

**Specification
for
Underwater Welding**

Keywords — Underwater welding, dry spot welding, habitat welding, one atmosphere welding, wet welding, hyperbaric welding

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An American National Standard

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Specification for **Underwater Welding**

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Prepared by
AWS Committee on Welding in Marine Construction
Subcommittee on Underwater Welding

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This specification covers the requirements for welding structures or components under the surface of water. It includes welding in both dry and wet environments. Sections 1 through 6 constitute the general requirements for underwater welding while sections 7 through 10 contain the special requirements applicable to four individual classes of weld:

- Class A** — Comparable to above-water welding
- Class B** — For less critical applications
- Class C** — Where load bearing is not a primary consideration
- Class O** — To meet the requirements of another designated code or specification



American Welding Society

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Foreword

(This Foreword is not a part of ANSI/AWS D3.6-93, *Specification for Underwater Welding*, but is included for information only.)

In 1975, the AWS Committee on Marine Construction requested the Subcommittee on Underwater Welding to establish a standard reflecting state-of-the-art technology relative to underwater welding. The first edition of the specification was published in 1983, with a subsequent edition issued in 1989.

This current edition is presented in a new format which is intended to facilitate its use. Sections 1 through 6 constitute the general requirements applicable to all classes of underwater welds. Sections 7 through 10 contain unique requirements applicable to each class. A cross-reference is included after the Table of Contents to enable users familiar with the previous format to locate specific data in this new edition.

Initially applied as a means of temporary repair for damaged steel-hulled vessels, underwater welding has evolved into an accepted method of construction and repair of engineered structures. Recent applications include engineered repair and alteration of off-shore structures, submerged marine pipelines, underwater port facilities and nuclear power plant components.

There are five basic methods of underwater welding currently in use:

- (1) Welding in a pressure vessel in which the pressure is reduced to approximately one atmosphere, independent of depth. (Dry welding at one atmosphere).
- (2) Welding at ambient pressure in a large chamber from which water has been displaced in an atmosphere such that the welder/diver does not work in diving equipment. (Dry welding in a habitat).
- (3) Welding at ambient pressure in a simple open-bottomed, dry chamber that accommodates, as a minimum, the head and shoulders of the welder/diver in full diving equipment. (Dry chamber welding).
- (4) Welding at ambient pressure in a small, transparent, gas-filled enclosure with the welder/diver outside in the water. (Dry spot welding).
- (5) Welding at ambient pressure with the welder/diver in the water without any mechanical barrier between the water and the welding arc. (Wet welding).

No sharp distinction exists between these methods; intermediate degrees of weldment and welder protection from the water are in use. Metal transfer characteristics, solidification behavior, weld appearance, mechanical properties, and other characteristics can vary with pressure, and each method of welding may differ from its usual behavior with conventional surface welding. Special quality requirements and inspection procedures must be established for underwater welds because of the altered environment and accessibility. This document is intended to define the important variables associated with underwater welding and to describe welding and inspection procedures so that work of a known quality level can be conveniently specified.

Four weld classes (A, B, C, and O) are specified herein. They encompass the range of quality and properties currently produced by application of the various methods. Each weld class defines a set of criteria for weldment properties that must be established during qualification, and a set of weld soundness requirements that are to be verified during construction. Welds in each class must meet all the criteria specified for that class. This specification does not address the selection of the class that meets the service requirements of a particular application. The selection of the class of weld to be provided is to be prescribed by the customer.

Comments and suggestions for the improvement of this standard are welcome. They should be addressed to the Secretary, Subcommittee on Underwater Welding, American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135. 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 at the American Welding Society. A formal reply will be issued after it has been reviewed by the appropriate personnel following established procedures.

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Specification for Underwater Welding

1. General Provisions

1.1 Scope

This specification covers underwater welding in both dry and wet environments. Operations required at the surface related to and in support of underwater welding are within the scope of this document, but welding above the surface is not. All provisions of this document apply equally to new construction and to modification and repair of existing structures underwater.

1.2 Purpose

This specification addresses fabrication and quality standards for underwater welding. This document may be used in conjunction with other applicable codes or specifications for design, construction, or repair.

1.3 Application

1.3.1 All references to the need for approval shall be interpreted to mean approval by a duly designated person acting for and in behalf of the Customer on all matters within the scope of this specification. The Customer may designate an engineer, inspector or other(s) to act in his behalf to assure that the requirements of this specification are fulfilled. The Customer should specify the authority of his or her authorized representatives. Hereinafter, the term *Customer* is used to mean the party contracting for the work or the authorized representative.

1.3.2 In this specification, the term *shall* indicates a mandatory requirement and has the significance of excluding the idea of discretion. The word *should* indicates a nonmandatory recommended

practice. The word *may* implies no obligation and expresses liberty or permission.

1.3.3 For Class O underwater welds (see 2.1.7), conflicts between referenced documents and this document shall be brought to the attention of the Customer for disposition. In general, the referenced documents may take precedence in matters not affected by the underwater environment. However, this document shall take precedence in matters related to the underwater welding environment and working conditions.

1.4 Base Metals

1.4.1 The base metals presently included under this specification are carbon, low alloy, and austenitic stainless steels commonly used in the fabrication of steel structures. The weldability of the steel and the procedures for welding it shall be established by qualification. Each procedure is qualified based on the carbon equivalent and strength of the base metal to be welded in production. Production welding on base metal of carbon equivalent or strength above that qualified shall require requalification of the procedure. (Carbon equivalent is not applicable to austenitic stainless steel base metals.)

1.4.2 This specification may be used for welding of other base metals. In such cases, applicability of specific requirements shall be determined by the Customer.

1.5 Welding Process

1.5.1 Gas metal arc welding (GMAW), gas tungsten arc welding (GTAW), flux cored arc welding (FCAW), plasma arc welding (PAW), and shielded

metal arc welding (SMAW) are the principal joining processes addressed by this specification. These processes may be used, provided the welding procedure is qualified in accordance with all applicable requirements of this document.

1.5.2 Other welding processes may be used at the discretion of the Customer, provided the applicable qualification requirements of this specification are met.

1.6 Definitions

The welding terms used in this specification shall be interpreted in accordance with the definitions given in the latest edition of ANSI/AWS A3.0, *Standard Welding Terms and Definitions*, supplemented by section 11 of this document (ANSI/AWS D3.6).

1.7 Welding and NDE Symbols

Welding and examination symbols shall be those shown in ANSI/AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Testing*. Special conditions shall be fully explained by added notes or details.

1.8 Safety and Health

This document does not address welding and diving safety and health standards. It is not a safety standard and does not establish performance requirements or provide other guidance on safety issues or procedures associated with diving or underwater welding. However, some pertinent welding safety information can be found in the document's references in section 12. In addition, manufacturer's safety literature on equipment and materials, as well as other pertinent documents, should be considered. Each contractor must determine independently whether the safety precautions contained in the referenced publications are adequate.

1.9 Standard Units of Measure

U.S. Customary units of measurement are the standard. SI units are used parenthetically and may be approximate.

1.10 Referenced Standards

It shall be the responsibility of the Customer to specify the appropriate editions of the standards referenced in this specification.

2. Classification and Design of Welded Connections

2.1 Classification of Welds

2.1.1 A *weld class* specifies a level of serviceability and a set of required properties, as defined by mechanical tests, surface appearance, and nondestructive examination requirements, to which welds of a given class must conform.

2.1.2 In any solicitation for work, contract, or bid, the Customer shall specify each weld class and any supplementary requirements for the proposed work. All welds produced in accordance with this specification shall be made in accordance with a qualified welding procedure and shall meet the general requirements applicable to all weld classes specified in sections 1 through 6 and the unique requirements for one or more of the weld classes specified in this section. Each designated weld must meet all the requirements for the weld class specified.

2.1.3 Toughness and hardness of welds that are made underwater may be significantly different from those properties of similar welds made above the surface. The Customer may specify supplemental requirements for any class of weld.

2.1.4 Class A Welds. Class A underwater welds are intended to be suitable for applications and design stresses comparable to their conventional surface welding counterparts by virtue of specifying comparable properties and testing requirements. The unique requirements for Class A welds are specified in section 7. Additional requirements may be appropriate for critical applications, and should be agreed to in advance and specified in the contract document.

2.1.5 Class B Welds. Class B underwater welds are intended for less critical applications where lower ductility, greater porosity, and other relatively large discontinuities can be tolerated. The unique requirements for Class B welds are specified in section 8. The suitability of a Class B weld for a particular application should be evaluated on a "Fitness for Purpose" basis.

2.1.6 Class C Welds. Class C underwater welds need only satisfy lesser requirements than class A, B, and O and are intended for applications where the load-bearing function is not a primary consideration. The unique requirements for Class C welds are specified in section 9. Selection of a Class C weld should include a determination that its use will not impair the integrity of the primary structure by creating fracture-initiation sites.

2.1.7 Class O Welds. Class O underwater welds must meet the requirements of some designated code or specification, as well as additional requirements, defined herein, to cope with the underwater welding environment and working conditions. The unique requirements for Class O welds are specified in section 10. The Customer shall specify the standard that applies to these types of welds.

2.2 Design

This specification does not address design considerations such as arrangement of parts or stress calculations. The Customer shall determine the service conditions, the required performance level, and the appropriate design stress level. The Customer shall specify selection of the weld class, inspection method, and acceptance criteria.

3. Workmanship

3.1 General

All welds produced in accordance with this specification shall be examined using the criteria specified for the particular weld class. This requirement is met when the results of all required examinations are submitted to and accepted by the Customer.

3.2 Base Metal Preparation

3.2.1 Corrosion pits or other discontinuities that would adversely affect the integrity of the weld shall be repaired. When repair by welding is required, the welding procedure shall be qualified to the specification requirements of section 5, for the weld class specified. The repair procedure shall be submitted to the Customer for approval before weld repair begins. The surfaces to be welded and the surfaces adjacent to the weld shall be free from scale, paint, marine growth, or other foreign matter.

3.2.2 In the repair of excessive discontinuities observed on cut edges, such as entrapped slag, refractory inclusions, deoxidation products, porosity, or blow holes, the amount of metal removed shall be the minimum necessary to eliminate the discontinuity, unless otherwise specified in the repair procedure.

3.2.3 Laminations in plate edges may, with the approval of the Customer, be repaired by welding. The repair shall include complete removal of the lamination or removal of metal to a distance equal to the lesser of half of the base metal thickness or 3/8 in. (9.5 mm) from the original prepared edge, using a method described in the approved repair procedure. Welding shall be performed with procedures qualified for production welding or with pro-

cedures qualified specifically for the repair. The Customer shall be notified before repair commences.

3.3 Assembly

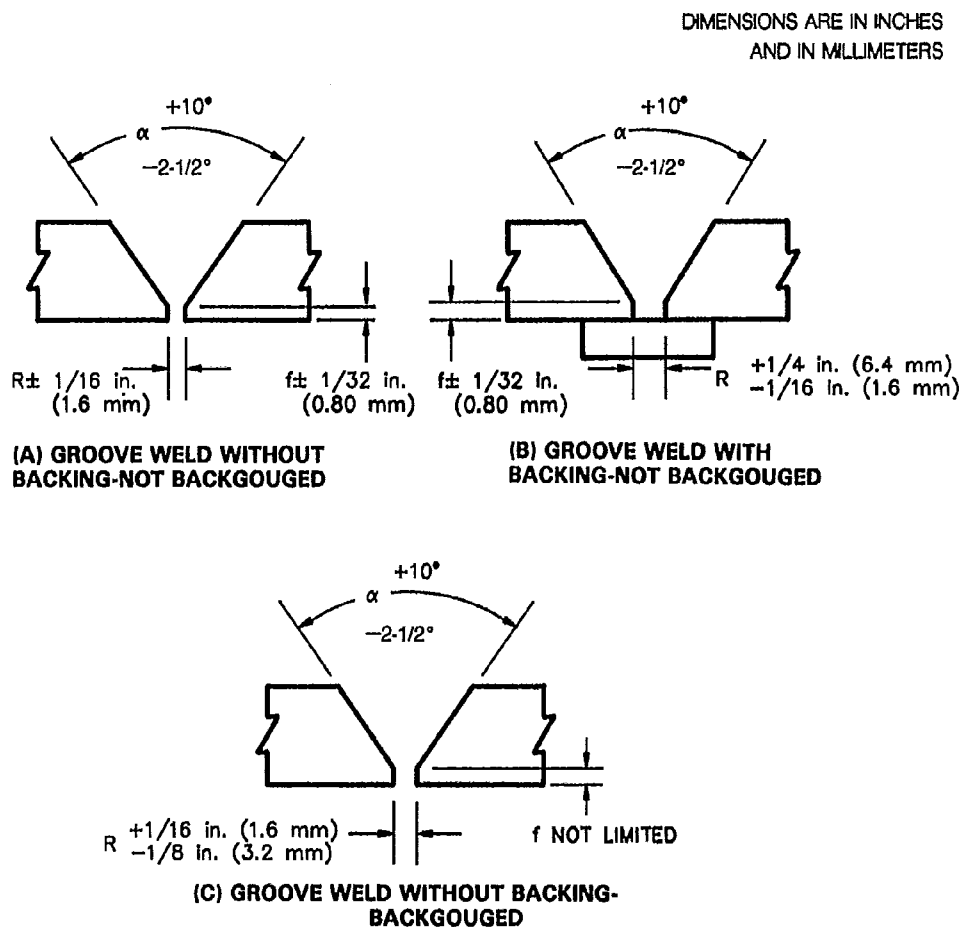
3.3.1 Dry Welding

3.3.1.1 Tolerances for the weld preparation and joint fit-up shall be developed during welding procedure qualification. Alternatively, the tolerances given on Figure 1 may be applied to groove welds. In either case, the qualified welding procedure shall define the limits.

Where irregularities prevent alignment or fit-up to limits identified in the qualified welding procedure, alternative methods may be used to achieve the limits, subject to the Customer's approval. Welding procedures utilized to achieve acceptable fit are also required to be qualified under the rules of this specification. See 5.9.3 for additional requirements.

3.3.1.2 The parts to be joined by fillet welds shall be brought into as close contact as practical. The root opening shall not exceed the maximum permitted by the qualified welding procedure. If the root opening cannot be closed to meet this tolerance, a suitable compensating technique approved by the Customer shall be required. Any increase in the size of the root opening beyond 1/16 in. (1.6 mm) shall require that the leg of the fillet weld be increased by a similar amount.

3.3.2 Wet Welding. Joint assembly tolerances shall be developed during welding procedure qualification. The assembly and fit-up tolerances shall be defined in the qualified welding procedure and approved by the Customer prior to the start of production welding.

**Notes:**

1. α groove angle.
2. R root opening.
3. f root face.
4. The groove configurations shown are for illustration only.

Figure 1 — Tolerances in Assembly of Groove Weld Butt Joints — Dry Welding

3.4 Confirmation Weld

3.4.1 General. A test weld shall be produced at the underwater work site, before production welding begins, to confirm that the welding system for each process is operating correctly. It is not intended to function as part of welding procedure or welder performance qualification. The procedure used for the

confirmation weld shall conform to the qualified welding procedure, except as amended by 3.4.2. Procedure qualification at the site shall satisfy the requirement for the confirmation weld. Where more than one welding system of a given type is used at a dive site, only one confirmation weld is required. The Customer shall designate the welding system that shall be used to make the confirmation weld.

3.4.2 Confirmation Base Metals

3.4.2.1 The base metal for the confirmation weld should have a carbon equivalent (C.E.) within 0.05 of the C.E. of the production base metal. The chemical composition restrictions of 5.6.1 are not applicable.

3.4.2.2 The joint root geometry shall conform to the production weld geometry, i.e., with or without open root, or with a joint backing strip. Where both fillet and groove welds will be made in production, one confirmation groove weld is sufficient.

3.4.2.3 Where the production weld is less than 1/2 in. (12.7 mm) in thickness, the confirmation weld shall be made on the thinnest metal to be used in production. Where the production weld exceeds 1/2 in. (12.7 mm) in thickness, the confirmation weld may be limited to 1/2 in. (12.7 mm) thickness. Multiple-pass production welding shall require a multiple-pass confirmation weld.

3.4.3 Position. Where the production weld is to be made in only one welding position, the confirmation weld shall be made in that position. Where welding in more than one position is necessary, the confirmation weld shall be made in the vertical or overhead position or the position in production in which the majority of welding will be done.

3.4.4 Length of Confirmation Weld. Confirmation weld length shall be 6 in. (150 mm) to 12 in. (300 mm) unless otherwise specified by the Customer.

3.4.5 Examination Requirements. The examination requirements of the confirmation weld should be the same as the production weld. The acceptability of the confirmation weld shall be evaluated, as a minimum, by visual examination.

3.5 Dimensional Tolerances

The sizes and lengths of welds shall not be smaller than those specified. Fillet weld sizes shall not exceed the specified sizes by more than 25% or 1/8 in. (3.2 mm), whichever is greater. The lengths of the weld shall not exceed the specified length by more than 1 in. (25 mm) or 15%, whichever is greater, without the Customer's approval. The lo-

cation of welds shall not be changed without the approval of the Customer.

3.6 Weld Profiles

All welds must be neat and workmanlike in appearance and shall, as a minimum, meet the visual acceptance criteria for weld profiles as defined in Part III of sections 7 through 10 for **Class A** through **O** welds, respectively.

3.7 Tack Welds and Temporary Welds

3.7.1 All tack welds incorporated in the final weld shall be subject to the same qualification requirements and acceptance criteria as the final welds.

3.7.2 The location and dimensions of temporary welds are subject to prior approval by the Customer. Temporary welds, including tack welds that are not incorporated in the final weld, shall be removed, unless otherwise permitted by the Customer. Removal of temporary welds shall be accomplished using a procedure that does not cause damage to the base metal. Temporary welds not removed shall conform to the requirements of this specification for the class of weld selected.

3.8 Repairs

3.8.1 The removal of weld metal or portions of the base metal shall be done by a method approved by the Customer, and in such a manner that the remaining weld metal or base metal is not damaged. The surfaces shall be restored to a suitable condition before rewelding.

3.8.2 Flaws may be removed by grinding. The base metal thickness shall not be reduced below the required minimum thickness. If the required minimum base metal thickness is violated, the surface shall be restored by welding, using a qualified procedure.

3.8.3 Prior approval shall be obtained from the Customer for all corrections. The repaired or replaced weld shall be reinspected using the technique and acceptance criteria as originally specified.

3.8.4 The correction shall be in accordance with the original welding procedure or with a procedure prepared specifically for the repair, and qualified in accordance with this specification.

3.9 Peening

The weld root shall not be peened. Peening of subsequent weld beads is permitted only with prior approval of the Customer. Care shall be taken to prevent slag entrapment, overlap, or cracking of the welds. The cap or toe of a finished weld may be peened with a blunt instrument, when approved by the Customer, but such peening shall be preceded by all required nondestructive examination and followed by an additional examination using magnetic particle methods.

3.10 Arc Strikes

Arc strikes outside the area of permanent welds should be avoided on any base metal. Cracks or blemishes caused by arc strikes shall be ground to a smooth contour.

3.11 Weld Cleaning

After completion of a weld, the weldment surfaces shall be cleaned and prepared such that surface finish conditions will not interfere with inspections or nondestructive examinations to be employed. Excessive slag and spatter shall be removed from the weld and adjacent base metal. Surface discontinuities which could mask weld defects shall be removed.

4. Technique

4.1 Filler Metal

4.1.1 After filler metals are removed from their original package, they shall be protected or stored so that their characteristics and welding properties are not adversely affected. Surface storage conditions shall conform to the filler metal manufacturer's recommended practice, or an alternate written procedure shall be submitted to the Customer for approval.

4.1.2 There shall be no addition or deletion of electrode coatings, e.g., waterproofing, from those used during welding procedure qualification.

4.1.3 Methods of underwater transport and storage of filler metals shall be specified in the welding procedure.

4.2 Measurement of Variable Conditions

Effective means of verifying variables (such as welding current, arc voltage, and shielding gas composition and flow rate) should be provided at the underwater worksite. If not measured at the worksite, provisions shall be made to ensure that compensation has been made for the effects of the leads, ambient pressure, and other operating conditions. Records of welding variables to be maintained during production shall be as specified by the Customer.

4.3 Weld Temperature Control

Where weld temperature control is utilized during procedure qualification, the procedure qualification record shall state the required temperature range and the time at temperature. The method used for temperature measurement and control and the maximum and minimum heating and cooling rates at temperatures exceeding 500°F (260°C) shall be specified.

5. Qualification

Part I General Requirements

5.1 Approved Procedure

5.1.1 Procedure Specification. All welding shall be performed in accordance with a Welding Procedure Specification (WPS) which meets the requirements of this section. The WPS employed shall be qualified prior to production welding in accordance with the requirements of this section. Satisfactory evidence that the procedure has been qualified shall be submitted to the Customer in the form of a Procedure Qualification Record (PQR) supporting the WPS and approved by the Customer prior to any production welding.

5.1.2 Procedure Qualification. A welding procedure specification is qualified by testing weldments produced under actual or simulated site conditions. The test welds shall demonstrate that a joint of required integrity can be made within the essential variables of the procedure specification. The specific tests required for each weld class are identified in Part I of sections 7 through 10 for Class A through O welds, respectively.

5.2 Previous Qualification

The Customer may accept evidence of previous qualification, provided all the requirements of this specification are met.

5.3 Performance Qualification

All persons performing any welding shall be qualified for a given weld class in accordance with this section. Satisfactory evidence that the requirements are met shall be submitted to and approved by the Customer prior to any production welding.

5.4 Qualification Responsibility

Each Contractor is responsible for the qualification of welding procedures and welders employed in performing work to this specification and shall conduct the tests required to accomplish these qualifications. Satisfactory evidence that the procedure and welders have been qualified shall be submitted to and approved by the Customer prior to production welding.

Part II Procedure Qualification

5.5 Limitation of Variables

5.5.1 Essential and Nonessential Variables. Each welding variable described in 5.6 is designated as either an essential or nonessential variable for each process.

5.5.2 Limitations on Essential and Nonessential Variables. Changes in essential variables beyond the limits specified in Tables 1 (Dry Welding Variables) and 2 (Wet Welding Variables), require development and qualification of a separate procedure or revision and requalification of an existing welding procedure. The qualified ranges of essential variables are those used during the procedure qualification test. Changes may be made in the nonessential variables without requalification of the procedure. This may be documented by revising or amending the original Welding Procedure Specification (WPS), or by preparing a new WPS.

5.5.3 Electrical Measurement Accuracy. Electrical measurements made under qualification and production conditions will involve different levels of accuracy. Accordingly, the electrical ranges discussed in this specification are considered nominal values.

Table 1
Welding Variables

Dry Welding by Shielded Metal Arc, Gas Metal Arc, Flux Cored Arc, Gas Tungsten Arc, and Plasma Arc Welding Processes	
A. Variables Common to All Welding Processes	
1. Joints	
(a) Fillet weld to groove weld	Essential
(b) Multiple pass fillet weld to single pass fillet weld and vice versa	Essential
(c) Omission of backing	Essential
(d) A change greater than 25% in the number of passes per unit area of groove weld cross-section	Essential
(e) A backing thickness change of 1/16 in. (1.5 mm) or 25%, whichever is greater	Essential
(f) Groove shape: a decrease in included angle, a decrease in root opening, or an increase in root face beyond the range specified in 5.9.3	Essential
(g) Groove weld to multiple pass fillet weld, subject to paragraph 5.9.2	Nonessential
(h) Fillet weld size: For fillet welding procedure qualification, the maximum production weld size (leg length) shall be 1.5t. The minimum production fillet weld size shall be 0.5t (subject to A.1.(b) above). Qualification on two different fillet weld sizes also qualifies for all intermediate sizes	Essential
2. Base Metal	
(a) Thickness: For groove welding procedure qualification with a test plate or pipe thickness, t, the maximum production thickness shall be 1.5t. The minimum production plate or pipe thickness shall be 0.50 t. Qualification on two different thicknesses of plate or pipe also qualifies all intermediate thicknesses	Essential
(b) A change in chemical composition beyond that qualified in 5.6.1	Essential
(c) An increase in specified minimum tensile strength beyond the greater of (a) the all-weld-metal tensile strength, or (b) the tensile strength measured in the transverse tension test	Essential
3. Filler Metal	
(a) AWS filler metal classification or type	Essential
(b) Procedure for underwater transport and storage	Essential
(c) Addition or deletion of supplementary coating	Essential
(d) An increase in exposure time of filler metal in the qualification depth atmosphere	Essential
4. Position	
(a) Any change beyond that qualified in Table 4	Essential
5. Weldment Temperature	
(a) A decrease in preheat or interpass temperature	Essential
(b) A decrease in postweld heat treatment temperature or time at postweld heat treatment temperature	Essential
6. Electrical Characteristics	
(a) Welding current type (direct current electrode positive, direct current electrode negative, pulsed current, and others)	Essential
(b) Type of power source (constant current, constant voltage)	Essential
(c) Welding current	Essential
(d) Arc voltage	Essential
7. Technique	
(a) Stringer bead to weave and vice versa	Essential
(b) Progression up or down	Essential
(c) Deletion of temper bead	Essential
(d) Decrease in accessibility or visibility from change in dimensions of shroud or components	Essential
(e) Change in travel speed or electrode run length	Essential
(f) Welding method (manual, semiautomatic, automatic)	Essential

(Continued)

Table 1 (Continued)

(g) Joint cleaning	Essential
(h) Addition or elimination of peening	Essential
(i) Addition of temper bead	Nonessential
(j) Progression direction for the initial pass on joints welded from both sides where the root pass is backgouged to sound weld metal prior to welding the second side	Nonessential
8. Environment	
(a) Change in depth beyond that allowed in 5.6.2	Essential
(b) Back side dry to wet	Essential
(c) Increase in oxygen partial pressure of the background gas	Essential
(d) Change in background gas composition beyond that associated with the depth change allowance in 5.6.2	Essential
(e) The introduction of new background gas into a previously qualified composition	Essential
(f) Back side wet to dry	Nonessential
(g) Diving mode	Nonessential
B. Shielded Metal Arc Welding	
3. Filler Metal	
(a) Manufacturer	Essential
(b) Manufacturer's type	Essential
(c) In root, hot, and cap passes, a change in electrode diameter (standard size)	Essential
(d) In fill passes, use of an electrode with a diameter not used during overall qualification	Essential
6. Electrical Characteristics	
(a) Welding current and arc voltage exceeding 15% of the maximum, or -15% of the minimum of that qualified	Essential
C. Gas Metal Arc Welding	
3. Filler Metal	
(a) Diameter	Essential
(b) Manufacturer's type ERXXS-G (AWS A5.18 or A5.28)	Essential
(c) Manufacturer	Nonessential
(d) Manufacturer's type except classification ERXXS-G	Nonessential
6. Electrical Characteristics	
(a) Welding current exceeding +10% of the maximum, or -10% of the minimum of that qualified	Essential
(b) Arc voltage exceeding +7% of the maximum, or -7% of the minimum of that qualified	Essential
(c) Mode of metal transfer (spray, globular, short-circuiting)	Essential
9. Gas	
(a) Addition or deletion of gas	Essential
(b) Composition	Essential
(c) Flow rate changes exceeding +25% of the maximum, or -25% of the minimum of that qualified	Essential
(d) Nozzle orifice diameter (size change)	Essential
D. Flux Cored Arc Welding	
3. Filler Metal	
(a) Manufacturer	Essential
(b) Manufacturer's types (even if both meet the same AWS Classification)	Essential
(c) Diameter	Essential
6. Electrical Characteristics	
(a) Welding current exceeding +10% of the maximum, or -10% of the minimum of that qualified	Essential

(Continued)

Table 1 (Continued)

(b) Arc voltage exceeding +7% of the maximum, or -7% of the minimum of that qualified	Essential
(c) Mode of metal transfer (spray, globular)	Essential
9. Shielding Gas	
(a) Addition or deletion of gas	Essential
(b) Composition	Essential
(c) Flow rate change exceeding +25% of the maximum, or -10% of the minimum of that qualified	Essential
(d) Nozzle orifice diameter (size change)	Essential
E. Gas Tungsten Arc and Plasma Arc Welding	
3. Filler Metal	
(a) Manufacturer	Essential
(b) Manufacturer's types (even if both meet the same AWS Classification)	Essential
(c) Diameter	Essential
6. Electrical Characteristics	
(a) Welding current exceeding +10% of the maximum, or -10% of the minimum of that qualified	Essential
(b) Arc Voltage exceeding +7% of the maximum or -7% of the minimum of that qualified	Essential
(c) Arc initiation method	Nonessential
(d) Electrode (non-consumable) type	Nonessential
(e) Electrode (non-consumable) size	Nonessential
9. Gas	
(a) Addition or deletion of gas	Essential
(b) Gas composition (shielding and orifice)	Essential
(c) Flow rate change exceeding +25% of the maximum, or -10% of the minimum of that qualified	Essential
(d) Nozzle orifice diameter (size change)	Essential

**Table 2
Welding Variables****Wet Welding by Shielded Metal Arc or Flux Cored Arc Welding****A. Variables Common to All Welding Processes****1. Joints**

(a) Fillet weld to groove weld	Essential
(b) Multiple pass fillet weld to single pass fillet weld and vice versa	Essential
(c) Omission of backing	Essential
(d) A change greater than 25% in the number of passes per unit area of the groove	Essential
(e) Groove shape: a decrease in included angle, a decrease in root opening, or an increase in root face beyond the range qualified (refer to 5.9.4)	Essential
(f) Groove weld to multiple pass fillet weld subject to paragraph 5.9.2	Nonessential
(g) Fillet weld size: For fillet welding procedure qualification, the maximum production weld size (leg length) shall be 1.5t. The minimum production fillet weld size shall be 0.5t (subject to A.1.(b) above). Qualification on two different fillet weld sizes also qualifies for all intermediate sizes	Essential

(Continued)

Table 2 (Continued)

2. Base Metal

- | | |
|---|-----------|
| (a) Thickness: For groove welding procedure, qualification with a test plate or pipe thickness, t , the maximum production plate or pipe thickness shall be 1.5 t . The minimum production plate or pipe wall thickness shall be 0.5 t . However, if the production weld thickness is 1/4 in. (6 mm) or less, the test weld shall be the same thickness | Essential |
| (b) An increase in carbon equivalent of the steel above that qualified | Essential |
| (c) An increase in the specified minimum tensile strength beyond that qualified | Essential |
| (d) A change in chemical composition beyond that qualified in 5.6.1 | Essential |

3. Filler Metal

- | | |
|--|-----------|
| (a) Manufacturer | Essential |
| (b) Manufacturer's types (even if both meet the same AWS Classification) | Essential |
| (c) Diameter | Essential |
| (d) Methods of underwater transport or storage | Essential |
| (e) Addition, deletion, or change of supplementary coatings or waterproofing | Essential |
| (f) An increase in exposure time of filler metal in the qualification depth atmosphere | Essential |

4. Position

- | | |
|---|-----------|
| (a) Any change beyond that qualified in Table 4 | Essential |
|---|-----------|

5. Weldment Temperature

- | | |
|------------------------------------|-----------|
| (a) A change in any heat treatment | Essential |
|------------------------------------|-----------|

6. Electrical Characteristics

- | | |
|---|-----------|
| (a) Welding current type (direct current electrode positive, direct current electrode negative, pulsed current, and others) | Essential |
| (b) Type of power source (constant current, constant voltage) | Essential |
| (c) Welding current exceeding +10% of the maximum, or -10% of the minimum of that qualified | Essential |
| (d) Arc voltage exceeding +10% of the maximum, or -10% of the minimum of that qualified | Essential |

7. Technique

- | | |
|---|--------------|
| (a) Stringer bead to weave or vice versa | Essential |
| (b) Progression up or down | Essential |
| (c) Deletion of temper bead | Essential |
| (d) Change in weld bead sequence | Essential |
| (e) Travel speed or electrode run length beyond the range qualified | Essential |
| (f) Joint cleaning | Essential |
| (g) Addition, deletion, or change in any type of barrier to restrict water access during welding or cooling | Essential |
| (h) Addition of temper bead | Nonessential |
| (i) Progression direction for the root pass on double welded joints where second side is back gouged to sound metal | Nonessential |

8. Environment

- | | |
|--|--------------|
| (a) Change in depth beyond that allowed in 5.6.2 | Essential |
| (b) Back side dry to wet if material thickness is 1/4 in. (6 mm) or greater | Essential |
| (c) Back side dry to wet and vice versa if material thickness is less than 1/4 inch (6 mm) | Essential |
| (d) Pressure differential between back and front side of weld greater than that qualified | Essential |
| (e) Diving mode | Nonessential |
| (f) Water current | Nonessential |
| (g) Salinity (salt water to fresh water and vice versa) | Nonessential |

5.6 Procedure Qualification Variables

Variables for welding procedure qualification are listed in Tables 1 and 2, and described in the following sections. In general, for Class O welds, the referenced documents take precedence. However, this document shall take precedence in regard to essential variables and the extent of nondestructive and destructive examination.

5.6.1 Requirements for Base Metals

5.6.1.1 The chemical composition and carbon equivalent (if applicable) of steel procedure qualification test plates shall be determined by chemical analysis.

5.6.1.2 The chemical compositions of all base metals to be welded in production shall be known or determined in accordance with any of the following methods.

(1) Specification limits — The chemical composition of the metal may be based on the maximum values permitted by the applicable specification(s), if it can be demonstrated that all heats of the metals to be welded in production were produced in accordance with the referenced specification(s).

(2) Certified Mill Test Reports — The chemical composition of the metal may be based on the maximum values from certified ranges provided by the supplier for the heats of metal to be welded in production.

(3) Analysis using standard test methods — the chemical composition of the metal may be based on the actual values as determined from analyses performed in accordance with ASTM Standard Test Methods for each heat of material to be welded in production.

(4) Historical data — The chemical composition of the metal may, with Customer approval, be estimated, based on the highest values from historical data, provided it can be demonstrated that the historical data is representative of all the metals to be welded in production.

5.6.1.3 The carbon equivalent of carbon and low alloy steels used for welding procedure qualification shall not be less than the carbon equivalent of the steel to be welded in production, as determined by the following formula:

$$CE = C + \frac{Mn}{6} + \frac{Cr + Mo + V}{5} + \frac{Ni + Cu}{15} \quad (\text{Eq. 1})$$

When only carbon and manganese are known, the following alternative formula may be used:

$$CE = C + \frac{Mn}{6} + 0.05 \quad (\text{Eq. 2})$$

The values for the elements in the above formulas are expressed in weight percent. Other methods of determining the carbon equivalent may be used if permitted by the Customer.

5.6.1.4 Procedure qualification testing shall be performed on material as near as practical to the chemical composition and tensile strength of the production metal, but in no case with a carbon content less than the metal to be welded in production.

