximum CE ³	0.38	0.48	0.63	—	0.74
<u>Maximum Chemical Limits⁶</u>					
Carbon	0.23	0.30	0.24	—	0.22
Manganese	0.90	1.35	1.65	—	1.50
Phosphorus	0.04	0.04	0.04	—	0.04
Sulfur	0.05	0.05	0.05	—	0.05
Silicon	0.60	0.60	0.90	—	0.90
Nickel	a	a	1.25	—	1.50
Chromium	a	a	1.00	—	2.00
Molybdenum*	a	a	0.25	—	0.65
Vanadium ^{4,5}	a	a	0.10 ^{4,5}	—	0.08 ⁵
Titanium	a	a	0.07	—	0.10
Zirconium	a	a	0.15	—	0.15
Columbium ⁴	a	a	0.04 ⁴	—	—
Copper	a	a	1.00	—	0.50
Boron	a	a	—	—	0.006

Notes:

1. Only ASTM A572, A656 and A715 (alloyed with some combination of columbium, vanadium, and nitrogen) are prequalified under Class IV. No nitrogen containing steel other than A572, A656 and A715 are prequalified under Class III.
2. Minimum yield strengths are generally the values published by the producer, or in the case where values are not published, then the value that is used for design purposes.
3. Carbon Equivalent, CE. The maximum CE values shown are based on the maximum composition limits of the materials, plus the check analysis tolerance; therefore, caution must be used when these maximum limits are approached.

$$\text{Carbon Steels: CE} = C + \frac{\text{Mn}}{4} + \frac{\text{Si}}{4} \text{ (percent)}$$

$$\text{High Strength Low Alloy Steel: CE} = C + \frac{\text{Mn}}{6} + \frac{\text{Ni}}{20} + \frac{\text{Cr}}{10} + \frac{\text{Mo}^*}{40} + \frac{\text{V}}{10} \text{ (percent)}$$

Where levels of Mo, Cr, Ni, and V total greater than 0.20 percent, use the CE formula for high strength low alloy steel.

*When molybdenum exceeds 0.50 percent, then Mo is added in the calculation of CE.

4. Maximum for columbium and vanadium = 0.10 percent.
5. When welds are to be thermally stress-relieved, the deposited weld metal shall not exceed 0.05 percent vanadium.
6. Residual levels of alloys can have an influence on weldability; therefore, their effects must be considered during calculation of CE.

Table 4
Minimum Preheat and Interpass Temperature^{1,2} for Prequalified Procedures

Welding Process																
Thickness of Thickest Part at Point of Welding		SMAW with Other than Low Hydrogen Electrodes				SMAW with Low Hydrogen Electrodes SAW, GMAW, or FCAW				SMAW with Low Hydrogen Electrodes; SAW with Carbon or Alloy Steel Wire, Neutral and Active Flux, ³ GMAW or FCAW				SAW with Carbon Steel Wire Alloy Flux ³		
		Steel														
in.	mm	Class I		Class II		Class I		Class II		& III	Class IV		Class V		Class V	
		°F	°C	°F	°C	°F	°C	°F	°C	°C	°F	°C	°F	°C	°F	°C
Thru 3/4 incl.	19.1	50	10	50	10	50	10	50	10	10	50	10	50	10	50	10
Over 3/4 thru 1-1/2	19.1 to 38.1	50	10	150	65	50	10	50	10	10	150	65	125	50	200	95
Over 1-1/2 thru 2-1/2	38.1 to 63.5	50	10	225	105	50	10	150	65	65	225	105	175	80	300	150
Over 2-1/2	63.5	200	95	300	150	150	65	225	105	105	300	150	225	105	400	205

Notes:

- When the base metal is below the temperature listed for the welding process being used and the thickness of material being welded, it shall be preheated (except as otherwise provided) in such manner that the surfaces of the parts on which weld metal is being deposited are at or above the specified minimum temperature for a distance equal to the thickness of the part being welded, but not less than 3 in. (76.2 mm), both laterally and in advance of the welding. Preheat and interpass temperatures must be sufficient to prevent crack formation. Temperature above the minimum shown may be required for highly restrained welds. For quenched and tempered steel, the maximum preheat and interpass temperature should not exceed 400°F (205°C) for thickness up to 1-1/2 in. (38 mm), inclusive, and 450°F (230°C) for greater thickness. When welding quenched and tempered steel, heat input should not exceed the steel producer's recommendations.
- In joints involving combinations of base metals, preheat shall be as specified for the higher strength steel being welded.
- Neutral Flux—flux whose primary purpose is to shield the weld metal.
Active Flux—flux whose primary purpose is to deoxidize the weld metal.
Alloy Flux—flux whose primary purpose is to alloy the weld metal.

welding positions and other circumstances pertaining to the work.

5.5.5.3 The maximum size of electrodes shall be as follows:

- (1) 5/16 in. (7.9 mm) for all welds made in the flat position, except root passes
- (2) 1/4 in. (6.4 mm) for horizontal fillet welds
- (3) 1/4 in. (6.4 mm) for root passes of fillet welds made in the flat position and of groove welds made in the flat position with backing, and with root opening of 1/4 in. (6.4 mm) or more
- (4) 5/32 in. (4 mm) for welds made with EXX14 and low-hydrogen electrodes in the vertical and overhead positions
- (5) 3/16 in. (4.8 mm) for root passes of groove welds and for all other welds not included under 5.5.5.3 (1), 5.5.5.3 (2), 5.5.5.3 (3), and 5.5.5.3 (4)

5.5.5.4 The minimum size of a root pass shall be such as to prevent cracking

5.5.5.5 The maximum thickness of layers subsequent to the root pass of fillet welds and of all layers of groove welds shall be

- (1) 1/4 in. (6.4 mm) for root passes of groove welds
- (2) 1/8 in. (3.2 mm) for subsequent layers of welds made in the flat position
- (3) 3/16 in. (4.8 mm) for subsequent layers of welds made in the vertical, overhead and horizontal positions

5.5.5.6 The maximum size fillet weld which may be made in one pass shall be

- (1) 3/8 in. (9.5 mm) in the flat position
- (2) 5/16 in. (7.9 mm) in horizontal or overhead positions
- (3) 1/2 in. (12.7 mm) in the vertical position

Table 5
Filler Metal Requirements^{1,2} for Prequalified Complete Joint Penetration Groove Welds

Base Metal ²	Welding Process			
	SMAW	SAW	GMAW	FCAW
Class I and Class II	AWS A5.1 E60XX or E70XX	AWS A5.17 F6X-EXXX or F7X-EXXX	AWS A5.18 ER70S-X	AWS A5.20 E6XTX-X or E7XTX-X (Except -2, -3, -10, -GS) ³
	AWS A5.5 E70XX-X	AWS A5.23 F7XEXXX-X		
Class III	AWS A5.1 E70XX ⁴	AWS A5.17 F7XX-EXXX	AWS A5.18 ER70S-X	AWS A5.20 E7XTX-X (Except -2, -3, -10, -GS) ³
Class IV	AWS A5.5 E80XX-X ⁴	AWS A5.23 F8X-EXXX-X	AWS A5.28 ER80S-X	AWS A5.29 E8XTX-X
	E90XX-X	F9X-EXXX-X	ER90S-X	E9XTX-X
Class V	AWS A5.5 E110XX-X ⁴	AWS A5.23 F11XX-EXXX-X	AWS A5.28 ER110S-X	AWS A5.29 E11XTX-X

Notes:

1. In joints involving base metals of different yield points or strengths, filler metals applicable to the low-strength base metal may be used.
2. A filler metal of a lower or higher strength may be used where specified by design.
3. If type EXXTX-2 filler metals are used on successfully tested prototype vehicles, this qualifies the use of type EXXTX-2 filler metals for production.
4. Low hydrogen classification.

5.5.5.7 The progression for welding in a vertical position for all passes shall be upwards. Undercut may be repaired vertically downwards when preheat is in accordance with Table 4.

5.5.5.8 Complete joint penetration groove welds made without the use of backing shall have the root gouged to sound metal before welding is started from the other (opposite) side of the joint.

5.5.5.9 Backing may be used to prevent melt-through for fillet welds and the roots of partial penetration welds.

5.5.6 Prequalified Procedures for Submerged Arc Welding (SAW) with Single Electrode

5.5.6.1 SAW, except for fillet welds, shall be performed in the flat position + 15 degrees. Fillet welds may be made in either the flat or horizontal position, except that single-pass fillet welds made in the horizontal position shall not exceed 5/16 in. (7.9 mm).

5.5.6.2 The thickness of weld layers, except root and surface layers, shall not exceed 1/4 in. (6.4 mm).

A multiple-pass split-layer technique shall be used when the root opening is 1/2 in. (12.7 mm) or greater. The split-layer technique shall also be used in making multiple-pass welds when the width of the layer exceeds 5/8 in. (15.9 mm).

5.5.6.3 The welding current, arc voltage and speed of travel shall be such that each pass will have complete fusion with the adjacent base metal and weld metal, and will have no excessive overlap or undercutting. The maximum welding current to be used in making groove welds and fillet welds shall be those listed in Table 6, except that the final layer may be made using a higher current.

5.5.6.4 The maximum welding current and thickness of weld layers may exceed the limitations given in 5.5.6.2 and 5.5.6.3, provided the manufacturer can demonstrate by nondestructive testing, or macroetch examination of sample welds, that sound welds are produced.

5.5.6.5 Backing may be used to prevent melt-through for fillet welds and the roots of partial penetration welds.

5.5.7 Prequalified Procedures for Submerged Arc Welding (SAW) with Multiple Electrodes

5.5.7.1 SAW with multiple electrodes, except for fillet welds, shall be made in the flat position + 15 degrees. Fillet welds may be made in either the flat or horizontal position, except that single-pass multiple-arc fillet welds made in the horizontal position shall not exceed 1/2 in. (12.7 mm).

5.5.7.2 The thickness of weld layers is not limited. Either single or multiple electrodes may be used in making the root pass of a groove weld. Backing bars or root faces shall be of adequate thickness to prevent melt-through. Multiple electrodes shall be displaced laterally, or a split-layer technique shall be used to assure adequate corner fusion when the width of a surface in a groove of which a layer of weld metal is to be deposited exceeds 1/2 in. (12.7 mm). A split-layer technique with electrodes in tandem shall be employed when the width of a previously deposited layer exceeds 1 in. (25.4 mm) and only two electrodes are used.

5.5.7.3 The welding current, arc voltage, speed of travel and relative location of electrodes shall be such that each pass will have complete fusion with the adjacent base metal and weld metal, and there will be no depressions or excessive undercutting at the toe of the weld. Excessive concavity of initial passes shall be avoided to prevent cracking in roots of joints under restraint. The maximum welding currents to be used in making groove and fillet welds shall be those listed in Table 6, except that the final layer may be made using higher current. These values may be exceeded, provided the manufacturer can demonstrate by non-destructive testing, or macroetch examination of sample welds, that sound welds are produced.

5.5.7.4 Multiple-arc welds may also be made in the root of the groove joints and for fillet welds using a combination of gas metal arc followed by multiple submerged arcs. The gas metal arc welding (GMAW) shall conform to the requirements of 5.5.8. The spacing between the GMAW head and the first following SAW head shall not exceed 15 in. (381 mm).

5.5.7.5 Preheat and interpass temperatures for multiple electrode SAW shall be in accordance with Table 4. Preheat and interpass temperatures may be established for single-pass groove or fillet welds, for combinations of metals being welded and for the heat input involved which are sufficient to reduce the hardness in the heat-affected zones of the base metal to less than 225 Vickers hardness number for steel hav-

Table 6
Maximum Amperages¹ for Submerged Arc Welding

Wire Diameter in.	Per Electrode Amperage	Per Twin Wire ² Wire Diameter in.	Amperage
5/64	400	.045	700
3/32	500	.052	800
1/8	600	1/16	900
5/32	800	5/64	1100
3/16	1000	3/32	1300
7/32	1100		
1/4	1200		

Notes:

1. For flat fillet and square groove welds; for horizontal fillet welds, reduce amperage value by 15 percent.
2. Two wires, common molten weld pool, single power source.

ing a minimum specified tensile strength not exceeding 60 000 psi (415 MPa). Heat-affected-zone hardness may not exceed 280 Vickers hardness number for steel having a specified tensile strength greater than 60 000 psi (415 MPa), but not exceeding 70 000 psi (485 MPa). Hardness determination of the heat-affected zones shall be made on the initial macroetch cross section of a sample test specimen.

