D3.6M:2017
An American National Standard

# Underwater Welding Code

American Welding Society®

Approved American National Standard
ANSI

**AWS D3.6M:2017**
**An American National Standard**

**Approved by the**
**American National Standards Institute**
**January 10, 2017**

# Underwater Welding Code

**6th Edition**

**Supersedes AWS D3.6M:2010**

Prepared by the
American Welding Society (AWS) D3 Committee on Marine Welding

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

## Abstract

This code covers the requirements for welding structures or components under the surface of water. It includes welding in both dry and wet environments. Clauses 1 through 8 constitute the general requirements for underwater welding, while clauses 9 through 11 contain the special requirements applicable to three individual classes of weld as follows:

**Class A**—Comparable to above-water welding
**Class B**—For less critical applications
**Class O**—To meet the requirements of another designated code or specification

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This standard is subject to revision at any time by the AWS D3 Committee on Welding in Marine Construction. It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are requested and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the AWS D3 Committee on Welding in Marine Construction and the author of the comments will be informed of the Committee's response to the comments. Guests are invited to attend all meetings of the AWS D3 Committee on Welding in Marine Construction to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

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# Foreword

This foreword is not part of this standard but is included for informational purposes 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 code was published in 1983, with subsequent editions issued in 1989, 1993, 1999, and 2010.

Clauses 1 through 8 constitute the general requirements applicable to all classes of underwater welds. Clauses 9 through 11 contain unique requirements applicable to each class. 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. Applications now include engineered repair and alteration of off-shore structures, submerged marine pipelines, underwater port facilities and nuclear power plant components.

This 6th edition incorporates the following major revisions:

(1) Cleaning requirements have been better defined (5.11)

(2) Acceptance of qualification to earlier editions of D3.6M is incorporated (7.1.3)

(3) Ultrasonic Examination Clause 8, Part IV, has been updated to better align with the UT technique described in AWS D1.1/D1.1M, *Structural Welding Code—Steel*

(4) Sample Forms have been revised (Annex A)

(5) An informative annex has been added to address the qualification of marine welding inspectors (Annex E)

(6) There is a restructuring of the clause numbers

(7) Ultrasonic Stress Relieving has been added to the document (Terms and Definitions, Workmanship, Welding Variables, and Annex C)

A vertical line in the margin or underlined text in clauses, tables, or figures indicates a technical or significant change from the 2010 edition.

Comments and suggestions for the improvement of this standard are welcome. They should be addressed to the Secretary, AWS D3B Subcommittee on Underwater Welding, American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

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# Table of Contents

**Page No.**

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# List of Tables

**Table** **Page No.**



# List of Figures

**Figure** **Page No.**

# List of Forms

**Form** **Page No.**

# Underwater Welding Code

## 1. General Requirements

**1.1 Scope.** This code covers underwater welding in both dry and wet environments. Five basic methods for underwater welding are covered in this specification as follows:

(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).

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.

Three weld classes (A, B, 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 code 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.

All provisions of this document apply equally to new construction and to modification and repair of existing structures underwater. This document may be used in conjunction with other applicable codes or specifications for design, construction, or repair.

**1.2 Units of Measurement.** This standard makes sole use of International System of Units (SI). Approximate mathematical equivalents in U.S. Customary Units are provided for comparison in parentheses or in appropriate columns in tables and figures.

**1.3 Safety.** Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein. Recommended Guidelines for Safety in Underwater Welding are found in Annex B (Informative).

Safety and health information is available from the following sources:

American Welding Society:

(1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*

(2) AWS Safety and Health Fact Sheets

(3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

(1) Safety Data Sheets supplied by materials manufacturers

(2) Operating Manuals supplied by equipment manufacturers

Association of Diving Contractors International:

(1) International Consensus Standards for Commercial Diving and Underwater Operations

International Marine Contractors Association:

(1) IMCA D 014, International Code of Practice for Offshore Diving

(2) IMCA D 045/IMCA R 015, Code of Practice for the Safe Use of Electricity Underwater

Applicable Regulatory Agencies

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous, and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

### 1.4 Application

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

**1.4.2** In this code, 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.

**1.4.3** Where alternative requirements are permitted by the specification, all requirements that modify this code shall be incorporated into contract documents.

**1.4.4** For Class O welds (see 4.1.6 and 7.5), 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.

### 1.5 Base Metals

**1.5.1** This standard covers the welding of low alloy, carbon steels, and austenitic stainless steels. The weldability of the steel and the procedures for welding it shall be established by qualification. The carbon content, carbon equivalent, and tensile strength of low alloy and carbon steels are critical variables for underwater welding. Production welding on low alloy and carbon steels with a carbon content, carbon equivalent, or tensile strength above that qualified shall require requalification of the procedure.

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

### 1.6 Welding Process

**1.6.1** 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 code. These processes may be used, provided the welding procedure is qualified in accordance with all applicable requirements of this document.

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

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

# 2. Normative References

The documents listed below are referenced within this publication and are mandatory to the extent specified herein. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply.