5.6.1.5 The known presence of the following elements in the base metal exceeding the indicated weight percentages shall require similar percentages of those elements in the procedure test plate:

- (1) cerium, 0.03%
- (2) chromium, 0.25%
- (3) copper, 0.40%
- (4) lead, 0.05%
- (5) molybdenum, 0.15%
- (6) nickel, 0.40%
- (7) columbium (niobium), 0.05%
- (8) phosphorous, 0.05%
- (9) sulfur, 0.05%
- (10) titanium, 0.05%
- (11) vanadium, 0.12%

5.6.2 Depth Range

5.6.2.1 Welding procedure qualification depth limitations shall be in accordance with Table 3.

5.6.2.2 For all welding, qualification at two depths qualifies for any depth between the two.

5.6.2.3 The effects of wave action when welding at shallow depths should be considered.

5.7 Types of Tests

The welded test assemblies required to qualify a welding procedure are described in Part I of

Table 3
Depth Limitations for Qualification Welding

Type of Welding	Depth of Production Welding	Max. Depth Qualified	Min. Depth Qualified
Dry welding	All	X plus 33 ft (10 m)	X minus 33 ft (10 m) or 0.2X, whichever is greater
Wet welding with mild steel filler metal	Greater than 10 ft	X plus 33 ft (10 m)	X minus 33 ft (10 m) or 0.2X, whichever is greater
	Equal to or less than 10 ft (3 m)	X plus 33 ft (10 m)	X
Wet welding with austenitic stainless steel filler metal	All	X plus 10 ft (3 m)	X minus 33 ft (10 m) or 0.2X, whichever is greater
Wet welding with other filler metal	All	X	X minus 33 ft (10 m) or 0.2X, whichever is greater

Notes:

1. X is qualification test depth.
2. For the maximum depth qualified, depth shall be measured from the lower extremity of the test weldment with a tolerance of plus or minus 9 in. (230 mm)
3. For the minimum depth qualified, depth shall be measured from the upper extremity of the test weldment with a tolerance of plus or minus 9 in. (230 mm)

Sections 7 through 10 for **Class A** through **O** welds, respectively. The assemblies shall be welded with the procedure that is to be qualified, and they shall satisfy all the test requirements for the weld class in the procedure.

5.8 Position of Test Welds

Welding positions for groove and fillet welds are defined in Figures 2 and 3, respectively.

5.8.1 Welding position is an essential variable. Production positions qualified by specific test positions are listed in Table 4.

5.8.2 After a groove weld procedure for plate has been qualified in one position, a smaller test plate and fewer tests are required to qualify additional positions. The "first position" and "additional position" test plates are identified in Part I of sections 7 and 8 for **Class A** and **B** welds, respectively. The

Customer shall determine which position is to be used for the first position (i.e., larger test plate).

5.8.3 After a groove weld procedure for pipe has been qualified in one position, additional positions may be qualified by making similar welds that are tested as identified in Part I of sections 7 and 8 for **Class A** and **B** welds, respectively. Each procedure shall be tested in the manner indicated in 5.8.5 and 5.8.7.

5.8.4 Plate Groove Welds.

In making the tests to qualify groove welds, test plates shall be welded in the following positions (illustrated in Figure 4):

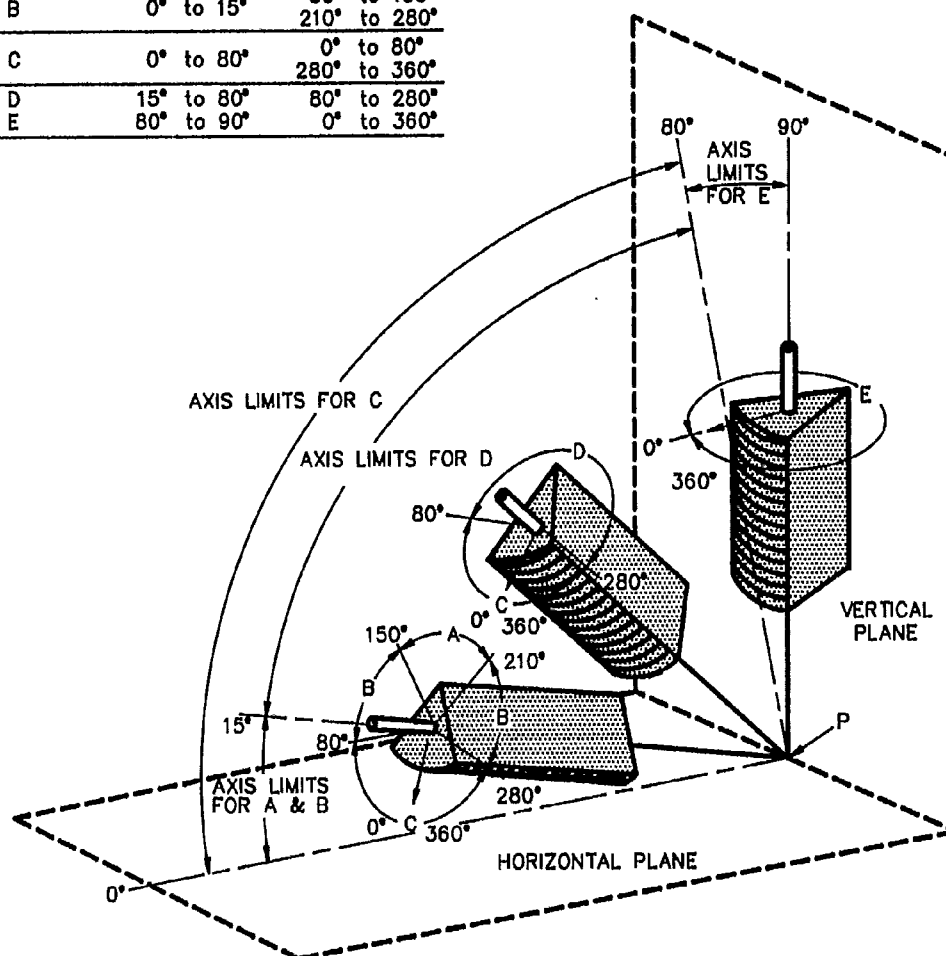
(1) Position 1G (Flat) — The plates are placed in an approximately horizontal plane and the weld metal is deposited from the upper side. See Figure 4(A).

(2) Position 2G (Horizontal) — The plates are placed in an approximately vertical plane with the groove approximately horizontal. See Figure 4(B).

(3) Position 3G (Vertical) — The plates are

TABULATION OF POSITIONS OF GROOVE WELDS

POSITION	DIAGRAM REFERENCE	INCLINATION OF AXIS	ROTATION OF FACE
FLAT	A	0° to 15°	150° to 210°
HORIZONTAL	B	0° to 15°	80° to 150° 210° to 280°
OVERHEAD	C	0° to 80°	0° to 80° 280° to 360°
VERTICAL	D	15° to 80°	80° to 280°
	E	80° to 90°	0° to 360°



Notes:

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

Figure 2 — 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°
	E	80° to 90°	0° to 360°

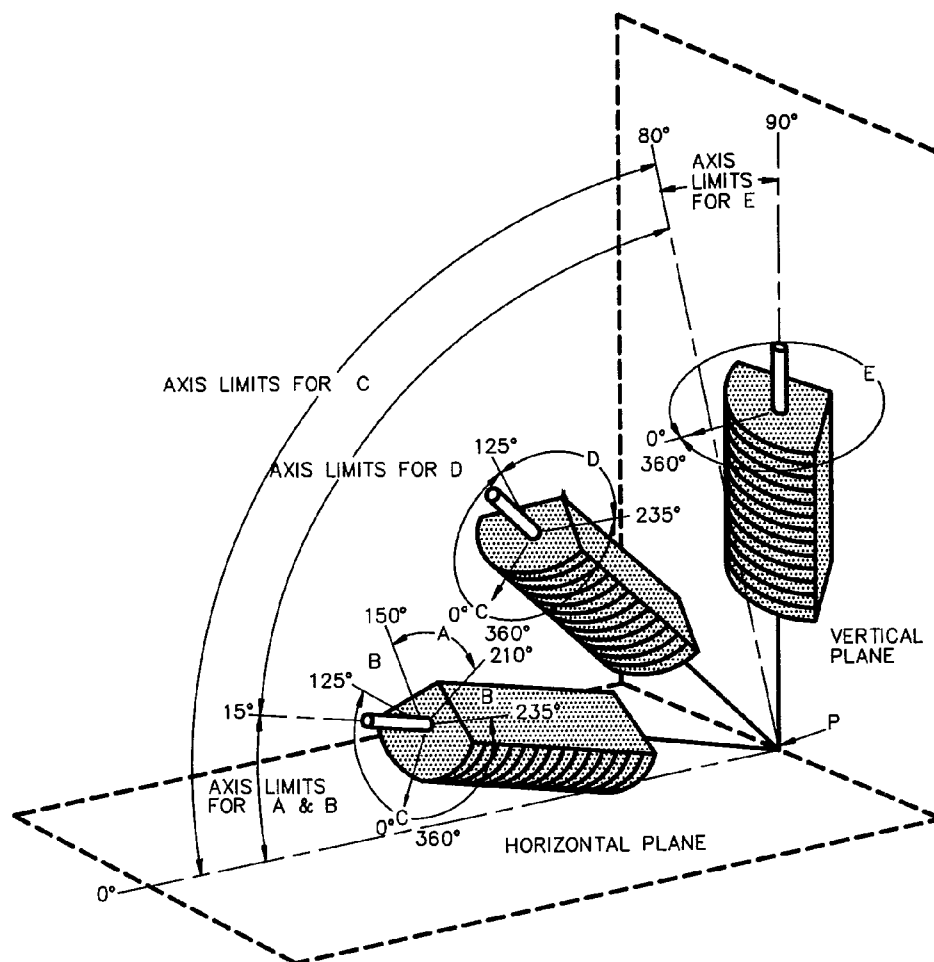


Figure 3 — Positions of Fillet Welds

Table 4
Procedure Qualification — Type and Position Limitations

Qualification Test		Type of Weld and Position of Welding Qualified ^(a)			
		Plate ⁽¹⁾		Pipe ⁽¹⁾	
Weld	Plate or Pipe Positions ^(b)	Groove	Fillet	Groove	Fillet ⁽³⁾
Plate-groove	1G	F	F	F	F
	2G	H	H	H	H
	3G	V	V		
	4G	OH	OH		
Plate-fillet	1F		F		
	2F		H		
	3F		V		
	4F		OH		
Pipe-groove	1G	F	F	F	F
	2G	H	H	H	H
	5G	F,V,OH	F,V,OH	F,V,OH	F,V,OH
	6G	F,H,V,OH ²	F,H,V,OH	F,H,V,OH ²	F,H,V,OH ²
	6GR	All	All	All	All
Pipe-fillet	1F		F		F
	2F		H		H
	2FR		H		H
	4F		OH		OH
	5F		All		All

Notes:

1. Plate qualifies for welding pipe or tubing over 24 in. (610 mm) in diameter
2. Qualifies for fillet and groove welds in all positions except for complete joint penetration groove welding of T-, Y- and K-connections.
3. See 5.9.2 and Part I of sections 7 through 10 for requirements.
- (a) Positions of welding F = flat, H = horizontal, V = vertical, OH = overhead.
- (b) Positions as defined in 5.8.

placed in an approximately vertical plane with the groove approximately vertical. See Figure 4(C).

(4) Position 4G (Overhead) — The plates are placed in an approximately horizontal plane, and the weld metal is deposited from the under side. See Figure 4(D).

5.8.5 Pipe Groove Welds. In making the tests to qualify groove welds, the positions shall be as indicated below (illustrated in Figure 5):

(1) Position 1G (Pipe Horizontal Rolled) — The pipe is placed with its axis horizontal and the groove in an approximately vertical plane. The pipe is rotated during welding, so the weld metal is deposited from the upper side. See Figure 5(A).

(2) Position 2G (Pipe Vertical) — The pipe is

placed with its axis vertical and the welding groove approximately horizontal. The pipe is not rotated during welding. See Figure 5(B).

(3) Position 5G (Pipe Horizontal Fixed) — The pipe is placed with its axis horizontal and the groove in an approximately vertical plane. The pipe is not rotated during welding. See Figure 5(C).

(4) Position 6G (Pipe Inclined Fixed) — The pipe is inclined at 45 degrees with the horizontal. The pipe is not rotated during welding. See Figure 5(D).

(5) Position 6GR (Test for complete joint penetration groove welds of tubular T-, Y-, and K-connections) — The pipe is inclined at 45 degrees with the horizontal. The pipe (or tube) is not rotated during welding. See Figure 5(E), and Figures 27 and 33.

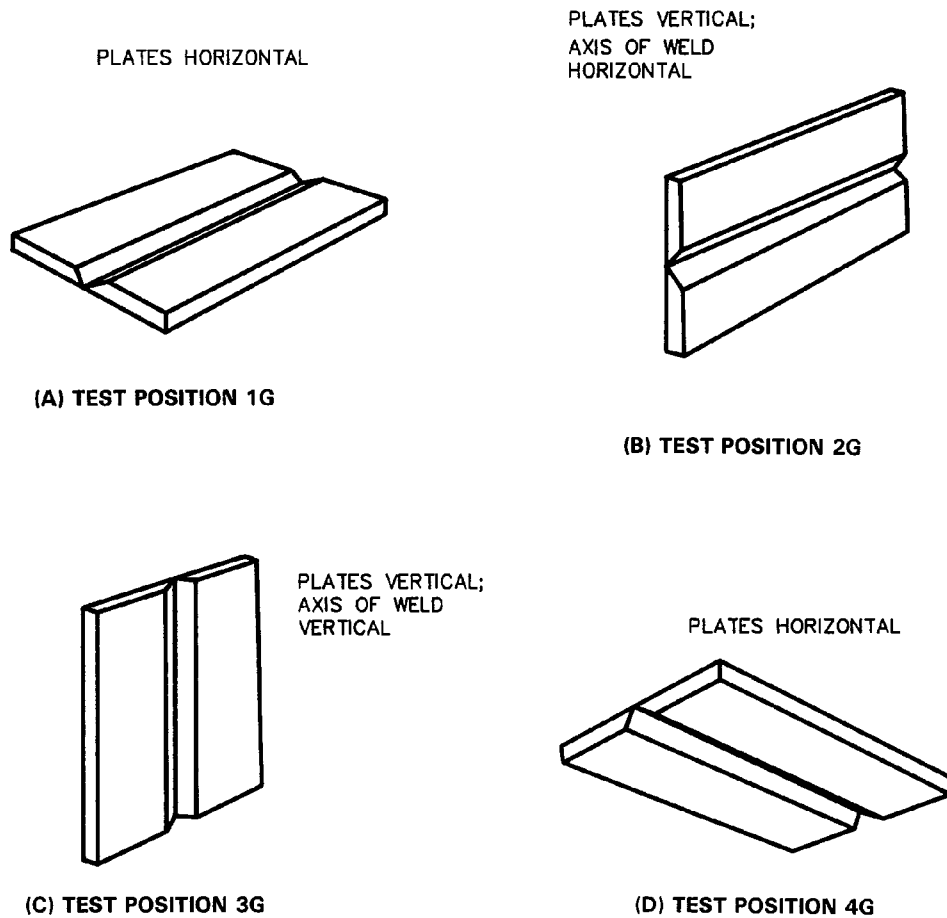


Figure 4 — Positions of Test Plate for Groove Welds

5.8.6 Plate Fillet Welds. In making the tests to qualify fillet welds, the test plate positions shall be as indicated below (illustrated in Figure 6):

(1) Position 1F (Flat) — The plates are placed such that each fillet weld is deposited with its axis approximately horizontal and its throat approximately vertical. See Figure 6(A).

(2) Position 2F (Horizontal) — The plates are placed such that each fillet weld is deposited on the upper side of a horizontal surface and against a vertical surface. See Figure 6(B).

(3) Position 3F (Vertical) — The plates are placed such that each fillet weld is deposited with its axis approximately vertical. See Figure 6(C).

(4) Position 4F (Overhead) — The plates are placed such that each fillet weld is deposited on the underside of a horizontal surface and against a vertical surface. See Figure 6(D).

5.8.7 Pipe Fillet Welds. In making tests to qualify fillet welds, test pipes shall be welded in the positions indicated below (illustrated in Figure 7):

(1) Position 1F (Flat) — The assembly is placed with the pipe axis inclined at 45 degrees to horizontal and rotated during welding; the weld metal is deposited from above and at the highest point of rotation of the joint. The axis of the weld at that

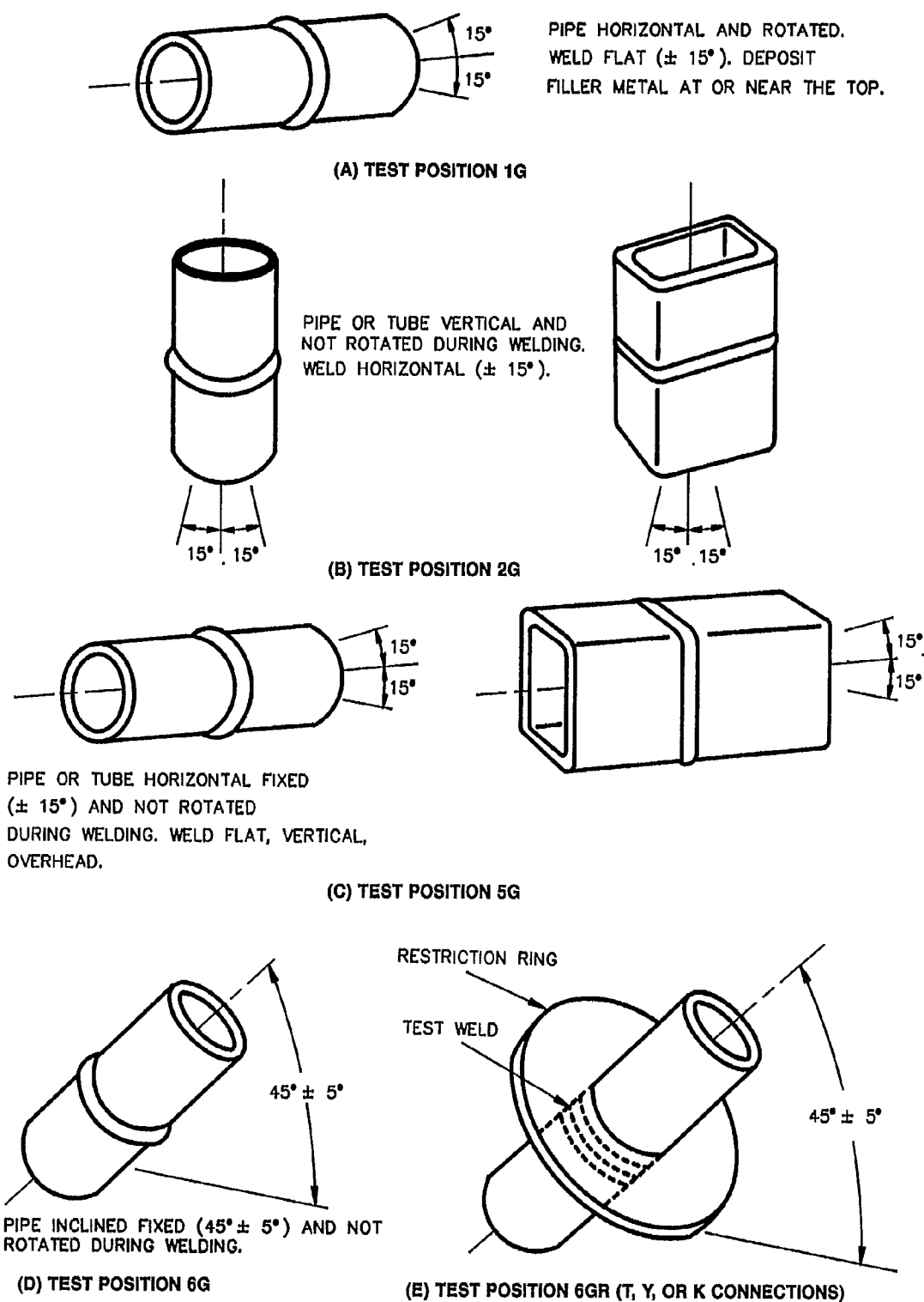


Figure 5 — Positions of Test Pipe or Tubing for Groove Welds

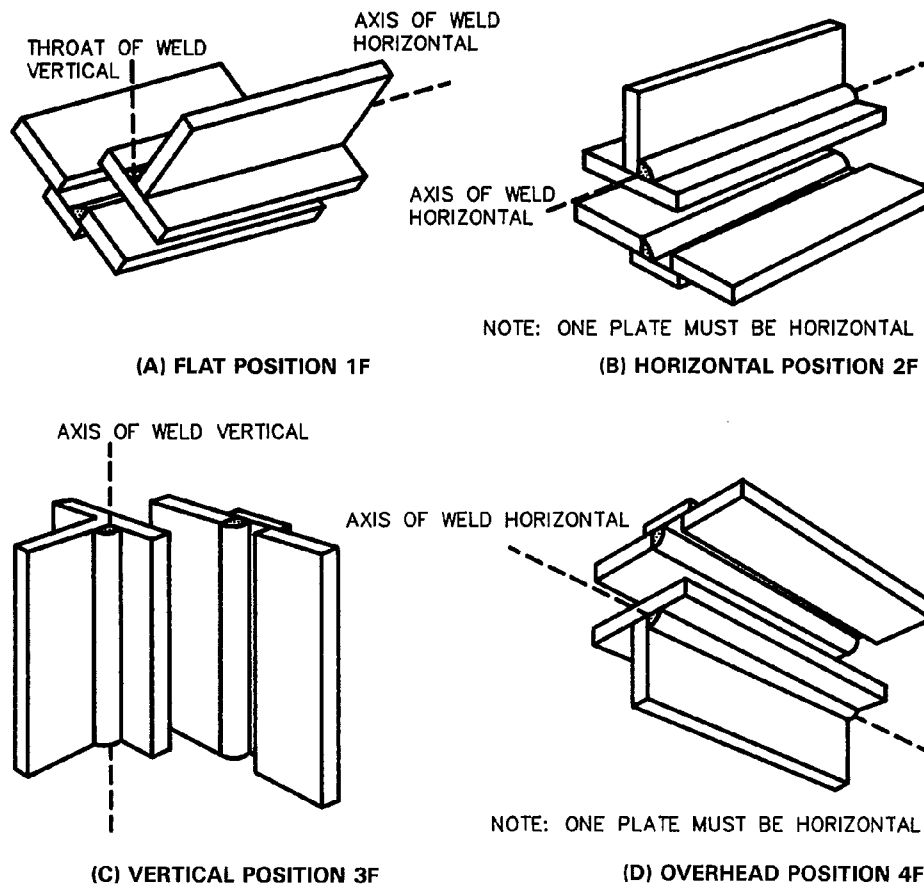


Figure 6 — Positions of Test Plates for Fillet Welds

point is horizontal and the throat vertical. Refer to Figure 7(A).

(2) Position 2F (Horizontal) — The assembly is placed with the pipe axis vertical so that the weld is deposited on the upper side of a horizontal surface and against a vertical surface. The axis of the weld is horizontal and the pipe is not rotated during welding. Refer to Figure 7(B).

(3) Position 2FR (Horizontal Rotated) — The assembly is placed with the pipe axis horizontal and rotated during welding. The weld metal is deposited at the highest point of rotation of the pipe, on the upperside of a horizontal surface and against a vertical surface. Refer to Figure 7(C).

(4) Position 4F (Overhead) — The assembly is placed with the pipe axis vertical so that the weld is deposited on the underside of a horizontal surface

and against a vertical surface. The axis of the weld is horizontal, and the pipe is not rotated during welding. Refer to Figure 7(D).

(5) Position 5F (Multiple Positions) — The assembly is placed with the pipe axis horizontal and the axis of the deposited weld in a vertical plane. The pipe is not rotated during welding. Refer to figure 7(E).

5.9 Joint Configuration

5.9.1 Joint configuration is an essential variable for welding procedure specifications. (Refer to Tables 1 and 2.)

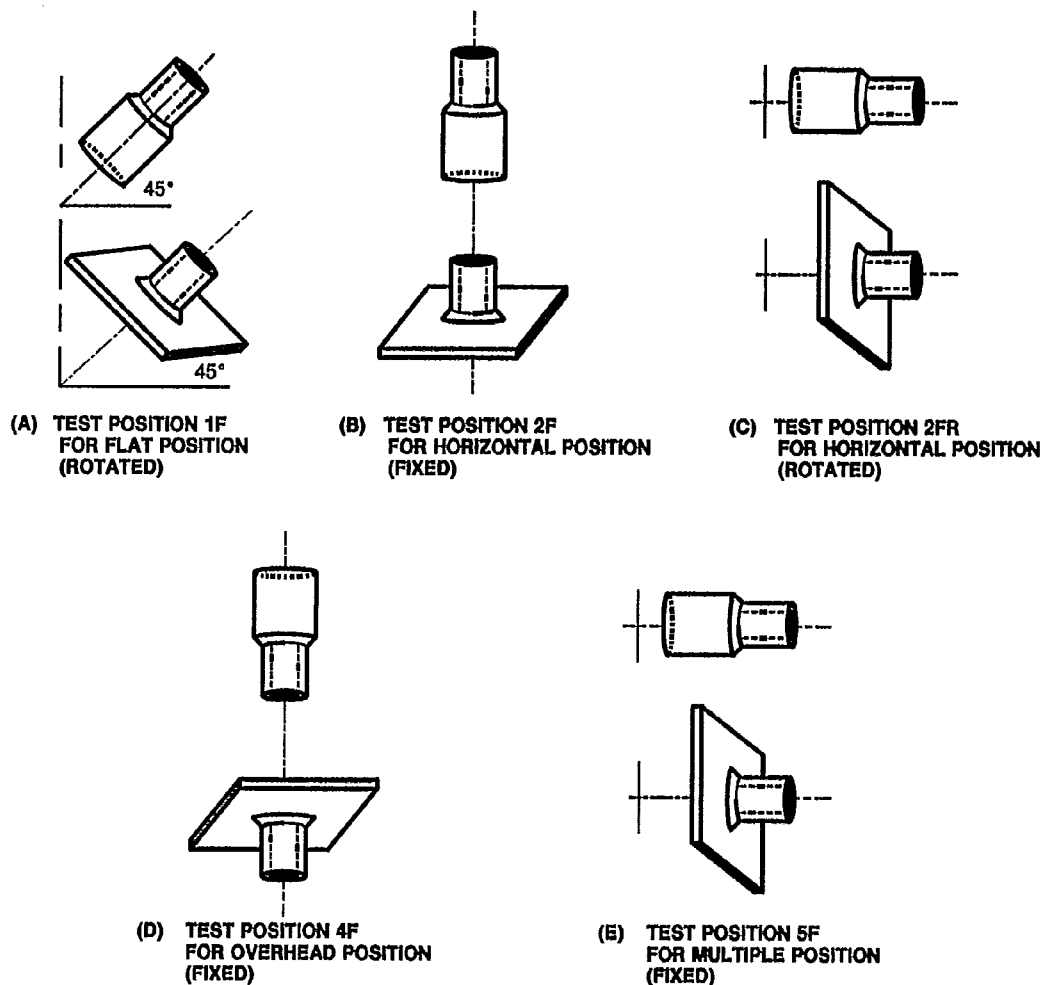


Figure 7 — Positions of Test Pipes for Fillet Welds

5.9.2 A procedure qualified to perform groove welds is qualified to perform multiple pass fillet welds. Single pass fillet welds are not qualified by groove weld qualification.

5.9.3 Tolerances for the weld preparation and joint fit-up for dry welding may be developed during weld procedure qualification. Where tolerances are not determined during welding procedure qualification, joints that vary from the nominal dimensions of Figure 1 shall require Customer approval. Where metal is brought together in preparation for welding, the deviation in joint alignment shall not

exceed 10 percent of the thickness of the thinner member or 1/8 in. (3.2 mm) whichever is less.

When the joint contains a backing bar, the separation between faying surfaces of butt joints landing on a backing shall not exceed 1/16 in. (1.6 mm). Where irregularities prevent alignment to limits qualified in the welding procedure, the methods used to meet those limits are subject to the Customer's approval. Welding procedures required to achieve the correct fit are also required to be qualified under the rules of this specification.

5.9.4 Joint assembly tolerances for wet welding shall be developed during welding procedure

qualification and identified on the welding procedure specification.

5.10 Test Specimens: Number and Type

The number and type of test specimens required for procedure qualification to test the first position and additional positions as required by 5.8, for one process are summarized in Part I of sections 7 through 10 for **Class A** through **O** welds, respectively. Specimens shall be removed and tested in accordance with 5.11. Test results shall be in accordance with Part I of sections 7 through 10, as applicable.

5.11 Preparation and Testing of Specimens

Test assemblies and specimens shall be prepared in accordance with the requirements of Part I of sections 7 through 10 for **Class A** through **O** welds, respectively. Unless otherwise specified in this document, ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*, shall apply to all testing. In addition, the following requirements shall apply.

5.11.1 Reduced-Section Tension Specimens. Specimens shall be prepared to the dimensions shown in Figure 8. Before testing, the least width and corresponding thickness of the reduced section shall be measured. The specimen shall be tested to rupture under tensile load, and the maximum load shall be determined. The cross-sectional area shall be obtained by multiplying the width of the reduced section, W , by the thickness t . The tensile strength shall be obtained by dividing the maximum load by the cross-sectional area.

5.11.2 Macroetch Test. Specimens shall be removed as shown in Figure 9 or 10. The cross-section surfaces cut from the test weld for macroscopic examination shall be prepared with a surface finish appropriate for macroetching. A suitable etching solution shall be used to give a clear definition of the weld metal and the heat-affected zone.

5.11.3 Root-, Face-, and Side-Bend Specimens. Transverse bend specimens, 3/8 in. (10 mm) thick,

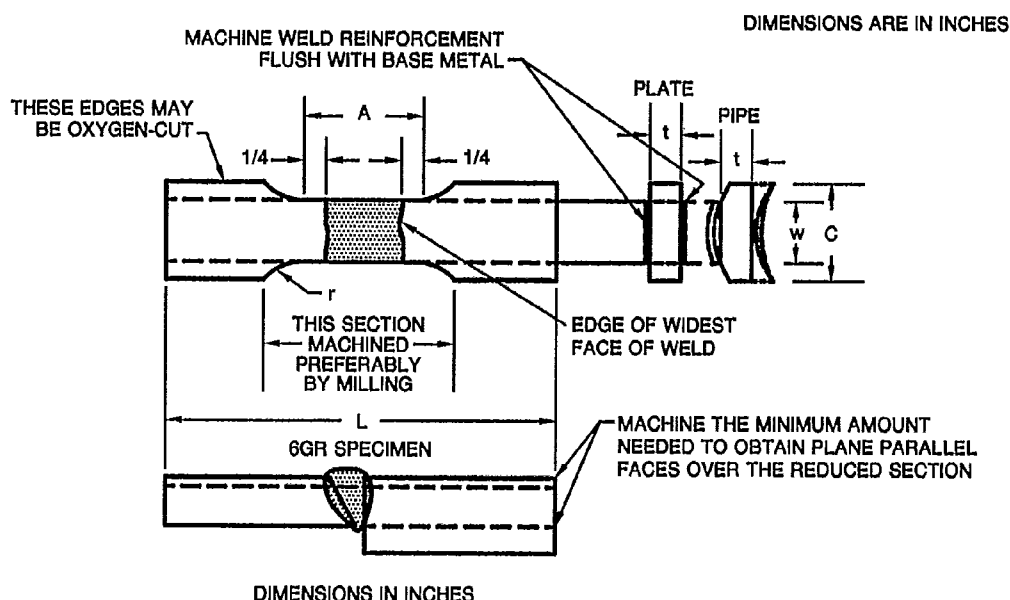
shall be prepared in accordance with Figures 11 or 12. Specimens may be machine cut or oxyfuel gas cut from the test plates. If they are oxyfuel gas cut, an additional 1/8 in. (3 mm) of metal shall be included on both sides of the rough-cut sample. The sample shall be machined or ground to the final dimensions. Each specimen shall be bent in a guided bend test jig having the contour dimensions shown in Figure 13. Bend radius shall be as specified in Part I of sections 7 through 10 for **Class A** through **O** welds, respectively.

5.11.3.1 Any convenient means may be used to move the plunger member of the guided bend test jig, Figure 13, with relation to the die member. The specimen shall be placed on the die member of the jig with the weld at midspan. Face-bend specimens shall be placed with the face of the weld toward the die member and root-bend specimens with the root of the weld toward the die member. Side-bend specimens shall be placed with that side showing the greater number of discontinuities, if any, toward the die member.

The plunger shall force the specimen into the die until the specimen assumes a U-shape. The weld and heat-affected zones shall be centered and shall be completely within the bent portion of the specimen after testing.

5.11.3.2 When using the alternate wrap-around jig, Figure 13, the specimen shall be firmly clamped on one end so that there is no sliding of the specimen during the bending operation. The weld and heat-affected zones shall be completely in the bent portion of the specimen after testing. Test specimens shall not be removed from the jig until the outer roll has been moved 180 degrees from the starting point. Bend specimens shall be positioned with respect to the fixed pin of diameter A in the same manner as with the plunger member of Figure 13.

5.11.4 All-Weld-Metal Tension Test. An all-weld-metal tension test specimen shall be prepared as shown in Figures 14 and 15. If approved by the Customer, the specimen may be machined from the procedure test weld. For hydrogen release, the sample may be aged at 200° to 220°F (93° to 104°C) for approximately 10 hours prior to testing. The test specimen shall be tested in accordance with ASTM A370, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*, or ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

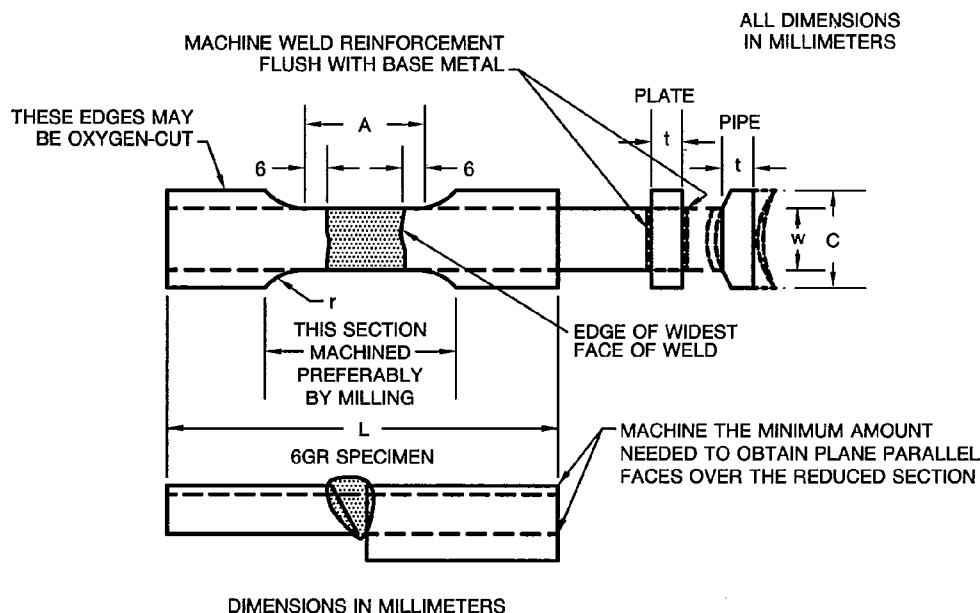


	Test Plate			Test Pipe	
	$T_p < 1$ in.	$1 < T_p < 1\text{-}1/2$ in.	$T_p > 1\text{-}1/2$ in.	Less than 6.625 in. Outside Diameter	6.625 in. and greater Outside Diameter
A — Length of reduced section	Widest face of weld + $1/2$ in., 2- $1/4$ min			Widest face of weld + $1/2$ in., 2- $1/4$ min (13 mm, 57 mm)	
L — Overall length, min (Note 2)	As required by testing equipment			As required by testing equipment	
W — Width of reduced section (Notes 3, 4)	$3/4$ in. min	$3/4$ in. min	$3/4$ in. min	$1/2 + 0.01$	$3/4$ in. min
C — Width of grip section (Notes 4, 5)	$W + 1/2$ in. min	$W + 1/2$ in. min	$W + 1/2$ in. min	$W + 1/2$ in. min	$W + 1/2$ in. min
t — Specimen thickness (Note 6)	T_p	T_p	T_p/n Note 6	Maximum possible with plane parallel faces within length A	
r — radius of fillet min	$1/2$	$1/2$	$1/2$	1	1

Notes:

1. T_p = Nominal Thickness of the Plate.
2. It is desirable, if possible, to make the length of the grip section large enough to allow the specimen to extend into the grips a distance equal to two-thirds or more of the length of the grips.
3. The ends of the reduced section shall not differ in width by more than 0.004 in. Also, there may be a gradual decrease in width from the ends to the center, but the width of either end shall not be more than 0.015 in. larger than the width at the center.
4. Narrower widths (W and C) may be used when necessary. In such cases, the width of the reduced section should be as large as the width of the material being tested permits. If the width of the material is less than W, the sides may be parallel throughout the length of the specimen.
5. For standard plate-type specimens, the ends of the specimen shall be symmetrical with the center line of the reduced section within 0.25 in.
6. For plates over 1- $1/2$ in. thick, specimens may be cut into n approximately equal strips. Each strip shall be at least $3/4$ in. thick. The test results of each strip shall meet the minimum requirements.