The frequency of such heat-affected-zone testing shall be at least one test area per weldment on the thicker metal involved in a joint for each 50 ft (15.2 m) of groove welds or pair of fillet welds. These hardness determinations may be discontinued after the procedure has been established.

5.5.7.6 No reduction of the preheat requirements of Table 4 shall be permitted for fillet welds 3/8 in. (9.5 mm) and under in size.

5.5.8 Prequalified Procedures for Gas Metal Arc Welding (GMAW) and Flux Cored Arc Welding (FCAW)

5.5.8.1 The following requirements are essential when using the gas metal arc process for prequalified procedures that are exempt from qualification testing:

- (1) Electrodes shall be in suitable condition for use.
- (2) The maximum electrode diameter shall be 1/16 in. (1.6 mm).
- (3) The maximum size fillet weld made in one pass shall be 3/8 in. (9.5 mm) for the flat position and 5/16 in. (7.9 mm) for the horizontal position.

(4) The thickness of weld layers, except the root, shall not exceed 1/4 in. (6.4 mm). A multiple-pass split-layer technique shall be used when the root opening of a groove weld is greater than 3/8 in. (9.5 mm). The split-layer technique shall also be used in making all multiple-pass welds (fillet or groove) when the width of the preceding layer exceeds 1/2 (12.7 mm).

5.5.8.2 The following requirements are essential when using the flux cored arc process for prequalified procedures that are exempt from qualification testing:

(1) Electrodes shall be dry and in suitable condition for use.

(2) The maximum electrode diameter shall be 7/64 in. (2.8 mm).

(3) The maximum size of a fillet weld made in one pass shall be 1/2 in. (12.7 mm) for the flat position and 5/16 in. (7.9 mm) for the horizontal position.

(4) The thickness of weld layers, except the root, shall not exceed 1/4 in. (6.4 mm). A multiple pass split-layer technique shall be used when the root opening of a groove weld is greater than 3/8 in. (9.5 mm). The split-layer technique shall also be used in making all multiple-pass welds when the width of the preceding layer exceeds 5/8 in. (15.9 mm).

5.5.8.3 The following requirements are essential when using either the gas metal arc or flux cored arc process for prequalified procedures that are exempt from qualification testing:

(1) The welding parameters shall be such that each pass will have complete fusion with adjacent base metal and weld metal, and there will not be excessive overlap, porosity, or undercutting.

(2) Complete joint penetration groove welds made without the use of steel backing shall have the root gouged to sound metal before welding is started from the second side.

(3) Backing may be used to prevent melt-through for fillet welds and the roots of partial penetration welds.

(4) Welding with external gas shielding shall not be done in a draft or wind that diverts the shielding gas from the weld pool.

6. Welding Personnel Qualification

6.1 Scope. The qualification tests described herein are especially designed to determine the ability of the welding personnel to produce sound welds.

It is not necessarily intended that the qualification tests shall be used as a guide for welding during actual

construction. The latter shall be performed in accordance with the requirements of the welding procedure specification. This section is organized into four distinct parts as follows:

(1) Welder Qualification (see 6.3)

(a) Method A

(b) Method B

(2) Welding Operator Qualification (see 6.4)

(3) Operator of Automatic Welding Equipment Qualification

(see 6.5)

(4) Qualification of Tack Welders (see 6.6)

6.2 General. The manufacturer shall be responsible for the choice of welding personnel qualification methods and maintaining the records of all tests demonstrating the ability of welding personnel to produce sound welds.

Qualification of welding personnel may be accomplished by the manufacturer, contractor, or under an independent testing facility under the supervision of the manufacturer.

Radiographic or ultrasonic examination may be used in lieu of bend tests for welding personnel qualification. The user is cautioned that procedure and technique will affect results. The user shall be responsible for assuring that test results reflect a quality level equal to or surpassing the minimum weld quality requirements of 7.5.2.

6.2.1 Welding personnel shall be qualified in accordance with AWS D10.9, *Specification for Qualification of Welding Procedures and Welders for Piping and Tubing*, or AWS D14.4, *Classification and Application of Welded Joints for Machinery and Equipment*, for complete joint penetration groove welds in pipe or tubing made in other than the flat or horizontal positions.

6.2.2 Limitation of Variables. All of the following rules shall apply for the qualification of welding personnel:

6.2.2.1 Qualification established with any one of the steels permitted by this specification shall be considered as qualification to weld, or tack weld, any of the other steels. Separate qualifications are required for each type of nonferrous base metal, (i.e. aluminum, bronze, copper, etc.).

6.2.2.2 Welding personnel shall be qualified for each welding process used separately (i.e., SMAW, GMAW, FCAW, SAW, etc.). Significant differences exist between the various modes of operation within these welding process categories, as in FCAW with

or without gas shielding, GMAW in spray, short-circuiting transfer or GMAW-P. Therefore, separate qualification tests are required for each of these modes of operation.

6.2.2.3 Welding personnel qualified for SMAW with an electrode identified in Table 7 shall be considered qualified to weld with any other electrode listed in the same or numerically lesser group designations.

6.2.2.4 Welding personnel qualified to weld with SAW, FCAW, or GMAW with an approved electrode and shielding medium combination shall be considered qualified to weld, or tack weld, with any other approved electrode and shielding medium combination for the same process within the limits of 6.2.2.2.

6.2.3 Positions for which welding personnel are qualified by the weld test position are listed in Table 8.

6.3 Welder Qualification^{6,7} (refer to Table 9)

6.3.1 Method A

6.3.1.1 Qualification Test for Unlimited Thickness. Joint detail as follows: 1 in. (25.4 mm) plate, single-V-groove, 45 degree included groove angle, 1/4 in. (6.4 mm) root opening with backing. Backing must be at least 3/8 x 3 in. (9.5 x 76.2 mm) or removed⁸ if radiography is used for testing, and at least 3/8 x 1 in. (9.5 x 25.4 mm) for mechanical testing. The minimum length of the welding groove shall be 5 in. (127 mm) (see Figures 23 and 24). This test will qualify the welder for groove and fillet welds on material of unlimited thickness for the test positions listed in Table 8 qualified by the weld test position.

6.3.1.2 Qualification Test for Limited Thickness. Joint detail as follows: 3/8 in. (9.5 mm) plate, single-V-groove, 45 degree included groove angle, 1/4 in. (6.4 mm) root opening with backing. Backing must be at least 3/8 x 3 in. (9.5 x 76.2 mm) or removed¹⁰ if radiography is used for testing and at least 3/8 x 1 in. (9.5 x 25.4 mm) for mechanical testing. The minimum length of the welding groove shall be 7 in. (177.8 mm) (see Figures 25 and 26). This

6. A **welder** is one who performs manual or semiautomatic welding.

7. Welders qualified in accordance with ANSI/AWS D1.1, and *Structural Welding Code Steel*, or Section IX, ASME *Boiler and Pressure Vessel Code*, shall be considered qualified to this specification within the limitations of 6.2.2.

8. Removal of backup bar shall not disturb deposited weld metal under it, or reduce joint thickness.

Table 7
Electrode Classification Groups—
Welder Qualification

Filler Metal Group Designation	AWS Electrode Classification
IV	EXX15, EXX16, EXX18
III	EXX10, EXX11
II	EXX12, EXX13, EXX14
I	EXX20, EXX24, EXX28

The letters "XX" used in the classification designations in this table stand for the various strength levels (60, 70, 80, 90, 100, 110, and 120 in ksi) of electrodes

test will qualify the welder for groove welds in material not over 3/4 in. (19.1 mm) in thickness and fillet welds on material of unlimited thickness for the test positions shown in Table 8 qualified by the position.

6.3.1.3 Qualification Test for Fillet Welds Only—Option 1. The test plate shall be in accordance with Figure 29. This test will qualify the welder for fillet welds on material of unlimited thickness in the position listed in Table 8.

6.3.1.4 Qualification Test for Fillet Welds Only—Option 2. Test plate in accordance with Figure 30. This test will qualify the welder for fillet welds on material of unlimited thickness in the positions listed in Table 8.

6.3.2 Test Specimens—Number, Type, and Preparation

6.3.2.1 Bend Test. Two side-bend specimens shall be cut from the unlimited thickness test joint, or one face- and one root-guided-bend test specimen from the limited thickness test joint. Bend specimens shall be prepared for testing in accordance with Figure 27 or 28, whichever is applicable.

6.3.2.2 Nondestructive Tests. The weld reinforcement may be ground flush with the surface of the test plate if methods such as radiographic or ultrasonic testing are used in lieu of the prescribed bend tests.

6.3.2.3 Fillet Welds—Option 1. One macroetch specimen and one fillet weld break specimen conforming to Figure 29.

6.3.2.4 Fillet Welds—Option 2. Two guided-root-bend tests (fillet weld soundness specimens) conforming to Figure 30.

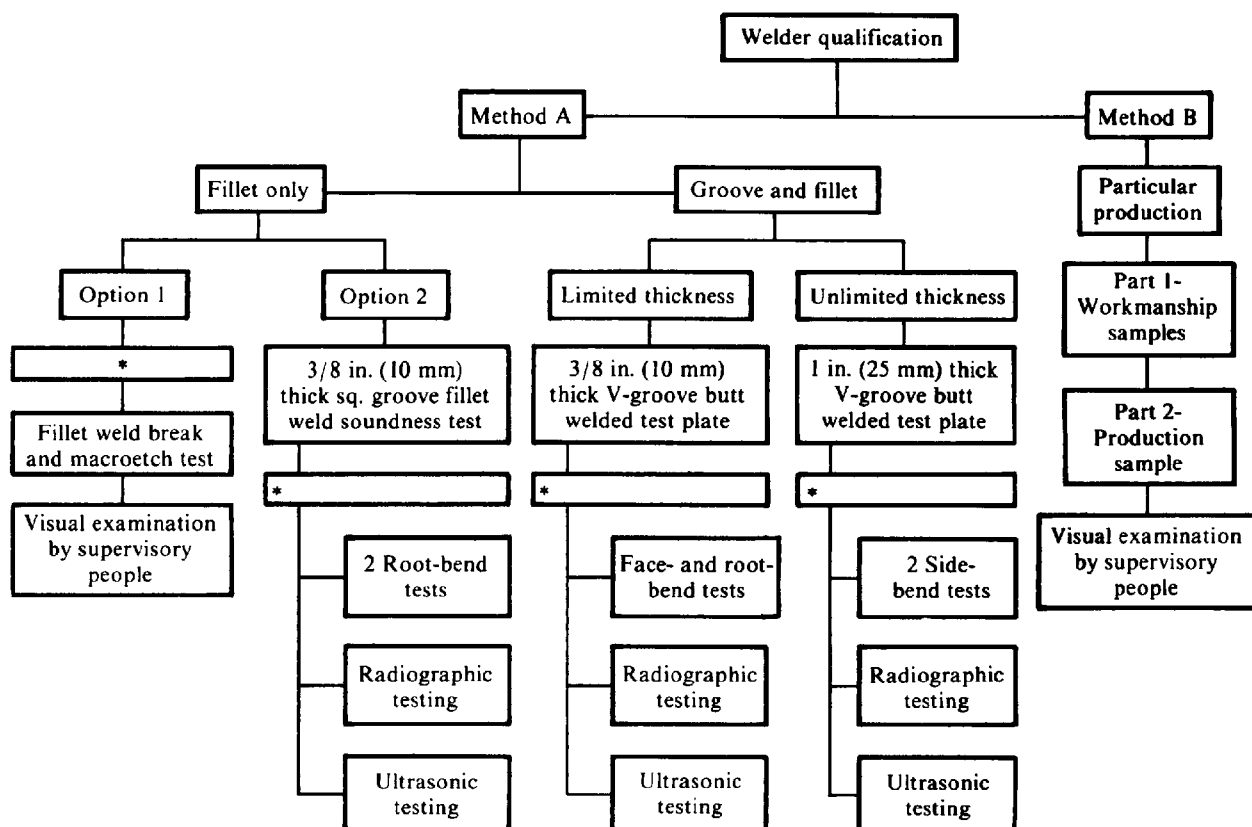
Table 8
Welding Personnel Qualification Type and
Position Limitations

Type of Welding and Position of Qualification Test		Welding Position Qualified ¹	
Weld Position		Groove	Fillet
Groove	1G	F	F,H
	2G	F,H	F,H
	3G	F,H,V	F,H,V
	4G	F,OH	F,H,OH
Fillet	1F		F
	2F		F,H
	3F		F,H,V
	4F		F,H,OH

Notes:

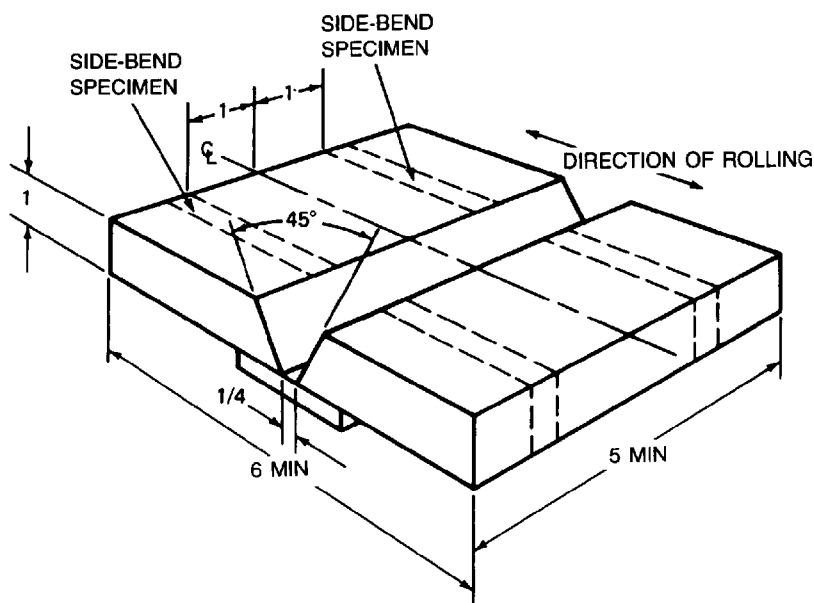
1. Positions of welding: F = flat, H = horizontal, V = vertical, OH = overhead. See Figures 6, 7, 8, and 9.

Table 9
Welder Qualification Tests¹



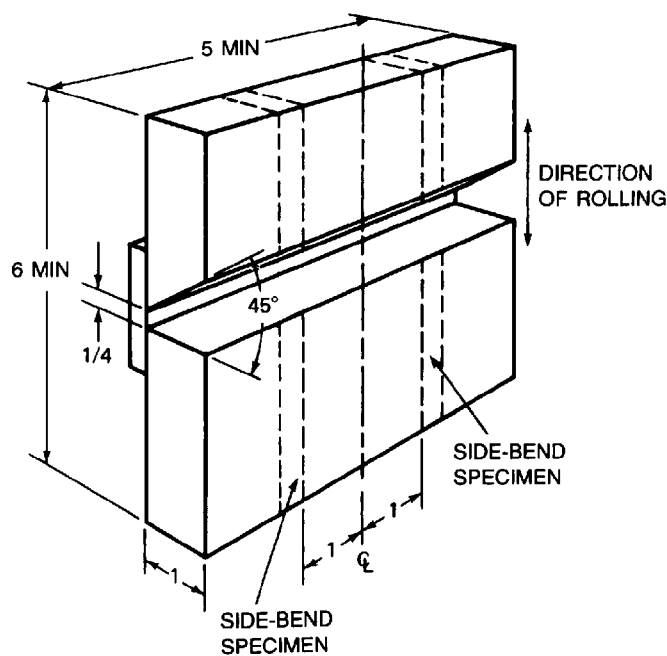
1. Welders qualified in accordance with ANSI/AWS D1.1, *Structural Welding Code-Steel or Section IX, ASME Boiler and Pressure Vessel Code* shall be considered qualified to this specification within the limitations of 6.2.

*Visual examination per Section 7.



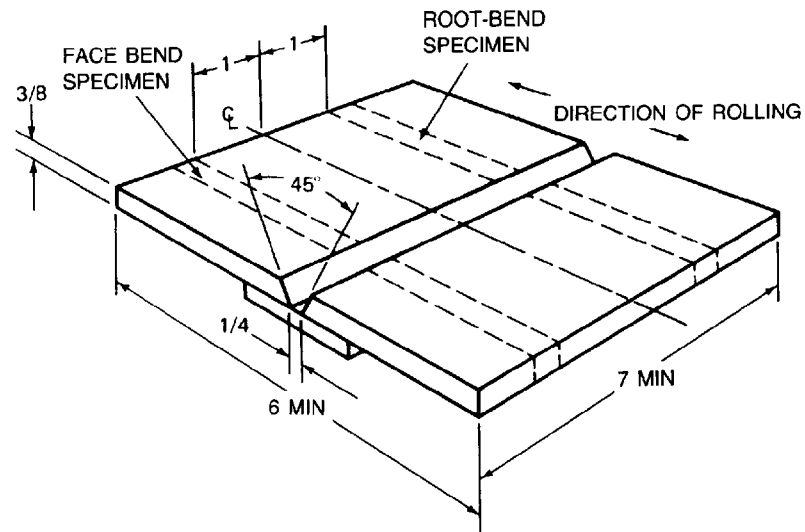
NOTE: WHEN RADIOGRAPHY IS USED FOR TESTING, NO TACK WELDS SHALL BE IN THE TEST AREA.

Figure 23—Test Plate for Unlimited Thickness—All Position—Welder Qualification



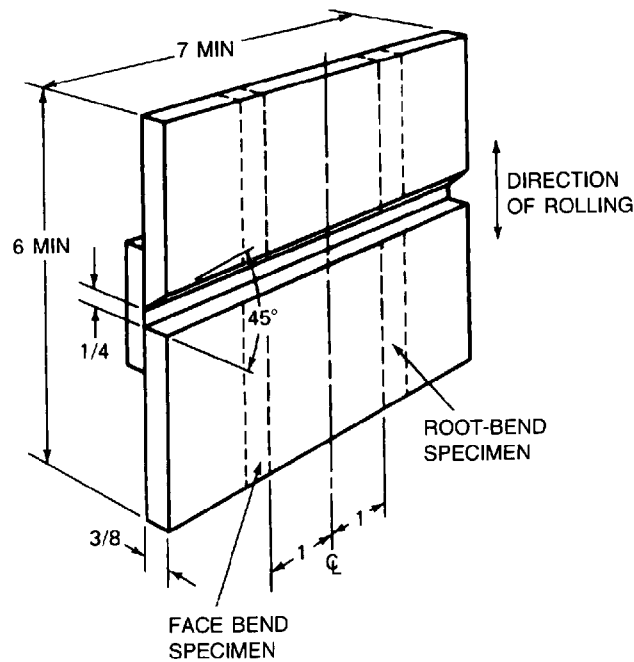
NOTE: WHEN RADIOGRAPHY IS USED FOR TESTING, NO TACK WELDS SHALL BE IN THE TEST AREA.

Figure 24—Optional Test Plate for Unlimited Thickness—Horizontal Position—Welder Qualification



NOTE: WHEN RADIOGRAPHY IS USED FOR TESTING, NO TACK WELDS SHALL BE IN THE TEST AREA.

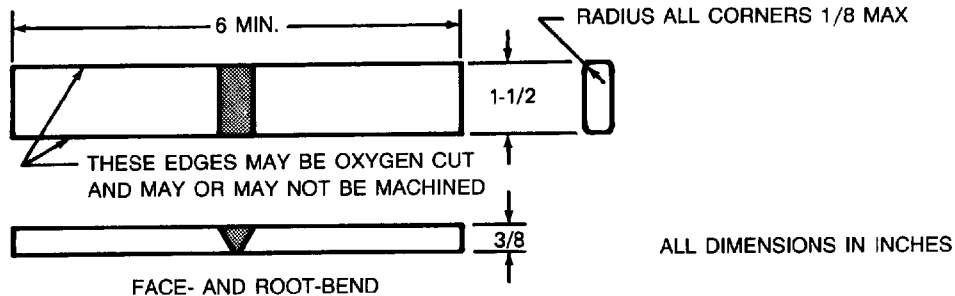
Figure 25—Test Plate for Limited Thickness—All Positions—Welder Qualification



NOTE: WHEN RADIOGRAPHY IS USED FOR TESTING, NO TACK WELDS SHALL BE IN THE TEST AREA.

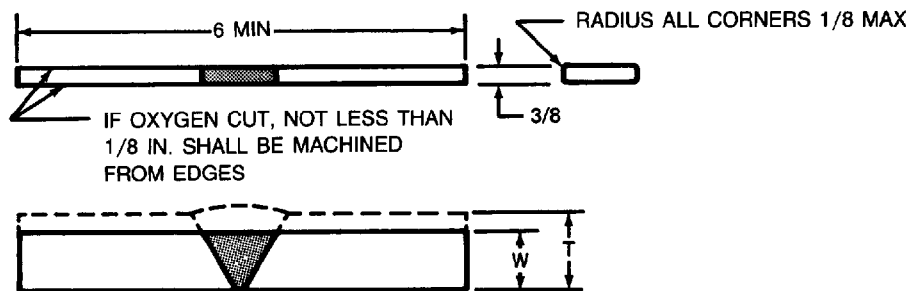
Figure 26—Optional Test Plate for Limited Thickness—Horizontal Position—Welder Qualification

A LONGER SPECIMEN LENGTH MAY BE NECESSARY WHEN USING A WRAPAROUND-TYPE BENDING FIXTURE OR WHEN TESTING STEEL WITH YIELD POINT OF 90 ksi (620 MPa) OR MORE



WELD REINFORCEMENT AND BACKING, IF ANY, SHALL BE REMOVED FLUSH WITH THE SURFACE OF THE SPECIMEN. IF A RECESSED BACKING IS USED, THIS SURFACE MAY BE MACHINED TO A DEPTH NOT EXCEEDING THE DEPTH OF THE RECESS TO REMOVE THE BACKING, IN SUCH CASES THE THICKNESS OF THE FINISHED SPECIMEN SHALL BE THAT SPECIFIED ABOVE.

Figure 27—Face and Root Bend Specimens



FOR PLATES 3/8 TO 1-1/2 in. (9.5 TO 38.1 mm), WIDTH W EQUALS PLATE THICKNESS T.
FOR PLATES OVER 1-1/2 in. (38.1 mm) THICK, CUT SPECIMENS INTO MINIMUM NUMBER OF APPROXIMATELY EQUAL STRIPS NOT EXCEEDING 1-1/2 in. (38.1 mm) IN WIDTH.

A LONGER SPECIMEN LENGTH MAY BE NECESSARY WHEN USING A WRAPAROUND-TYPE BENDING FIXTURE OR WHEN TESTING STEEL WITH YIELD POINT OF 90 KSI (620 MPa) OR MORE

Figure 28—Side Bend Specimen

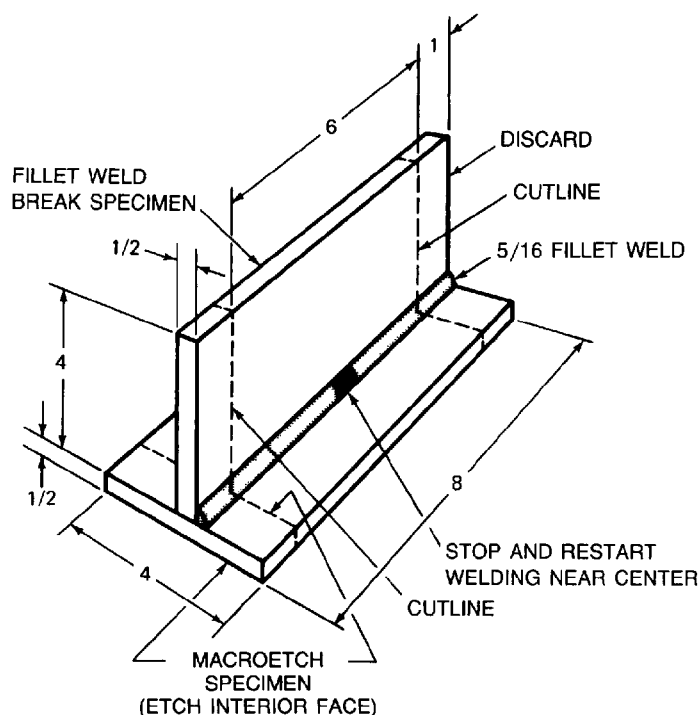


Figure 29—Fillet Weld Break and Macroetch Test Plate—Welder Qualification – Option 1

6.3.3 Method of Testing Specimens

6.3.3.1 Root-, Face- and Side-Bend Specimens (see 6.3.1.1). Each specimen shall be bent to the contour shown in Annex E and otherwise substantially in accordance with that figure. Any convenient means may be used for moving the plunger member with relation to the die member. The face bend specimen shall be placed on the die with the face of the weld directed toward the gap. Root bend and fillet weld soundness specimens shall be placed with the root of the weld directed toward the gap. Side-bend specimens shall be placed with the side showing the most significant discontinuities, if any, directed toward the gap.