Figure 8 — Reduced-Section Tension Specimens

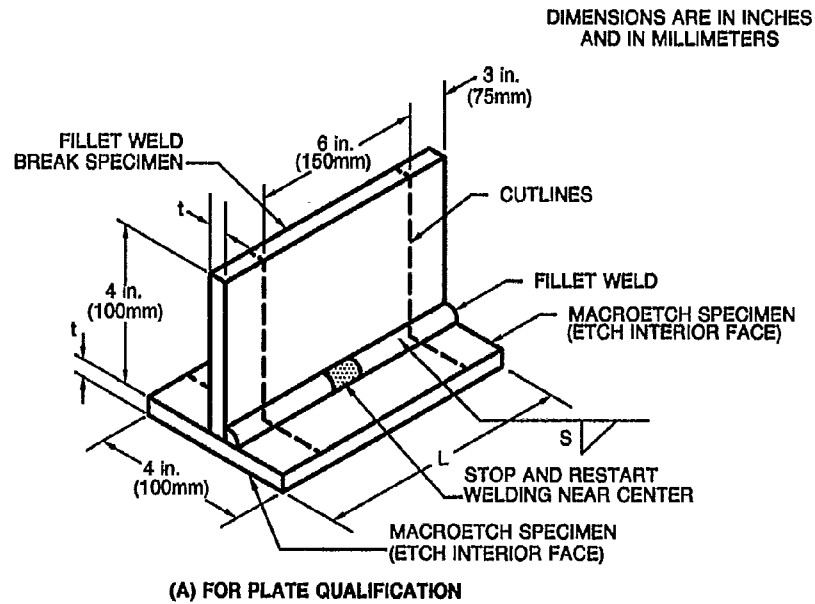


	Test Plate			Test Pipe	
	$T_p \leq 25 \text{ mm}$	$25 < T_p < 40 \text{ mm}$	$T_p \geq 40 \text{ mm}$	Less than 150 mm diameter	150 mm diameter or larger job size pipe
A — Length of reduced section	Widest face of weld + 13 mm, 60 mm min			Widest face of weld + 13 mm, 60 mm min	
L — Overall length, min (Note 2)	As required by testing equipment			As required by testing equipment	
W — Width of reduced section (Notes 3, 4)	20 mm min	20 mm min	20 mm min	$13 \pm .25 \text{ mm}$	20 mm min
C — Width of grip section (Notes 4, 5)	$W + 13 \text{ mm min}$	$W + 13 \text{ mm min}$	$W + 13 \text{ mm min}$	$W + 13 \text{ mm min}$	$W + 13 \text{ mm min}$
t — Specimen thickness (Note 6)	T_p	T_p	T_p/n Note 6	Maximum possible with plane parallel faces within length A	
r — Radius of fillet mm min	13	13	13	25	25

Notes:

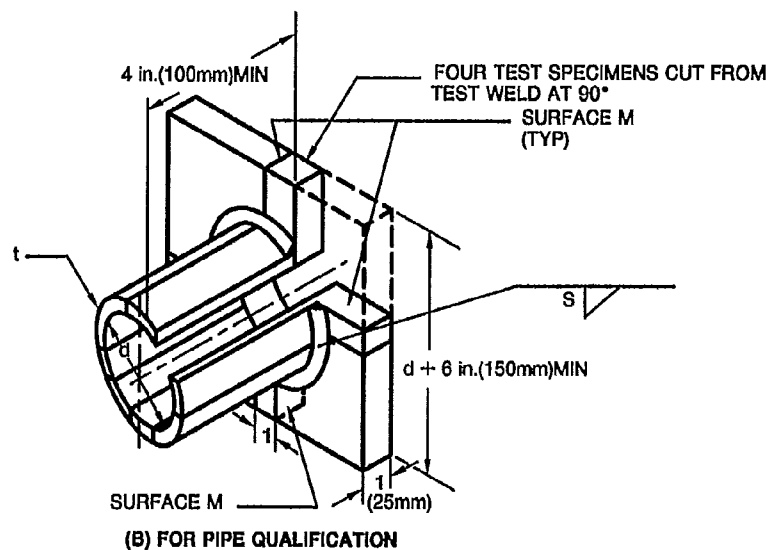
1. T_p = Nominal Thickness of the Plate.
2. It is desirable, if possible, to make the length of the grip section large enough to allow the specimen to extend into the grips a distance equal to two-thirds or more of the length of the grips.
3. The ends of the reduced section shall not differ in width by more than 0.10 mm. Also, there may be a gradual decrease in width from the ends to the center, but the width of either end shall not be more than 0.40 mm larger than the width at the center.
4. Narrower widths (W and C) may be used when necessary. In such cases, the width of the reduced section should be as large as the width of the material being tested permits. If the width of the material is less than W, the sides may be parallel throughout the length of the specimen.
5. For standard plate-type specimens, the ends of the specimen shall be symmetrical with the center line of the reduced section within 6 mm.
6. For plates over 40 mm thick, specimens may be cut into n approximately equal strips. Each strip shall be at least 20 mm thick. The test results of each strip shall meet the minimum requirements.

Figure 8M — Reduced-Section Tension Specimens (Metric)



Notes:

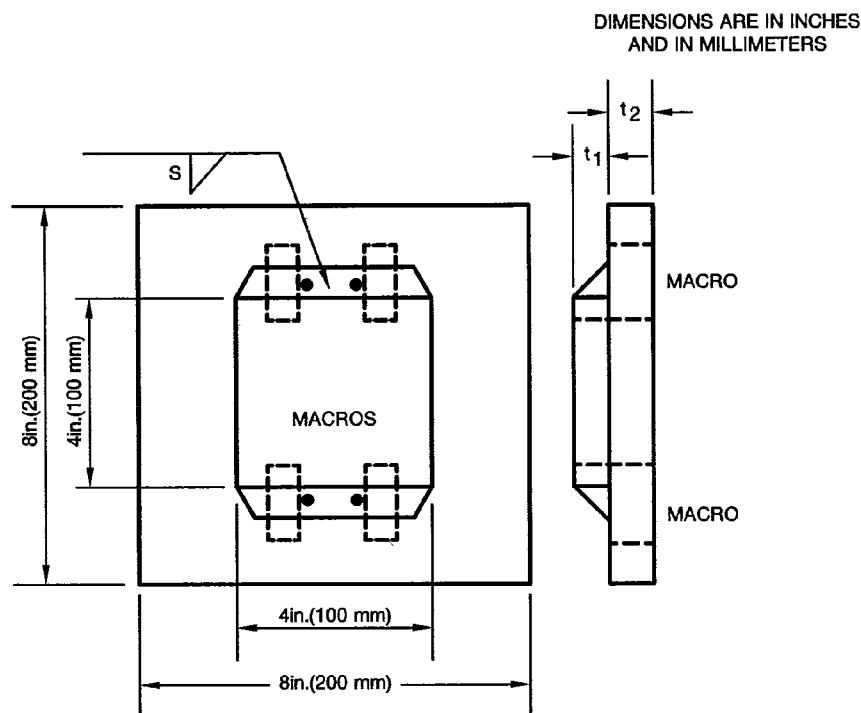
1. t in accordance with Tables 1 [Item A.1(h)], and 2 [Item A.1(g)]. As a minimum, $t = s + 1/8$ in. (3 mm).
2. L — equal to 12 in. (100 mm)
3. Fillet weld break specimen may be cut in sections to facilitate breaking.



Notes:

1. Diameter d selected from Table 6 to qualify for production pipe sizes (welder qualification only).
2. Thicknesses t in accordance with Tables 1 [Item A.1(h)] and 2 [Item A.1(g)]. As a minimum, $t = s + 1/8$ in. (3 mm).
3. Surfaces M to be examined for macroetch test. Hardness tests, when required, shall be made on the specimen from the six o'clock position.

Figure 9 — Fillet Weld Break and Macroetch Test Specimens



Note: Thicknesses t_1 and t_2 are to be in accordance with Tables 1 and 2. As a minimum, $t_1, t_2 = s + 1/8$ in. (3 mm).

Figure 10 — Lap Joint Fillet Macroetch Test Assembly and Specimen Location

5.11.5 Charpy Impact Tests. The locations, orientation, and dimensions for Charpy V-notch impact specimens are shown in Figures 14, 15, and 16. For groove weld qualifications, five Charpy V-notch impact specimens shall be machined from the weld metal and five from the heat-affected zone. For qualification of fillet welds, five Charpy V-notch impact specimens shall be machined from the weld metal only. Specimen preparation and testing shall be in accordance with ASTM A370, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*. The test temperature shall be the

minimum design service temperature, unless a different test temperature is specified by the Customer.

5.11.6 Hardness Test. The specimen used for macro test shall be prepared and tested in accordance with ASTM E92, *Standard Test Method for Vickers Hardness of Metallic Materials*. The location of indentations shall be as shown in Figure 17. An alternate hardness test, such as Rockwell, may be used when approved by the Customer.

6 MIN (SEE NOTE 1)

W

NOTE 2

NOTE 3

3/8

t

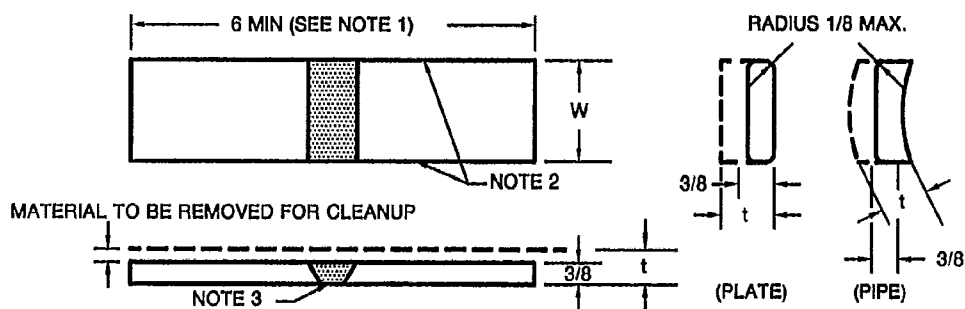
RADIUS 1/8 MAX.

(PLATE)

(PIPE)

MATERIAL TO BE REMOVED FOR CLEANUP

(A) FACE-BEND SPECIMEN

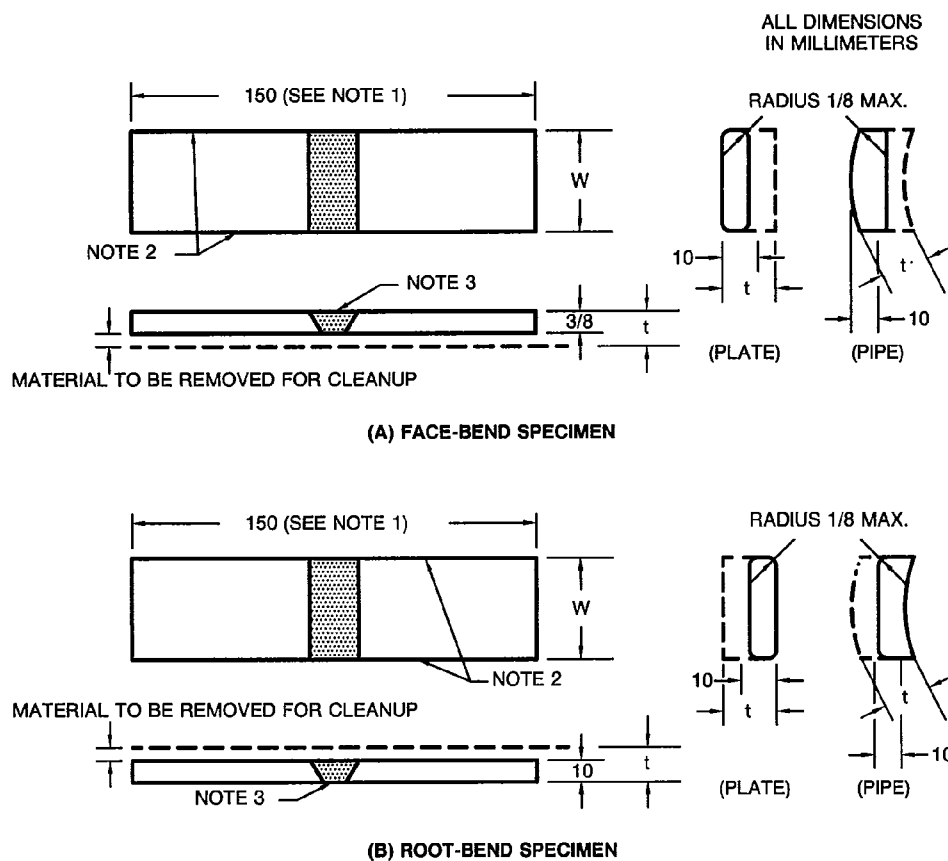


(B) ROOT-BEND SPECIMEN

DIMENSIONS	
TEST WELDMENT	TEST SPECIMEN WIDTH, (W) in.
PLATE	1-1/2
TEST PIPE < 6.625 in. IN OUTSIDE DIAMETER	1
TEST PIPE 6.625 in. AND GREATER IN OUTSIDE DIAMETER	1-1/2

1. A longer specimen length may be necessary when using a wrap-around type bending fixture when testing steel with a yield strength of 90 ksi or more, or when testing type "B" welds.
2. These edges may be oxygen cut and may or may not be machined.
3. The 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. Cut surfaces shall be smooth and parallel.
4. t = plate or pipe thickness.

Figure 11 — Face- and Root-Bend Specimens

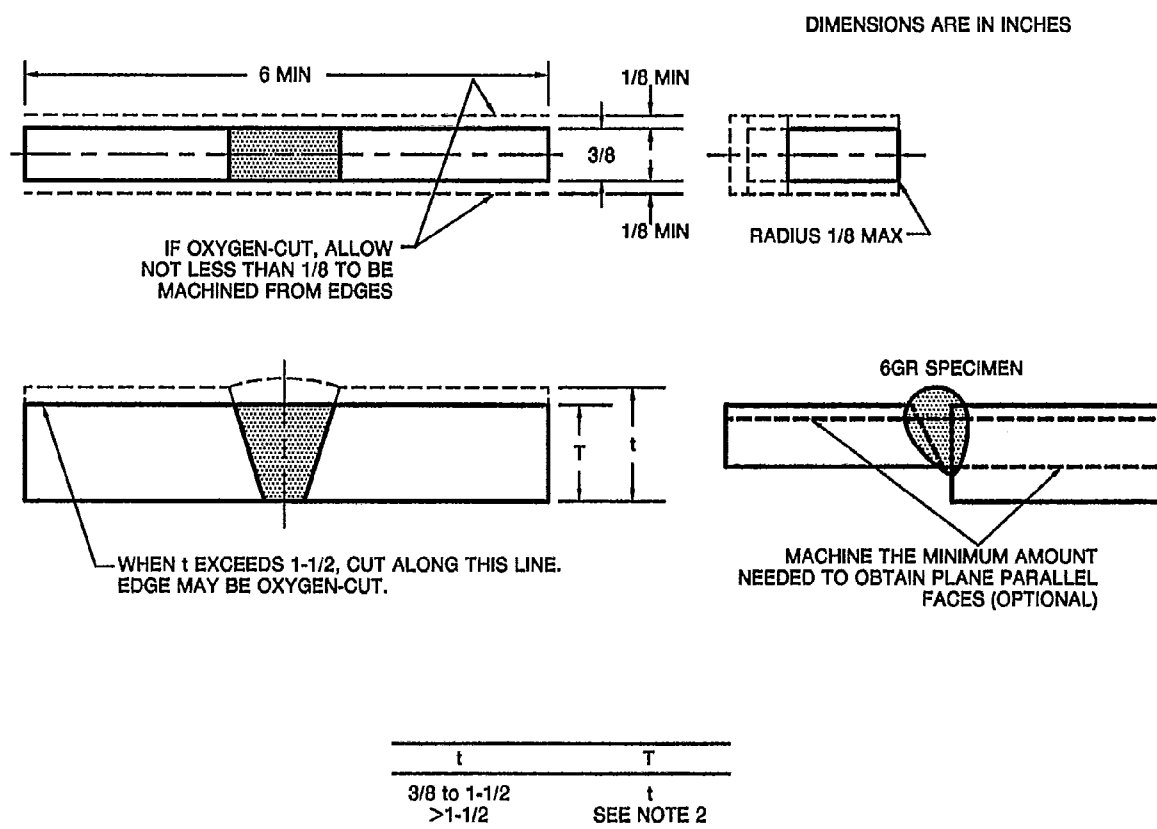


Metric DIMENSIONS	
TEST WELDMENT	TEST SPECIMEN WIDTH, (W) (mm)
PLATE	40
TEST PIPE < 168 mm IN OUTSIDE DIAMETER	25
TEST PIPE 168 mm AND GREATER IN OUTSIDE DIAMETER	40

Notes:

1. A longer specimen length may be necessary when using a wrap-around type bending fixture when testing steel with a yield strength of 600 MPa or more, or when testing type "B" welds.
2. These edges may be oxygen cut and may or may not be machined.
3. The 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. Cut surfaces shall be smooth and parallel.
4. t = plate or pipe thickness.

Figure 11M — Face- and Root-Bend Specimens (Metric)

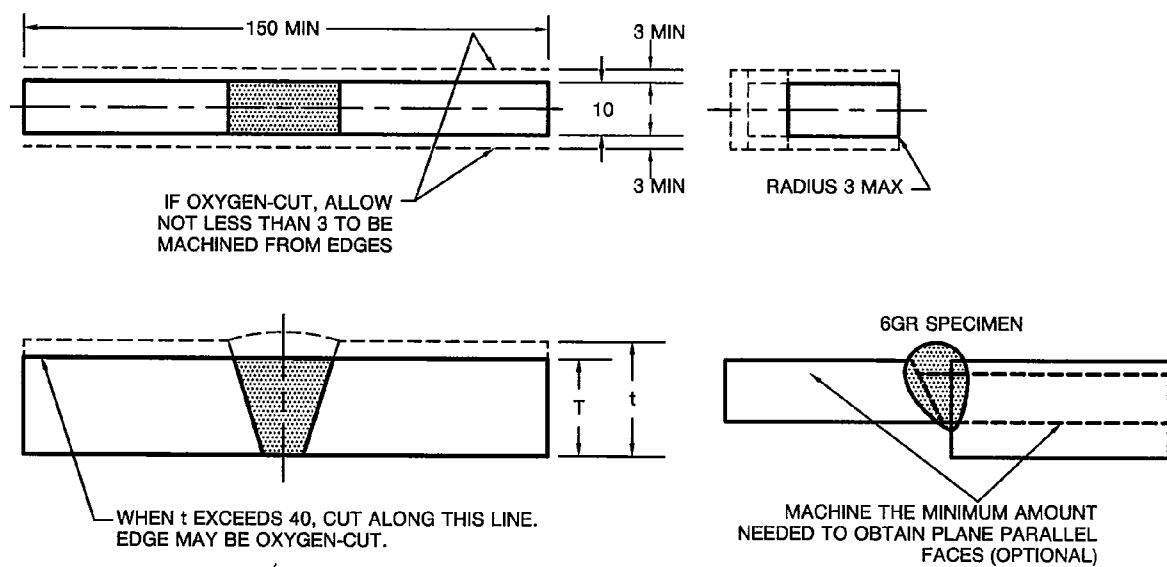


Notes:

1. A longer specimen may be necessary when using a wrap-around type bending fixture or when testing bends with greater than 3T bend radius. A longer specimen will be necessary for testing Class B welds with 6T bend radius.
2. For plates over 1-1/2 in. thick, cut the specimen into approximately equal strips with T between 3/4 in. and 1-1/2 in. and test each strip.
3. t = plate or pipe thickness.

Figure 12 — Side-Bend Specimens

ALL DIMENSIONS
IN MILLIMETERS

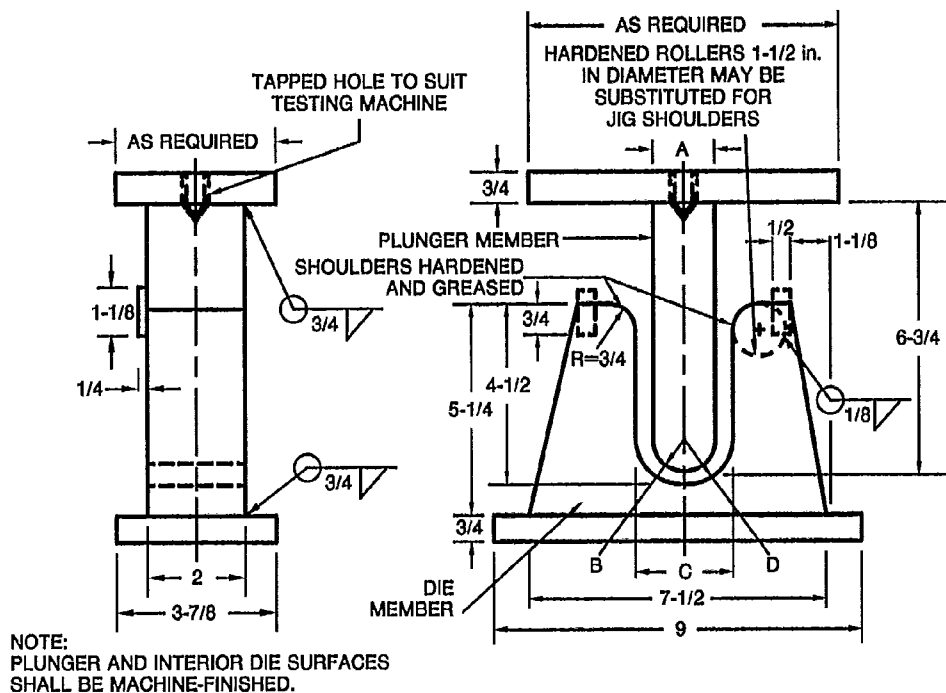


t	T
10 TO 40	t
>40	SEE NOTE 2

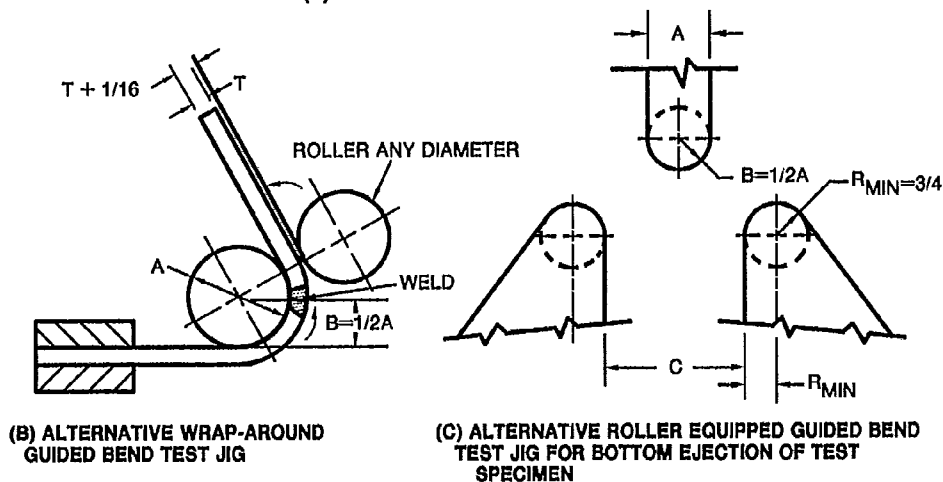
Notes:

1. A longer specimen may be necessary when using a wrap-around type bending fixture or when testing bends with greater than 3T bend radius. A longer specimen will be necessary for testing Class B welds with 6T bend radius.
2. For plates over 40 mm thick, cut the specimen into approximately equal strips with T between 20 mm and 40 mm and test each strip.
3. t = plate or pipe thickness.

Figure 12M — Side-Bend Specimens (Metric)

DIMENSIONS ARE
IN INCHES

(A) GUIDED-BEND TEST JIG

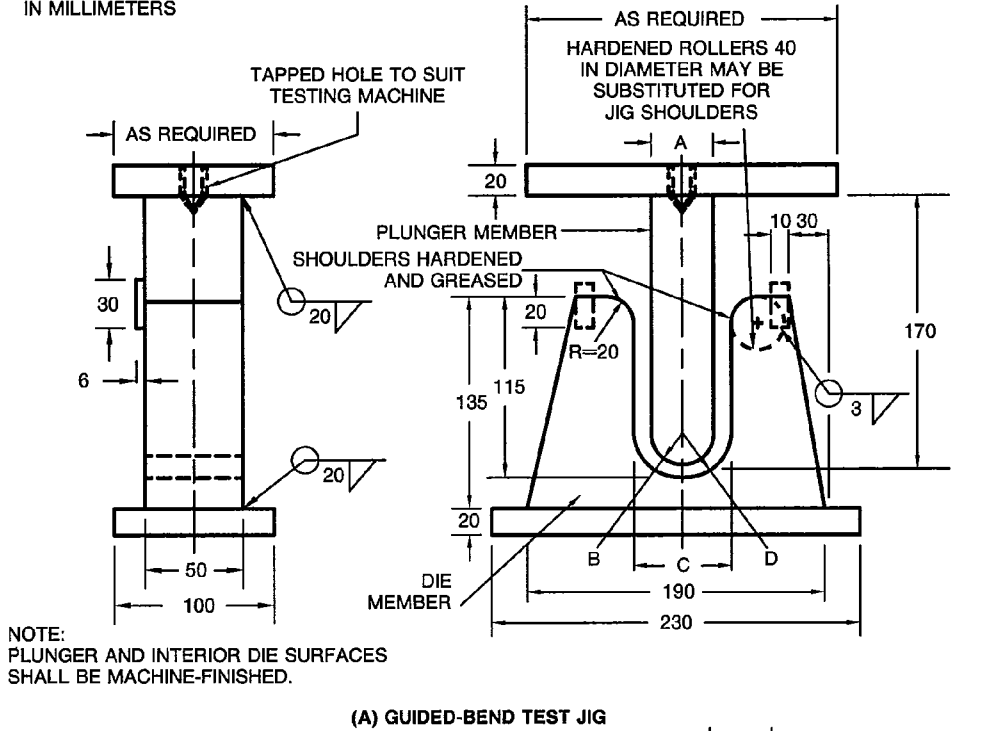


Bend Radius (B)	Dimensions			
	A in.	B in.	C in.	D in.
2T	1-1/2	3/4	2-3/8	1-3/16
2-2/3T	2	1	2-7/8	1-7/16
3-1/3T	2-1/2	1-1/4	3-3/8	1-11/16
6T	4-1/2	2-1/4	5-3/8	2-11/16

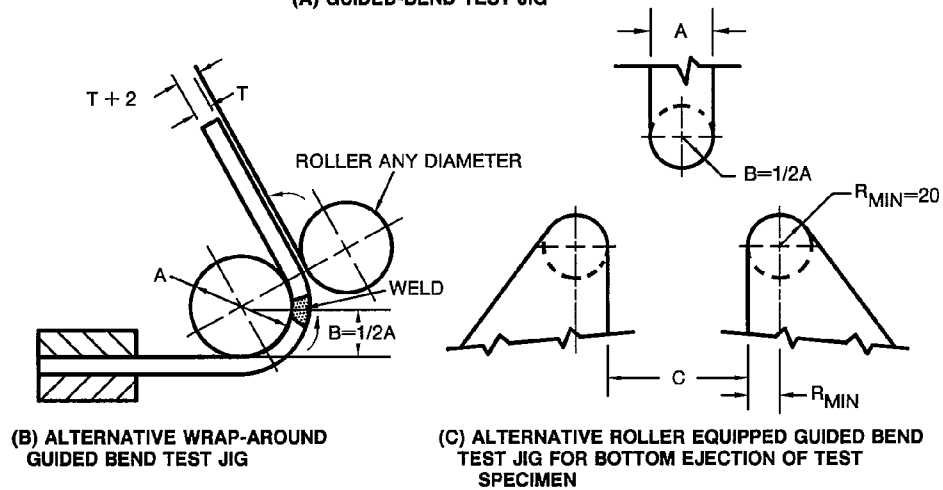
Note: For required radius refer to Parts I and II of Section 7 through 10 for Class A through O welds, respectively. Bending fixture dimensions are for specimen radius bends on 3/8 in. thick specimens. If qualification welds are required on thinner material, fixture dimensions may be altered so bending radius remains as specified. T equals thickness of bend specimen.

Figure 13 — Bend Test Jigs

ALL DIMENSIONS
IN MILLIMETERS



(A) GUIDED-BEND TEST JIG



(B) ALTERNATIVE WRAP-AROUND GUIDED BEND TEST JIG

**(C) ALTERNATIVE ROLLER EQUIPPED GUIDED BEND
TEST JIG FOR BOTTOM EJECTION OF TEST
SPECIMEN**

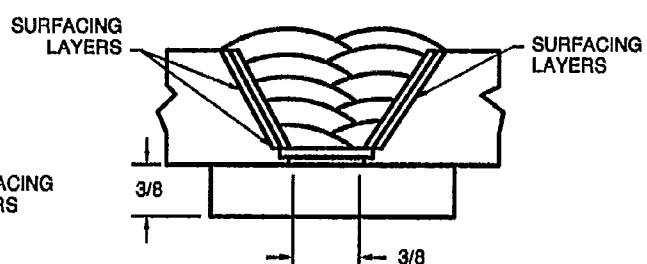
	Radius (B)			
	Metric Dimensions (mm)			
Bend Radius (B)	A mm	B mm	C mm	D mm
2T	40	20	62	31
2-2/3T	54	27	76	38
3-1/3T	66	33	88	44
6T	120	60	142	71

Note: For required radius refer to Parts I and II of Section 7 through 10 for Class A through O welds, respectively. Bending fixture dimensions are for specimen radius bends on 10 mm thick specimens. If qualification welds are required on thinner material, fixture dimensions may be altered so bending radius remains as specified. T equals thickness of bend specimen.

Figure 13M — Bend Test Jigs (Metric)



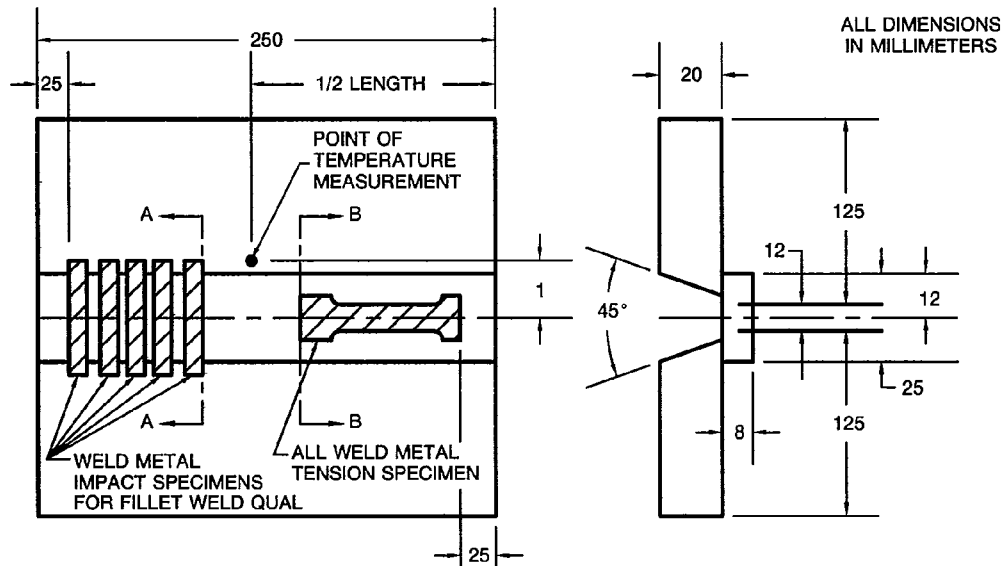
(C) LOCATION OF ALL-WELD-METAL TENSION SPECIMEN



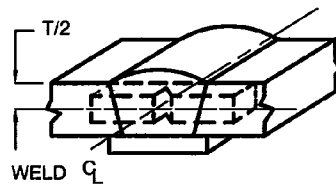
NOTE: EITHER SEQUENCE IS ACCEPTABLE.

(D) SEQUENCE FOR DEPOSITING THE WELD METAL

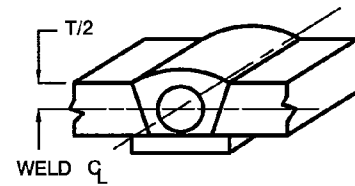
Figure 14 — All-Weld-Metal Tension and Impact Specimen Test Plate Design and Specimen Locations



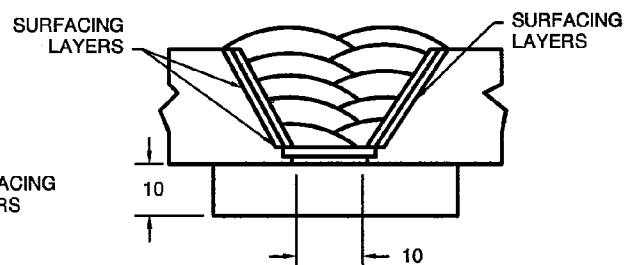
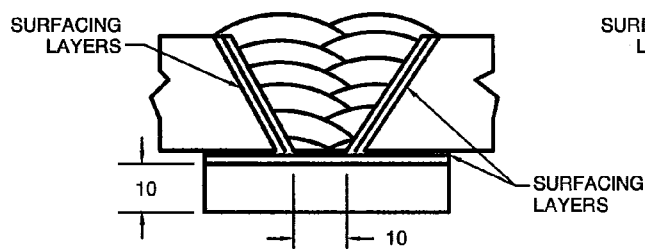
(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



(B) ORIENTATION AND LOCATION OF WELD METAL IMPACT SPECIMEN (SEE ALSO 5.11.5 AND FIGURE 24)



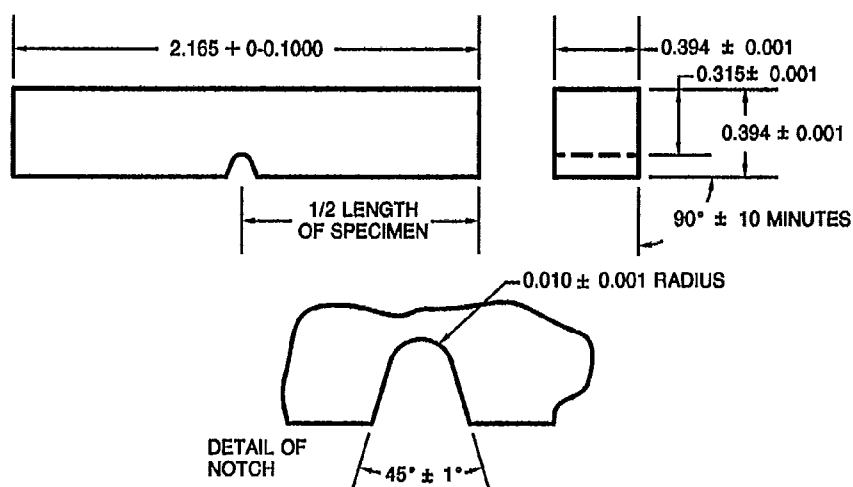
(C) LOCATION OF ALL-WELD-METAL TENSION SPECIMEN



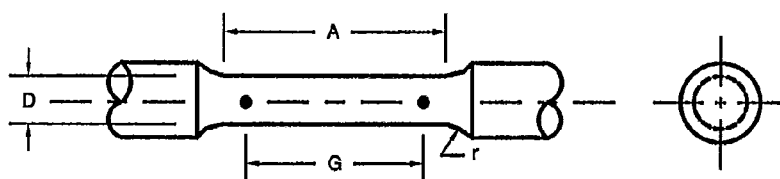
NOTE: EITHER SEQUENCE IS ACCEPTABLE.