6.3.3.2 Macroetch Test. Specimens shall be etched with a suitable solution to give a clear definition of the weld.

6.3.3.3 Fillet Weld Break Test. The entire length of the fillet weld shall be examined visually, and then the 6 in. (152.4 mm) long specimen shall be loaded in such a way that the root of the weld is in tension, as shown in Annex E, Figure E4. The load shall be

steadily increased or repeated until the specimen fractures or bends flat upon itself.

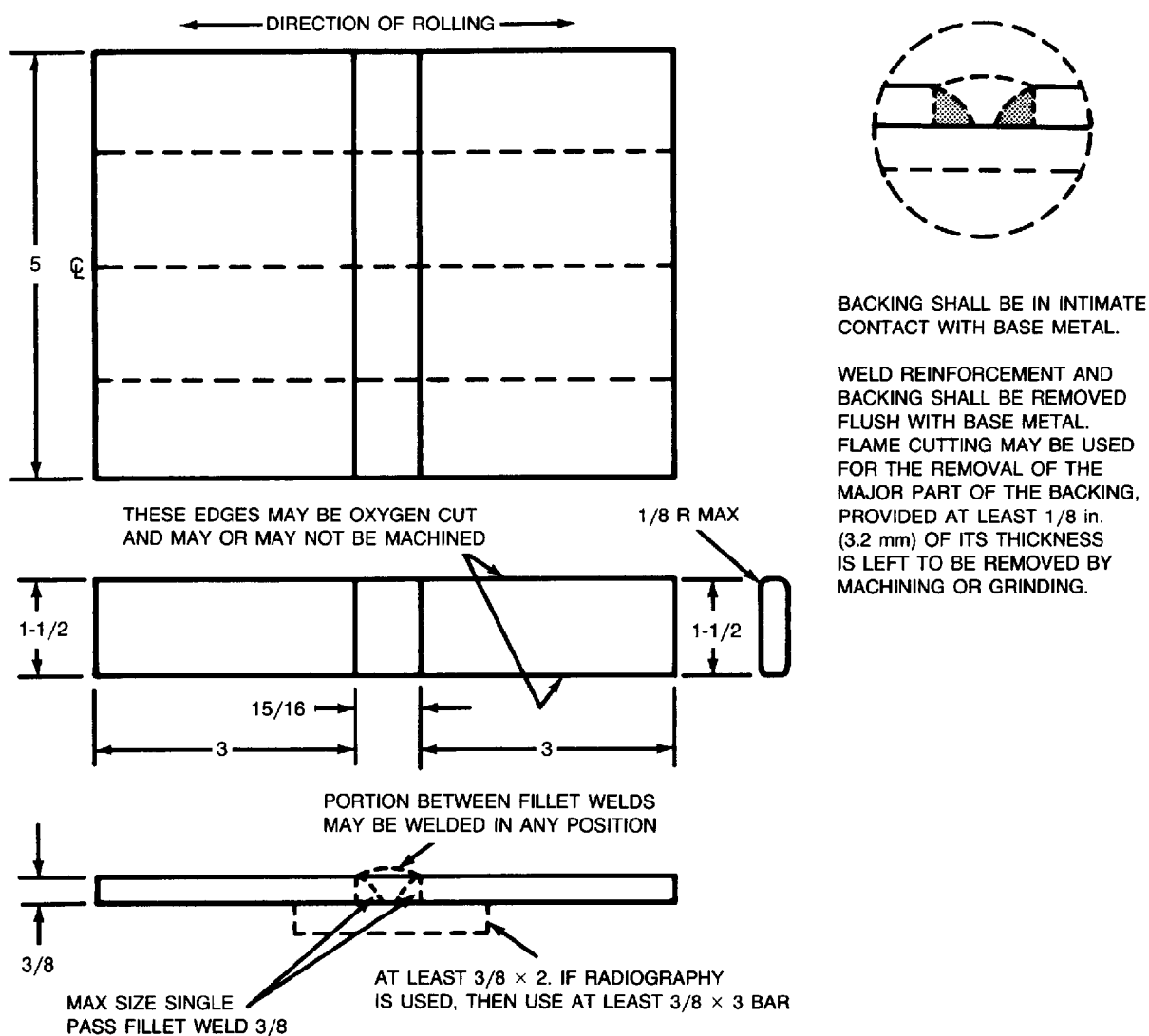
6.3.3.4 Fillet Weld Soundness Test. Each specimen shall be bent to the contour shown in Annex E and otherwise substantially in accordance with that figure. Any convenient means may be used for moving the plunger member with relation to the die member. Fillet weld soundness specimens shall be placed with the root of the weld directed toward the gap.

6.3.3.5 Nondestructive Test. The weld shall meet the weld quality requirements of 7.5.2 to pass the radiographic or ultrasonic examination.

6.3.3.6 Visual Examination. The welds shall meet the requirements of 7.5.1 to pass the visual examination.

6.3.4 Test Results Required

6.3.4.1 Root-, Face- and Side-Bend Tests. The convex surface of the bend test specimen shall be visually examined for surface discontinuities. For acceptance, the surface shall contain no discontinuities exceeding the following dimensions:



**Figure 30—Fillet Weld Soundness (Guided Root Bend) Test Plate—
Welder Qualification – Option 2**

(1) 1/8 in. (3.2 mm) measured in any direction on the surface

(2) 3/8 in. (9.5 mm) — the sum of the greatest dimensions of all discontinuities exceeding 1/32 in. (0.8 mm), but less than or equal to 1/8 in. (3.2 mm)

(3) 1/4 in. (6.4 mm) — the maximum corner crack, except when that corner crack resulted from visible slag inclusion or other fusion-type discontinuities, then the 1/8 in. (3.2 mm) maximum shall apply

Specimens with corner cracks exceeding 1/4 in. (6.4 mm) with no evidence of slag inclusions or other fusion-type discontinuities shall be disregarded and a replacement test specimen from the original weldment shall be tested.

6.3.4.2 Macroetch Test. The specimen shall be visually examined for defects and considered as failed if defects prohibited by 7.5.1 are revealed. The weld shall show fusion to the root, but not necessarily beyond, and both legs shall be equal within 1/8 in. (3.2 mm). Convexity and concavity shall not exceed the limits specified in 7, Workmanship and Weld Quality Requirements.

6.3.4.3 Fillet Weld Break Test. The specimen shall pass the test if it bends flat upon itself. The fractured surface (in this event) shall show complete fusion to the root of the joint, exhibit no incomplete fusion to the base metal, and have no inclusion or porosity larger than 3/32 in. (2.4 mm) in greatest dimension. The sum of the greatest dimensions of all inclusions and porosity shall not exceed 9/16 in. (14.5 mm) in the 6 in. (152.4 mm) long specimen.

6.3.4.4 Fillet Weld Soundness Test. The convex surface of the root bend specimen shall be visually examined for surface discontinuities. For acceptance, the surface shall contain no discontinuities exceeding the following dimensions:

(1) 1/8 in. (3.2 mm) measured in any direction on the surface.

(2) 3/8 in. (9.5 mm) — the sum of the greatest dimensions of all discontinuities exceeding 1/32 in. (0.8 mm), but less than or equal to 1/8 in. (3.2 mm).

(3) 1/4 in. (6.4 mm) — the maximum corner crack, except when that corner crack resulted from visible slag inclusion or other fusion-type discontinuities, then the 1/8 in. (3.2 mm) maximum shall apply.

Specimens with corner cracks exceeding 1/4 (6.4 mm) with no evidence of slag inclusions or other fusion-type discontinuities shall be disregarded and a replacement test specimen from the original weldment shall be tested.

6.3.4.5 Nondestructive Test. The weld shall meet the weld quality requirements of 7.5.2 to pass the radiographic or ultrasonic examination.

6.3.4.6 Visual Examination. The welds shall meet the requirements of 7.5.1 to pass the visual examination.

6.3.5 Method B—Welder Qualification Test. Method B consists of two parts for qualification: Workmanship Sample and Production Sample.

6.3.5.1 Workmanship Sample. A workmanship sample similar to the production welds shall be made (see Figures 31, 32 and 33) that represents the required degree of manipulative ability. The type and number of samples to be made shall be determined by the manufacturer to represent the type of work the welder will be doing. This test shall be witnessed, evaluated and recorded by qualified personnel. The samples shall be tested using visual inspection, appropriate sectioning and etching of the sample, and shall meet the requirements of 7, Workmanship and Weld Quality Requirements.

6.3.5.2 Production Sample. The capability of the welder to satisfactorily perform production welding shall be determined after a tryout at the job station only after successful completion of the workmanship sample. Qualification shall be achieved when the welder produces a typical production part that meets the quality requirements of this specification, as witnessed and recorded by an authorized individual.

6.3.6 Retests—Welder Qualification Methods A and B. A retest may be allowed if a welder fails to meet the requirements of one or more test welds under the following conditions:

(1) An immediate retest may be made which shall consist of two test welds of each type failed. All test specimens shall meet all the requirements for such welds.

(2) A retest may be made, provided there is evidence that the welder has had further training or practice. In this case, a complete retest shall be made.

6.3.7 Period of Effectiveness—Welder Qualification Methods A and B. The welder qualification shall remain in effect indefinitely unless (1) the welder is not engaged in a given process of welding for which the welder is qualified for a period exceeding six months, or (2) there is some specific reason to question a welder's ability. In case (1) above, the requalification test needs to be made only in the 3/8 in. (9.5 mm) thickness.

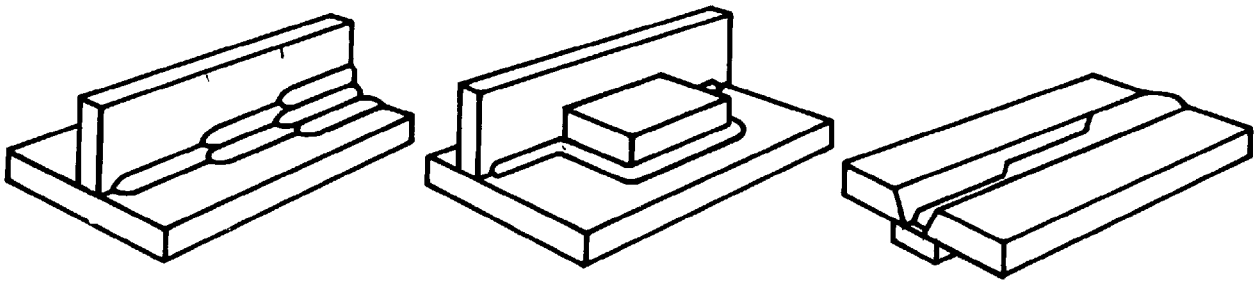


Figure 31—Example of Workmanship Sample

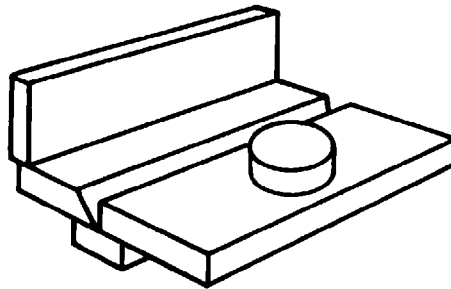


Figure 32—Example of Workmanship Sample

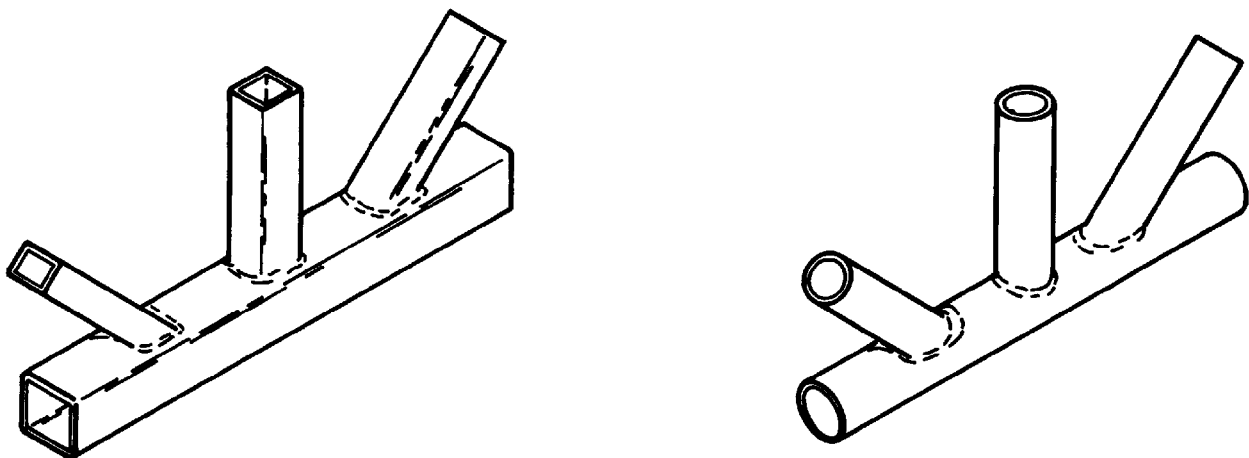


Figure 33—Example of Workmanship Sample

6.3.8 Records—Welder Qualification Methods A and B. Records of the test results shall be kept by the manufacturer and shall be available as required by the contract.

6.4 Welding Operator Qualification

6.4.1 Welding Operator Qualification Tests. The qualification test for a welding operator⁹ shall consist of welding a test assembly which meets the following requirements:

6.4.1.1 Complete penetration groove weld joint selected from Figure 18 for submerged arc welding.

6.4.1.2 Complete penetration groove weld joint selected from Figure 20 for gas metal arc or flux cored arc welding.

6.4.1.3 Welding in accordance with the requirements of the welding procedure specification.

6.4.1.4 Suitable test pieces conforming to the actual production joint in size, mass and materials shall be made if the welding process does not lend itself to making basic groove welds, or the welded joints covered by the welding procedure specification do not comply with Figures 18 through 22.

6.4.2 Macroetch specimens shall be prepared from the welded test assembly by sectioning through the weld in at least two locations, and by polishing and etching with a suitable solution to give a clear definition of weld.

6.4.3 Test Results Required. The welded test assembly shall meet the visual requirements of 7.5.1.

6.4.3.1 The macroetched specimens shall be examined for defects, and if defects prohibited by 7, Workmanship and Welding Quality Requirements, are found, the test shall be considered as failed. The weld shall show fusion to the root and shall be free from fusion defects. Convexity and concavity of fillet welds shall not exceed the limits specified in 7, Workmanship and Welding Quality Requirements, and both legs of the fillet shall be equal within 1/8 in. (3.2 mm).

6.4.4 Retests. A retest may be allowed if a welding operator fails to meet the requirements of one or more test welds under the following conditions:

9. A *welding operator* is one who operates adaptive control, automatic, mechanized or robotic welding equipment. Welding operators qualified in accordance with ANSI/AWS D1.1, Structural Welding Code—Steel or Section IX ASME Boiler and Pressure Vessel Code are considered qualified according to this specification.

(1) An immediate retest may be made which shall consist of two test welds of each type failed. All test specimens shall meet all the requirements for such welds.

(2) A retest may be made, provided there is evidence that the welder has had further training or practice. In this case, a complete retest shall be made.

6.4.5 Period of Effectiveness. The welding operator qualification shall remain in effect indefinitely unless (1) the welding operator is not engaged in a given process of welding for which the welder is qualified for a period exceeding six months, or (2) there is some specific reason to question a welding operator's ability. In case (1) above, the requalification test need be made only in the 3/8 in. (9.5 mm) thickness.

6.4.6 Records. Records of the test results shall be kept by the manufacturer and shall be available as required by the contract.

6.5 Operators of Automatic Welding Equipment. The manufacturer shall be responsible for determining the capability of operators¹⁰ of automatic welding equipment to satisfactorily perform welding as prescribed by the manufacturer's recorded welding procedure specification.

6.6 Qualification of Tack Welders

6.6.1 Limitation of Variables. The following rules [in addition to those found in 6.2.2, shall apply for the qualification of a tack welder.

6.6.1.1 A tack welder qualified for shielded metal arc welding with an electrode listed in Table 10 shall be considered qualified to tack weld with any other electrode in the same group designation.

6.6.1.2 A tack welder shall be qualified by one test plate made in each position in which the tack welder is to tack weld [flat, horizontal, vertical-up, vertical-down, and overhead; see Figures 6, 7, 8, and 9. A tack welder qualified in the vertical-up position for a particular process shall also be considered qualified in the flat and horizontal positions for that process. Qualification in the overhead position shall also be considered qualified for the flat position for the same process. (See Table 8.)

6.6.2 Test Specimens—Number, Type and Preparation. The tack welder shall make a 1/4 in. (6.4 mm) maximum-size weld approximately 2 in. (50.8 mm) long on the fillet weld break specimen as shown in Figure 34.

10. An *operator* is one who operates adaptive control, automatic, mechanized, or robotic welding equipment.

Table 10
Electrode Classification Groups—
Tack Welder Qualification

Group Designation	AWS Electrode Classification
IV	EXX15, EXX16, EXX18
III	EXX10, EXX11
II	EXX12, EXX13, EXX14
I	EXX20, EXX24, EXX27, EXX28

The letters "XX" used in classification-designation in this table stand for the various strength level (60, 70, 80, 90, 100, 110, and 120) of electrodes.

6.6.3 Method of Testing Specimen. A force shall be applied to the specimen as shown in Figure 35 until rupture occurs. The force may be applied by any convenient means.

6.6.4 Test Results Required

6.6.4.1 The tack weld shall present a reasonably uniform appearance and shall be free of cracks, excessive overlap, and undercut. There shall be no porosity visible on the surface of the weld.

6.6.4.2 The fractured surface of the tack weld shall show fusion to the root, but not necessarily beyond, and shall exhibit complete fusion to the base metal without any inclusions or porosity larger than 3/32 in. (2.4 mm) in greatest dimension.

6.6.4.3 A tack welder who passes the fillet weld break test shall be eligible to tack weld all types of

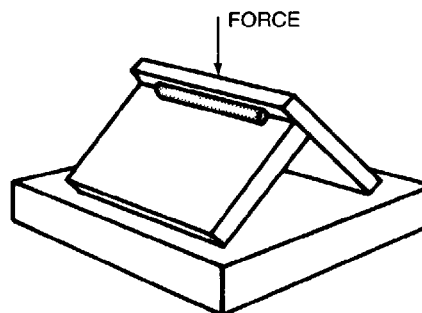


Figure 35—Method of Rupturing Specimen—Tack Welder Qualification

joints for the process and in the positions in which the tack welder has qualified.

6.6.5 Retests. The tack welder may make one retest without additional training in case of failure to pass the above test.

6.6.6 Period of Effectiveness. The tack welder qualification shall remain in effect indefinitely in the position and with the processes for which the tack welder is qualified unless there is some specific reason to question the tack welder's ability. In such case, the tack welder shall be required to demonstrate the ability to make sound tack welds by again passing the prescribed tack welding test.

6.6.7 Records. Records of the test results shall be kept by the manufacturer as required by the contract.

7. Workmanship and Welding Quality Requirements

7.1 Scope. This section presents quality and workmanship levels which may be expected to be normally attainable within this industry. General or specific applications and designs may allow levels different than those listed here. Such differences, when specified and documented, may be applied.

7.2 General Requirements

7.2.1 All requirements of this section shall be observed in the production and inspection of welded assemblies covered under this specification.

7.2.2 Welding shall not be done when the temperature of the part to be welded is lower than that specified on the engineering drawing or welding proce-

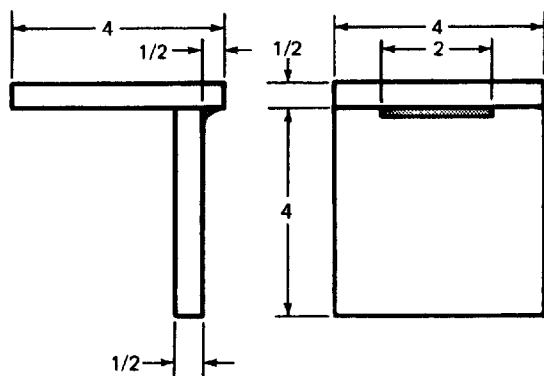


Figure 34—Fillet Weld Break Specimen—Tack Welder Qualification

ture specification, nor shall welding be done when the weldment is exposed to high winds, drafts, or moisture. The temperature of the part, when not specified, shall not be lower than 50°F (10°C). Winds or drafts must be limited to avoid affecting gas shielding with appropriate processes [see 5.5.8.3(4)]. In addition, winds and drafts shall also be limited to avoid excessive cooling rates which may affect properties of the weld and heat-affected zone.

7.3 Preparation of Materials

7.3.1 Joint edges shall be uniform and free from fins, notches, tears, cracks, and other irregularities that will adversely affect the quality or strength of the weld or member. The welding surface shall also be free from moisture, loose or thick scale, slag, heavy rust, grease, or other foreign material that will adversely affect quality or strength of the weld.

7.3.2 Surfaces within 1/2 in. (12.7 mm) of any weld location shall be free from material that will prevent proper welding.

7.3.3 Mechanical or thermal processes may be used for weld joint preparation. The resulting surfaces shall be reasonably smooth for welding. As a guide for oxyfuel cut surfaces, refer to AWS C4.1, *Surface Roughness Guide for Oxygen Cut Surfaces*. Back gouging or the removal of unacceptable work or material may be carried out by any appropriate means such as chipping, grinding, carbon arc, plasma arc, or oxyfuel gas gouging. Caution shall be taken when oxyfuel gas cutting or gouging is used on any structural weldment where stresses due to adverse heating conditions may be considered detrimental to the end product. The gouged or cut surfaces may require grinding to remove a carburized layer resulting from these operations. Exercising care in the use of the gouging or cutting process may produce surfaces which are usable without subsequent preparation.

7.4 Assembly

7.4.1 Fillet Welds

7.4.1.1 The parts to be joined by fillet welds shall be brought into as close contact as practicable. The gap between parts shall normally not exceed 1/8 in. (3.2 mm), except in cases involving plates 3 in. (76.2 mm) or greater in thickness or structural shapes when, after straightening and in assembly, the gap cannot be closed sufficiently to meet this tolerance.

7.4.1.2 The separation between faying surfaces of lap joints shall not exceed 1/16 in. (1.6 mm).

7.4.1.3 Corrective action, such as increasing weld size to avoid loss of effective throat, shall be taken for gaps in excess of 1/16 in. (1.6 mm) unless allowance for such gaps is permitted in the design criteria.

7.4.2 Groove Welds

7.4.2.1 Dimensions of the cross section of groove joints shall not vary from those shown on the detail drawing by more than the workmanship tolerance listed in Table 11.

7.4.2.2 Root openings wider than the thickness of the thinner member, may be built up by welding to acceptable dimensions prior to the joining of the parts by welding.

7.4.3 Use of Fillers. The use of fillers to correct a gap condition is prohibited, except when specified on the detail drawing.

7.5 Quality of Welds¹¹

7.5.1 Visual Requirements

7.5.1.1 All weld lengths and sizes shall conform to the requirements shown on the drawing.

7.5.1.2 All craters shall be filled to at least 85 percent of the full cross section of the welds and shall terminate where required by the drawing.

7.5.1.3 There shall be no cracks in the weld or adjacent base metal surfaces.

7.5.1.4 The sum of diameters of visual or surface porosity,¹² including piping porosity,¹³ shall not exceed 3/8 in. (9.5 mm) in any 4 in. (101.6 mm) length of weld and shall not exceed 3/4 in. (19 mm) in any 12 in. (304.8 mm) length of weld, with no single void exceeding 3/32 in. (2.4 mm) in diameter.

7.5.1.5 Weld overlap shall not exceed 1/16 in. (1.6 mm) beyond the fusion line of the weld.

11. The quality of welds defined in 7.5.1 shall be determined by visual inspection and nondestructive testing if so specified. When Nondestructive Testing (NDT) is required, it shall be performed according to methods developed by the manufacturer or in accordance with provisions of AWS D14.4 *Classifications and Application of Welded Joints for Machinery and Equipment*.

12. *Porosity* is cavity-type discontinuities formed by gas entrapment during solidification.