(D) SEQUENCE FOR DEPOSITING THE WELD METAL

Figure 14M — All-Weld-Metal Tension and Impact Specimen Test Plate Design and Specimen Locations (Metric)



(A) CHARPY V-NOTCH IMPACT TEST SPECIMEN



Dimensions (inches)

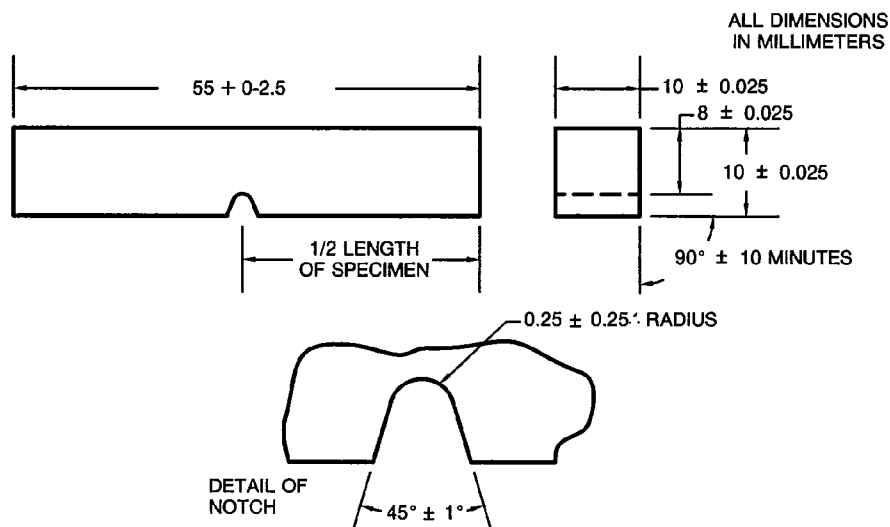
Nominal diameter	Standard specimen	Small-size specimens proportional to standard	
	0.500 in. round	0.350 in. round	0.250 in. round
G — Gage length	2.000 ± 0.005	1.400 ± 0.005	1.000 ± 0.005
D — Diameter (Note 1)	0.500 ± 0.010	0.350 ± 0.007	0.250 ± 0.005
r — Radius of fillet, min	3/8	1/4	3/16
A — Length of reduced section (Note 2) min	2-1/4	1-3/4	1-1/4

Notes:

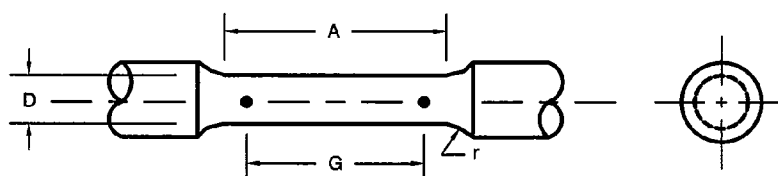
1. The reduced section may have a gradual taper from the ends toward the center, with the ends not more than one percent larger in diameter than the center (controlling dimension).
2. If desired, the length of the reduced section may be increased to accommodate an extensometer of any convenient gage length. Reference marks for the measurement of elongation should 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. If the ends are to be held in wedge grips, it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two-thirds or more of the length of the grips.
4. The surface finish with the A dimension shall be no rougher than 63 μ in.
5. If necessary, a subsize specimen, as shown in the filler metal specification, may be used.
6. The position of the all-weld-metal tension coupon may be in the 1G (flat) position.

(B) ALL-WELD-METAL TENSION TEST SPECIMEN DIMENSIONS

Figure 15 — Charpy V-Notch Impact and All-Weld-Metal Test Specimen Design



(A) CHARPY V-NOTCH IMPACT TEST SPECIMEN



Dimensions (metric version per ASTM E 8M)

Nominal diameter	Standard specimen	Small-size specimens proportional to standard	
	12.5 mm round	9 mm round	6 mm round
G — Gage length, mm	62.5 ± 0.1	45.0 ± 0.1	30.0 ± 0.1
D — Diameter (Note 1), mm	12.5 ± 0.2	9.0 ± 0.1	6.0 ± 0.1
r — Radius of fillet, mm. min	10	8	6
A — Length of reduced section, mm (Note 2). min	75	54	36

Notes:

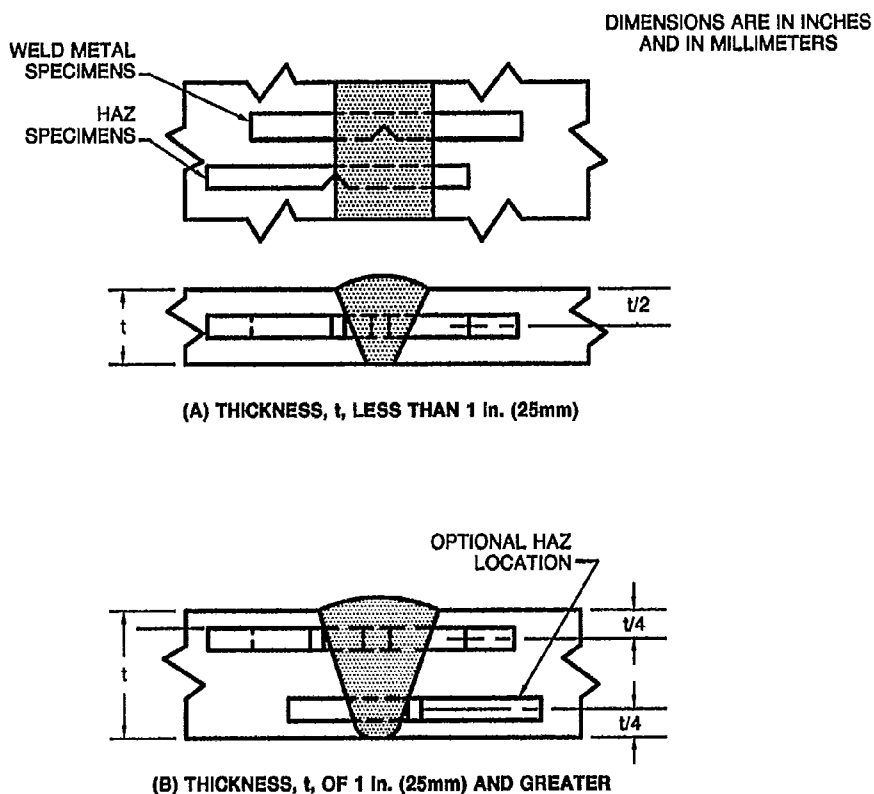
1. The reduced section may have a gradual taper from the ends toward the center, with the ends not more than one percent larger in diameter than the center (controlling dimension).
2. If desired, the length of the reduced section may be increased to accommodate an extensometer of any convenient gage length. Reference marks for the measurement of elongation should 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. If the ends are to be held in wedge grips, it is desirable, if possible, to make the length of the grip section great enough to allow the specimen to extend into the grips a distance equal to two-thirds or more of the length of the grips.
4. The surface finish with the A dimension shall be no rougher than 1.6 μm .
5. If necessary, a subsize specimen, as shown in the filler metal specification may be used.
6. The position of the all-weld-metal tension coupon may be in the 1G (flat) position.

(B) ALL-WELD-METAL TENSION TEST SPECIMEN DIMENSIONS

Figure 15M — Charpy V-Notch Impact and All-Weld-Metal Test Specimen Design (Metric)

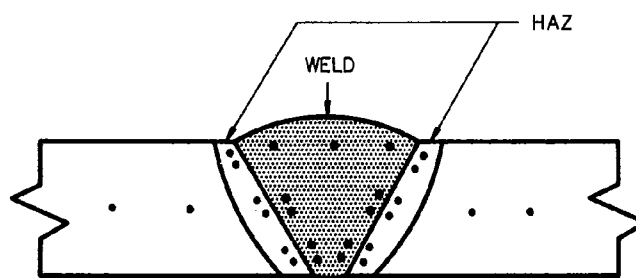
5.11.7 Fillet Weld Break Test. The coupon prepared for the fillet weld break test shall conform to Figure 9(A) for plate and 9(B) for pipe qualifications. The entire length of the fillet weld shall be examined visually. Then, for plate, a weld specimen 6 in. (150 mm) long and for pipe, four specimens -- each containing approximately 1 in. (25 mm) of weld -- shall be loaded in such a way that the root of the weld is in tension.

5.11.8 Fillet Weld Shear Strength Test. The specimen prepared for the fillet weld shear strength testing shall conform to Figures 18, 19, or 20. The specimen type and welding position are to be specified by the Customer. Position of welding may have a significant effect on the properties of the weld, and the Customer should take this into consideration in design and in selection of the first and other positions during procedure qualification.

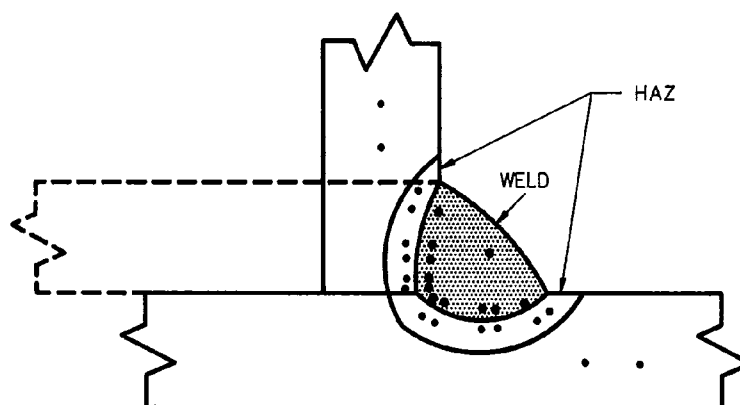


NOTE: NOTCH IN EACH SPECIMEN IS TO RUN PERPENDICULAR TO THE PLATE SURFACE.

Figure 16 — Location of Charpy V-Notch Impact Test Specimen in Test Weld



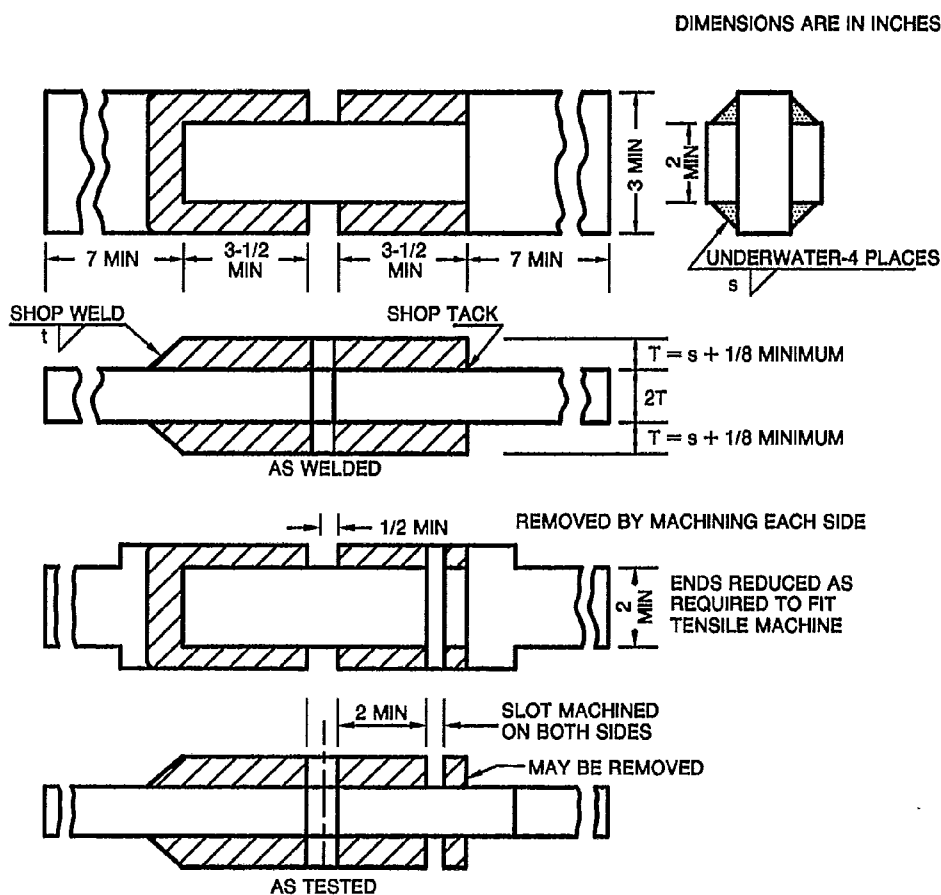
(A) GROOVE WELD



(B) FILLET WELD, T- OR LAP JOINT

Note: Heat-affected zone impressions shall be located on the base metal side of the weld interface, as close to the interface as possible. Minimum number of HAZ impressions shall be two at each side of the weld reinforcement, two at each side of the midwall and two at each side of the root of the weld. Minimum weld metal impressions shall be three at the face reinforcement, two at each side of the midwall, and two at each side of the root. There is no limit for the maximum number of readings to be reported.

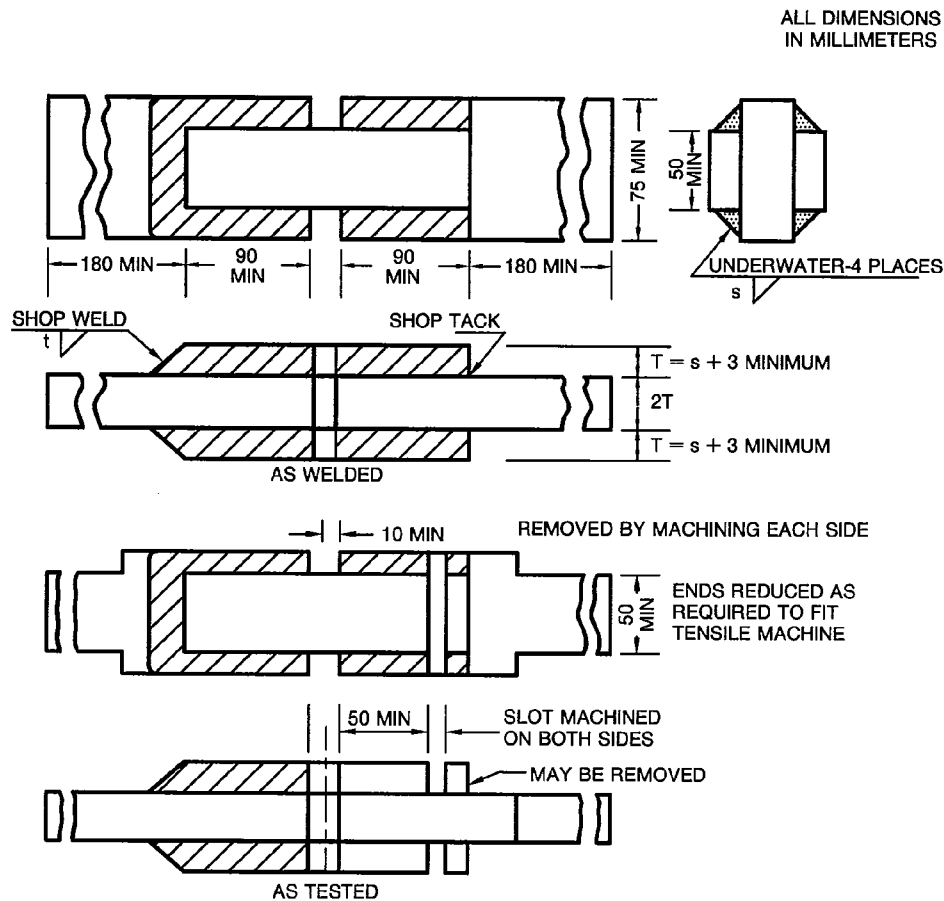
Figure 17 — Location of Hardness Impressions



Notes:

1. Test fillet weld size $s = 3/8$ in. except for single-pass fillet welds.
2. Other plate thicknesses and fillet weld sizes may be used by agreement.
3. Total length of fillet weld tested in shear shall not exceed the total length of the shop fillet weld. The test length is determined by the distance between the machined slots. Minimum length of underwater fillet weld to be tested is 8 in.
4. Prior to testing, the average throat and total test length of the test fillet weld shall be measured. The throat of the weld is the minimum distance from the root of the joint to the face of the fillet weld. Root penetration is disregarded. The weld area in shear is calculated by multiplying the average throat by the total test length.
5. The specimen shall be tested in tension to failure, which shall be by shear through the test fillet welds. The maximum load is recorded.
6. The shear strength is determined by dividing the maximum load by the total weld area (throat times length) in shear.
7. Wider cover plates may be necessary to prevent tensile failure across the cover plates. Higher tensile strength plate may be used.
8. This specimen may also be used for procedure qualification of fillet welds on pipe.

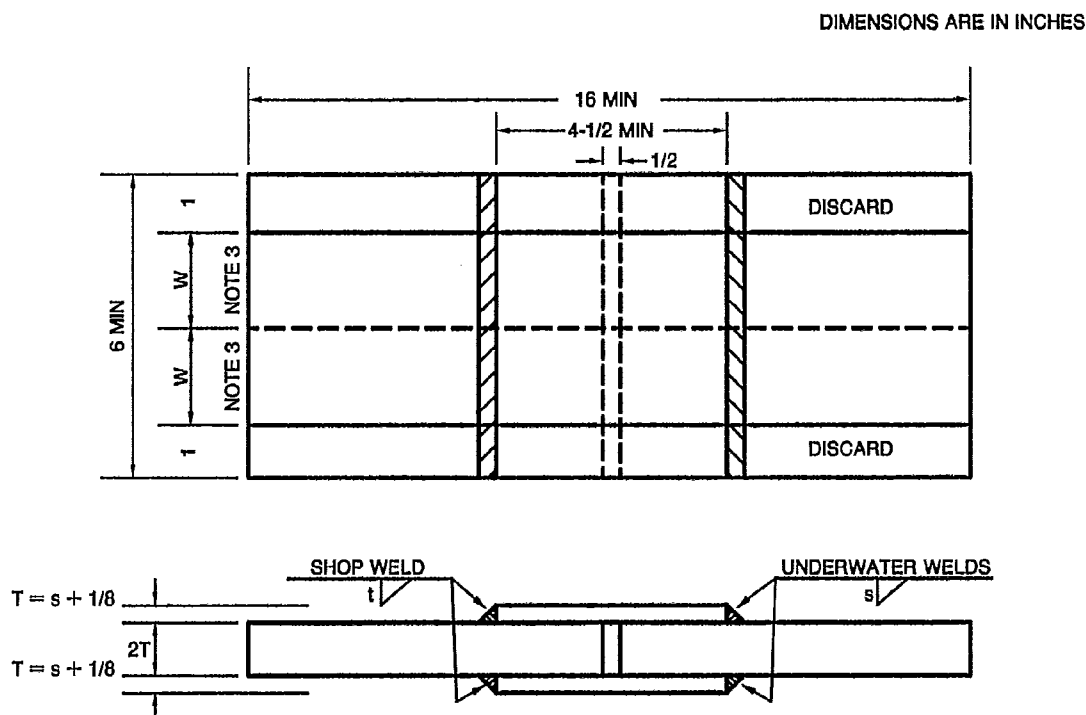
Figure 18 — Fillet Weld Shear Strength Specimens — Longitudinal from Plate



Notes:

1. Test fillet weld size $s = 10$ mm except for single-pass fillet welds.
2. Other plate thicknesses and fillet weld sizes may be used by agreement.
3. Total length of fillet weld tested in shear shall not exceed the total length of the shop fillet weld. The test length is determined by the distance between the machined slots. Minimum length of underwater fillet weld to be tested is 200 mm.
4. Prior to testing, the average throat and total test length of the test fillet weld shall be measured. The throat of the weld is the minimum distance from the root of the joint to the face of the fillet weld. Root penetration is disregarded. The weld area in shear is calculated by multiplying the average throat by the total test length.
5. The specimen shall be tested in tension to failure, which shall be by shear through the test fillet welds. The maximum load is recorded.
6. The shear strength is determined by dividing the maximum load by the total weld area (throat times length) in shear.
7. Wider cover plates may be necessary to prevent tensile failure across the cover plates. Higher tensile strength plate may be used.
8. This specimen may also be used for procedure qualification of fillet welds on pipe.

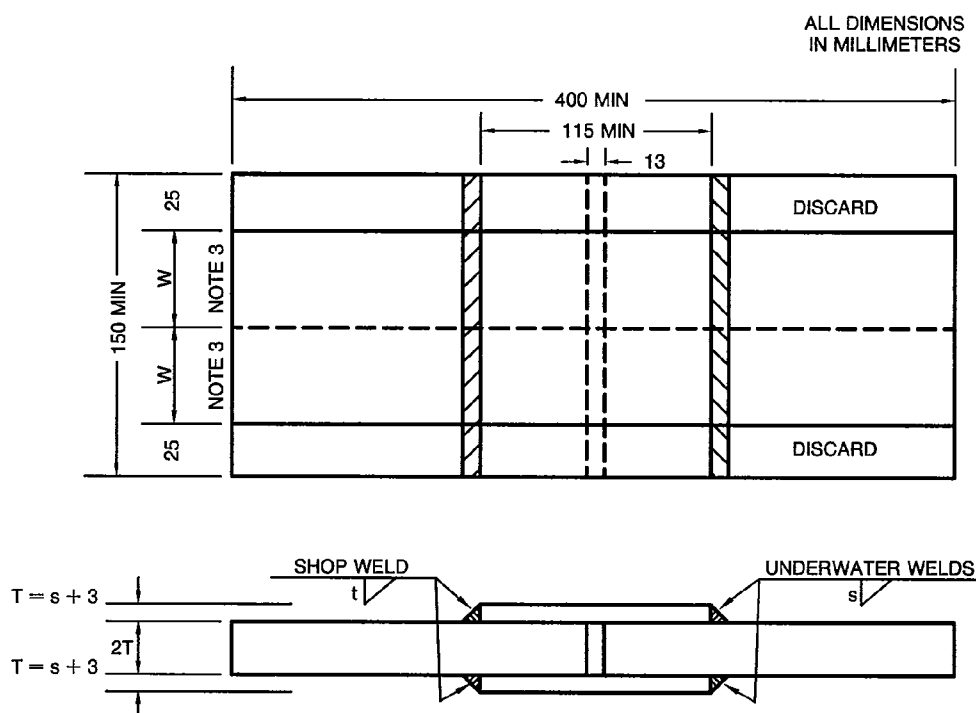
Figure 18M — Fillet Weld Shear Strength Specimens — Longitudinal from Plate (Metric)



Notes:

1. Test fillet weld size $s = 3/8$ in. except for single-pass fillet welds.
2. Other plate thicknesses and fillet weld sizes may be used by agreement.
3. The number of specimens (straps) cut from the coupon, and their width, W , may be controlled by testing machine capacity. The minimum total length of underwater weld to be tested is 8 in., i.e., 4 in. on top and 4 in. on bottom of the coupon as indicated.
4. Specimens shall be machine cut, with edges smooth and parallel.
5. Prior to testing, the average throat and total test length of each fillet weld test specimen shall be measured. The throat of the weld is the minimum distance from the root of the joint to the face of the fillet weld. Root penetration is disregarded. The weld area in shear is calculated by multiplying the average throat by the total test length.
6. Each specimen shall be tested in tension to failure, which shall be by shear through the test fillet welds. The maximum load is recorded.
7. The shear strength for each specimen is determined by dividing the maximum load by the total weld area (throat times length) in shear. The reported shear strength is the overage of the shear strengths of all specimens from the transverse fillet weld test coupon.
8. This specimen may also be used for procedure qualification of fillet welds on pipe.

Figure 19 — Fillet Weld Shear Strength Specimens — Transverse from Plate

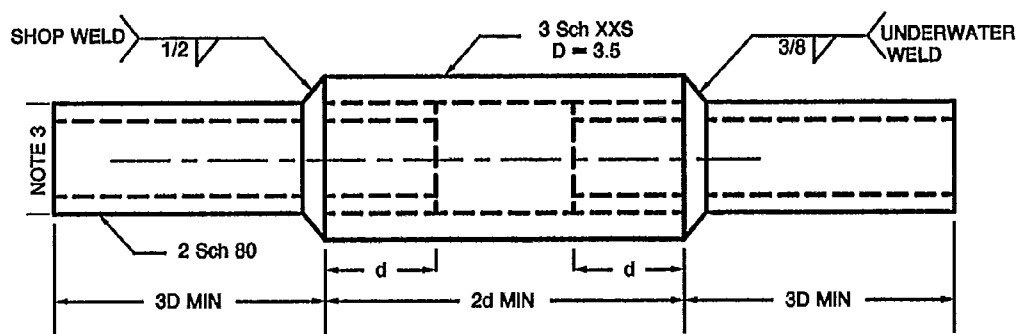
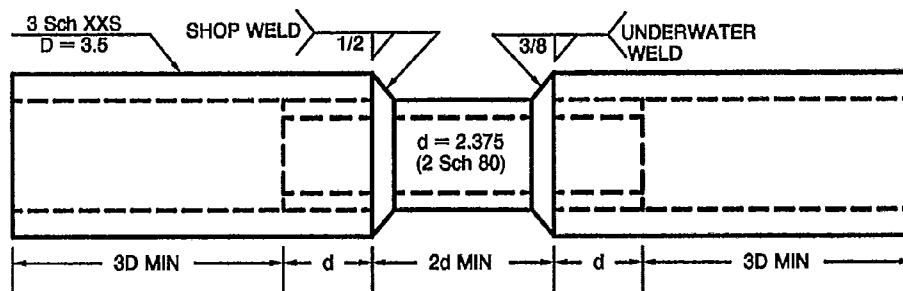


Notes:

1. Test fillet weld size $s = 10$ mm except for single-pass fillet welds.
2. Other plate thicknesses and fillet weld sizes may be used by agreement.
3. The number of specimens (straps) cut from the coupon, and their width, W , may be controlled by testing machine capacity. The minimum total length of underwater weld to be tested is 200 mm, i.e., 100 mm on top and 100 mm on bottom of the coupon as indicated.
4. Specimens shall be machine cut, with edges smooth and parallel.
5. Prior to testing, the average throat and total test length of each fillet weld test specimen shall be measured. The throat of the weld is the minimum distance from the root of the joint to the face of the fillet weld. Root penetration is disregarded. The weld area in shear is calculated by multiplying the average throat by the total test length.
6. Each specimen shall be tested in tension to failure, which shall be by shear through the test fillet welds. The maximum load is recorded.
7. The shear strength for each specimen is determined by dividing the maximum load by the total weld area (throat times length) in shear. The reported shear strength is the overage of the shear strengths of all specimens from the transverse fillet weld test coupon.
8. This specimen may also be used for procedure qualification of fillet welds on pipe.

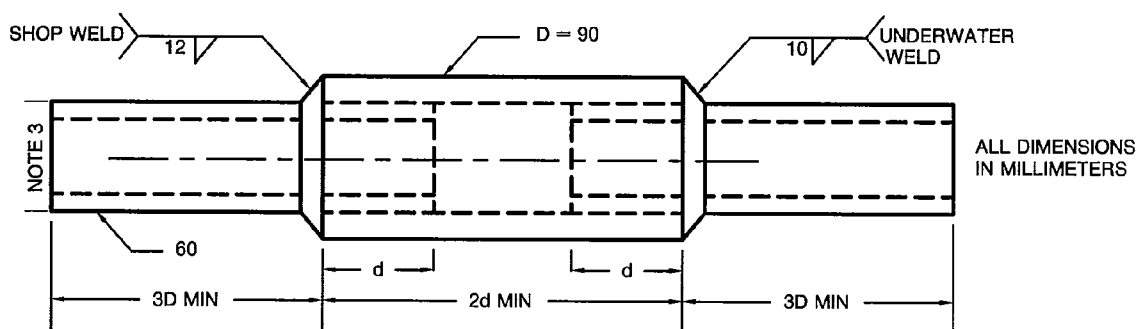
Figure 19M — Fillet Weld Shear Strength Specimens — Transverse from Plate (Metric)

DIMENSIONS ARE IN INCHES

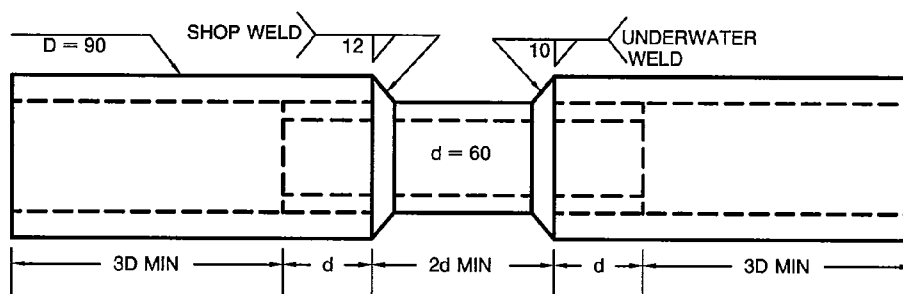
(A) TRANSVERSE FILLET WELD SHEAR TEST
COUPON FROM PIPE(B) ALTERNATE TRANSVERSE FILLET WELD SHEAR TEST
COUPON FROM PIPE**Notes:**

1. Other pipe and fillet weld sizes may be used by agreement.
2. Pipe I.D. may be machined for joint fitup.
3. $d = 2.375$ in. [or 2 in. nominal pipe size]. Larger pipe sizes may result in breaking strengths exceeding usual testing machine capacities.
4. The coupon length shall be sufficient to accommodate the plug and testing machine jaws as shown in ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.
5. Prior to testing, the average throat dimension and total fillet weld test length (i.e., $3.14 \times [d + S/2]$) shall be measured. The throat of the weld is the minimum distance from the root of the joint to the face of the fillet weld. Root penetration is disregarded. The weld area in shear is calculated by multiplying the average throat by the total test length.
6. The specimen shall be tested in tension to failure, which must be by shear through the test fillet welds. The maximum load is recorded.
7. The shear strength is determined by dividing the maximum load by the total weld area (throat times length) in shear.
8. The specimen may also be used for procedure qualification of fillet welds on plate.

Figure 20 — Fillet Weld Shear Strength Specimens — Transverse and Alternate Transverse from Pipe



(A) TRANSVERSE FILLET WELD SHEAR TEST
COUPON FROM PIPE



(B) ALTERNATE TRANSVERSE FILLET WELD SHEAR TEST
COUPON FROM PIPE

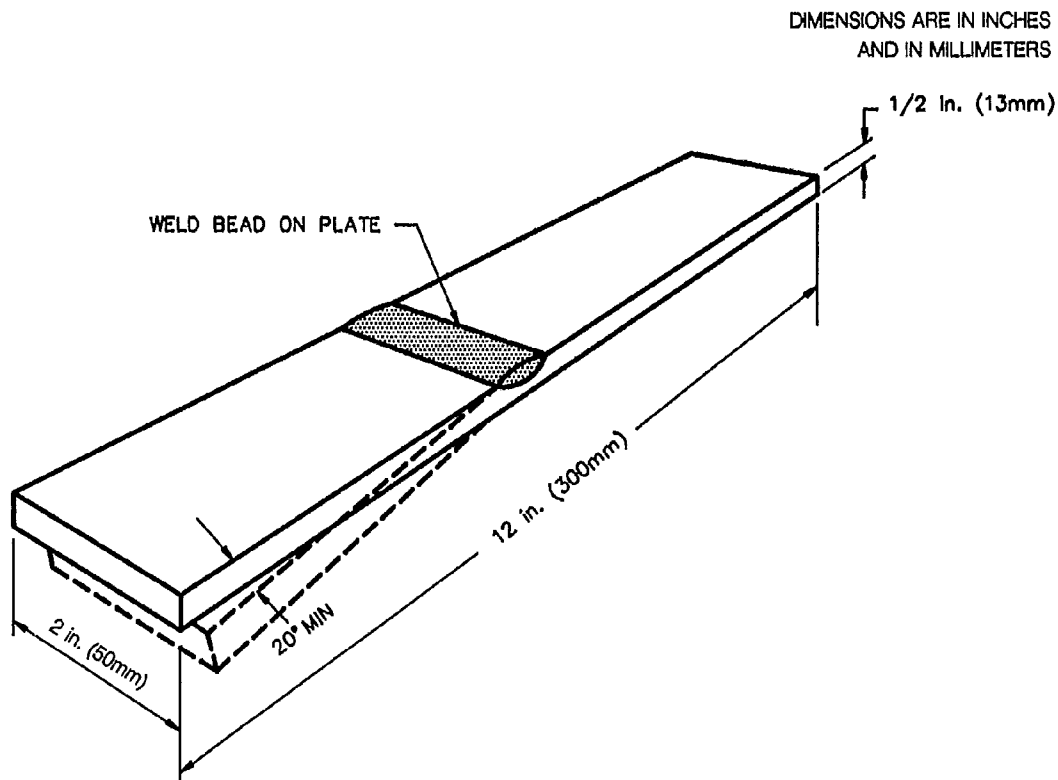
Notes:

1. Other pipe and fillet weld sizes may be used by agreement.
2. Pipe I.D. may be machined for joint fitup.
3. $d = 60$ mm. Larger pipe sizes may result in breaking strengths exceeding usual testing machine capacities.
4. The coupon length shall be sufficient to accommodate the plug and testing machine jaws as shown in ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.
5. Prior to testing, the average throat dimension and total fillet weld test length shall be measured. The throat of the weld is the minimum distance from the root of the joint to the face of the fillet weld. Root penetration is disregarded. The weld area in shear is calculated by multiplying the average throat by the total test length.
6. The specimen shall be tested in tension to failure, which must be by shear through the test fillet welds. The maximum load is recorded.
7. The shear strength is determined by dividing the maximum load by the total weld area (throat times length) in shear.
8. The specimen may also be used for procedure qualification of fillet welds on plate.

Figure 20M — Fillet Weld Shear Strength Specimens — Transverse and Alternate Transverse from Pipe (Metric)

Before testing, the average throat and length of the test weld shall be measured. The throat of the fillet weld is the distance from the root of the joint preparation to the face of the weld, minus any convexity, disregarding any root penetration. The specimen shall be ruptured under tensile load, and the maximum load shall be determined. The cross-sectional area shall be obtained by multiplying the average throat of the weld by the length. The shear strength shall be obtained by dividing the maximum load by the cross-sectional area.

5.11.9 Bridge Bend Test. The weld test coupons shall be made as shown in Figure 21. The coupons shall be bent with the weld bead in tension. Bending shall proceed until a minimum angle of 20 degrees has been developed in the coupon on either side of the bead. The test will pass if no cracks have opened up in either the weld or heat-affected zone. The specimen is unacceptable if a crack is detected. This test is intended to demonstrate that a particular weld does not act as a fracture initiation site under one-time quasi-static loading to a modest plastic strain.



Notes:

1. Test weld to be made with a single pass.
2. Sample to be bent with the face in tension.
3. Bending is to proceed until the sample has a permanent bend angle of 20 degrees min.

Figure 21 — Bridge Bend Test

5.12 Test Results Required

Required results for procedure qualification testing are identified in Part I of sections 7 through 10 for Class A through O welds, respectively.

5.13 Supplemental Requirements

At the discretion of the Customer, supplemental testing may be specified for qualification of any welding procedure.

5.14 Records

The procedure qualification record shall indicate the types of specimen used for the qualification, the welding position(s) and the test results obtained. The records of welding procedure test results shall be maintained for a minimum of one year.