13. *Piping porosity* is elongated porosity whose major dimension lies in a direction approximately normal to weld surface. Frequently it is referred to as "pin holes" when the porosity extends to the weld surface.

Table 11
Workmanship Tolerances for Groove Welds

	Root not Backgouged*	Root Backgouged
Root face of joint	$\pm 1/8$ in. (3.2 mm) -1/16 in. (1.6 mm)	Not limited
Root opening of joints without steel backing	+1/8 in. (3.2 mm) -1/16 in. (1.6 mm)	$\pm 1/8$ in. (3.2 mm)
Root opening of joints with steel backing	+1/4 in. (6.4 mm) -1/16 in. (1.6 mm)	Not Applicable
Groove angle of joint	+10 degrees -5 degrees	+10 degrees -5 degrees

*Backgouging: The forming of a bevel or groove on the other side of a partially welded joint to assure complete penetration upon subsequent welding from that side.

7.5.1.6 Undercut shall not exceed the following:

In primary load bearing members, undercut shall be no more than 0.01 in. (0.25 mm) deep when the weld is transverse to tensile stress. In all other cases, undercut shall not exceed the following:

(1) Material thickness to and including 1/4 in. (6.4 mm)—10 percent of material thickness.

(2) Material thicknesses greater than 1/4 in. (6.4 mm) —1/32 in. (0.8 mm).

In addition, 1/16 in. (1.6 mm) undercut depth up to 1 in. (25.4 mm) continuous length in any 12 in. (304.8 mm) weld length is permissible; the accumulative length is not to exceed 1.5 in. (38.1 mm) in the same 12 in. (304.8 mm) length.

7.5.1.7 Subsurface quality of welds shall meet the following minimum criteria:

(1) Underbead cracks are not permissible.

(2) Planar-type discontinuities (lack of fusion, slag inclusion or fissures) are permissible to 25 percent of specified weld size, or less than 25 percent of joint penetration in height or width. The length of an individual discontinuity, or the sum of the discontinuities, shall not exceed 10 percent of the weld length for up to 7 in. (177.8 mm) of weld.

(3) Three dimensional-type discontinuities are permissible in discontinuous distribution, provided the largest dimension of any single discontinuity does not exceed the following:

(a) 20 percent of the weld size or joint penetration for welds 3/8 in. (9.5 mm) and under

(b) 15 percent of the weld size or joint penetration for welds over 3/8 in. (9.5 mm)

The sum total of the largest dimensions shall not

exceed 3/8 in. (9.5 mm) in any linear inch of weld, nor 10 percent of the weld length.

7.5.2 Radiographic and Ultrasonic Requirements

7.5.2.1 The following requirements apply when radiographic or ultrasonic testing is specified. These requirements are in addition to those specified in 7.5.1.

7.5.2.2 Underbead cracks are not permissible.

7.5.2.3 Planar-type discontinuities (lack of fusion, slag inclusions, or fissures) are permissible to 25 percent of specified weld size, or less than 25 percent of joint penetration in height or width. The length of an individual discontinuity, or the sum of the discontinuities, shall not exceed 10 percent of the weld length for up to 7 in. (177.8 mm) of weld.

7.5.2.4 Three dimensional-type discontinuities are permissible in discontinuous distribution, provided the largest dimension of any single discontinuity does not exceed the following:

(1) Twenty percent of the weld size or joint penetration for welds 3/8 in. (9.5 mm) and under.

(2) Fifteen percent of the weld size or joint penetration for welds over 3/8 in. (9.5 mm).

The sum total of the largest dimensions shall not exceed 3/8 in. (9.5 mm) in any linear inch of weld, nor 10 percent of the weld length.

7.5.3. Magnetic Particle and Liquid Penetrant Requirements. Test result requirements for magnetic particle and liquid penetrant testing, when required, shall be those specified in 7.5.1.

7.5.4 Tack Welds

7.5.4.1 Tack welds which are to be incorporated into the final weld shall be

(1) Subject to the same quality as the final weld. The termination location of welds, when required, shall be specified on the drawing.

(2) Cleaned, except when deposited with the GMAW process.

7.5.4.2 Tack welds that are not to be incorporated into the final weld shall be subject to the same quality as final welds.

7.5.4.3 Multiple-pass tack welds shall have cascaded ends.

7.5.5 Fillet Welds

7.5.5.1 All fillet welds shall be of desirable or acceptable types as shown in Figure 36(A) and (B).

7.5.5.2 Fillet weld leg size shall conform to the following tolerances based on a measurement of fused leg length:

- (1) Weld sizes under 3/8 in. (9.5 mm)
 - 1/32 in. (0.8 mm)
 - +1/8 in. (3.2 mm)
- (2) Weld sizes 3/8 in. (9.5 mm) and over
 - 1/16 in. (1.6 mm)
 - +1/8 in. (3.2 mm)

The average weld size of a given length of weld shall not be less than the weld size specified on the engineering drawing. The average weld size is determined by the average of leg length measurements obtained at 3 in. (76.2 mm) intervals along the weld length. For welds under 3 in. (76.2 mm) in length, the above tolerances are applied directly. For welds exceeding these tolerances, see 7.6.6 and 7.6.7.

7.5.6 Groove Welds. Groove welds in butt joints shall preferably be made with a slight or minimum reinforcement, except as may be otherwise provided, and shall have no defects such as those shown in Figure 36 (E). The height of reinforcement shall not exceed 1/8 in. (3.2 mm) for a joint or weld sizes up to and including 2 in. (50.8 mm). The weld reinforcement of weld size over 2 in. (50.8 mm) shall not exceed 3/16 in. (4.8 mm), as shown in Figure 36 (D).

7.6 Repair of Weld Defects

7.6.1 All repair welding shall be performed in conformance to the welding requirements of this specification and the qualified procedure for the weld joint involved.

7.6.2 Underfilled Craters. Underfilled craters shall be rewelded and filled to at least 85 percent of the full cross section of the weld size.

7.6.3 Cracks, Porosity, and Lack of Fusion. Unacceptable cracks (fissures, see 7.5.1.7) unacceptable porosity, and fusion-type discontinuities shall be completely removed by appropriate means. The areas from which these discontinuities are removed shall be inspected by an approved method, such as magnetic particle or penetrant testing, to assure complete removal of the discontinuity prior to repair welding.

7.6.4 Undercut. Unacceptable undercut shall be filled with weld metal or, if strength will not be adversely affected, blended out by appropriate means.

7.6.5 Overlap. Unacceptable overlap shall be removed by appropriate means. Additional weld metal may be added after removal of the overlap condition in order to restore the specified weld size and shape.

7.6.6 Undersize Welds. Undersize welds shall be repaired to size by depositing additional weld metal as required.

7.6.7 Oversize Welds. Oversize welds shall be reduced to specified size by appropriate means only when they will cause interference with other parts, or will otherwise produce an adverse effect upon the weldment.

7.6.8 The area of repaired work shall be reinspected.

7.7 Cleaning. Slag shall be cleaned from all welds prior to inspection.

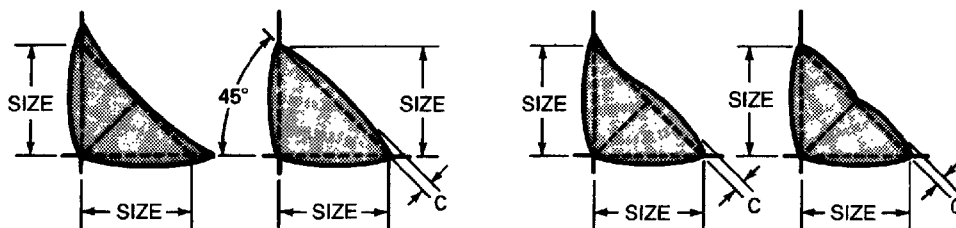
7.8 Dimensional Tolerance. The dimensions of welded structural members shall be within the tolerance of the general specifications governing the work.

8. Inspection

The manufacturer shall provide appropriate personnel to assure that all fabrication by welding is performed in accordance with this specification. Inspection practices and controlling methods shall be used which assure the following:

8.1 Welding Procedures shall comply with 5, Welding Procedure Qualification.

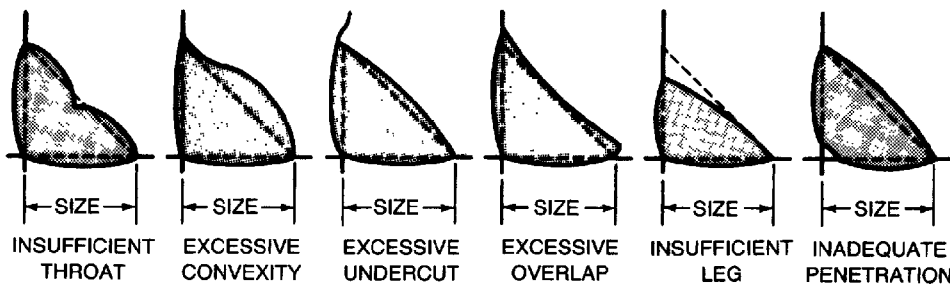
8.2 Welding personnel shall be qualified in accordance with 6, Welding Personnel Quality, and they shall be observed at specified intervals to make certain that the workmanship requirements of 7, Work-



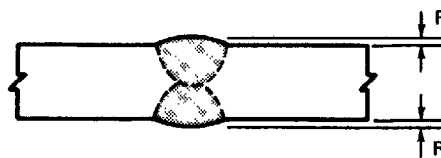
NOTE: CONVEXITY C SHALL NOT EXCEED 0.1 TIMES ACTUAL LEG SIZE, OR THE LONGER LEG IN THE CASE OF AN UNEQUAL LEG FILLET WELD, PLUS 0.06 IN. (0.3 MM).

(A) DESIRABLE FILLET WELD PROFILES

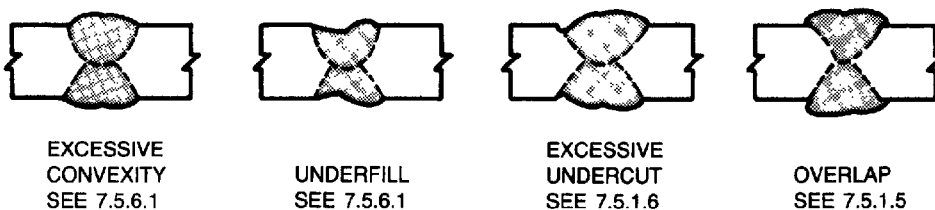
(B) ACCEPTABLE FILLET WELD PROFILES



(C) UNACCEPTABLE FILLET WELD PROFILES



(D) ACCEPTABLE GROOVE WELD PROFILE



(E) UNACCEPTABLE GROOVE WELD PROFILE

Figure 36—Acceptable and Unacceptable Weld Profiles

manship and Welding Quality Requirements are maintained.

8.3 Inspection procedures and personnel involved in nondestructive testing and evaluation (including visual examination) shall be qualified to determine weld quality levels in compliance with 7, Workmanship and Welding Quality Requirements.

8.4 Weld quality shall comply, or be corrected to conform, with the provisions of 7, Workmanship and Welding Quality Requirements.

8.5 When the quality performance of welding personnel is found to be consistently below the requirements of this specification, that person shall be requalified to the requirements of 6, Welding Personnel Quality.

9. Field Repair

9.1 Field repair welding should not be done without instruction from the manufacturer. Generalized weld-

ing instructions covering the entire structure are sufficient where compatible with the structure design.

9.2 Specific instruction provided shall indicate (by outline diagrams or other means) those areas and materials which require specific welding procedures and techniques necessary to assure weldability (e.g., preheat, postheat, filler metals, etc.).

9.3 Recommended practices for preheat to supplement generalized welding instructions are listed in Table 4.

9.4 All field repair welding shall be performed by personnel qualified to perform welding in the basic welding positions as may be necessary.

Annex A

Sample of Welding Procedure Specification and Qualification Test Record

(This Annex is not a part of ANSI/AWS D14.3–94, *Specification for Welding Earthmoving and Construction Equipment*, but is included for information only.)

Sample Welding Procedure Specification and Qualification Test Record

Test conducted at (plant name)		Test no.		Machine model		Date		Weld joint detail (show pass sequence)			
Welding process ☐ Manual ☐ Machine		Pass no.	Elec-trode size	Wire feed	Current		Travel speed				
					Amps	Volts					
Joint no. & position											
Electrode class or grade											
Mfg. trade name											
Electrode extension		Total no. of passes									
Shielding gas or flux		Flow									
Minimum preheat temperature		Maximum inter-pass temp.									