Part III Welder Qualification

5.15 General

All welders employed in executing work in accordance with the requirements of this specification shall be qualified prior to production welding in accordance with the requirements of this section. Each Contractor shall conduct the tests required to qualify the welders. The welder performance tests are intended to establish each welder's ability to make sound welds using a qualified welding procedure specification. The Customer shall verify compliance with this section. In general, for **Class O** welds, the referenced documents take precedence. However, this document shall take precedence in regard to essential variables and the extent of non-destructive and destructive examination.

5.16 Limitations of Variables

Welders shall be qualified to weld with each procedure used for production. A welder shall re-qualify to weld with an appropriately qualified

procedure when there are changes in the following essential variables:

- (1) Welding mode or exposure to water (wet, dry chamber, habitat, etc.).
- (2) Welding process.
- (3) Change in AWS electrode classification (for example: EXX10 to EXX11) or proprietary type, including waterproofing.
- (4) Change in shielding gas beyond the limits of Tables 1 or 2.
- (5) Position different from that qualified in accordance with Table 5.
- (6) Pipe diameter or wall thickness range beyond the limits of Tables 1, 2, or 6. Qualification on two thicknesses or diameters shall qualify for all intermediate values.
- (7) Direction of vertical travel (upward or downward).
- (8) Omission of backing but not vice versa.
- (9) Change from a mixed background gas to air.
- (10) Change in type of diving suit protection which would adversely affect performance.
- (11) A change in depth beyond the limits specified in 5.6.2.
- (12) A change from hot-rolled or normalized steel to quenched-and-tempered steel.
- (13) The visibility condition under which production welding is performed shall not be substantially less than that provided during welding of the qualification coupons. If visibility for production welding is less than 6 in. (150 mm), the welder-diver shall be qualified with visibility less than 6 in. (150 mm).
- (14) The thermal environment and length of exposure experienced by the welder-diver in production welding should not be so severe, as compared to the environment experienced during welding of the qualification coupon, that performance is adversely affected.
- (15) The welder-diver shall not be provided with less support during production welding than was provided during welding of the qualification coupons.

5.17 Qualification Tests Required

5.17.1 A welder may be qualified either under simulated conditions or at the site of the production welds, provided the essential variables for welder qualification are satisfied.

Table 5
Positions for Welder Qualification

Qualification Test		Type of Weld and Position of Welding Qualified ^(a)			
		Plate		Pipe ¹	
Weld	Plate or Pipe Positions ^(b)	Groove	Fillet	Groove	Fillet
Plate - groove	1G	F	F,H	F	F,H
	2G	F,H	F,H	F,H	F,H
	3G	F,H,V	F,H,V		F,H
	4G	F,OH	F,H,OH		
	3G and 4G	All	All		F,H
Plate - fillet	1F		F		F
	2F		F,H		F,H
	3F		F,H,V		
	4F		F,H,OH		
	3F and 4F		All		
Pipe - Groove	1G	F	F,H	F	F,H
	2G	F,H	F,H	F,H	F,H
	5G	F,V,OH	F,V,OH	F,V,OH	F,V,OH
	6G	All	All	All ²	All
	2G and 5G	All	All	All ²	All
	6GR	All	All	All	All
Pipe - fillet	1F		F		F
	2F or 2FR		F,H		F,H
	4F		F,H,OH		OH
	5F		F,H,V,OH		F,H,V,OH

Notes:

1. Plate qualifies pipe or tubing over 24 in. (600 mm) in diameter.
2. Except complete joint penetration groove welds in tubular T-, Y-, and K- connections.
- a. Position of welding: F-flat, H-horizontal, V-vertical, OH-overhead.
- b. Positions as defined in 5.8.

Table 6
Pipe Diameter Groups for
Welder Qualification

Test Pipe Diameter, D, in. (mm)	Diameter of Production Pipe Qualified
4 (100) and under	0.7D to 2D
Over 4 (100) up to 12 (300)	0.50D to 2D
12 (300) and over	0.50D and above

Notes:

1. See Tables 1 and 2 for range of thickness qualified.
2. See section 5.16 for other welder qualification variables.
3. See Figures 26 and 32 for required number of test specimens.

5.17.2 The Customer may accept evidence of previous qualification, provided all the requirements of this specification are met.

5.17.3 Groove Welds. Test assemblies shall be welded for position, thickness, and diameters in accordance with the requirements for variables and positions of 5.16 and Table 5, to qualify a welder for groove welding in plate or pipe. The required type and number of specimens are described in Part II of sections 7 through 10 for Class A through O welds, respectively.

5.17.4 T-, Y-, or K-Connections. To qualify a welder for complete joint penetration groove welds in tubular T-, Y-, or K-connections, a welded 6GR test assembly (Ref. Figure 27 or 33) is required in

accordance with 5.16. Testing on 1/2 in. (13 mm) or greater wall thickness qualifies for welding T-, Y-, or K-connections for all wall thicknesses and diameters for which the welder is qualified with a given procedure. The type and number of specimens required to qualify from each assembly are described in Part II of sections 7 and 8 for **Class A** and **B** welds, respectively.

5.17.5 Fillet Welds. The welder shall weld fillet-weld test assemblies in accordance with the requirements of variables and positions of 5.16 and Table 5. The required type and number of specimens are described in Part II of sections 7 through 10 for **Class A** through **O** welds, respectively.

5.18 Method of Testing

5.18.1 Visual and radiographic examination of welder qualification coupons shall be accomplished in accordance with section 6, Parts II and III, as applicable.

5.18.2 Bend specimens shall be tested in accordance with the requirements of 5.11.3.

5.18.3 Fillet weld specimens shall be tested in accordance with 5.11.6, 5.11.7, and 5.11.8, as applicable.

5.18.4 Macroscopic specimens shall meet the requirements of 5.11.2.

5.19 Test Results Required

Required results for welder qualification testing are identified in Part II of sections 7 through 10 for **Class A** through **O** welds, respectively.

5.20 Retests

If a welder fails to satisfy the requirements of this section in a given position, the welder may be retested in that position by welding two test welds. Both welds shall satisfy the requirements of this section. If either or both welds are unsatisfactory, the welder must provide evidence of further training prior to retest.

5.21 Period of Effectiveness

Qualified welders shall remain qualified for one year from their last qualification or acceptable production weld within the range of variables in 5.16. Nevertheless, when a qualified welder has not welded with the procedure at any time during the previous 90 days, an 8 in. (200 mm) long weld shall be welded in the vertical or overhead position or the position in production in which the majority of the welding will be done. Thickness of material and weld size shall be within the range qualified by the welding procedure qualification. The welder shall remain qualified if visual (for fillet welds) and visual and radiographic (for groove welds) inspections meet the acceptance criteria for the class of weld. Macro examinations may be substituted for radiographic examination as specified in 7.6.1 or 8.6.1.

5.22 Records

Records of welder qualification test results shall be maintained by the Contractor and shall be available to those authorized to examine them.

6. Inspection

Part I **General Requirements**

6.1 General

6.1.1 The Contractor shall assure that materials, fabrication, and examination procedures conform to this specification. The Customer shall verify this conformance.

6.1.2 All classes of weld shall, as a minimum, receive visual examination in accordance with the requirements of Part II of this section. Welds shall meet the inspection requirements and acceptance criteria specified in Part III of sections 7 through 10 for **Class A** through **O** welds, respectively.

6.1.3 When nondestructive examination is required, the Customer shall designate the welds to be examined, extent of examination of each weld, method of examination, required resolution, and acceptance standards. Contract documents and drawings shall show the size, type, class, and location of welds to be made and the method of examination required for each weld where other than visual examination is required.

6.1.4 The Customer shall be notified prior to the start of welding operations.

6.2 Inspection of Materials

6.2.1 The Customer may not have access to the work site in some operations; therefore, special consideration for the collection and recording of data will generally be necessary.

6.2.2 The Customer shall have the right to examine the materials, welding consumables, and supporting documentation to verify that they are qualified for use in production welding.

6.3 Inspection of Procedure Qualification and Equipment

6.3.1 The Contractor shall not proceed with production welding until the Customer has approved the procedure qualification records and has verified that the procedure qualification is appropriate for the materials to be welded.

6.3.2 The Customer shall have the right to examine the equipment to verify that it is qualified for use in production welding.

6.4 Inspection of Performance Qualification

6.4.1 The Contractor shall furnish the Customer with evidence that all welders are qualified in accordance with the requirements of section 5. Evidence of previous qualification may be accepted by the Customer if the qualification meets all applicable criteria of this specification. The Contractor shall maintain a record at the job site of the qualifications of all welders, all procedure qualifications or other tests that are made, and such other information as required by the Customer.

6.4.2 The Contractor shall have sufficient evidence submitted to and approved by the Customer to verify that the confirmation weld meets the requirements of 3.4.

6.4.3 Where the Customer judges that a welder's work may not meet this specification, the welder shall produce a requalification weld made in accordance with section 5, Part III. At the Customer's discretion, an alternate test suitable for the type of welding involved (e.g., fillet weld break test) may be performed.

6.5 Inspection of Work and Records

6.5.1 All welds, including repair welds, shall be examined. The examination procedures are described in Part II, *Visual Examination*, Part III, *Radiography*, Part IV, *Ultrasonic Examination*, Part V, *Magnetic Particle Examination*, and Part VI, *Eddy Current Examination* all in this section. Acceptance standards are described in Part III of sections 7 through 10 for **Class A** through **O** welds, respectively. Satisfactory results for all required examinations shall be submitted to and approved by the Customer. Surface condition of the material shall be such that an adequate examination of the weld can be made with the pertinent examination method.

6.5.2 The Contractor shall provide sufficient evidence to the Customer to verify that the size, length, and location of all welds conform to the requirements of this standard and to the detail drawings, that no specified welds are omitted, and that no unspecified welds have been added without approval.

6.5.3 The Customer shall have the right of inspection of all welds by supplementary visual means (i.e., photographic, video, etc.), by radiographic or other nondestructive methods, and by destructive testing. Inspection may be made both during the welding operation and after the welding has been completed.

6.5.4 If nondestructive examination other than visual is not specified herein or in the original contract agreement but is subsequently requested by the Customer, the Contractor shall perform such requested examination or permit the examination to be performed in accordance with 6.7 of this specification.

6.6 Obligations of Contractor

6.6.1 The Contractor shall be responsible for initial visual examination of all welds in accordance with the requirements of the contract. The Contractor shall correct defective welds in accordance with the welding procedure specification and the requirements of this specification.

6.6.2 In the event that faulty welding, or removal of faulty welding for repair, damages the base metal and, in the judgment of the Customer, retention of the base metal is not in accordance with the intent of the drawings and specifications, the Contractor shall remove and replace the damaged base metal or shall otherwise correct the deficiency in a manner approved by the Customer.

6.6.3 When nondestructive examination other than visual examination is specified in the contract, it shall be the Contractor's responsibility to ensure that all specified welds meet the acceptance criteria specified in Part III of Sections 7 through 10 for **Class A** through **O** welds, respectively.

6.7 Inspection Methods

6.7.1 Welds examined nondestructively that do not meet the requirements of this specification shall be repaired by the methods permitted by section 3.

6.7.2 When visual or supplemental visual examination is used, the procedure and technique shall be in accordance with 6.10.

6.7.3 When radiographic examination is used, the procedure and technique shall be in accordance with 6.12.

6.7.4 When ultrasonic examination is used, the procedure and technique shall be in accordance with 6.14.

6.7.5 When magnetic particle examination is used, the procedure and technique shall be in accordance with 6.16.

6.7.6 For detecting discontinuities that are open to the surface, dye penetrant examination procedures suitable at hyperbaric pressures may be used for welds in a dry environment. The standard methods set forth in ASTM Specification E165 shall be used for dye penetrant examination. This method is not generally suitable for examination of welds in an underwater wet environment.

6.7.7 When eddy current examination is used, the procedure and techniques shall be in accordance with 6.18.

6.8 Personnel Qualification

6.8.1 When inspection is to be conducted in a wet environment, the nondestructive examination operators and technician/divers shall provide supplementary evidence of training and experience establishing their capability to operate the equipment and perform examinations in the underwater environment to the satisfaction of the Customer. Personnel interpreting nondestructive examination results shall be qualified in accordance with the current edition of American Society for Nondestructive Testing, *Recommended Practice No. SNT-TC-1A*. Individuals qualified for NDT Level II or Level III or equivalent qualification as determined by the Customer, may interpret nondestructive testing.

6.8.2 Additional Ultrasonic Qualification Requirements. In addition to the requirements of 6.8.1, when ultrasonic examinations of T-, Y-, and K-connections are to be performed, the operator shall be required to demonstrate ability to apply the special techniques required for such examination. Practical tests for this purpose shall be performed upon mock-up welds, as specified in API RP2X (Reference No. N.9), similar to the welds to be inspected, including a representative range of dihedral angles and thicknesses to be encountered in production, using the applicable qualified and approved procedure.

Each mock-up shall contain natural or artificial discontinuities that yield ultrasonic indications above and below the reject criteria specified in the approved procedure to be used. Performance shall be judged based upon the ability of the operator to determine the size and classification of each discontinuity with an accuracy required to accept or reject each weldment and to locate accurately the rejectable discontinuities along the weld and within the cross section of the weld.

At least 70 percent of the rejectable discontinuities shall be correctly identified as rejectable, and performance shall otherwise be to the satisfaction of the Customer (with particular regard to the level of false alarms). For work on nonredundant structures, all of the serious discontinuities (those exceeding rejectable dimensions by a factor of 2 and amplitude of 6 dB) shall be located and reported.

6.8.3 Additional Eddy Current Qualification Requirements. Operators manipulating the probe coil

assembly shall be qualified to the minimum level outlined in SNT-TC-1A-ET1 for either the wet or dry environment, as applicable. Personnel interpreting the ET results shall be qualified to SNT-TC-1A-ET2 in either the wet or dry environment, as applicable.

Part II Visual Examination

6.9 General

6.9.1 The procedure and standards described herein shall govern the visual examination of welds in both dry and wet environments.

6.9.2 Variation in procedure, equipment, or criteria may be used upon agreement with the Customer.

6.9.3 Welds which do not meet the visual acceptance criteria specified in Part III of sections 7 through 10, as applicable for the class of weld inspected, shall be corrected in accordance with section 3.

6.10 Procedure

6.10.1 The Customer may verify that the inspection meets the requirements of this section, and that the weld meets the visual acceptance criteria of Part III of sections 7 through 10 for the class of weld inspected.

6.10.2 Visual examination techniques shall employ aids to provide adequate resolution. The method to be used shall be included in a written examination procedure. The procedure shall be qualified by the Contractor and approved by the Customer prior to examination of production welds.

6.10.3 Each weld shall be uniquely identified on all visual examination records.

6.10.4 All videotapes and photographs, and a report interpreting the inspection results, shall be submitted to the Customer. This data shall include documentation of unacceptable conditions prior to and subsequent to repair. Approval of the data by the Customer shall constitute acceptance of the

weld. Retention or disposition of inspection data, or both, is the responsibility of the Customer.

Part III ***Radiographic Examination***

6.11 General

6.11.1 The procedure and standards described herein shall govern radiographic examination of welds when such examination is required. These procedures shall be used for examining groove welds in both wet and dry environments.

6.11.2 Variations in examination procedure, equipment, and acceptance standards may be used upon agreement with the Customer. Variations may be necessary to accommodate location, application, or operator safety. Such variations include but are not limited to: (1) the radiographic examination of fillet, T-joint, or corner welds; (2) changes in source-to-film distances; (3) application of film for unusual geometries; (4) unusual penetrameter application; (5) film types or densities; and (6) film exposure or development variations. The Customer may require that the applicability of other procedures be demonstrated prior to use.

6.11.3 When spot radiographic examination is specified, the number of spots in each designated category of weld or the number required to be made in a stated length of weld shall be included in the contract. Each spot examined shall cover at least 4 in. (100 mm) of the weld length. When spot examination reveals discontinuities that require repair, two additional spots selected by the Inspector shall be radiographically examined. If discontinuities requiring repair are revealed in either of these, the entire length of the weld in that welded joint shall be radiographically examined.

6.11.4 When radiography is required, welds which do not meet the radiographic acceptance criteria of Part III in section 7 through 10 as applicable for the class of weld inspected, shall be corrected in accordance with section 3.

6.12 Procedure

6.12.1 All radiographic examinations (RT) shall be in accordance with a procedure complying with the requirements of this specification and which has been prepared or approved by an individual qualified to SNT-TC-1A Level III. A written procedure specifying equipment and operations required to radiograph the weld shall be submitted to the Customer for approval prior to its use on production welding.

6.12.2 The size of discontinuities, as a percent of the thickness of the weld, that must be resolved in the radiograph shall be 2% or less of the base metal thickness. A radiographic image quality indicator (IQI) shall be used to provide proof of resolution.

6.12.3 If, in the Customer's judgment, film processing defects have obscured objectionable weld defects, the weld shall be reexamined.

6.12.4 If, in the judgment of the Customer, weld surface irregularities may obscure rejectable weld defects, the surface shall be smoothed by a procedure submitted to and approved by the Customer.

6.12.5 Radiographs shall have an H & D density of not less than 1.8 nor more than 4.0. Densities within the range of 2.5 to 3.5 are preferred.

6.12.6 The source of radiation shall be approximately centered with respect to the length being examined. An image quality indicator shall be located within 1 in. (25 mm) of each end of the applicable length of film, and it shall be placed on the side of the work nearer the source, where accessible.

When a complete girth weld in pipe is radiographed in a single exposure using a source inside the pipe, a minimum of three image quality indicators equally spaced around the circumference shall be used. The perpendicular distance from the radiation source to the film shall be no less than seven times the maximum thickness of the weld under examination, and the rays shall not penetrate the weld at an angle greater than 26-1/2 degrees from a line perpendicular to the film surface. Where the source side is not accessible for locating the IQI, the procedure test shall establish the required IQI on the film side.

6.12.7 Each radiograph shall show the following:

- (1) The specified sensitivity of the IQI
- (2) An IQI identification number
- (3) A radiograph identification code
- (4) Weld sector identification

6.12.8 A radiographic procedure shall be resubmitted for approval when one or more of the following apply:

- (1) The IQI is transferred from the film side to the source side of the weld or vice versa.
- (2) Intensification or absorption screens are added or deleted.
- (3) The type of radiation source is changed (x-ray, gamma ray, etc.).
- (4) The type or grade of film is changed.

6.12.9 The Contractor shall provide a suitable high-intensity viewer with sufficient capacity to illuminate radiographs with a density of 4.0 without difficulty. (It is recommended that at least a two-level or variable intensity illuminator be used.)

6.12.10 Before a weld subject to radiographic examination is accepted, all radiographs, including any revealing unacceptable indications prior to repair, and a report interpreting the results shall be submitted to and approved by the Customer. Approval of the radiographs by the Customer shall constitute acceptance of the weld.

Part IV **Ultrasonic Examination**

6.13 General

Procedure requirements described herein are conventional contact methods only. Other properly qualified methods may be used when approved by the Customer. (For example, ANSI/AWS D1.1, *Structural Welding Code — Steel*, 6.15, Ultrasonic Equipment.)

6.14 Procedure

All ultrasonic examinations (UT) shall be in accordance with procedures written in compliance with the requirements of this specification and which have been prepared or approved by a qualified individual experienced in UT of welded struc-

tures. Prior to use on production welds, the procedure and acceptance criteria shall be approved by the Customer, and personnel shall have been successfully qualified per 6.8. When T-, Y-, and K-connections are to be examined, the UT specialist shall also be experienced in examination of those types of weldment.

6.14.1 Minimum Requirements. The written procedure shall contain as a minimum the following information regarding the UT method and techniques:

- (1) Type of weld joint configuration to be examined (i.e., the applicable range of thickness, diameter, and local dihedral angle¹)
- (2) Acceptance criteria for each type and size of weld
- (3) Description of UT instrumentation (make and model)
- (4) Length of coaxial cable (connecting cable from UT instrument to search unit)
- (5) Transducer (search unit) frequency, size and shape of active area, beam angle, and type of wedge on angle beam probes²
- (6) Functions to be performed by and information displays available to diver and topside technician
- (7) Surface preparation and couplant (where used)
- (8) Type of calibration test block and reference reflector
- (9) Method of calibration and required accuracy for distance (sweep), beam spread, vertical linearity, angle sensitivity, and resolution
- (10) Recalibration interval for each item
- (11) Method for determining acoustical continuity of base metal (see 6.14.3) and for establishing weld geometry as a function of local dihedral angle and thickness
- (12) Scanning pattern and sensitivity (see 6.14.4)
- (13) Adjustment for depth (pressure) effects

1. Conventional techniques are limited to diameters of 12-3/4 in. (320 mm) and above, thicknesses of 1/2 in. (13 mm) and above, and local dihedral angles of 30 degrees or greater. Special techniques for small sizes may be used provided they are qualified as described herein, using the smallest size of application.

2. Procedures using transducers with frequency up to and including 6 MHz, size down to and including 1/4 in. (6 mm), and various geometric shapes may be used provided they are also used during the procedure qualification.

(14) Transfer correction for surface curvature and roughness, where amplitude methods are used [see 6.14.2.2 (3)]

(15) Methods for determining effective beam angle (in curved material), indexing root area, and flaw location

(16) Method of determining discontinuity length and width

(17) Method of defect verification during excavation and repair

6.14.2 Calibration. UT equipment qualifications and calibration methods shall be established in the approved procedure and shall meet the following requirements.

6.14.2.1 Range (Distance) Calibration. Calibration shall include, as a minimum, the entire sound path distance to be used during the specified examination. This may be adjusted to represent either sound path travel, surface distance, or equivalent depth below the contact surface, displaced along the instrument horizontal scale, as described in the approved procedure.

6.14.2.2 Sensitivity Calibration. Standard sensitivity ARL (Amplitude Reject Level) for examination of production welds using amplitude techniques shall be the sum of the basic sensitivity, the distance amplitude correction, and the transfer correction. This calibration shall be performed at least once for each joint to be tested.

(1) Basic sensitivity — Reference level screen height shall be obtained using maximum reflection from the 0.060 in. (1.5 mm) diameter hole of the IIW block (or other block which results in the same basic calibration sensitivity) as described in the approved procedure.

(2) Distance amplitude correction — The sensitivity level shall be adjusted to provide for attenuation loss throughout the range of sound path to be used either by distance amplitude correction curves, by electronic means, or by other means as described in the approved procedure.

(3) Transfer correction — Instrument sensitivity shall be adjusted to compensate for differences between the calibration standard contact surface curvature and roughness, versus those of the material being examined. This may be determined by noting the difference between responses received from the same reference reflector (e.g., a second search unit acting as a reflector) in both situations, after correcting for distance as described above.

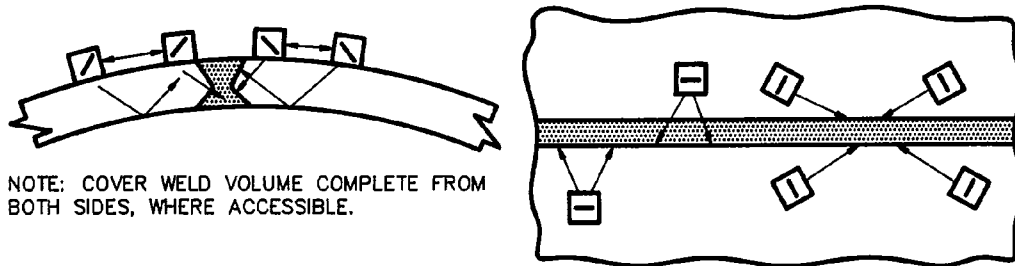
6.14.2.3 Reference may be made to the ultrasonic examination requirements of section 6 of ANSI/AWS D1.1, for establishing procedures regarding ultrasonic instrumentation and calibration requirements.

6.14.3 Base Metal Examination. The entire area subject to ultrasonic scanning shall be examined by the longitudinal wave technique to detect laminar reflectors that could interfere with the intended, directed sound wave propagation. All areas containing laminar reflectors shall be marked for identification prior to weld examination. Welds in that area shall be examined using an alternate weld scanning procedure, if applicable. Base material discontinuities that exceed the limits of applicable base material specifications or other established requirements shall be brought to the attention of the Customer.

6.14.4 Weld Scanning. Scanning of normal groove welds shall be in accordance with the requirements of Figure 22, or as established in the approved procedure. Scanning of T-, Y-, and K-connections shall be performed from the attachment surface (see Figure 22), or as established in the approved procedure. All examinations shall be made in leg I and II where possible. For initial scanning, the sensitivity shall be increased by 12 dB above the Amplitude Reject Level (ARL) established in 6.14.2.2 at the maximum sound path. Indication evaluation shall be performed with reference to the standard sensitivity.

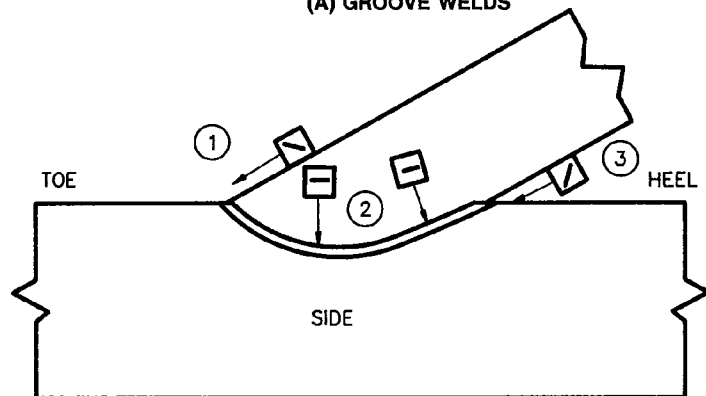
6.14.5 Optimum Angle. Indications found in the root areas of groove welds in butt joints, and along fusion faces of all welds, shall be further evaluated with a 70, 60, or 45 degree search unit angle, whichever is nearest to being perpendicular to the expected fusion face.

6.14.6 Discontinuity Evaluation. Discontinuities shall be evaluated using a combination of beam boundary and amplitude techniques. Sizes shall be given as length, and height (depth dimension) or amplitude, as applicable. Amplitude shall be related to "standard calibration". In addition, discontinuities shall be classified as linear or planar, versus spherical, by noting changes in amplitude as the transducer is swung in an arc centered on the reflector. The location (position) of discontinuities within the weld cross section, as well as from an established reference point along the weld axis, shall be determined. See Figure 23 for additional evaluation requirements.

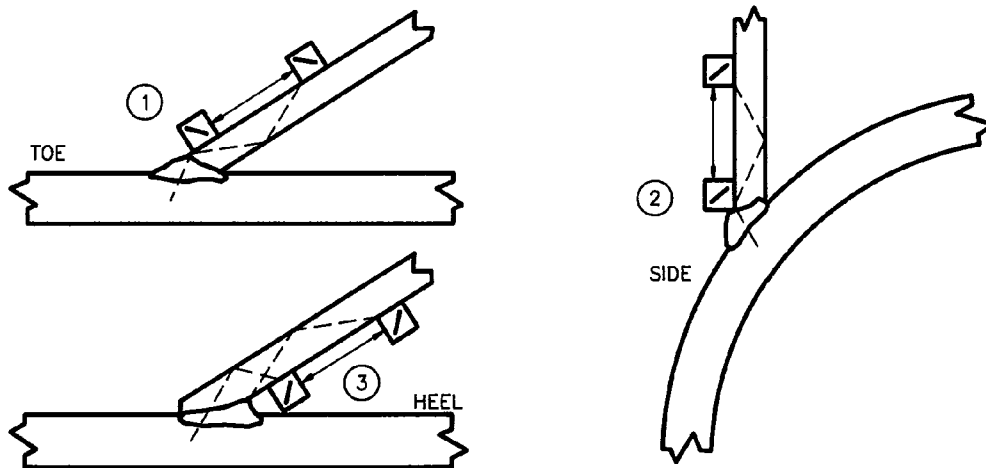


NOTE: COVER WELD VOLUME COMPLETE FROM BOTH SIDES, WHERE ACCESSIBLE.

(A) GROOVE WELDS



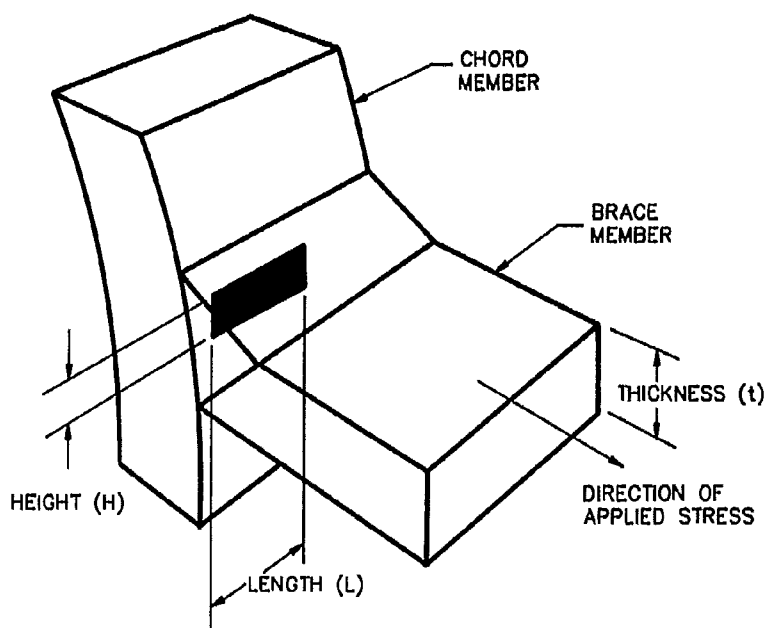
BEAM DIRECTION—MAINTAIN SOUND BEAM PERPENDICULAR TO THE WELD.



V-PATHS—USE SINGLE AND MULTIPLE LEGS AND VARIOUS ANGLES, AS REQUIRED, TO COVER THE COMPLETE WELD INCLUDING THE ROOT AREA.

(B) T-, Y-, AND K- CONNECTIONS

Figure 22 — Ultrasonic Scanning Techniques



WELD THROAT THICKNESS = (T)

BRACE MEMBER DIAMETER = (D)

Evaluation Requirements:

- (1) Use combination of beam boundary and amplitude.
- (2) Give size as length (L) and height (H).
- (3) Determine "class": Linear/Planar versus Spherical.
- (4) Length (L) and height (H) shall be based upon a rectangle that totally encloses the indicated discontinuity.
- (5) Aligned discontinuities separated by less than $(L_1 + L_2)/2$ and parallel discontinuities separated by less than $(H_1 + H_2)/2$ shall be evaluated as being continuous.
- (6) Accumulative flaws shall be evaluated over a 6 in. (150 mm) or $D/2$ length of weld, whichever is less.
- (7) Root area shall be defined as that lying within $1/4$ in. (6 mm) or $T/4$, whichever is greater, of the root of the theoretical weld.
- (8) Record the position (location) of discontinuities within the weld cross section as well as from an established reference point along the weld axis.

Figure 23 — Discontinuity Evaluation

6.14.7 Acceptance Criteria. Refer to 7.12.

6.14.8 Reporting

6.14.8.1 A report clearly defining the environment (depth, etc.) and identifying the part and the area of inspection shall be completed by the ultra-

sonic technician at the time of inspection. A detailed report including a sketch showing the location along the weld axis, location within the weld cross section, size, extent, orientation, and classification for each discontinuity shall be completed for each weld in which significant indications are found. A recommended form is included

in Appendix A. Report forms shall be submitted to the Customer upon completion of the work.

6.14.8.2 When specified, discontinuities approaching rejectable size, particularly those about which there is some question in their evaluation, shall also be reported.

6.14.8.3 Areas of any part for which complete inspection was not practicable shall also be explained in the report.

6.14.8.4 Unless otherwise specified, the reference position and the location and extent of rejectable flaws shall also be marked physically on the workpiece.

Part V ***Magnetic Particle Examination***

6.15 General

6.15.1 The procedure and standards described herein shall govern magnetic particle examination, when such an examination is required. This method is used for detecting linear discontinuities at or very near the surface of welds in magnetic materials.

6.15.2 Variations in the examination procedure, equipment, and acceptance criteria may be used with approval of the Customer. Such variations may include means used to magnetize the weld or to apply magnetic particles.

6.15.3 When magnetic particle examination is required, welds which do not meet the surface acceptance criteria of Part III in sections 7 through 10, as applicable for the class of welds inspected, shall be corrected in accordance with section 3. Light grinding may be employed to determine relevancy of indications.

6.16 Procedure

6.16.1 Technique. When magnetic particle examination is to be used in a wet or dry environment, the procedure and technique shall be in accordance with ASTM Specification E709 (Dry and Wet Powder).

6.16.2 Magnetization. Alternating current, direct current, or permanent magnets may be used to magnetize the weld. The magnetizing current or ampere turns used shall be specified in accordance with ASTM E709. The examination procedure shall state whether the magnetizing current shall be maintained during the readout of indications.

6.16.3 Particles. The ferromagnetic particles shall be of a color contrasting to the surface. Fluorescent magnetic particles may be used with a black light.

6.16.4 Preparation and Disposition of Reports

6.16.4.1 A report clearly identifying the work and the area of examination shall be completed by the magnetic particle interpreter at the time of examination. Reports for acceptable welds need only contain sufficient information to identify the weld, the segment inspected, the interpreter (signature), examination variables, and the acceptability of the weld. When specified by the Customer, indication of defects shall be documented by photography. Reports shall be submitted to the Customer upon completion of the work.

6.16.4.2 Before a weld subject to magnetic particle examination is accepted, all reports pertaining to the weld, including any identifying unacceptable indications prior to repair, shall be submitted to and approved by the Customer. Approval of the reports by the Customer shall constitute acceptance of the weld.

Part VI ***Eddy Current Examination***

6.17 General

6.17.1 The procedure and standards described herein shall govern eddy current (electromagnetic, or ET) examination when such examination is required. This method is used for detecting linear discontinuities at or very near the surface of welds in ferritic and austenitic materials.

6.17.2 Variation in the examination procedure, equipment, or acceptance criteria may be used with approval of the Customer.

6.17.3 When eddy current examination is required, welds or other materials which do not meet the surface acceptance criteria of Part III in sections 7 through 10, as applicable for the class of weld inspected, shall be corrected in accordance with section 3. Light grinding may be employed to determine relevancy of indications.

6.18 Procedure

6.18.1 Technique. When using ET examination in wet or dry environment, the procedure and technique shall be in accordance with ASTM Specification E309 or E426. References in this specification to ASTM E309 and E426 which refer to tubular material, may also apply to nontubular materials.

6.18.2 Supplemental Examination. When indications of defects are found using ET examination, those areas may also be examined with the magnetic particle method, in accordance with Part V of this section, for purposes of verification.

6.18.3 Communications. During examinations in the wet or dry environment, communications be-

tween the probe manipulator and the interpreting person (see 6.8.3) shall be continuous and clear in nature, utilizing a dedicated system.

6.18.4 Preparation and Disposition of Reports

6.18.4.1 A report clearly identifying the work and the area of examination shall be completed by the ET interpreter at the time of the examination. Reports for acceptable welds need only contain sufficient information to identify the weld, the segment inspected, the interpreter (signature), examination variables, and the acceptability of the weld. When specified by the Customer, indications of defects shall be documented by photography. Reports shall be submitted to the Customer upon completion of the work.

6.18.4.2 Before a weld subject to ET examination is accepted, all reports pertaining to the weld, including any identifying unacceptable indications prior to repair, shall be submitted to and approved by the Customer. Approval of the reports by the Customer shall constitute acceptance of the weld.

7. Class A Welds

7.1 Application

The requirements of this section apply to **Class A** welds. **Class A** defines a set of requirements for underwater welds that are intended to be suitable for structural applications involving design stresses comparable to similar above-water applications. This class of weld will meet the Customer's requirements for a particular structure and shall satisfy the requirements of this specification for **Class A** welds.

7.1.1 Welding procedure specifications for **Class A** welds shall be qualified in accordance with the general requirements of section 5, Parts I and II, and the specific requirements of Part I of this section.

7.1.2 All welders, including tack welders, making **Class A** welds shall be qualified prior to production welding in accordance with the general requirements of section 5, Parts I and III, and with the specific requirements of Part II of this section.

7.1.3 Minimum examination requirements for all **Class A** production welds and acceptance criteria for all inspection and examination of **Class A** welds, including that performed during procedure and performance qualification, are defined in Part III of this section.

Part I *Procedure Qualification*

7.2 Testing Requirements

The number and type of test specimens required for procedure qualification to test the first position and additional positions for **Class A** welds are summarized in Table 7.

7.3 Groove Welds

7.3.1 Test Specimens. Test specimens for **Class A** groove welds shall be located in accordance with Figures 24 and 25. All-weld-metal specimens shall be prepared and located in accordance with 5.11.4 and Figures 14 and 15. As an option, the length of the procedure qualification test assembly (Figure 24) may be increased and the all-weld-metal tension specimen may be removed from the procedure qualification test assembly.

7.3.2 Test Results. Procedure qualification test results for **Class A** groove welds shall meet the following requirements:

(1) Visual examination — The welds shall meet the visual acceptance criteria of 7.9.

(2) Radiographic examination — The welds shall meet the acceptance criteria of 7.10.

(3) Reduced-section tension test — The tensile strength shall equal or exceed the specified minimum tensile strength of the base metal for each sample.

(4) All-weld-metal tension tests — The yield strength and tensile strength shall exceed the minimums specified for the base metal. The minimum acceptable elongation shall be dependent on the base metal specified minimum yield strength as follows:

Yield strength, ksi (MPa)	Minimum elongation, %
Up to 50 (350)	19
51 (351) to 89 (599)	14
90 (600) and higher	12

(5) Bend tests — The bending fixture shall conform to Figure 13 of section 5, Part II. Bend radius (B) for testing shall be determined as follows:

Table 7
Weld Procedure Qualification — Number and Type of Test Specimens for Class A Welds^a

Joint Type	Coupon Thickness in. (mm)	Visual (See 6.10)	Radiographed (See 6.12) ^d	Reduced Section Tension (See 5.11.1)	Fillet		All-Weld- Metal Tension (See 5.11.4)		Root Bends (See 5.11.3)	Face Bends (See 5.11.3)		Side Bends (See 5.11.3)	Macroetch Test (Sec 5.11.2)	Vickers Hardness (See 5.11.6) ^e	Charpy Impact (See 5.11.5) ^f	Fillet Weld Break (See 5.11.7)
					Weld Shear (See 5.11.8)	Shear	Tension	Bends		Bends	Bends					
Plate Groove	$t \leq 3/8$ (10)	Yes	Yes	2	0	0	1	2	2	0	0	0	1	1	WM and HAZ	0
	$3/8 < t < 3/4$	Yes	Yes	2	0	0	1	Note b	Note b	Note b	Note b	0	1	1	WM and HAZ	0
	$t \geq 3/4$ (20)	Yes	Yes	2	0	0	1	0	0	0	4	1	1	1	WM and HAZ	0
Pipe Groove	$\leq 3/8$ (10)	Yes	Yes	2	0	0	1	2	2	2	0	0	1	1	WM and HAZ	0
	$3/8 < t < 3/4$	Yes	Yes	2	0	0	1	Note b	Note b	Note b	Note b	0	1	1	WM and HAZ	0
	$t \geq 3/4$ (20)	Yes	Yes	2	0	0	1	0	0	0	4	1	1	1	WM and HAZ	0
Plate Fillet	All ^c	Yes	No	0	1	1	1	0	0	0	0	0	2	1	WM	1
Pipe Fillet	All ^c	Yes	No	0	1	1	1	0	0	0	0	0	4	1	WM	4

Notes: WM = Weld Metal
HAZ = Heat-Affected-Zone

≤ Less than or equal to
≥ Greater than or equal to

< less than
> greater than

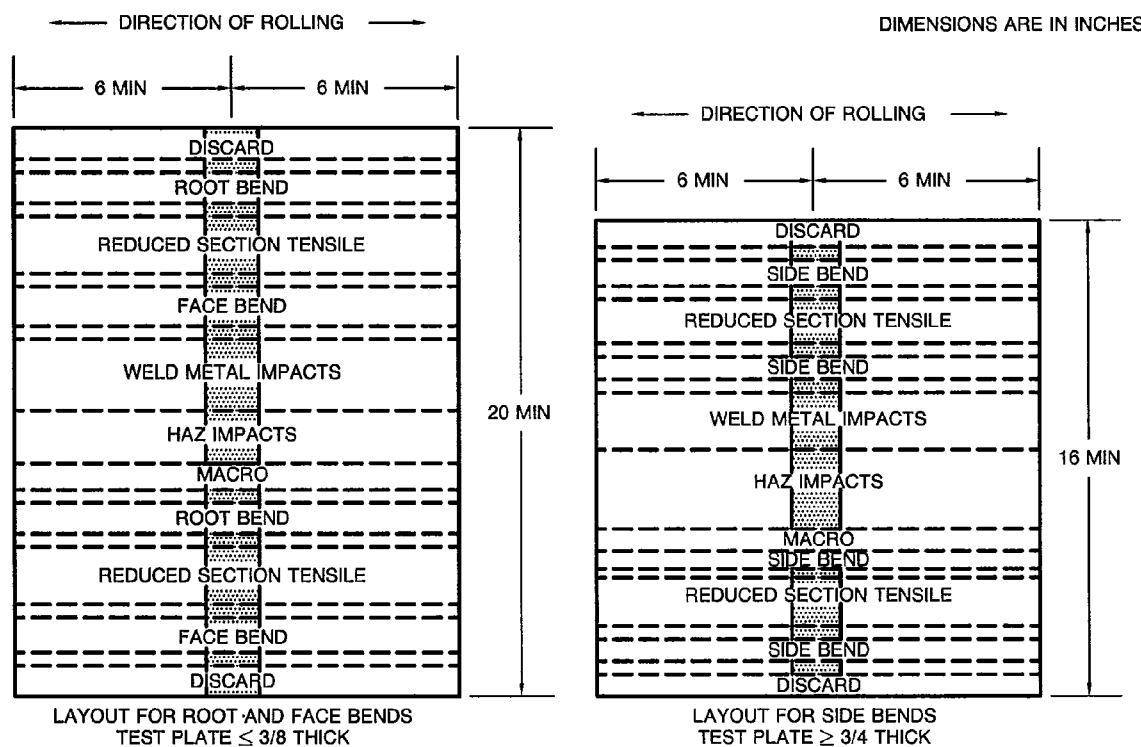
a. First position only. Qualification for additional positions will omit groove weld tension, macroetch, hardness Charpy tests, fillet weld shear strength tests and all-weld-metal tension tests. Whenever qualification is required for vertical-up welding, that position/coupon shall be the one from which impacts are taken.

b. For plate or pipe between 3/8 in. (10 mm) and 3/4 in. (20 mm) thick, the Customer shall specify either two root and two face bend tests or four side bend tests.

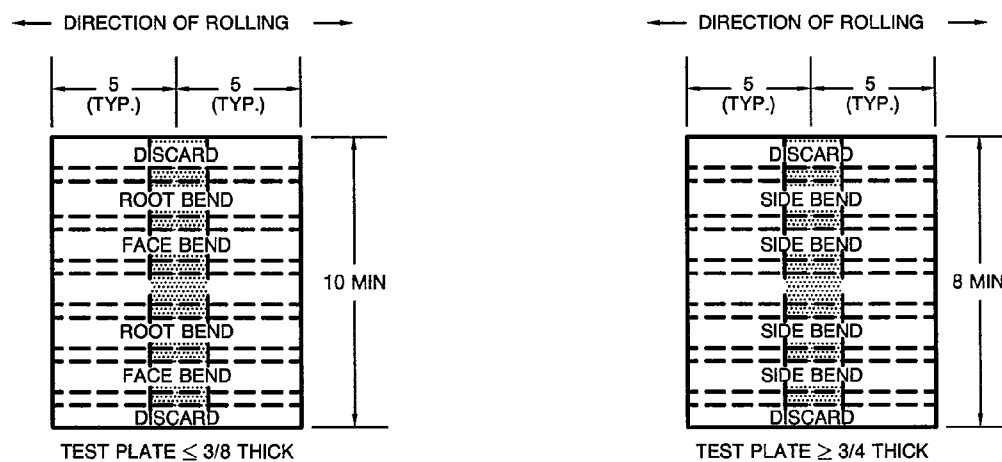
c. Multiple pass fillet welds are considered qualified by groove weld qualification. (See 5.9.2)

d. Groove welds only are radiographed.

e. Vickers Hardness and Charpy impact tests not applicable for austenitic stainless steel base metals.



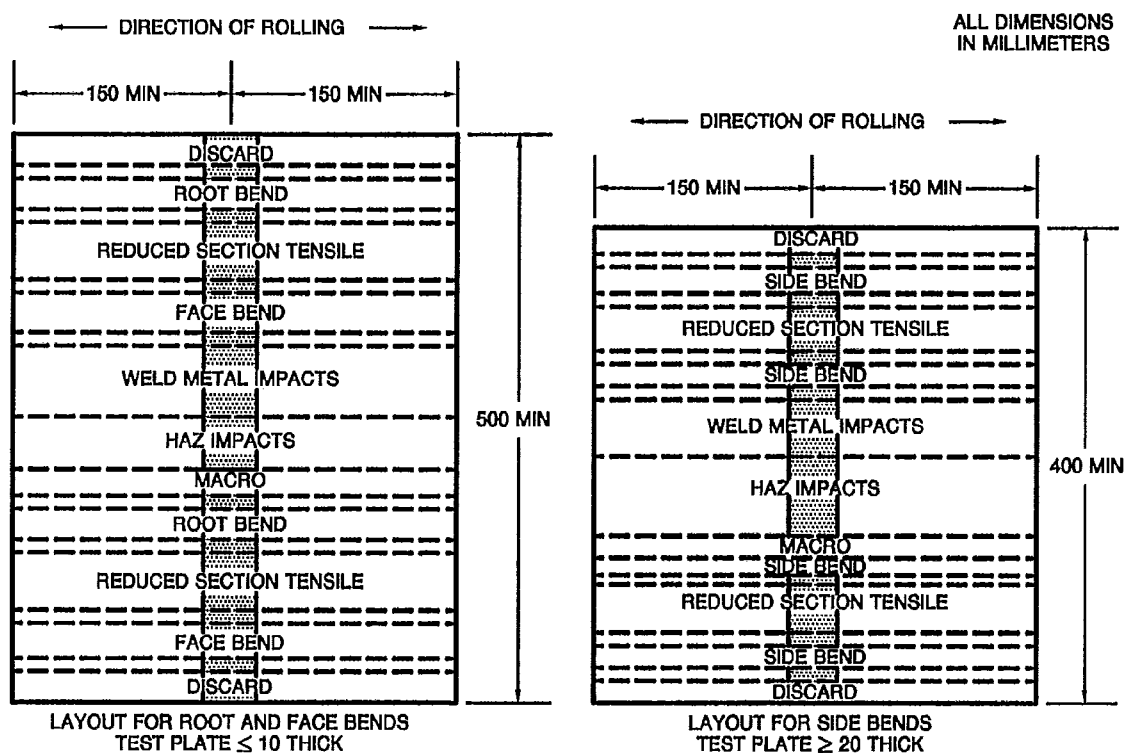
(A) FIRST POSITION PLATES



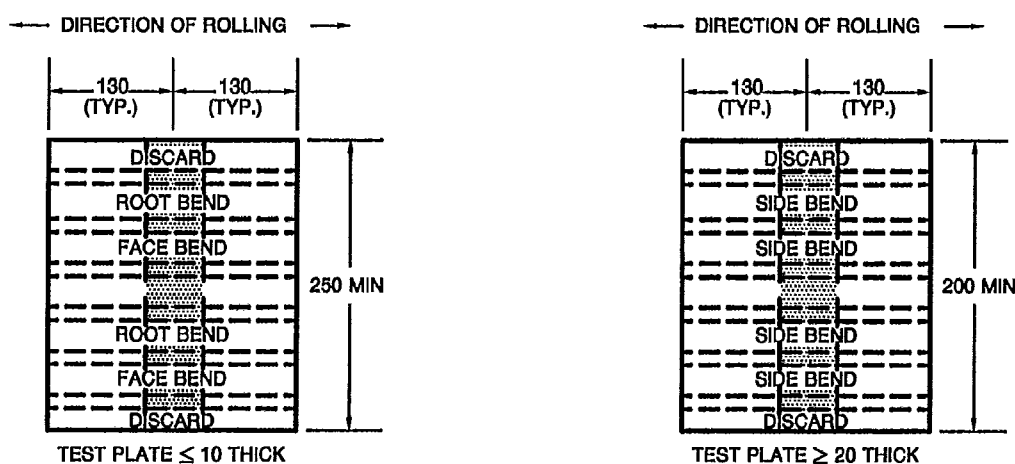
(B) ADDITIONAL POSITIONS PLATES

Note: As an option, the length of the test plate may be increased to provide for the all-weld-metal tensile test specimen in accordance with 7.3.1 when the plate thickness is $\geq 3/4$ in. For plates between $3/8$ in. and $3/4$ in., Customer may specify root and face bends or side bends for first and additional position plates.

Figure 24 — Location and Types of Test Specimens on Welded Plated Test Procedure Qualification Assembly, Class A Groove Welds



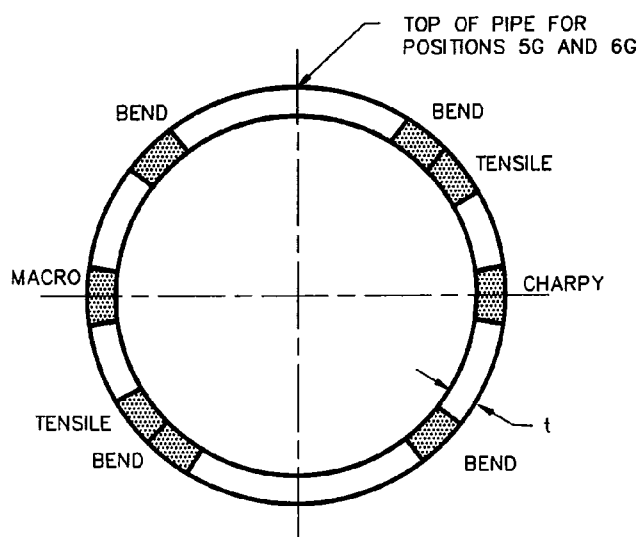
(A) FIRST POSITION PLATES



(B) ADDITIONAL POSITIONS PLATES

Note: As an option, the length of the test plate may be increased to provide for the all-weld-metal tensile test specimen in accordance with 7.3.1 when the plate thickness is ≥ 20 mm. For plates between 10 and 20 mm, Customer may specify root and face bends or side bends for first and additional position plates.

Figure 24M — Location and Types of Test Specimens on Welded Plate Test Procedure Qualification Assembly, Class A Groove Welds (Metric)



Notes:

1. If the pipe diameter is too small to permit all specimens to be machined from a single weld, additional welds shall be made to provide sufficient material for test.
2. First position weld, test all specimens shown. Additional position welds, test bend specimens only.
 - (a) $t \leq 3/8$ in. (10 mm) — two root and two face bends.
 - (b) $t \geq 3/4$ in. (20 mm) — four side bends.
 - (c) t between $3/8$ in. (10 mm) and $3/4$ in. (20 mm). Customer may specify root and face or side bends.
 - (d) Specimen length as described in Figures 11 and 12.

Figure 25 — Location and Types of Test Specimens on Welded Pipe Test Procedure Qualification Assembly, Class A Groove Welds in Pipe

Minimum specified base metal yield strength, ksi (MPa)	Bend Radius (B) (Figure 13)
50 (350)	2T
Up to 51 (351) to 89 (599)	2-2/3T
90 (600) and higher	3-1/3T

Four samples shall be tested, and they shall not reveal tears or other defects exceeding $1/8$ in. (3 mm) in the weld metal or fusion zone after bending. Tears which originate at the corner of the specimen and are less than $1/4$ in. (6 mm) long shall not be cause for rejection unless they are associated with a defect.

(6) Macro — Macrosections transverse to the weld shall reveal no cracks at 5X magnification. Slag, porosity, or other defects exceeding $1/8$ in. (3 mm) in height or width shall be cause for rejection. Microhardness measurements shall not exceed 325 HV 10 (see 5.11.6).

(7) Charpy impact test — The highest and lowest Charpy impact absorbed energy values shall be discarded. The average and minimum Charpy energy values of the three remaining specimens shall satisfy the following requirements, unless more stringent requirements are specified by the Customer:

Specified minimum tensile strength of base metal, ksi (MPa)	Charpy V-notch impact energy*, average/minimum, ft-lb (J)
70 (485) or lower	15/10 (20/14)
71 to 80 (486 to 550) inclusive	20/14 (27/19)
81 to 100 (551 to 690)	25/17 (34/23)

* When tested at the minimum design service temperature or the temperature specified by the Customer (see 5.11.5).

7.4 Fillet Welds

7.4.1 Test Specimens. A groove weld for the all-weld-metal tension specimen and Charpy V-notch impact specimens shall be produced in accordance with 5.11.4 and 5.11.5. Fillet weld shear specimens shall be produced in accordance with the requirements of 5.11.8 (refer to Figures 18 and 19 for plate qualification and Figure 20 for pipe qualification). Fillet weld break test coupons shall be produced in accordance with the requirements of 5.11.7 (refer to Figure 9 for plate and pipe qualification). As an option, the Contractor may choose to qualify a multiple-pass fillet weld procedure on the basis of a groove weld qualification in accordance with the requirements of 5.9.2.

7.4.2 Test Results. Procedure qualification test results for **Class A** fillet welds shall meet the following requirements:

(1) Visual examination — All test welds shall meet the visual acceptance criteria of 7.9.

(2) Radiographic examination — The groove weld for the all-weld-metal tension and Charpy V-notch impact specimens shall meet the acceptance criteria of 7.10.

(3) Fillet weld shear strength test — The minimum acceptable shear strength of the weld shall be 60% of the minimum tensile strength of the filler metal measured in the all-weld-metal tension test.

(4) All-weld-metal tension test — The test specimen machined from the groove weld, as described in 5.11.4, shall be tested in accordance with ASTM A370. The yield strength and tensile strength shall exceed the minimum values specified for the base metal. The minimum acceptable elongation shall be dependent on base metal specified minimum yield strength as follows:

Minimum Yield strength, ksi (MPa)	Minimum elongation, %
Up to 50 (350)	19
51 (351) to 89 (599)	14
90 (600) and higher	12

(5) Fillet-weld-break test — The specimen shall pass the test if it bends flat upon itself. If the fillet weld fractures, the fractured surface shall meet the requirements of 7.10. The weld shall have fusion to the root of the joint but not necessarily beyond.

(6) Macro — Macrosections transverse to the weld shall reveal no cracks at 5X magnification and shall meet the requirements of 7.10. Microhardness tests on the surfaces shall not exceed 325 HV 10. (See 5.11.6)

(7) Charpy impact test — Weld metal Charpy impact test specimens, as described in 5.11.5, shall be prepared and tested. They shall meet the impact requirements for **Class A** welds listed in 7.3.2(7). Charpy impact testing of the heat-affected zone is not required.

Part II Welder Qualification

7.5 Testing Requirements

The number and type of test specimens required for welder qualification for **Class A** welds are summarized in Table 8.

7.6 Groove Welds

7.6.1 Test Specimens. Test specimens for welder qualification shall be prepared and located in accordance with Figure 26 for groove welds, and Figure 27 for T-, Y-, and K-connections on pipe or tubing. Four bend specimens shall be removed from each weld coupon. In lieu of radiographic or ultrasonic inspection, three macrosections may be removed from the weld adjacent to the required bend specimens; such specimens shall be prepared and etched in accordance with 5.11.2 and shall meet the requirements of 7.6.2(2).

7.6.2 Test Results. Welder qualification test results for **Class A** groove welds shall meet the following requirements:

Table 8
Welder Performance Qualification — Number and Type of Test Specimens for Class A Welds
(Per Welder)

Coupon	Joint Type	Thickness Tested in. (mm)	Visual ^d (see 6.9)	Radiographic ^d (see 6.11)	Bends ^b (See 5.11.3)		Macro ^c	Fillet Weld Break (See Fig. 9)
					Root and Face	Side		
Plate	Groove	≤3/8 (10)	Yes	Yes ^a	2 each			
		>3/8 <3/4	Yes	Yes ^a	2 each	or 4		
		≥3/4 (20)	Yes	Yes ^a		4		
Pipe	Groove	≤3/8 (10)	Yes	Yes ^a	2 each			
		>3/8 <3/4	Yes	Yes ^a	2 each	or 4		
		≥3/4 (20)	Yes	Yes ^a				
Plate	Fillet	All	Yes				2	1
Pipe	Fillet	All	Yes				4	4

Notes:

a. Ultrasonic or three Macros may be substituted. See 7.6.1.

b. For plate and pipe between 3/8 in. (10 mm) and 3/4 in. (20 mm) thick, Customer shall specify either root and face bends or side bends.

c. See 5.11.2, 7.7, and Figure 9. Hardness tests not required.

d. See Section 6, Part II for visual examination, Part III for radiographic examination.

≤ : Equal to or less than. ≥ : Equal to or greater than

(1) Visual examination — The welds shall meet the visual acceptance criteria of 7.9.

(2) Radiographic or ultrasonic (or macroscopic) — The welds shall meet the acceptance criteria of 7.10.

(3) Bend tests — The bending fixture shall conform to Figure 13 of section 5, Part II, with the bend radius as specified in 7.3.2(5). Four samples shall be tested, and they shall not reveal cracks or other defects exceeding 1/8 in. (3 mm) in the weld metal or fusion zone after bending. Cracks which originate at the corner of the specimen and are less than 1/4 in. (6 mm) long shall not be cause for rejection unless they are associated with a defect.

7.7 Fillet Welds

7.7.1 Test Specimen. The welder shall weld fillet-weld-break and macroetch test assemblies as shown in Figure 9 in accordance with the requirements of variables and positions of 5.16 and Table 5. The number and type of specimens required to qualify from each assembly are shown on Table 8.

7.7.2 Test Results. Welder qualification test results for Class A fillet welds shall meet the following requirements:

(1) Visual examination — All test welds shall meet the visual acceptance criteria of 7.9.

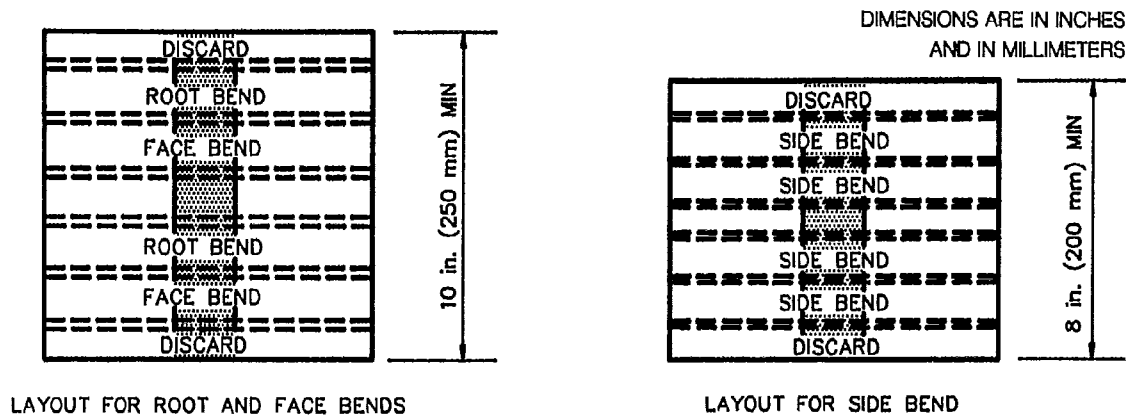
(2) Macro — Macrosections transverse to the weld shall reveal no cracks at 5X magnification and shall meet the acceptance criteria of 7.10.

(3) Break tests — A fillet weld break test shall pass the bend test if it bends flat upon itself. If the fillet weld fractures, porosity or slag shall not exceed the limitations of 7.10. The weld shall have fusion to the root of the joint but not necessarily beyond.

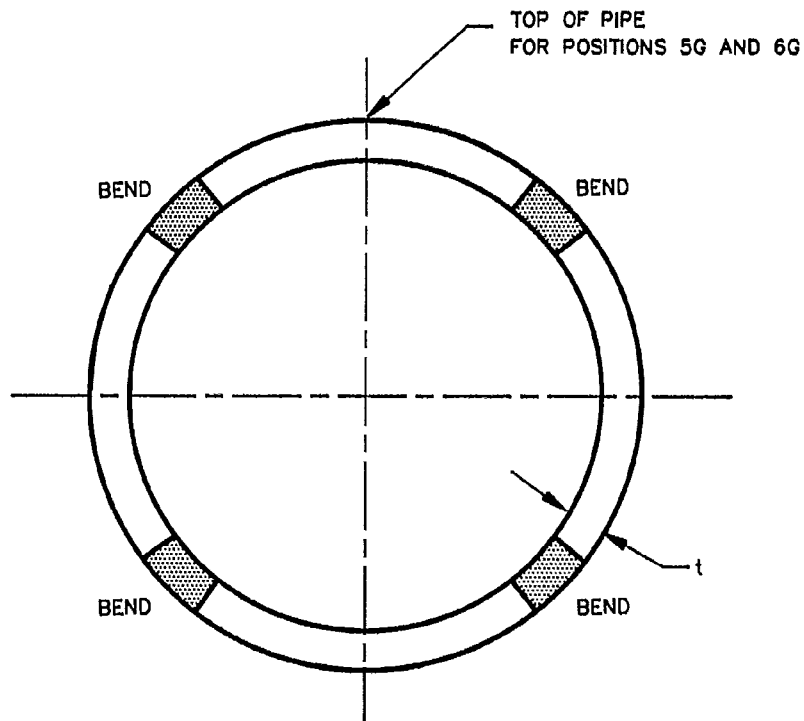
Part III Examination

7.8 Examination Requirements

All Class A production welds shall be visually examined in accordance with section 6, Part II. In addition, unless otherwise specified by the customer, full penetration welds shall be either radiographed (section 6, Part III) or ultrasonically examined (section 6, Part IV); partial penetration and fillet welds shall be examined by the magnetic particle method (section 6, Part V). Acceptance criteria shall be in accordance with the following.



(A) FOR PLATE



(B) FOR PIPE

Note: For plates or pipe the following apply:

- (a) $t \leq 3/8$ in. (10 mm) — two root and two face bends.
- (b) $t \geq 3/4$ in. (20 mm) — four side bends.
- (c) t between $3/8$ and $3/4$ in. (10 and 20 mm) — the Customer may specify root and face or side bends.
- (d) Specimen length as described in Figures 11 and 12.

Figure 26 — Type and Location of Bend Test Specimens for Welder Qualification, Class A Groove Welds

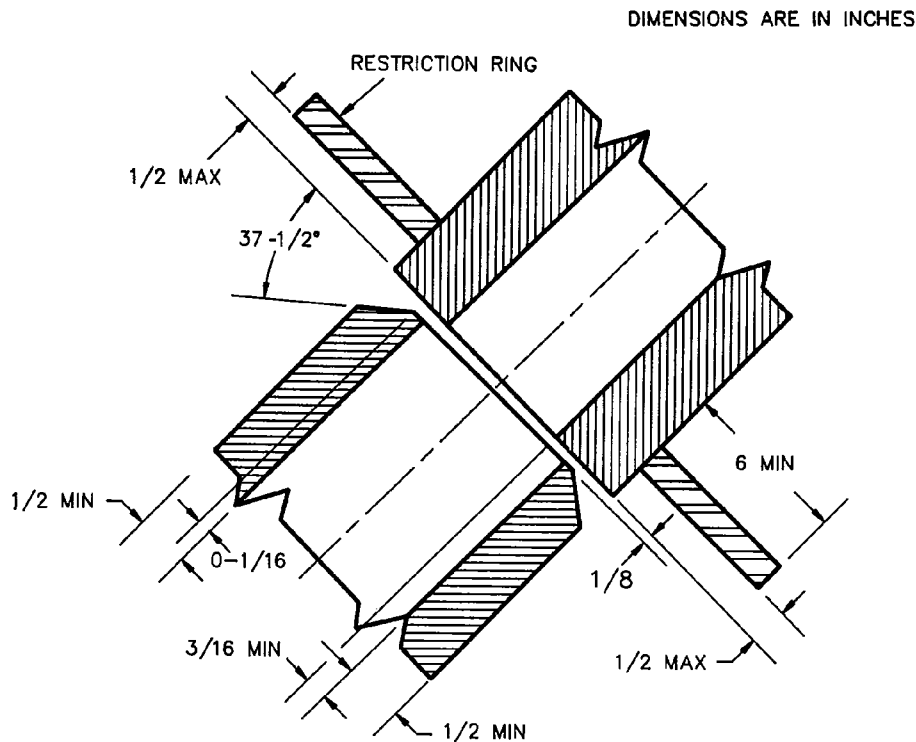


Figure 27 — Test Assembly for T-, Y-, or K-Connections on Pipe or Square or Rectangular Tubing — Welding Procedure and Welder Performance Qualification, Class A welds

7.9 Visual Acceptance Criteria

The following acceptance criteria, in accordance with the procedures and standards of section 6, Part II, shall apply to all Class A welds, during visual examination for surface defects:

- (1) The weld shall have no cracks, surface porosity, or entrapped slag.
- (2) Complete fusion shall exist between adjacent weld beads, and between weld metal and base metal.
- (3) All craters shall be filled.
- (4) Weld profiles shall be in accordance with Figure 28 (A), (B) or (D).
- (5) Undercut shall not exceed 1/32 in. (0.8 mm) in depth, and the length of any undercut exceeding 1/64 in. (0.4 mm) in depth shall not exceed 2 in. (50 mm) in length in any continuous 12 in. (300 mm) of weld.
- (6) The root surface of single-welded groove

welds without backing that require complete joint penetration shall be inspected, where accessible, and there shall be no incomplete fusion or incomplete joint penetration.

- (7) The maximum root surface underfill shall be 1/16 in. (1.5 mm), and the maximum melt-through shall be 1/8 in. (3 mm). The weld thickness shall be equal to or greater than that of the base metal.

7.10 Radiographic and Macroscopic Acceptance Criteria

The following acceptance criteria for Class A production and qualification welds, as applicable, shall be satisfied.

- (1) The welds shall be free of cracks.
- (2) If the base metal thickness, t , is 1/4 in. (6 mm) or less, the greatest dimension of any individual discontinuity shall be less than 1/8 in. (3 mm).

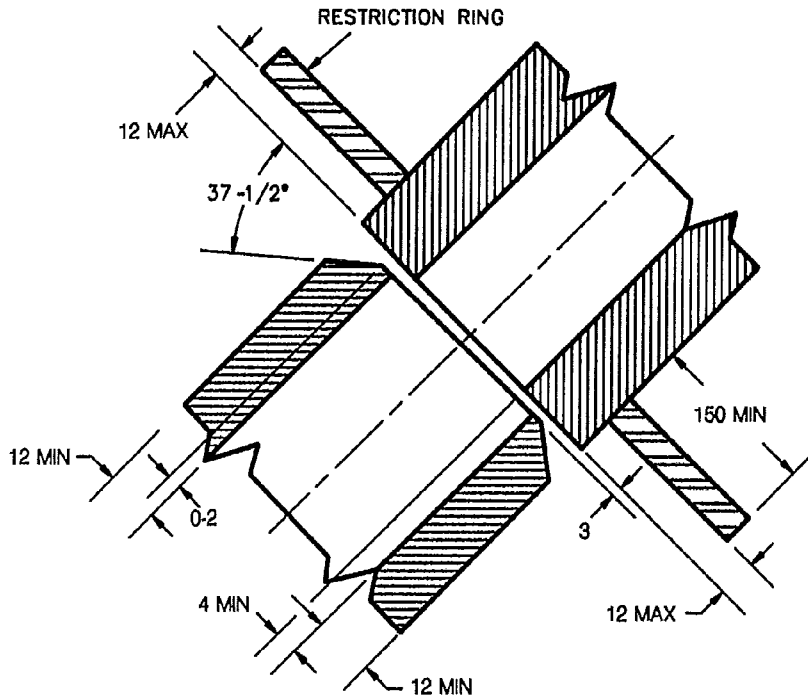
ALL DIMENSIONS
IN MILLIMETERS

Figure 27M — Test Assembly for T-, Y-, or K-Connections on Pipe or Square or Rectangular Tubing — Welding Procedure and Welder Performance Qualification, Class A welds (Metric)

If t is more than 1/4 in. (6 mm) but less than or equal to 1-3/32 in. (30 mm), the greatest dimension of any individual discontinuity shall not exceed two-thirds of the effective throat or two-thirds of the weld size.

If t is greater than 1-3/32 in. (30 mm), the greatest dimension of any discontinuity shall not exceed 3/4 in. (20 mm).

(3) No discontinuity shall be closer than three times its greatest dimension to the end of a groove weld subject to primary tensile stress.

(4) For a group of discontinuities in line, the sum of the greatest dimensions of all discontinuities in any portion of the weld equal in length to six times the effective throat or weld size, shall be less than the effective throat or weld size. When the length of the weld being examined is less than six times the effective throat or weld size, the permissible sum of the greatest dimensions shall be

directly proportionate (i.e., $1/6 \times$ effective throat or weld size.).

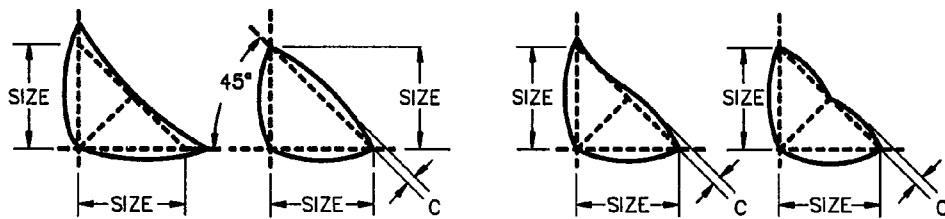
(5) The space between two adjacent linear discontinuities shall be at least three times the greatest dimension of the larger of the discontinuities in the pair being considered.

(6) Independent of the requirements of 7.10(2) through 7.10(5), the sum of the greatest dimensions of all discontinuities with a greatest dimension of less than 1/8 in. (3 mm) shall not exceed 3/8 in. (10 mm) in any continuous 1 in. (25 mm) of weld.

7.11 Surface Examination Acceptance Criteria

The acceptance criteria of 7.9 and 7.10 shall apply to nondestructive surface examination

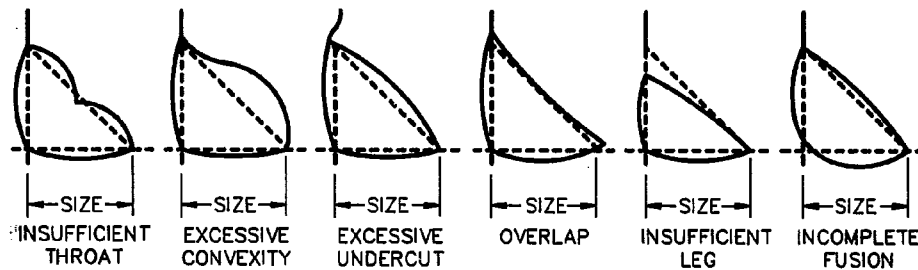
DIMENSIONS ARE IN INCHES
AND IN MILLIMETERS



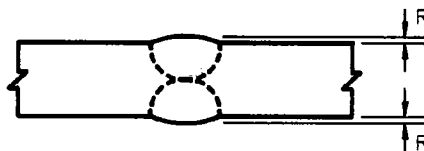
NOTE: CONVEXITY C SHALL NOT EXCEED 0.1 TIMES ACTUAL LEG SIZE, OR THE LONGER LEG IN THE CASE OF AN UNEQUAL LEG FILLET WELD, PLUS 1/16 in. (1.5 mm).