Postheat treatment	Temperature	Time	hr.	min.	Power source __ Generator __ Transformer __ Rectifier	Base metal specification	Test material			
	Other:				Polarity __ AC __ DC+ __ DC-	(1)	Thickness	Width	Length	O.D.
					Manufacturer & rating	(2)				

Welded by (name - clock no.) _____ Witnessed by _____

Laboratory analysis	☐ Radiograph ☐ Ultrasonic test ☐ Magnetic particle ☐ Liquid penetrant		Results															
	Chemical	Weld metal	C	Mn	P	S	Si	Ni	Cr	Mo	Cu	Al	Ti	V	Cb	B		Carbon equivalent
		Base metal (1)																
		Base metal (2)																
	Reduced tension tensile	Specimen no.	Dimensions			Area	Ultimate load	Tensile strength		Location of fracture								
			Width	Thickness	Diameter													
	Bend	Radius	Side	1.	3.	Face		1.	Root		1.							
				2.	4.	2.			2.									
	Fillet weld (macroetch)	Minimum size multiple pass																
		Maximum size single pass																
Charpy V-notch	Test temperature	Weld metal	Fusion line ()	Heat-affected zone ()	Base metal ()	☐ Micro ☐ Macro Results:												
	Energy absorbed																	
	Average																	
					Hardness	☐ VPN load _____ KG ☐ Ra ☐ Rb ☐ Rc												
						Line	Weld metal	Heat-affected zone	Base metal									
						a												
						b												
						c												
						d												

We, the undersigned, certify that the statements in this record are correct and that the tests welds were prepared, welded and tested in accordance with the requirements of Section 5 of AWS D14.3, Specification for Welding Earthmoving and Construction Equipment.

Manufacturer or contractor _____

Authorized by _____

Date _____

Annex B

Recommended Practices for Treatment of Shielded Metal Arc Electrodes

(This Annex is not a part of ANSI/AWS D14.3–94, *Specification for Welding Earthmoving and Construction Equipment*, but is included for information only.)

All electrodes having low-hydrogen coverings conforming to ANSI/AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*, and to ANSI/AWS A5.5, *Specification for Low Alloy Steel Covered Arc Welding Electrodes*, should be purchased in hermetically sealed containers.

Electrodes removed from hermetically sealed containers, or dried electrodes, should be stored in a holding oven at 250°F (120°C) minimum.

Exposure time after removal from hermetically sealed containers, or from holding ovens, should be limited as follows:

E70X5, E70X6, E70X8	4 hours
E80X5, E80X6, E80X8	2 hours
E90X5, E90X6, E90X8	1 hour
E100X5, E100X6, E100X8	1/2 hour
E110X5, E110X6, E110X8	1/2 hour

Exposure times greater than these may require redrying. Instructions for redrying vary with regard to specific electrodes and manufacturer's recommendations. It is recommended that redrying temperatures and times specified by electrode manufacturers be used.

Annex C

Commonly Used Metric Conversions

(This Annex is not a part of ANSI/AWS D14.3–94, Specification for Welding Earthmoving and Construction Equipment, but is included for information only.)

Commonly Used Metric Conversions

Inch—millimeter conversion

1 in. = 25.4 mm exactly

To convert inches to millimeters, multiply the inch value by 25.4

To convert millimeters to inches, divide the millimeter value by 25.4

Inch and Millimeter Decimal Equivalents of Fractions of an Inch

Inch		Millimeter	Inch		Millimeter
Fraction	Decimal		Fraction	Decimal	
1/64	0.015	0.396	33/64	0.515	13.096
1/32	0.031	0.793	17/32	0.531	13.493
3/64	0.046	1.190	35/64	0.546	13.890
1/16	0.062	1.587	9/16	0.562	14.287
5/64	0.078	1.984	37/64	0.578	14.684
3/32	0.093	2.381	19/32	0.593	15.081
7/64	0.109	2.778	39/64	0.609	15.478
1/8	0.125	3.175	5/8	0.625	15.875
9/64	0.140	3.571	41/64	0.640	16.271
5/32	0.156	3.968	21/32	0.656	16.668
11/64	0.171	4.365	43/64	0.671	17.065
3/16	0.187	4.762	11/16	0.687	17.462
13/64	0.203	5.159	45/64	0.703	17.859
7/32	0.218	5.556	23/32	0.718	18.256
15/64	0.234	5.953	47/64	0.734	18.653
1/4	0.250	6.350	3/4	0.750	19.050
17/64	0.265	6.746	49/64	0.765	19.446
9/32	0.281	7.143	25/32	0.781	19.843
19/64	0.296	7.540	51/64	0.796	20.240
5/16	0.312	7.937	13/16	0.812	20.637
21/64	0.328	8.334	53/64	0.828	21.034
11/32	0.343	8.731	27/32	0.843	21.431
23/64	0.359	9.128	55/64	0.859	21.828
3/8	0.375	9.525	7/8	0.875	22.225
25/64	0.390	9.921	57/64	0.890	22.621
13/32	0.406	10.318	29/32	0.906	23.018
27/64	0.421	10.715	59/64	0.921	23.415
7/16	0.437	11.112	15/16	0.937	23.812
29/64	0.453	11.509	61/64	0.953	24.209
15/32	0.468	11.906	31/32	0.968	24.606
31/64	0.484	12.303	63/64	0.984	25.003
1/2	0.500	12.700	1	1.000	25.400

Annex D

Conversions for Fahrenheit-Celsius Temperature Scales

(This Annex is not a part of ANSI/AWS D14.3–94, Specification for Welding Earthmoving and Construction Equipment, but is included for information only.)

Conversions for Fahrenheit – Celsius Temperature Scales

Find the number to be converted in the center (boldface) column. If converting Fahrenheit degrees, read the Celsius equivalent in the column headed “°C.” If converting Celsius degrees, read the Fahrenheit equivalent in the column headed “°F.”

°C	°F	°C	°F	°C	°F	°C	°F
-273	-459	-40	-40	-40	24.4	76	168.8
-268	-450	-34	-30	-22	25.6	78	172.4
-262	-440	-29	-20	- 4	26.7	80	176.0
-257	-430	-23	-10	14	27.8	82	179.6
-251	-420	-17.8	0	32	28.9	84	183.2
-246	-410	-16.7	2	35.6	30.0	86	186.8
-240	-400	-15.6	4	39.2	31.1	88	190.4
-234	-390	-14.4	6	42.8	32.2	90	194.0
-229	-380	-13.3	8	46.4	33.3	92	197.6
-223	-370	-12.2	10	50.0	34.4	94	201.2
-218	-360	-11.1	12	53.6	35.6	96	204.8
-212	-350	-10.0	14	57.2	36.7	98	208.4
-207	-340	- 8.9	16	60.8	37.8	100	212.0
-201	-330	- 7.8	18	64.4	43	110	230
-196	-320	- 6.7	20	68.0	49	120	248
-190	-310	- 5.6	22	71.6	54	130	266
-184	-300	- 4.4	24	75.2	60	140	284
-179	-290	- 3.3	26	78.8	66	150	302
-173	-280	- 2.2	28	82.4	71	160	320
-168	-270	- 1.1	30	86.0	77	170	338
-162	-260	-454					
-162	-260	-436	0.0	32	89.6	82	180
-157	-250	-418	1.1	34	93.2	88	190
-151	-240	-400	2.2	36	96.8	93	200
-146	-230	-382	3.3	38	100.4	99	210
-140	-220	-364	4.4	40	104.0	100	212
-134	-210	-346	5.6	42	107.6	104	220
-129	-200	-328	6.7	44	111.2	110	230
-123	-190	-310	7.8	46	114.8	116	240
-118	-180	-292	8.9	48	118.4	121	250
-112	-170	-274	10.0	50	122.0	127	260
-107	-160	-256	11.1	52	125.6	132	270
-101	-150	-238	12.2	54	129.2	138	280
- 96	-140	-220	13.3	56	132.8	143	290
- 90	-130	-202	14.4	58	136.4	149	300
- 84	-120	-184	15.6	60	140.0	154	310
- 79	-110	-166	16.7	62	143.6	160	320
- 73	-100	-148	17.8	64	147.2	166	330
- 68	- 90	-130	18.9	66	150.8	171	340
- 62	- 80	-112	20.0	68	154.4	177	350
- 57	- 70	- 94	21.1	70	158.0	182	360
- 51	- 60	- 76	22.2	72	161.6	188	370
- 46	- 50	- 58	23.3	74	165.2	193	380

(Continued)

Conversions for Fahrenheit – Celsius Temperature Scales (Continued)

°C	°F	°C	°F	°C	°F	°C	°F
432	810	1490	738	1360	2480	1043	1910
438	820	1508	743	1370	2498	1049	1920
443	830	1526	749	1380	2516	1054	1930
449	840	1544	754	1390	2534	1060	1940
454	850	1562	760	1400	2552	1066	1950
460	860	1580	766	1410	2570	1071	1960
466	870	1598	771	1420	2588	1077	1970
471	880	1616	777	1430	2606	1082	1980
477	890	1634	782	1440	2624	1088	1990
482	900	1652	788	1450	2642	1093	2000
488	910	1670	793	1460	2660	1099	2010
493	920	1688	799	1470	2678	1104	2020
499	930	1706	804	1480	2696	1110	2030
504	940	1724	810	1490	2714	1116	2040
510	950	1742	816	1500	2732	1121	2050
516	960	1760	821	1510	2750	1127	2060
521	970	1778	827	1520	2768	1132	2070
527	980	1796	832	1530	2786	1138	2080
532	990	1814	838	1540	2804	1143	2090
538	1000	1832	843	1550	2822	1149	2100
543	1010	1850	849	1560	2840	1154	2110
549	1020	1868	854	1570	2858	1160	2120
554	1030	1886	860	1580	2876	1166	2130
560	1040	1904	866	1590	2894	1171	2140
566	1050	1922	871	1600	2912	1177	2150
571	1060	1940	877	1610	2930	1182	2160
577	1070	1958	882	1620	2948	1188	2170
582	1080	1976	888	1630	2966	1193	2180
588	1090	1994	893	1640	2984	1199	2190
593	1100	2012	899	1650	3002	1204	2200
599	1110	2030	904	1660	3020	1210	2210
604	1120	2048	910	1670	3038	1216	2220
610	1130	2066	916	1680	3056	1221	2230
616	1140	2084	921	1690	3074	1227	2240
621	1150	2102	927	1700	3092	1232	2250
627	1160	2120	932	1710	3110	1238	2260
632	1170	2138	938	1720	3128	1243	2270
638	1180	2156	943	1730	3146	1249	2280
643	1190	2174	949	1740	3164	1254	2290
649	1200	2192	954	1750	3182	1260	2300
654	1210	2210	960	1760	3200	1266	2310
660	1220	2228	966	1770	3218	1271	2320
666	1230	2246	971	1780	3236	1277	2330
671	1240	2264	977	1790	3254	1282	2340
677	1250	2282	982	1800	3272	1288	2350
682	1260	2300	988	1810	3290	1293	2360
688	1270	2318	993	1820	3308	1299	2370
693	1280	2336	999	1830	3326	1304	2380
699	1290	2354	1004	1840	3344	1310	2390
704	1300	2372	1010	1850	3362	1316	2400
710	1310	2390	1016	1860	3380	1321	2410
716	1320	2408	1021	1870	3398	1327	2420
721	1330	2426	1027	1880	3416	1332	2430
727	1340	2444	1032	1890	3434	1338	2440
732	1350	2462	1038	1900	3452	1343	2450

$$C = 5/9 (F - 32) \quad F = 9/5 C + 32$$

Annex E

Guided Bend Test Jigs

(This Annex is not a part of ANSI/AWS D14.3–94, *Specification for Welding Earthmoving and Construction Equipment*, but is included for information only.)