(A) DESIRABLE FILLET WELD PROFILES

(B) ACCEPTABLE FILLET WELD PROFILES

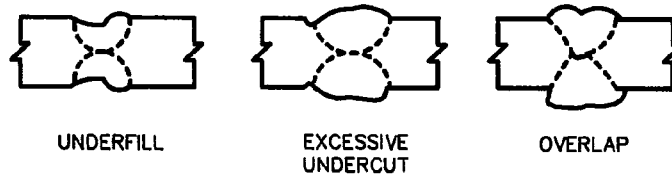


(C) UNACCEPTABLE FILLET WELD PROFILES



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

(D) ACCEPTABLE GROOVE WELD PROFILE



(E) UNACCEPTABLE GROOVE WELD PROFILES

Figure 28 — Acceptable and Unacceptable Weld Profiles for Class A Welds

(magnetic particle, liquid penetrant or eddy current) performed on Class A welds.

7.12 Ultrasonic Examination Acceptance Criteria

The customer shall designate the Class, X or R, which applies to all welds to be examined.

7.12.1 Disregard all DRL (Disregard Level) indications having half (6dB) or less amplitude compared to the standard sensitivity level (with due regard for 6.14.6).

7.12.2 Indications exceeding the DRL shall be evaluated as follows:

(1) Class X (applicable to T-, Y-, or K-connections in redundant structures of notch-tough steels)

(a) Spherical reflectors shall be evaluated as described in Class R, except that any indications within the limits of Figure 29 for linear or planar are acceptable.

(b) Linear or planar reflectors shall be evaluated using beam boundary techniques, and those

that have dimensions exceeding the limits of Figure 29 shall be retested. Discontinuities in the backup weld³ shall be disregarded.

(2) Class R (applicable when UT is used as an alternative to radiography and for T-, Y-, or K-connections of steels without controlled notch toughness and with nonredundant design)

(a) Isolated, random spherical reflectors, with 1 in. (25 mm) minimum separation, shall be accepted up to the standard sensitivity level. Larger reflectors shall be evaluated as linear or planar.

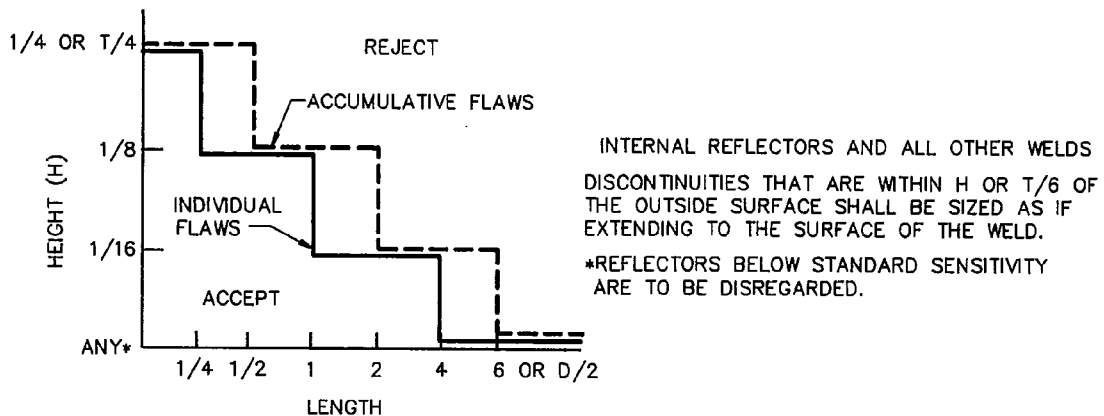
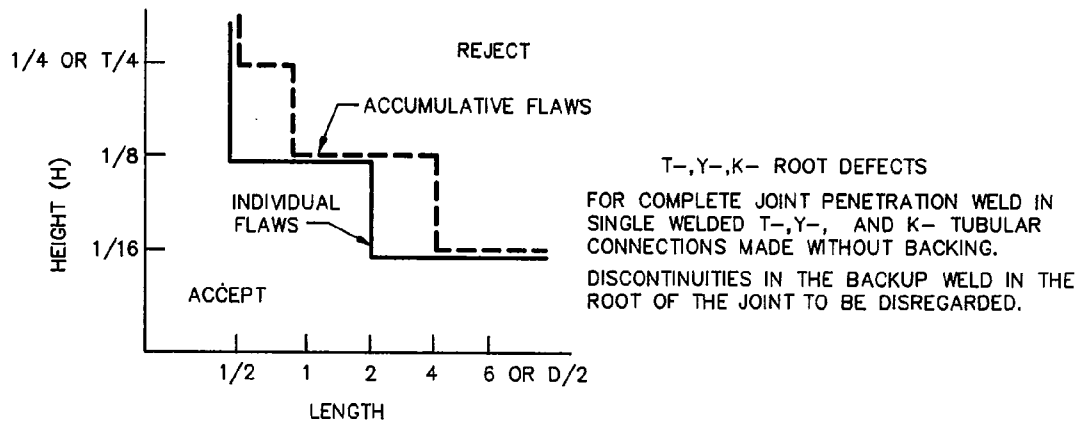
(b) Aligned spherical reflectors shall be evaluated as linear reflectors.

(c) Clustered spherical reflectors having a density of more than one per square inch (645 mm²) with indications above the disregard level [projected area normal to the direction of applied stress, averaged over a 6 in. (150 mm) length of weld] shall be rejected.

(d) Linear or planar reflectors, whose lengths (extent) exceed the limits of Figure 29 shall be rejected.

3. As defined for tubular T-, Y-, K- connections in AWS D1.1.

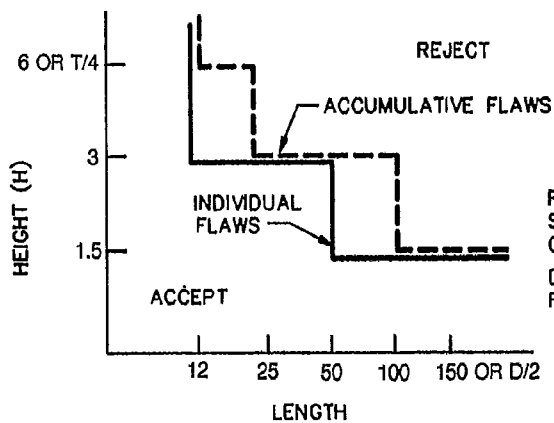
DIMENSIONS ARE IN INCHES



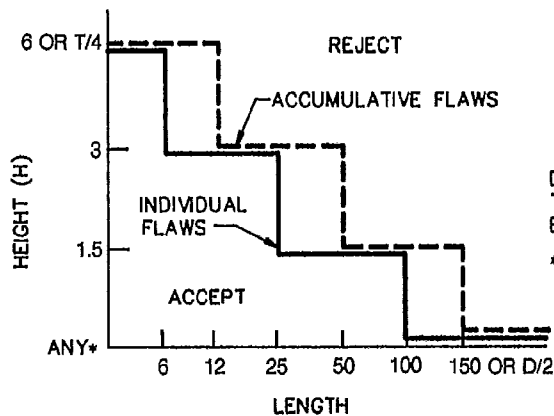
(A) CLASS X INDICATIONS

Figure 29 — Ultrasonic Inspection Acceptance Criteria

ALL DIMENSIONS
IN MILLIMETERS



T-, Y-, K- ROOT DEFECTS
FOR COMPLETE JOINT PENETRATION WELD IN
SINGLE WELDED T-, Y-, AND K- TUBULAR
CONNECTIONS MADE WITHOUT BACKING.
DISCONTINUITIES IN THE BACKUP WELD IN THE
ROOT OF THE JOINT TO BE DISREGARDED.



INTERNAL REFLECTORS AND ALL OTHER WELDS
DISCONTINUITIES THAT ARE WITHIN H OR T/6 OF
THE OUTSIDE SURFACE SHALL BE SIZED AS IF
EXTENDING TO THE SURFACE OF THE WELD.

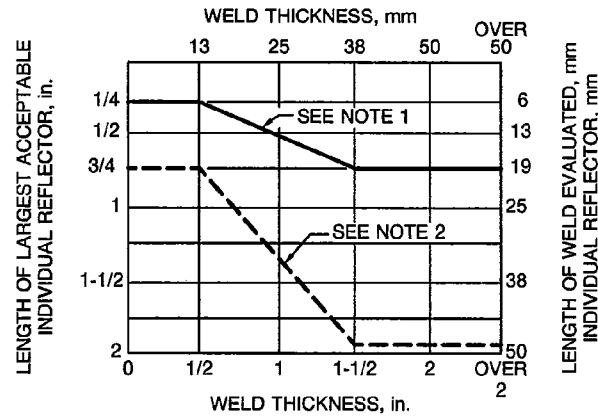
*REFLECTORS BELOW STANDARD SENSITIVITY
ARE TO BE DISREGARDED.

(A) CLASS X INDICATIONS

Figure 29M — Ultrasonic Inspection Acceptance Criteria (Metric)

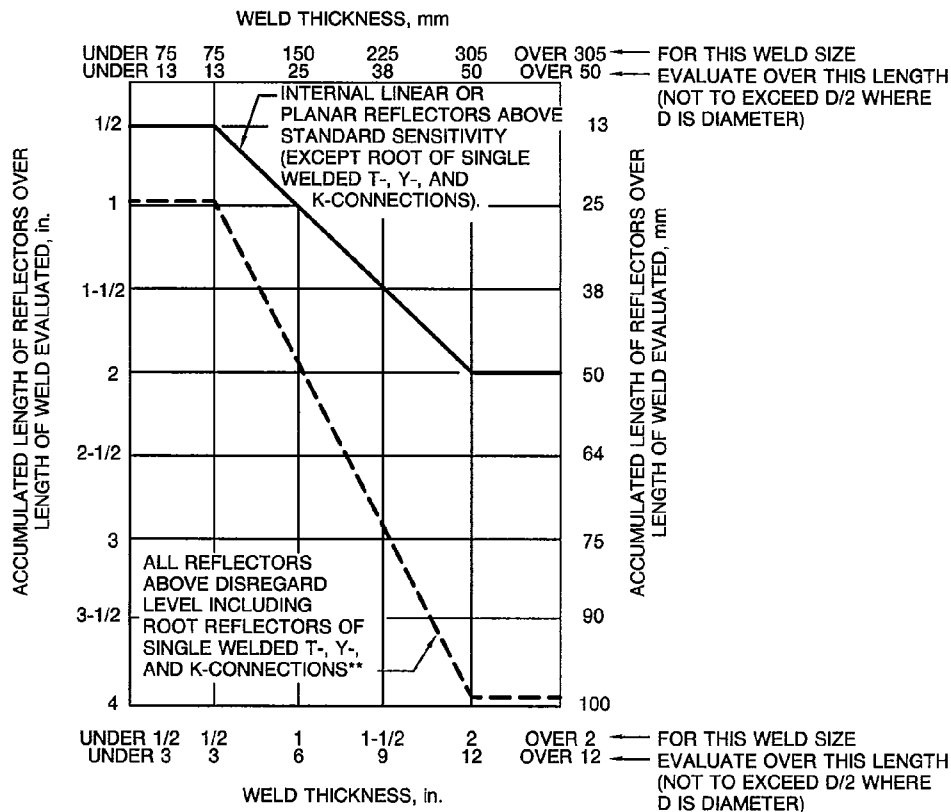
DIMENSIONS ARE IN INCHES
AND IN MILLIMETERS

77



NOTE:

1. Internal linear or planar reflectors above standard sensitivity (except root of single welded T-, Y-, and K-connections)
 2. Minor reflectors* (above disregard level up to and including standard sensitivity)
- * Adjacent reflectors separated by less than their average length shall be treated as continuous.



**ROOT AREA DISCONTINUITIES FALLING OUTSIDE THEORETICAL WELD

(B) CLASS R INDICATIONS

Figure 29 (Continued) — Ultrasonic Inspection Acceptance Criteria

8. Class B Welds

8.1 Application

The requirements of this section apply to **Class B** welds. **Class B** underwater welds are intended for less critical applications where lower ductility, greater porosity and other larger discontinuities can be tolerated. This class of weld shall meet the requirements of this specification for **Class B** welds, and shall satisfy the Customer's requirements for a particular application.

8.1.1 Welding procedure specifications for **Class B** welds shall be qualified in accordance with the general requirements of section 5, Parts I and II, and the specific requirements of Part I of this section.

8.1.2 All welders, including tack welders, making **Class B** welds shall be qualified prior to production welding in accordance with the general requirements of section 5, Part I and III, and the specific requirements of Part II of this section.

8.1.3 Minimum examination requirements for all **Class B** production welds and acceptance criteria for all inspection and examination of **Class B** welds, including that performed during procedure and performance qualification, are outlined in Part III of this section.

Part I Procedure Qualification

8.2 Testing Requirements

The number and type of test specimens required for procedure qualification to test the first position and additional positions for **Class B** welds are summarized in Table 9.

8.3 Groove Welds

8.3.1 Test Specimens. Test specimens for **Class B** welds shall be located in accordance with Figures 30 and 31.

8.3.2 Test Results. Procedure Qualification test results for **Class B** groove welds shall meet the following requirements:

(1) Visual examination — The weld shall meet the visual acceptance criteria of 8.9.

(2) Radiographic examination — The weld shall meet the radiographic acceptance criteria of 8.10.

(3) Reduced-section tension tests — The tensile strength shall equal or exceed the specified minimum tensile strength of the base metal for each sample.

(4) Bend tests — The bending fixture shall conform to Figure 13 of section 5, Part II. Bend radius for testing shall be 6T. Four samples shall be tested, and none shall reveal tears or other defects exceeding 1/8 in. (3 mm) in the weld metal or fusion zone after the bending. Tears which originate at the corner of the specimen and are less than 1/4 in. (6 mm) long shall not be cause for rejection unless they are associated with a defect.

(5) Macro — Macrosections transverse to the weld shall contain no cracks at 5X magnification. Slag and porosity greater than 5% of the surface area of the weld metal shall be cause for rejection. The maximum dimension of a single defect in the plane of the section shall not exceed 1/8 in. (3 mm) (see 8.10).

8.4 Fillet Welds

8.4.1 Test Specimens. Fillet weld shear strength specimens shall be produced in accordance with the requirements of 5.11.8 (refer to Figures 18 and 19 for plate qualification and Figure 20 for pipe qualification). Fillet weld break test coupons shall be produced in accordance with the requirements

Table 9
Weld Procedure Qualification — Number and Type of Test Specimens for Class B Welds*

Coupon	Joint Type	Coupon Thickness in. (mm)	Visual (Sec 6.9)	Radiograph (Sec 6.12) ^d	Reduced Section Tension (Sec 5.11.1)	Fillet Weld Shear (Sec 5.11.1)	Root Bends (Sec 5.11.3)	Face Bends (Sec 5.11.3)	Side Bends (Sec 5.11.3)	Macroetch Test (Sec 5.11.2)	Fillet Weld Break (Sec 5.11.7)
Plate	Groove	$t \leq 3/8$ (10)	Yes	Yes	2	0	2	2	0	1	0
		$3/8 < t < 3/4$	Yes	Yes	2	0	Note b	Note b	Note b	1	0
		$t \geq 3/4$ (20)	Yes	Yes	2	0	0	0	4	1	0
Pipe	Groove	$t \leq 3/8$ (10)	Yes	Yes	2	0	2	2	0	1	0
		$3/8 < t < 3/4$	Yes	Yes	2	0	Note b	Note b	Note b	1	0
		$t \geq 3/4$ (20)	Yes	Yes	2	0	0	0	4	1	0
Plate	Fillet	All ^c	Yes	No	0	1	0	0	0	2	1
Pipe	Fillet	All ^c	Yes	No	0	1	0	0	0	4	4

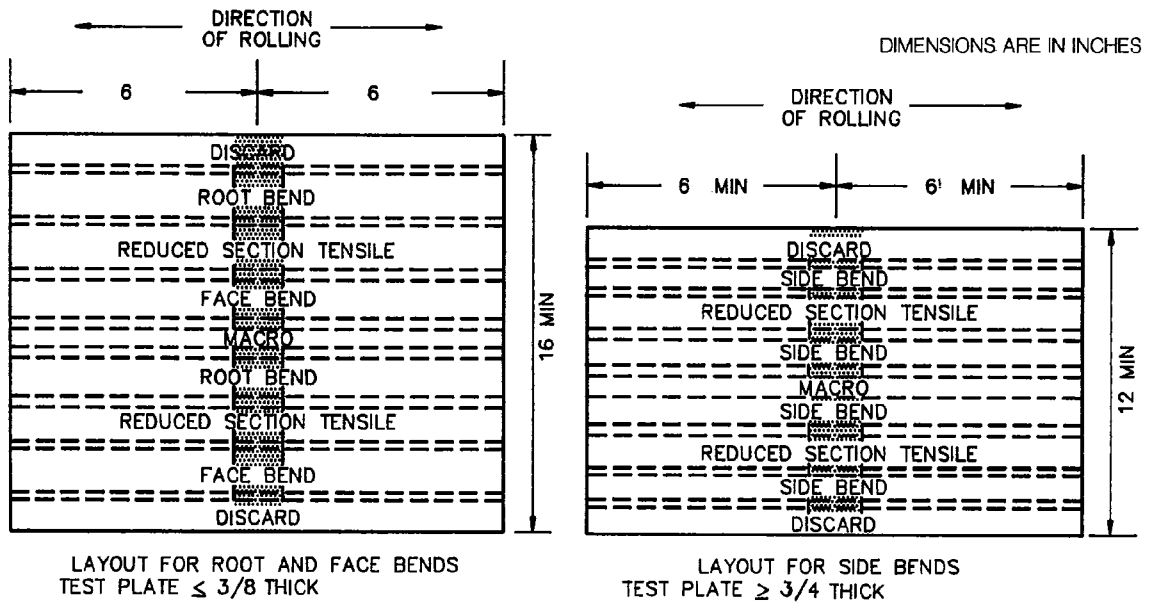
a. First position only. Qualification for additional positions will omit groove weld tension, macroetch, and fillet weld shear strength tests.

b. For plate or pipe between $3/8$ in. (10 mm) and $3/4$ in. (20 mm) thick, the Customer shall specify either two root and two face bend tests or four side bend tests.

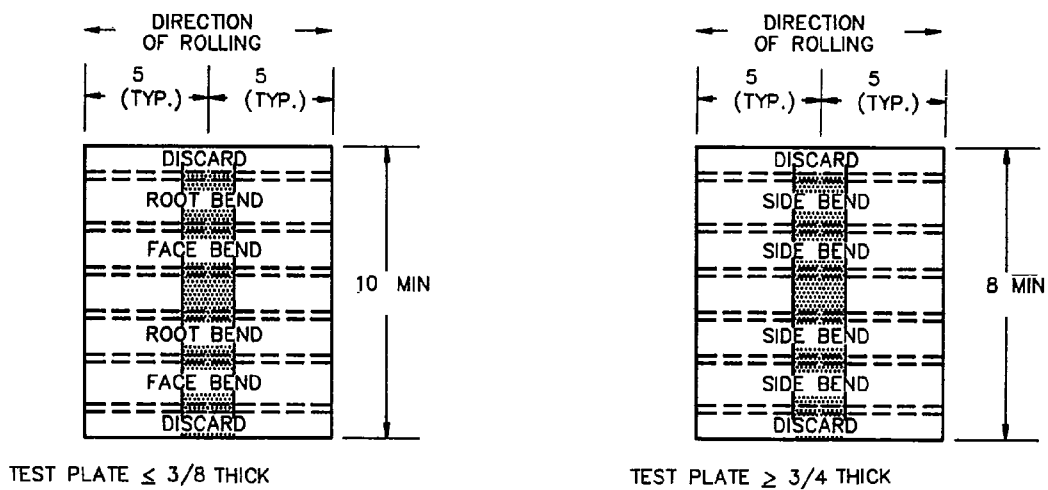
c. Multiple pass fillet welds are considered qualified by groove weld qualification. (5.9.2)

d. Groove welds only are radiographed.

$\leq$: less than equal to $\geq$: greater than equal to $<$: less than $>$: greater than



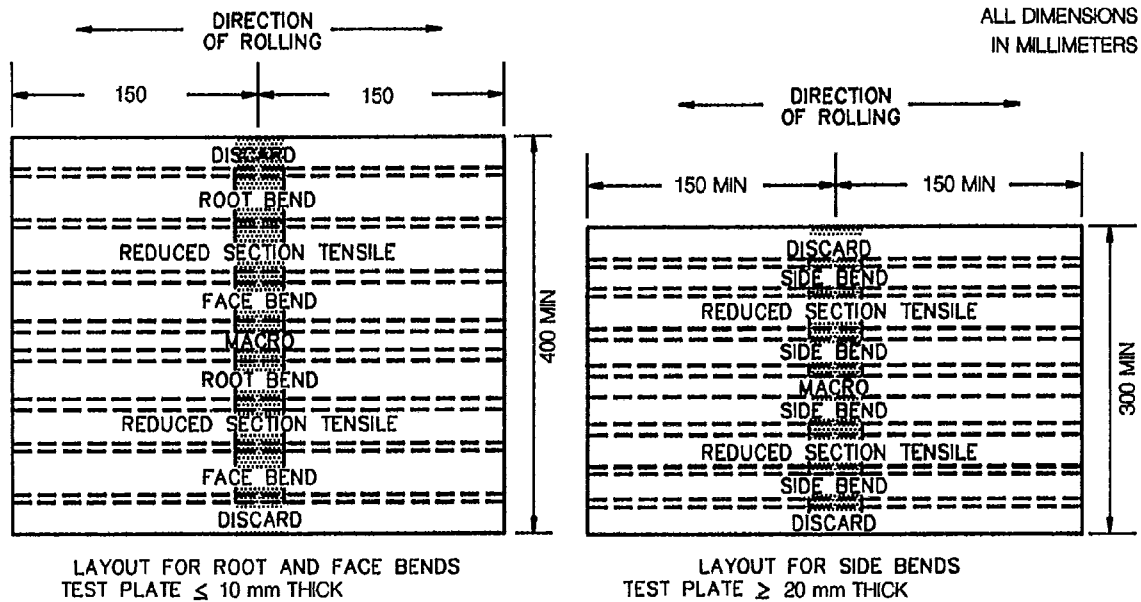
(A) FIRST POSITION PLATES



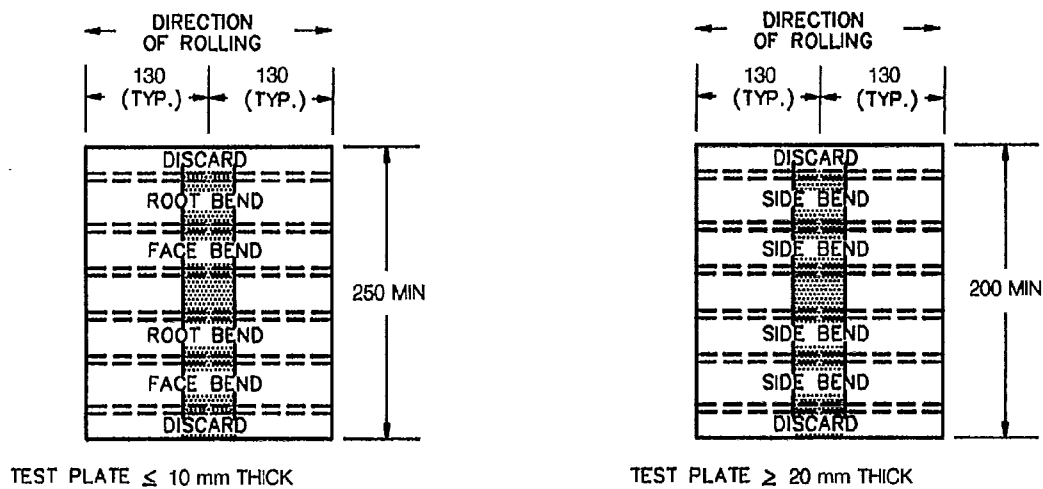
(B) ADDITIONAL POSITION PLATES

Note: For plates between $3/8$ in. and $3/4$ in. thick, the Customer may specify root and face bends or side bends.

Figure 30 — Location and Types of Test Specimens on Welded Plate Test Procedure Qualification Assembly, Class B Groove Welds



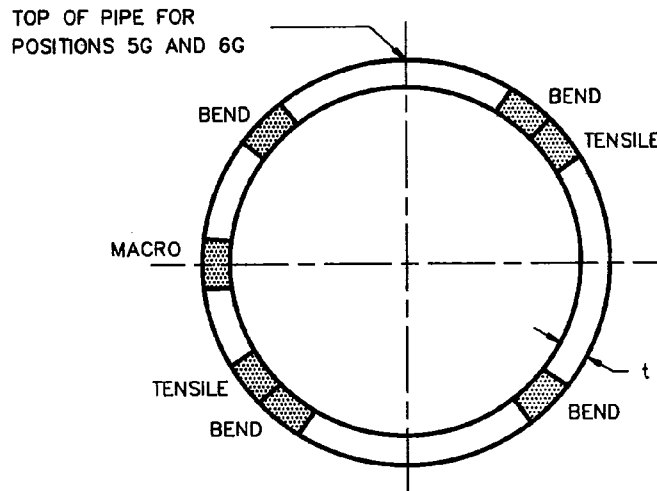
(A) FIRST POSITION PLATES



(B) ADDITIONAL POSITION PLATES

Note: For plates between 10 mm and 20 mm thick, the Customer may specify root and face bends or side bends.

Figure 30M — Location and Types of Test Specimens on Welded Plate Test Procedure Qualification Assembly, Class B Groove Welds (Metric)



Notes:

1. If the pipe diameter is too small to permit all specimens to be machined from a single weld, additional welds shall be made to provide sufficient material for test.
2. First position weld: test all specimens shown. Additional position welds: test bend specimens only.
3. Type of bend specimens to be used:
 - (a) $t \leq 3/8$ in. (10 mm) — two root and two face bends.
 - (b) $t \geq 3/4$ in. (20 mm) — four side bends.
 - (c) t between $3/8$ in. (10 mm) and $3/4$ in. (20 mm) — Customer may specify root and face or side bends.
 - (d) Specimen length as described in Figures 22 and 23.

Figure 31 — Location and Types of Test Specimens on Welded Pipe Test Procedure Qualification Assembly, Class B Groove Welds in Pipe

of 5.11.7 (Refer to Figure 9 for plate and pipe qualification). As an option, the contractor may choose to qualify a multiple-pass fillet weld procedure on the basis of a groove weld qualification in accordance with the requirements of 5.9.2.

8.4.2 Test Results. Procedure qualification test results for **Class B** fillet welds shall meet the following requirements:

- (1) Visual examination — All test welds shall meet the visual acceptance criteria of 8.9.
- (2) Fillet weld shear test — The minimum ac-

ceptable shear strength of the weld shall be 60% of the specified minimum tensile strength of the base metal to be welded in production.

(3) Fillet-weld-break test — The specimen shall pass the test if it bends flat upon itself. If the fillet weld fractures, the fractured surface shall meet the requirements of 8.10. The weld shall have fusion to the root for at least 90% of the length of the joint but not necessarily beyond the root.

(4) Macro — Macrosections transverse to the weld shall reveal no cracks at 5X magnification and shall meet the requirements of 8.10.

Part II Welder Qualification

8.5 Testing Requirements

The number and type of test specimens required for welder qualification for **Class B** welds are summarized in Table 10.

8.6 Groove Welds

8.6.1 Test Specimens. Test specimens for welder qualification shall be located in accordance with Figure 32 for groove welds and Figure 33 for T-, Y-, and K-connections on pipe or tubing. Four bend specimens shall be removed from each weld coupon. In lieu of radiographic or ultrasonic inspection, three macrosections may be removed from the weld adjacent to the required bend specimens; such specimens shall be prepared and etched in accordance with 5.11, and meet the requirements of 8.6.2(2).

8.6.2 Test Results. Welder qualification test results for **Class B** groove welds shall meet the following requirements:

(1) Visual examination — The weld shall meet the visual acceptance criteria of 8.9.

(2) Radiographic or ultrasonic (or macroscopic) examination — The weld shall meet the acceptance criteria of 8.10.

(3) Bend tests — The bending fixture shall conform to Figure 13 of section 5, Part B. Bend radius for testing shall be 6T. Four samples shall be tested, and none shall reveal tears or other defects exceeding 1/8 in. (3 mm) in the weld metal or fusion zone after the bending. Tears which originate at the corner of the specimen and are less than 1/4 in. (6 mm) long shall not be cause for rejection unless they are associated with a defect.

8.7 Fillet Welds

8.7.1 Test Specimens. The welder shall weld fillet-weld-break and macroetch test assemblies as shown in Figure 9 in accordance with the requirements of variables and positions of 5.16 and Table 5. The number and type of specimens required to qualify from each assembly are shown on Table 10.

8.7.2 Test Results. Welder qualification test results for **Class B** fillet welds shall meet the following requirements:

(1) Visual examination — All test welds shall meet the visual acceptance criteria of 8.9.

Table 10
Welder Performance Qualification — Number and Type of Test Specimens for Class B Welds (Per Welder)

Coupon	Joint Type	Thickness Tested in. (mm)	Visual (See 6.9)	Radiographic (See 6.11)	Bends ^b (See 5.11.3)		Macro ^c	Fillet Weld Break (See Fig. 9)
					Root and Face	Side		
Plate	Groove	≤ 3/8 (10)	Yes	Yes ^a	2 each	—	—	—
		> 3/8 < 3/4	Yes	Yes ^a	2 each	or 4	—	—
		≥ 3/4 (20)	Yes	Yes ^a	—	4	—	—
Pipe	Groove	≤ 3/8 (10)	Yes	Yes ^a	2 each	—	—	—
		> 3/8 < 3/4	Yes	Yes ^a	2 each	or 4	—	—
		≥ 3/4 (20)	Yes	Yes ^a	—	4	—	—
Plate	Fillet	All	Yes	—	—	—	2	1
Pipe	Fillet	All	Yes	—	—	—	4	4

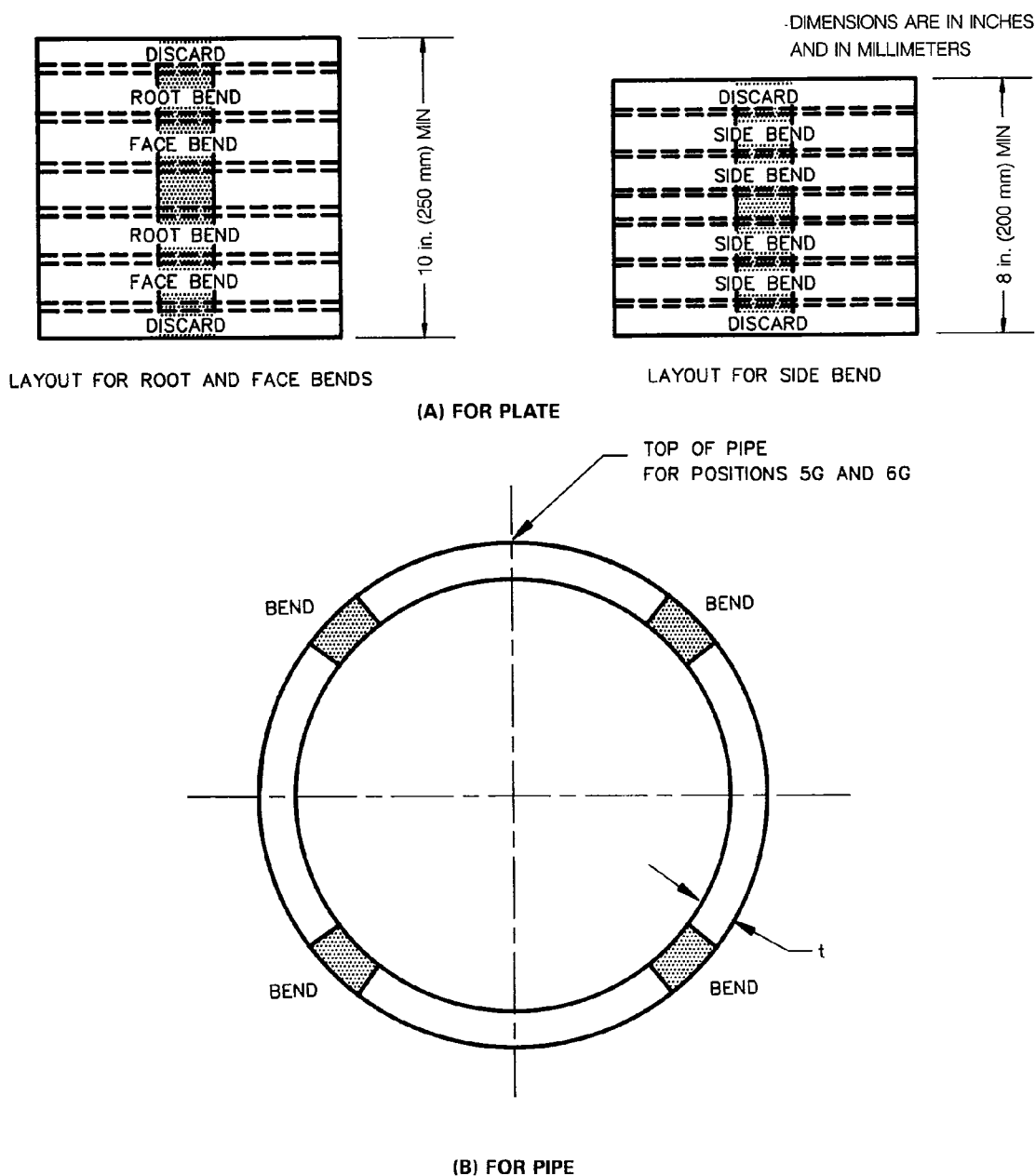
Notes:

a. Ultrasonic or three Macros may be substituted see 8.6.1.

b. For plate and pipe between 3/8 in. (10 mm) and 3/4 in. (20 mm) thick, Customer shall specify either root and face bends or side bends.

c. See 5.11.2, 8.7 and Figure 9. Hardness tests not required.

≤: Less than equal to ≥: Greater than equal to



Note: For plate or pipe the following apply:

- (a) $t \leq 3/8$ in. (10 mm) — two root and two face bends.
- (b) $t \geq 3/4$ in. (20 mm) — four side bends.
- (c) t between $3/8$ and $3/4$ in. (10 and 20 mm) — the Customer may specify root and face or side bends.
- (d) Specimen length as described in Figures 11 and 12.

Figure 32 — Types and Location of Bend Test Specimens for Welder Qualification, Class B Groove Welds

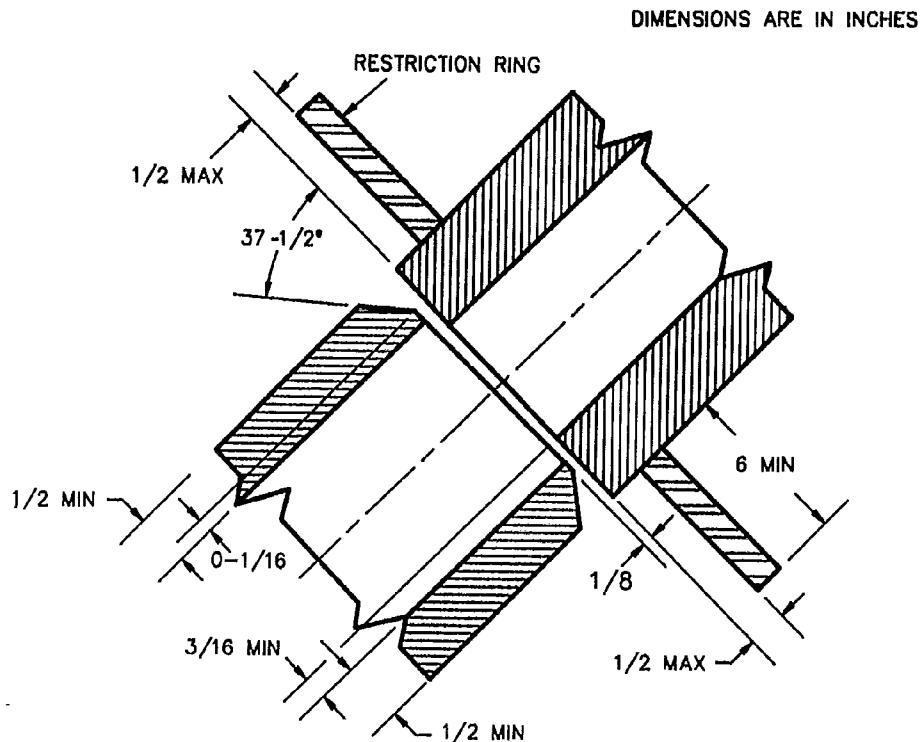


Figure 33 — Test Assembly for T-, Y-, or K-Connections on Pipe or Square or Rectangular Tubing-Welding Procedure and Welder Performance Qualification, Class B Welds

(2) Macro — Macrosections transverse to the weld shall reveal no cracks at 5X magnification and shall meet the acceptance criteria of 8.10.

(3) Break tests — A fillet weld break test shall pass the test if it bends flat upon itself. If the fillet weld fractures, porosity or slag shall not exceed the limitations of 8.10. The weld shall have fusion to the root for at least 90% of the length of the joint but not necessarily beyond the root.

Part III Examination

8.8 Examination Requirements

All Class B production welds shall, as a minimum, be visually examined in accordance with section 6, Part II. Any additional examination shall be as specified by the Customer, and performed in ac-

cordance with the requirements of section 6, as applicable. Acceptance criteria shall be in accordance with the following.

8.9 Visual Acceptance Criteria

The following acceptance criteria, in accordance with the procedures and standards of section 6, Part II, shall apply to all Class B welds, during visual examination for surface defects.

- (1) The weld shall have no cracks.
- (2) Complete fusion shall exist between adjacent weld beads and full penetration shall exist between weld metal and base metal. Fillet welds shall have fusion to the joint root, but not necessarily beyond.
- (3) All craters shall be filled.
- (4) Weld profiles shall be in accordance with Figure 34 (A), (B), or (D).
- (5) The sum of the diameters of visible piping

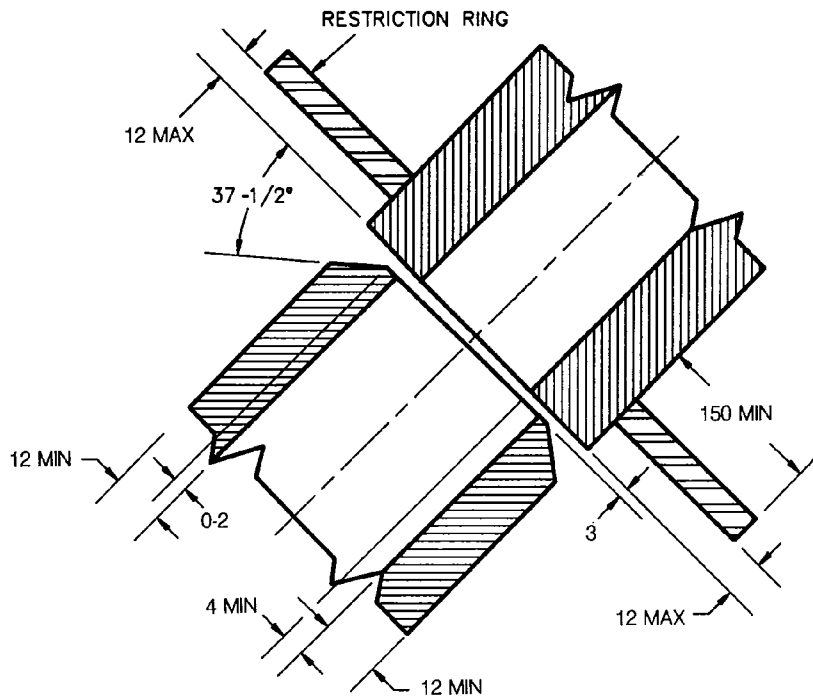
ALL DIMENSIONS
IN MILLIMETERS

Figure 33M — Test Assembly for T-, Y-, or K-Connections on Pipe or Square or Rectangular Tubing—Welding Procedure and Welder Performance Qualification, Class B Welds (Metric)

porosity which exceeds 1/16 in. (1.5 mm) in diameter shall not exceed 3/8 in. (10 mm) in any linear 1 in. (25 mm) of weld.

(6) Undercut shall not exceed 1/16 in. (1.5 mm) in depth with the following exception. Isolated undercut over 1/16 in. but not more than 1/8 in. (3 mm) or 20% of the base metal thickness in depth, whichever is less, is permitted, provided it is separated by a minimum of 6 in. (150 mm) from adjacent undercut that is deeper than 1/16 in. (1.5 mm). The maximum length of undercut between 1/32 in. (0.8 mm) and 1/16 in. in depth shall not exceed 4 in. (100 mm) in any continuous 12 in. (300 mm) of weld. Undercut less than 1/32 in. in depth shall be acceptable without restrictions.

(7) When root surfaces are present and accessible, drop-through is not limited. Inadequate joint penetration or excessive melt-through is limited to 1/8 in. (3 mm) maximum depth and 4 in. (100 mm)

maximum length in any 12 in. (300 mm) of weld length. **Class B** welds are frequently fillet or groove welds with a backing strip and, therefore, root surfaces may not be visible.

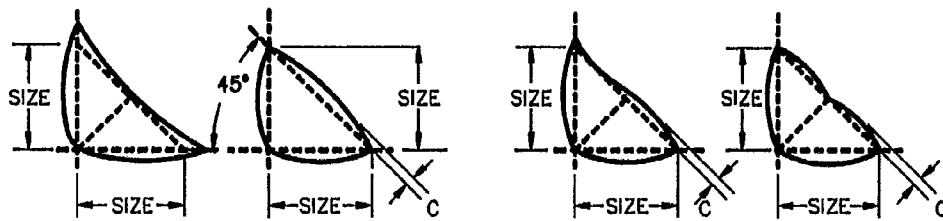
8.10 Radiographic and Macroscopic Acceptance Criteria

The following acceptance criteria for **Class B** production and qualification welds, as applicable, shall be satisfied. Discontinuities found by radiography and macroscopic examination shall not exceed the dimensions specified.

(1) Cracks — The welds shall be free of cracks, except for crater cracks less than 5/32 in. (4 mm) in length.

(2) Porosity — Dispersed pores in a size range of from 1/16 in. (1.5 mm) diameter to 3/16 in. (5 mm)

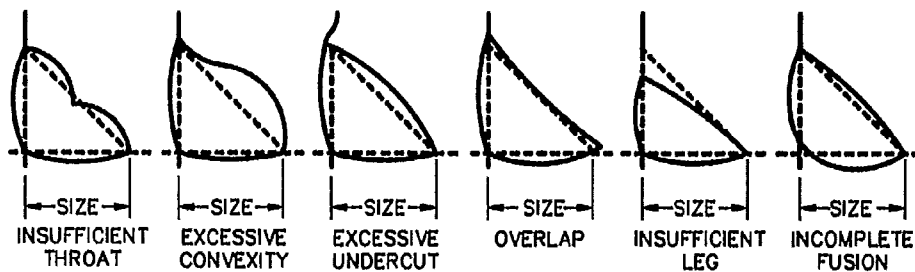
DIMENSIONS ARE IN INCHES
AND IN MILLIMETERS



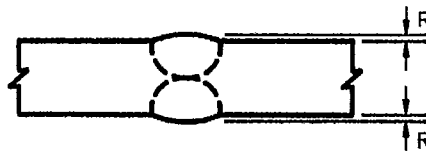
NOTE: CONVEXITY C SHALL NOT EXCEED 0.2 TIMES ACTUAL LEG $+3/64$ in. (1.5 mm).

(A) DESIRABLE FILLET WELD PROFILES

(B) ACCEPTABLE FILLET WELD PROFILES

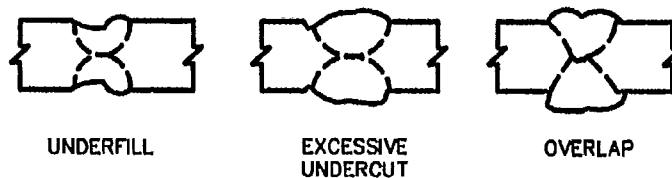


(C) UNACCEPTABLE FILLET WELD PROFILES



NOTE: REINFORCEMENT R SHALL NOT EXCEED $3/16$ in. (5 mm).

(D) ACCEPTABLE GROOVE WELD PROFILE



(E) UNACCEPTABLE GROOVE WELD PROFILES

Figure 34 — Acceptable and Unacceptable Weld Profiles for Class B Welds

diameter shall not exceed 7 per linear inch of weld per inch of weld thickness. The maximum pore size shall not exceed 3/16 in. (5 mm). Pores smaller than 1/16 in. (1.5 mm) in diameter shall not be restricted in number.

(3) Slag — The maximum width of isolated slag inclusions shall not exceed 1/8 in. (3 mm). The maximum length of any slag inclusions shall not exceed 2 in. (50 mm). The total length of slag inclusions between 1/32 in. (0.8 mm) and 1/8 in. (3 mm) in width shall not exceed 4 in. (100 mm) in any continuous 12 in. (300 mm) of weld. Adjacent slag inclusions greater than 1/32 in. (0.8 mm) wide shall be separated by 3/16 in. (5 mm) minimum.

(4) Inadequate Joint Penetration — Image areas indicating inadequate joint penetration shall not have a radiographic density greater than that of the base-metal, and for this purpose, the maximum height of face reinforcement shall not exceed 1/8 in. (3 mm), unless specifically approved by the Customer.

(5) Incomplete Fusion — The maximum continuous length of any single defect shall not exceed the base-metal thickness, and the maximum cumulative total length of all defects shall not exceed 4 in. (100 mm) in any 12 in. (300 mm) of weld. Incom-

plete fusion defects that appear to be continuous from one bead or layer to the next are unacceptable regardless of length.

(6) Root Underfill — Image areas indicating root underfill shall not have a radiographic density greater than that of the base metal. For the purpose of this measurement, the maximum face reinforcement shall not exceed 1/8 in. (3 mm) unless specifically approved by the Customer.

(7) Melt-through — The length of any unpaired excessive melt-through shall not exceed the base-metal thickness.

(8) Accumulation of Discontinuities — The total accumulative length of all discontinuities shall not exceed 4 in. (100 mm) in 12 in. (300 mm).

8.11 Surface Examination Acceptance Criteria

The acceptance criteria of 8.9 and 8.10 shall apply to nondestructive surface examination (magnetic particle, liquid penetrant or eddy current) performed on **Class B** welds.

9. Class C Welds

9.1 Application

The requirements of this section apply to **Class C** welds. **Class C** underwater welds are intended for applications where the load-bearing function is not a primary consideration. Fillet welds are the only type of **Class C** weld addressed in this specification.

9.1.1 Welding procedure specification for **Class C** welds shall be qualified in accordance with the general requirements of section 5, Part I and II, and the specific requirements of Part I of this section.

9.1.2 All welders, including tack welders, making **Class C** welds shall be qualified prior to production welding in accordance with the general requirements of section 5, Parts I and III, and the specific requirements of Part II of this section.

9.1.3 Minimum examination requirements for all **Class C** production welds and acceptance criteria for all inspection and examination of **Class C** welds, including that performed during procedure and performance qualification, are defined in Part III of this section.

Part I Procedure Qualification

9.2 Testing Requirements

One fillet weld test coupon (four macroetch test specimens) is required in each position required by Table 4 for procedure qualification for **Class C** welds.

9.3 Groove Welds

This specification does not address **Class C** groove welds.

9.4 Fillet Welds

9.4.1 Test Specimens. Fillet welded test coupons, each consisting of four macroetch specimens, as shown in Figure 10 for plate qualification and Figure 9(B) for pipe qualification, shall be prepared in accordance with 5.11.2. Additionally, a bridge bend-test coupon as shown in Figure 21 shall be produced in accordance with 5.11.9. The coupons shall satisfy the requirements for welding variables and positions of Tables 1, 2, and 5.

9.4.2 Test Results. Procedure qualification test results for **Class C** fillet welds shall meet the following requirements.

(1) Visual examination — The welds shall meet the visual acceptance criteria of 9.9:

(2) Macro — Macrosections transverse to the weld shall reveal no cracks at 5X magnification and shall meet the requirements of 9.10.

(3) Bridge Bend (Figure 21) — The test will pass if no cracks open up in either the weld or heat-affected zone. The specimen is unacceptable if a crack is detected.

Part II Welder Qualification

9.5 Testing Requirements

One fillet weld test coupon (four macroetch test specimens) is required in each position required by Table 5 for performance qualification for **Class C** fillet welds.

9.6 Groove Welds

This specification does not address welder qualification for Class C groove welds.

9.7 Fillet Welds

9.7.1 Test Specimen. The test coupons shall be produced in accordance with Figure 9 for pipe and Figure 10 for plate. Four macros each shall be removed from each coupon from locations shown in Figure 9 or Figure 10 and shall be prepared in accordance with 5.11.2. (Ref. Table 6)

9.7.2 Test Results.

Welder qualification test results for Class C fillet welds shall meet the following requirements:

(1) Visual examination — The welds shall meet the visual acceptance criteria of 9.9.

(2) Macro — Macrosections transverse to the weld shall reveal no cracks at 5X magnification and shall meet the requirements of 9.10.

(1) The weld shall have no cracks.

(2) Complete fusion shall exist between adjacent weld beads, and full penetration shall exist between weld metal and base metal. Fillet welds shall have fusion to the joint root, but not necessarily beyond.

(3) All craters shall be filled.

(4) Weld profiles shall be in accordance with Figure 35.

(5) Porosity is not restricted.

(6) Undercut shall not exceed 1/16 in. (1.5 mm) in depth with the following exception. Isolated undercut over 1/16 in. but not more than 1/8 in. (3 mm) or 20% of the base metal thickness in depth, whichever is less, is permitted, provided it is separated by a minimum of 6 in. (150 mm) from adjacent undercut that is deeper than 1/16 in. The maximum length of undercut between 1/32 in. (0.8 mm) and 1/16 in. in depth shall not exceed 4 in. (100 mm) in any continuous 12 in. (300 mm) of weld. Undercut less than 1/32 in. (0.8 mm) in depth shall be acceptable without restrictions.

Part III Examination

9.8 Examination Requirements

All Class C production welds shall, as a minimum, be visually examined in accordance with section 6, Part II. Any additional examination shall be as specified by the Customer, and performed in accordance with the requirements of section 6, as applicable. Acceptance criteria shall be in accordance with the following.

9.9 Visual Acceptance Criteria

The following acceptance criteria, in accordance with the procedures and standards of section 6, Part II, shall apply to all Class C welds, during the visual examination for surface defects:

9.10 Macroscopic Acceptance Criteria

When examined, Class C welds shall be free of cracks, and shall meet the criteria of 9.9.

9.11 Surface Examination Acceptance Criteria

The acceptance criteria of 9.9 shall apply to non-destructive surface examination performed on Class C welds.

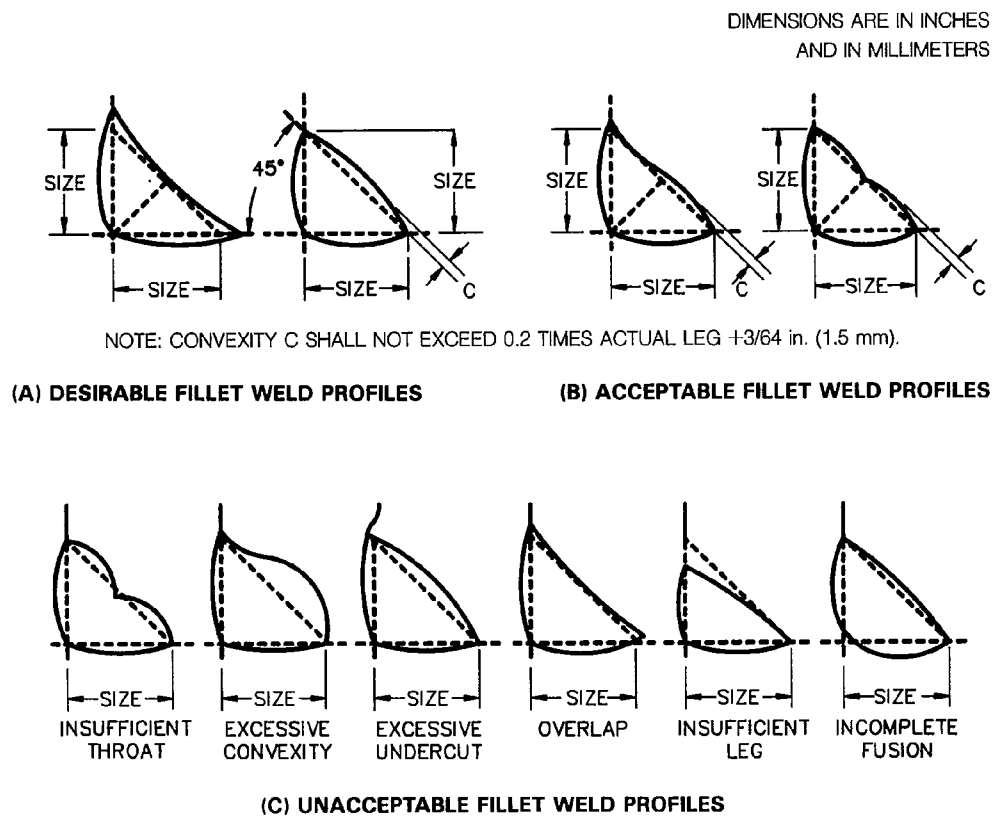


Figure 35 — Acceptable and Unacceptable Weld Profiles for Class C Welds

10. Class O Welds

10.1 Application

The requirements of this section apply to **Class O** welds. **Class O** underwater welds are intended to meet the requirements of some other code or specification designated by the Customer or the jurisdictional authority. **Class O** welds shall also meet the requirements identified in this section.

10.1.1 Welding procedure specification for **Class O** welds shall be qualified in accordance with the general requirements of section 5, Parts I and II, and the specific requirements of Part I of this section.

10.1.2 All welders, including tack welders, making **Class O** welds shall be qualified prior to production welding in accordance with the general requirements of section 5, Parts I and III, and the specific requirements of Part II of this section.

10.1.3 Minimum examination requirements for all **Class O** production welds and acceptance criteria for all inspection and examination of **Class O** welds, including that performed during procedure and performance qualification, are defined in Part III of this section.

Part I Procedure Qualification

10.2 Testing Requirements

The number and type of test specimens required for procedure qualification to test the first position and additional positions, for **Class O** welds are summarized in Table 11. (Refer also to 5.6)

10.3 Groove Welds

10.3.1 Test Specimens. Welded test assemblies shall satisfy the dimensional requirements of the standard designated by the Customer. Provision should be made to remove a macrosection from the procedure qualification test coupon. If the base metal on both sides of the weld is required to be impact tested, the weld metal and heat-affected zone in the procedure qualification test coupon shall also be impact tested.

When an all-weld metal tension test is specified, a second welded test assembly should be prepared as shown in Figure 14 and 15(B). (This should not be mandatory for dry **Class O** welds unless specifically required by the Customer or referenced standard). As an option, the length of the procedure qualification test assembly may be increased, and the all-weld-metal tension specimen may be removed from the procedure qualification test assembly.

10.3.2 Test Results. Procedure qualification test results for **Class O** groove welds shall meet the following requirements:

(1) The visual and nondestructive examination acceptance criteria and mechanical property requirements shall satisfy the standard designated by the Customer.

(2) Radiography — Radiographic examination is required for groove welds and shall satisfy the designated standard for production welds.

(3) All-weld-metal tension tests — The yield and tensile strength shall not be less than the specified minimum required of the base metal. When no all-weld-metal elongation requirement is specified by the governing standard, the minimum acceptable elongation shall be dependent on the base metal yield strength as follows:

Yield strength, ksi (MPa)	Minimum Elongation, %
Up to 50 (350)	19
51 (351) to 89 (599)	14
90 (600) and higher	12

Table 11
Weld Procedure Qualification — Number and Type of Test Specimens for Class O Welds^a

Coupon	Thickness in. mm	Visual (See 6.9)	Radiograph (See 6.11)	Reduced Section		Fillet Weld Shear ^b (See 5.11.8)	All-Weld- Metal		Root	Face Bends		Side Bends	Macroetch Test (See 5.22.3)	Vickers Hardness (See 5.11.6) ^c	Charpy (See 5.11.5) ^c (5.11.7)	Fillet Weld Break ^b (5.11.7)
				Tension (See 5.11.1)	Note d		Tension	Note d		Note d	Note d					
All	All	Yes	Note c			0	1		Note d	Note d	Note d		1	1	Note d	Note d

a. First position only. Qualification for additional positions will omit groove weld tensile, macroetch, hardness, Charpy tests, fillet weld shear strength tests and all-weld-metal tension tests.
 b. Multiple pass fillet welds are considered qualified by groove weld qualification. (See 5.9.2)

c. Groove welds only are radiographed.

d. Mechanical test requirements shall satisfy the specific code referenced by the Customer. Weld metal and HAZ Charpy toughness testing is required only if Charpy toughness is required of the base metal on both sides of the weld.

e. Vickers hardness and Charpy Impact tests not applicable to austenitic stainless steel.

(4) Macro — Macrosections transverse to the weld shall reveal no cracks at 5X magnification. Slag, porosity, and other defects, as well as hardness exceeding limits specified by the designated standard, shall be cause for rejection. (See Part III of this section).

(5) Charpy impact tests — If Charpy notch toughness testing is required in the referenced standard, the qualification weld shall be tested and shall satisfy those requirements. The weld metal shall also be impact tested if the base material on both sides of the weld must meet impact test requirements. The minimum absorbed energy values and testing temperatures shall be specified by the Customer.

10.4 Fillet Welds

10.4.1 Test Specimens. The coupons required for fillet weld qualification in the standard referenced by the Customer shall be produced. Allowance should be included to permit removal of a weld macroetch specimen. A groove weld shall be produced in accordance with Figure 14 for the all-weld-metal tensile and the Charpy V-notch weld metal tests.

10.4.2 Test Results. The provisions of 10.3.2(1) and 10.3.2(3) through (5) shall apply to fillet weld test results.

Part II *Welder Qualification*

10.5 Requirements

The number and type of test specimens and the required test results for welder qualification for **Class O** groove and fillet welds shall be in accordance with the requirements of the standards specified by the Customer. Refer also to 5.15.

Part III *Examination*

10.6 Examination Requirements

All **Class O** welds shall, as a minimum, be visually examined in accordance with section 6, Part II. Unless otherwise specified by the Customer, all **Class O** production welds shall also be examined in accordance with the requirements of the standard specified.

10.7 Acceptance Criteria

Acceptance criteria for inspection and examination of **Class O** welds shall be in accordance with the requirements of the standard specified by the Customer.

11. Glossary

The terms and definitions in this glossary are unique to underwater welding and applicable to this specification.

ambient pressure - Pressure of the environment surrounding the welding arc.

arc-dry - A condition in which the welding arc and any shielding gas are separated from the aqueous environment by a mechanical barrier.

arc-wet - A condition in which no mechanical barrier exists between the welding arc and the aqueous environment.

background gas - Gas which serves to displace water, but is not necessarily intended to shield the arc. It may or may not be breathable.

bell - Compartment, either open or closed, which allows the diver to be transported to and from the underwater work area, and which may be used as a temporary refuge during diving operations.

bottom time - Time normally used in diving to calculate decompression. In this specification, it is taken to be the total elapsed time measured in minutes, from the time when the diver leaves the surface in descent, to the time that the diver begins ascent.

carbon equivalent - Carbon equivalent (CE) is an empirical guide relating the chemical composition of steel with hydrogen induced cracking tendencies. Carbon Equivalent is calculated in accordance with 5.6.1.3.

caisson - A watertight chamber used underwater in construction work or as a foundation.

coffer dam - A watertight barrier that surrounds the weld site. When the water is evacuated, the weld site is at atmospheric pressure.

coffer dam welding - Welding below the water surface inside a coffer dam. Both the welder and the arc are in a dry environment.

confirmation weld - A test weld made in accordance with the qualified welding procedure at the underwater work site prior to production welding to demonstrate adequate performance of welder

and welding equipment during underwater welding.

controlled rolling - A thermomechanical treatment for forming steel plate. The final thickness reduction is made near the critical temperature, producing a fine-grained steel of improved toughness.

crack - A fracture-type discontinuity characterized by a sharp tip and high ratio of length and width to opening displacement.

customer - See 1.3.1.

depth - Distance below the water surface at which underwater welding is executed.

direct visual examination - Examination of the surface appearance of a weld performed at the weld site.

dive site - A surface or vessel from which diving operation is conducted.

dive team - Divers and support personnel involved in a diving operation, including the designated person-in-charge.

diver - An employee working in water using underwater apparatus that supplies compressed breathing gas at the ambient pressure.

diving mode - A type of diving requiring specific equipment, procedures, and techniques (i.e., SCUBA, surface-supplied air, mixed gas saturation diving, etc.)

dry-backed weld joint - The condition in which all water is excluded from contact with any part of the weld joint for a distance of at least 6 in. (150 mm).

dry chamber welding - A hyperbaric underwater welding method, in which the weldment is in a dry environment provided by a chamber fitted over the joint to be welded. Water is displaced from the chamber by gas at ambient pressure. The chamber may be of any size, and is such that diving dress is required.

dry-spot welding - An underwater welding method in which only the arc is in a dry environment, and where the protective welding gases are maintained at the arc by a mechanical barrier.

dry welding - Any welding in which water is excluded from the immediate vicinity of the arc by a mechanical barrier.

essential variable - Essential variables are those for which a change may affect the mechanical properties of the weldment, or the operating characteristics of the procedure.

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

gas diving - Use of gases other than air for the breathing gas.

habitat welding - A hyperbaric underwater welding method in which the weldment and the welder are in a dry environment, provided by a chamber of sufficient size to contain the welder and to permit free movement by the welder inside of it. Water is displaced from the chamber by gas at ambient pressure. The chamber is such that diving dress is not required during welding.

heavy gear - Diver-worn deep sea dress including helmet, breastplate, dry suit, and weighted shoes.

hyperbaric conditions - Pressure conditions in excess of surface pressure.

image quality indicator (IQI) - A device whose image in a radiograph is used to determine radiographic quality level. It is not intended for use in judging the size nor for establishing acceptance limits of discontinuities. It is commonly referred to as a *penetrameter*.

indirect visual examination - Examination of the surface appearance of a weld by methods that do not require that the inspector be at the weld site. Methods may include photographic, video, or other means approved by the Customer.

inspector - See 1.3.1.

inspector/diver - A person capable of conducting an investigation, such as visual or radiographic, at an underwater site.

mixed-gas diving - A diving mode in which the diver is supplied in the water with a breathing gas other than air.

one-atmosphere welding - Welding underwater in a pressure vessel, in which the pressure is main-

tained at approximately one atmosphere independent of depth.

saturation diving - A diving mode which does not impose limits on exposure time, nor require decompression until the diver's work is completed. This mode is used, when pressure at working depths makes surface diving impractical, due to limited exposure time and extended decompression after each dive.

scuba diving - A diving mode, independent of surface supply, in which the diver uses open-circuit self-contained underwater breathing apparatus.

surface diving - Diving mode in which the diver returns to atmospheric conditions after each dive. The breathing mixture, air or mixed gas, is supplied to the diver from the surface.

T-, Y-, or K-connections - A truss joint or node in tubular structures formed by members whose axes intersect in T, Y, K, or other configuration.

underwater stage - A suspended underwater platform which supports a diver in the water.

underwater welding - Any welding performed below the water surface.

underwater work site - The location underwater where work is performed.

visual examination - A general term which includes both supplementary and direct examination of the surface of a weld.

welding system - All welding equipment and supplies used for making a weld.

weld type - A group of groove or fillet welds having similar mechanical properties, similar surface appearance requirements and quality, and capable of withstanding similar operating conditions.

wet-backed weld joint - A weld joint contained in a dry chamber, when a water wet surface is less than 6 in. (150 mm) from the joint.

wet welding - Welding at ambient pressure with the welder/diver in the water and with no mechanical barrier around the arc.

welder/diver - A person who is qualified in accordance with this specification to perform underwater welding.

12. References

The following documents may be referred to for additional information concerning diving, construction standards, welding, and testing.

C. Construction Standards

(1) **ASME Boiler and Pressure Vessel Code**, American Society of Mechanical Engineers, New York, NY

(2) **Guide for Building and Classing Fixed Offshore Structures**, American Bureau of Shipping, Paramus, NJ

(3) **API RP 2A, Recommended Practice for Planning, Designing, and Constructing Fixed Offshore Platforms**, American Petroleum Institute, Washington, DC

(4) **Rules for Building and Classing Offshore Mobile Drilling Units**, American Bureau of Shipping, Paramus, NJ

(5) **Rules for Building and Classing Steel Vessels**, American Bureau of Shipping, Paramus, NJ

(6) **ANSI/AWS D1.1, Structural Welding Code — Steel**, American Welding Society, Miami, FL

D. Diving

(1) **Manual of Safe Practices in Commercial Diving Operations**, Association of Diving Contractors, Gretna, LA

(2) **NAVSHIPS 0994-001-9010, U.S. Navy Diving Manual**

(3) **1910.420, OSHA Diving Regulations**, OSHA Safe Practices Manual

(4) **NOAA Diving Manual**, U.S. Department of Commerce

(5) **197.420, U.S. Coast Guard Operations Manual**

N. Nondestructive Examination

(1) **ASTM E142, Controlling Quality of Radiographic Testing**, American Society for Testing Materials, Philadelphia, PA

(2) **ANSI/AWS B1.10, Guide for the Nondestructive Inspection of Welds**, American Welding Society, Miami, FL

(3) **ANSI/AWS B1.11, Guide for the Visual Inspection of Welds**, American Welding Society, Miami, FL

(4) **Metals Handbook**, "Nondestructive Inspection and Quality Control," American Society for Metals, Metals Park, OH

(5) **ASTM E165, Recommended Practice for Liquid Penetrant Inspection**, American Society for Testing and Materials, Philadelphia, PA

(6) **ASTM E709, Recommended Practice for Magnetic Particle Inspection**, American Society for Testing and Materials, Philadelphia, PA

(7) **ASTM E94, Recommended Practice for Radiographic Testing**, American Society for Testing and Materials, Philadelphia, PA

(8) **ASTM E164, Recommended Practice for Ultrasonic Contact Examination of Weldments**, American Society for Testing and Materials, Philadelphia, PA

(9) **API RP 2X, Recommended Practice for Ultrasonic Examination of Offshore Structural Fabrication and Guidelines for Qualification of Ultrasonic Technicians**, American Petroleum Institute, Washington, DC

(10) **Rules for Nondestructive Testing of Hull Welds**, American Bureau of Shipping, Paramus, NJ

(11) **ASTM A577, Specification for Angle-Beam Examination of Steel Plates**, American Society for Testing and Materials, Philadelphia, PA

(12) **ASTM A578, Specification for Straight Beam Ultrasonic Examination of Plain and Clad Steel Plates for Special Applications**, American Society for Testing and Materials, Philadelphia, PA

(13) **Welding Inspection**, 2nd Ed., 1980, American Welding Society, Miami, FL

(14) **ASNT-TC-1A, American Society for Nondestructive Testing Recommended Practice**

S. Safety

(1) **National Electrical Code**, National Fire Protection Association, Boston, MA

(2) **ANSI Z87.1, Practice for Occupational and Educational Eye and Face Protection**, American National Standards Institute, New York, NY

(3) **Safety and Health Regulations for Ship Repairing**, (See Code of Federal Regulations (OSHA), Title 29, Chapter SII, Part 1915; Subpart D pertains to welding, cutting, and heating during ship repairs)

(4) **ANSI/ASC Z49.1, Safety in Welding and Cutting**, American Welding Society, Miami, FL

(5) **NFPA 51B, Standard for Fire Prevention in the Use of Cutting and Welding Processes**, National Fire Protection Association, Boston, MA

(6) **NFPA No. 51, Standard for the Installation and Operation of Oxygen-Fuel Gas Systems for Welding and Cutting**, National Fire Protection Association, Boston, MA

W. Welding

(1) **ASME Boiler and Pressure Vessel Code**, Section IX, Welding and Brazing Qualifications, American Society of Mechanical Engineers, New York, NY

(2) **MIL-STD-1628 Fillet Weld Size, Strength and Efficiency Determination**,

(3) **MIL-STD-271, Nondestructive Testing Requirements for Metals**

(4) **API RP 1107, Recommended Pipelines Maintenance Welding Practices**, American Petroleum Institute, Production Department, Dallas, TX

(5) **ANSI/AWS A5.18, Specification for Bare Carbon Steel Filler Metals for Gas Shielded Arc Welding**, American Welding Society, Miami, FL

(6) **ANSI/AWS A5.1, Specification for Carbon Steel Covered Arc Welding Electrodes**, American Welding Society, Miami, FL

(7) **ANSI/AWS A5.20, Specification for Carbon Steel Electrodes for Flux Cored Arc Welding**, American Welding Society, Miami, FL

(8) **ANSI/AWS A5.5, Specification for Low Alloy Steel Covered Arc Welding Electrodes**, American Welding Society, Miami, FL

(9) **ANSI/AWS A5.29, Specification for Low Alloy Steel Filler Metal for Flux Cored Arc Welding**, American Welding Society, Miami, FL

(10) **ANSI/AWS A5.28, Specification for Low Alloy Steel Filler Metals for Gas Shielded Arc Welding**, American Welding Society, Miami, FL

(11) **ANSI/AWS B4.0, Standard Methods for Mechanical Testing of Welds**, American Welding Society, Miami, FL

(12) **API Std. 1104, Standard for Welding Pipelines and Related Facilities**, American Petroleum Institute, Production Department, Dallas, TX

(13) **ANSI/AWS A3.0, Standard Welding Terms and Definitions**, American Welding Society, Miami, FL

(14) **ANSI/AWS D1.1, Structural Welding Code — Steel**, American Welding Society, Miami, FL

(15) **NAVSEA SO300-BB-MAN-010, U.S. Navy Underwater Cutting and Welding Manual**

(16) **MIL-STD-248, Welding and Brazing Procedure and Performance Qualification**

(17) **MIL-STD-22, Welded Joint Designs**

(18) **ANSI/AWS A2.4, Standard Symbols for Welding, Brazing and Nondestructive Examination**, American Welding Society, Miami, FL

(19) **IIW DOC SCUW I24-90 Standard Guidelines for Specification of Underwater Fusion Welding**

(20) **Det Norske Veritas; Recommended Practice RP B604**, January 1987

(21) **Bureau Veritas; Underwater Welding, General Information and Recommendation**, January 1986

INSPECTOR

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D3.6	Specification for Underwater Welding
D3.7	Guide for Aluminum Hull Welding
Additional Documents of Fundamental Subject Matter	
A1.1	Metric Practice Guide for the Welding Industry
A2.4	Standard Symbols for Welding, Brazing and Non-destructive Examination
A3.0	Standard Welding Terms and Definitions

For ordering information, contact the Order Department, American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135. Phone: 1-800-334-9353