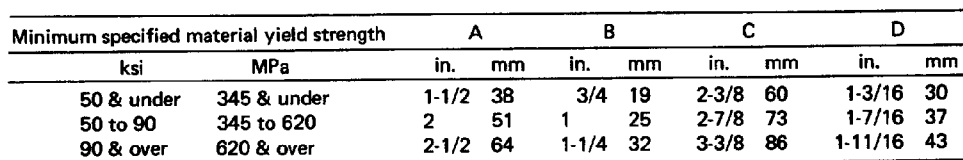


Figure E1—Guided Bend Test Jigs

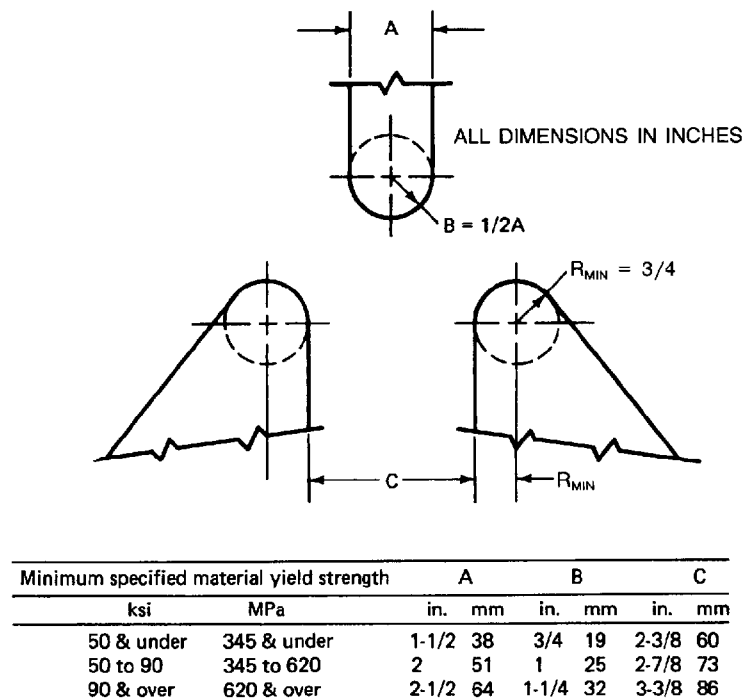


Figure E2—Alternative Roller-Equipped Guided Bend Test Jig for Bottom Ejection of Test Specimen

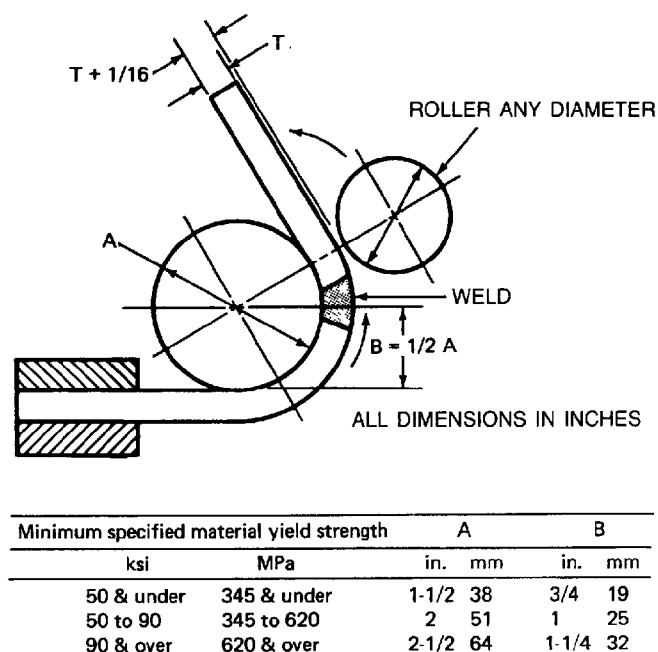


Figure E3—Alternative Wraparound Guided Bend Test Jig

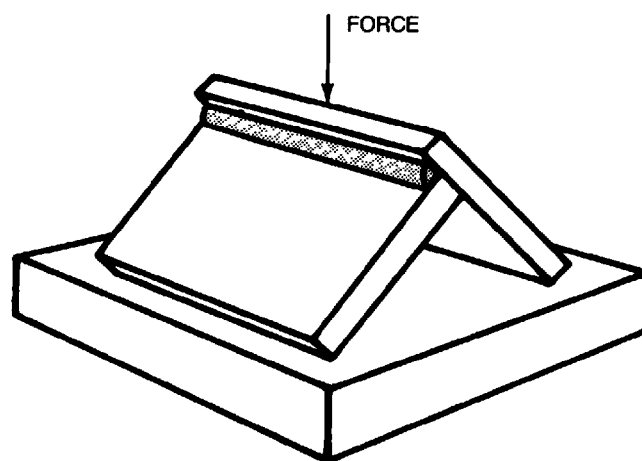


Figure E4—Method of applying load on Fillet Weld break test specimen (Reference 6.3.2.3, Option 1)

Annex F

Safety Considerations

WARNING: Protect yourself and others from possible serious injury or death. The following safety considerations are intended to alert users of this document to potential hazards that may be present during manufacture or repair of weldments on earthmoving and construction equipment. For further detailed information and instruction, refer to ANSI/ASC Z49.1, *Safety in Welding and Cutting*.

(1a) The electrode lead and workpiece lead are electrically “hot” when the welding power source is on. Do not touch these electrically hot parts with your bare skin or wet clothing. Wear dry, hole-free gloves to insulate hands.

(b) In semiautomatic or automatic wire welding, the electrode, electrode reel, welding head, nozzle or semiautomatic welding gun are also electrically “hot.”

(c) Protect yourself from work or ground using dry insulation. When welding in damp locations, on metal framework such as floors, gratings or scaffolds, and when in positions such as sitting or lying, make certain the insulation is large enough to cover your full area of physical contact with work and ground.

(d) Always be sure the workpiece cable makes a good electrical connection with the metal being welded. The workpiece lead connection should be as close as possible to the area being welded.

(e) Ground the work or metal to be welded to a good electrical (earth) ground.

(f) Maintain the electrode holder, work clamp, welding cable and welding machine in good, safe operating condition. Replace damaged insulation.

(g) Never dip the electrode holder or arc welding gun in water.

(h) Never simultaneously touch electrically “hot” parts of electrode holders connected to two welders

because voltage between the two can be the total of the open circuit voltage of both welders.

(i) When working above floor level, protect yourself from a fall should you get a shock.

(j) Also see Items (4c) and (6).

Arc Rays Can Burn

(2a) Use a shield with the proper filter and cover plates to protect your eyes from sparks and the rays of the arc when welding or observing open arc welding. Headshield and filter lens should conform to ANSI Z87.1 standards.

(b) Use suitable clothing made from durable flame-resistant material to protect your skin and that of your helpers from the arc rays.

(c) Protect other nearby personnel with suitable nonflammable or fire retardant screening or warn them not to watch the arc nor expose themselves to the arc rays or to hot spatter or metal.

(d) Read and understand the manufacturer’s instructions for all equipment and the consumables to be used, including the material safety data sheet (MSDS) and follow your employer’s safety practices.

(e) Also see Item (7b).

Fumes and Gases can be Dangerous

(3a) Welding may produce fumes and gases hazardous to health. Avoid breathing these fumes and gases. When welding, keep your head out of the plume. Use enough ventilation or exhaust, or both, at the arc to keep fumes and gases away from the breathing zone. When welding on galvanized, lead, or cadmium plated steel and other metals which produce toxic fumes, even greater care must be taken.

(b) Do not weld in locations near chlorinated hydrocarbon vapors coming from degreasing, cleaning, or spraying operations. The heat and rays of the arc can react with solvent vapors to form phosgene, a highly toxic gas, and other irritating products.

(c) Shielding gases used for arc welding can displace air and cause injury or death. Always use enough ventilation, especially in confined areas, to ensure breathing air is safe.

(d) Read and understand the manufacturer's instructions for all equipment and the consumables to be used, including the material safety data sheet (MSDS), and follow your employer's safety practices.

(e) Also see item (7b).

Welding Sparks can Cause Fire or Explosion

(4a) Remove fire hazards from the welding area. If this is not possible, cover them to prevent the welding sparks from starting a fire. Remember that welding sparks and hot materials from welding can easily go through small cracks and openings to adjacent areas. Have a fire extinguisher readily available.

(b) Where compressed gases are to be used at the job site, special precautions should be used to prevent hazardous situations. Refer to ANSI/ASC, Z49.1, *Safety in Welding and Cutting* and the operating information for the equipment being used.

(c) When not welding, make certain no part of the electrode circuit is touching the work or ground. Accidental contact can cause overheating and create a fire hazard.

(d) Do not heat, cut or weld tanks, drums, or containers until the proper steps have been taken to ensure that such procedures will not cause flammable or toxic vapors from substances inside. They can cause explosion or fires even though they have been "cleaned." For information purchase ANSI/AWS F4.1, *Recommended Safe Practices for the Preparation for Welding and Cutting of Containers and Piping That Have Held Hazardous Substances*.

(e) Vent hollow castings or containers before heating, cutting, or welding. The heat of welding or cutting can cause gases to expand and explode.

(f) Sparks and spatter are generated by certain welding processes. Wear oil-free protective garments such as leather gloves, heavy shirt, cuffless trousers, high shoes and a cap over your hair. Wear ear plugs when welding out of position or in confined places. Always wear safety glasses with side shields when in a welding area.

(g) Connect the work cable to the work as close to the welding area as practical. Work cables connected

to the building framework or other locations away from the welding area increase the possibility of the welding current passing through lifting chains, crane cables, or other alternate circuits. This can create fire hazards or overheat lifting chains or cables until they fail.

(h) Also see Item (7c).

Cylinder may Explode if Damaged

(5a) Use only compressed gas cylinders containing the correct shielding gas for the process used and properly operating regulators designed for the gas and pressure used. All hoses, fittings, etc. should be suitable for the application and maintained in good condition.

(b) Always keep cylinders in an upright position securely chained to an undercarriage or fixed support.

(c) Cylinders should be located:

*Away from areas where they may be struck or subjected to physical damage.

*A safe distance from arc welding or cutting operations and any other source of heat, sparks, or flame.

(d) Never allow the electrode, electrode holder, or any other electrically "hot" parts to touch and damage a cylinder.

(e) Keep your head and face away from the cylinder valve outlet when opening the cylinder valve.

(f) Valve protection caps should always be in place and handtight except when the cylinder is in use or connected for use.

(g) Read and follow the instructions on compressed gas cylinders, associated equipment, and CGA publication P-1, *Precautions for Safe Handling of Compressed Gases in Cylinders*, available from the Compressed Gas Association, 1235 Jefferson Davis Highway, Arlington, VA 22202.

For Electrically Powered Equipment

(6a) Turn **OFF** input power using the disconnect switch at the fuse box before working on the equipment.

(b) Install equipment in accordance with the National Electrical Code, all local codes and the manufacturer's recommendations.

(c) Ground the equipment in accordance with the National Electrical Code and the manufacturer's recommendations.

For Engine Powered Equipment

(7a) Turn the engine **OFF** before troubleshooting and maintenance work unless the maintenance work requires it to be running.

(b) Operate engines in open, well-ventilated areas or vent the engine exhaust fumes outdoors.

(c) Do not spill fuel near an open flame, welding arc or when the engine is running. Stop the engine and allow it to cool before refueling to prevent spilled fuel from vaporizing on contact with hot engine parts and igniting. Do not spill fuel when filling tank. If fuel is spilled, wipe it up and do not start engine until fumes have been eliminated.

(d) Keep all equipment safety guards, covers, and devices in position and in good repair. Keep hands, hair, clothing and tools away from V-belts, gears, fans, and all other moving parts when starting, operating, or repairing equipment.

(e) In some cases it may be necessary to remove safety guards to perform required maintenance. Re-

move guards only when necessary and replace them when the maintenance requiring their removal is complete. Always use the greatest care when working near moving parts.

(f) Do not put your hands near the engine fan. Do not attempt to override the governor or idler by pushing on the throttle control rods while the engine is running.

(g) To prevent accidentally starting gasoline engines while turning the engine or welding generator during maintenance work, disconnect the spark plug wires, distributor cap, or magneto wire as appropriate.

(h) To avoid scalding, do not remove the radiator pressure cap when the engine is hot.

AWS Documents on Machinery and Equipment

Document Code	Title
D14.1	Specification for Welding of Industrial and Mill Cranes and Other Material Handling Equipment
D14.2	Specification for Metal Cutting Machine Tool Weldments
D14.3	Specification for Welding of Earthmoving and Construction Equipment
D14.4	Classification and Application of Welded Joints for Machinery and Equipment
D14.5	Specification for Welding of Presses and Press Components
D14.6	Specification for Welding of Rotating Elements of Equipment

For ordering information, contact the Order Department, American Welding Society, 550 NW LeJeune Road, Miami, FL 33126. Phone: 1-800-443-9353.