American Welding Society (AWS) standards:

AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Testing*

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*

AWS B4.0, *Mechanical Testing of Welds*

AWS D1.1/D1.1M, *Structural Welding Code—Steel*

American National Standards Institute (ANSI) standard:

ANSI Z49. 1, *Safety in Welding, Cutting and Allied Processes*

American Petroleum Institute (API) standard:

API RP2X, *Recommended Practice for Ultrasonic and Magnetic Examination of Offshore Structural Fabrication and Guidelines for Qualification of Technicians*

American Society of Mechanical Engineers (ASME) standard:

ASME BPV Code, Section IX, QW-470, *Etching Processes and Reagents*

American Society for Nondestructive Testing (ASNT) standard:

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

ASTM International standards:

ASTM A370, *Standard Methods and Definitions for Mechanical Testing of Steel Products*

ASTM E92, *Standard Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials*

ASTM E164, *Standard Practice for Contact Ultrasonic Testing of Weldments*

ASTM E165/E165M, *Standard Practice for Liquid Penetrant Examination for General Industry*

ASTM E309, *Standard Practice for Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation*

ASTM E340, *Standard Practice for Macroetching Metals and Alloys*

ASTM E426, *Standard Practice for Electromagnetic (Eddy Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys*

ASTM E709, *Standard Guide for Magnetic Particle Testing*

ASTM E1219, *Standard Practice for Fluorescent Liquid Penetrant Testing Using the Solvent-Removable Process*

ASTM E1220, *Standard Practice for Visible Penetrant Testing Using Solvent-Removable Process*

ASTM E1416, *Standard Practice for Radioscopic Examination of Weldments*

ASTM E1444/E1444M, *Standard Practice for Magnetic Particle Testing*

International Organization for Standardization (ISO) standards:

ISO 148, *Metallic materials—Charpy pendulum impact test—Part 1: Test method*

ISO 3452, *Nondestructive testing—Penetrant testing—General principles*

ISO 4136, *Destructive tests on welds in metallic materials—Transverse tensile test*

ISO 4969, *Steel— Etching method for macroscopic examination*

ISO 6892, *Metallic materials—Tensile testing—Part 1: Method of test at room temperature*

ISO 6947, *Welding and allied processes—Welding positions*

ISO 9015-2, *Destructive tests on welds in metallic materials—Hardness testing—Part 2: Microhardness testing of welded joints*

ISO 9016, *Destructive tests on welds in metallic materials—Impact tests—Test specimen location, notch orientation and examination*

# 3. Terms and Definitions

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*, provides the basis for terms and definitions used herein. However, the following terms and definitions are included below to accommodate usage specific to this document.

**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.

**bottom time.** Time normally used in diving to calculate decompression. In this code, 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.

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

**carbon equivalent.** Carbon equivalent (CE) is an empirical guide relating the chemical composition of steel with hydrogen-induced cracking tendencies. CE is calculated in accordance with 7.5.1.3.

**cofferdam.** A watertight barrier that surrounds the weld site. When the water is evacuated, the weld site is at atmospheric pressure.

**cofferdam welding.** Welding below the water surface inside a cofferdam. Both the welder and the arc are in a dry environment.

**confirmation weld.** A test weld made at the underwater work site prior to production welding. The confirmation weld is intended to demonstrate proper functioning of the welding system (e.g., power supply and welding leads) under actual conditions (e.g., wave action, visibility, current). It is not intended to be used as requalification of the welding procedure, welder, or both.

**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.** The party contracting for the work, or its authorized representative, which may include an applicable Classification Society, or other third party organizations.

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

**direct visual examination.** Examination performed at the weld site of the surface appearance of a weld. (See also *indirect visual examination*.)

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

**diving mode.** A type of diving requiring specific equipment, procedures, and techniques (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 150 mm (6 in) or greater.

**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.

**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. (See also *direct visual examination*.)

**inspector.** A duly designated person who acts for, and on behalf of, the Customer on all inspection and quality matters within the scope of the code and the contract documents.

**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 maintained 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-, and K-connections.** A truss joint or node in tubular structures formed by members whose axes intersect in T-, Y-, and/or K-configurations.

**temper bead.** An overlapping weld bead applied adjacent to, but not in contact with, the base metal with the intent to minimize hardness, and—when applied within defined time constraints—to promote hydrogen release in the base metal heat-affected zone.

**ultrasonic stress relieving process.** A process in which ultrasonic energy is used to impart compressive residual stress into a weld joint and base material mitigating harmful tensile stresses.

**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 indirect and direct examination of the surface of a weld.

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

**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 150 mm (6 in) from the joint.

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

# 4. Classification and Design of Welded Connections

**4.1 Classification of Welds**

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

**4.1.2** 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 code shall be made in accordance with a qualified welding procedure and shall meet the general requirements applicable to all weld classes specified in Clauses 1 through 8 and the unique requirements for one or more of the weld classes specified in this clause. Each designated weld must meet all the requirements for the weld class specified.

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

**4.1.4 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 Clause 9. Additional requirements may be appropriate for critical applications, and should be agreed to in advance and specified in the contract document.

**4.1.5 Class B Welds.** Class B underwater welds are intended for less critical applications where lower ductility, moderate porosity, and other limited discontinuities can be tolerated. The unique requirements for Class B welds are specified in Clause 10. The suitability of a Class B weld for a particular application should be evaluated on a "Fitness for Purpose" basis.

**4.1.6 Class O Welds.** Class O underwater welds must meet the requirements of another designated code or standard, as well as additional requirements, specified herein, to cope with the underwater welding environment. The unique requirements for Class O welds are specified in Clause 11. The Customer shall specify the standard that applies to this class of weld.

**4.2 Design.** This code 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 the weld class, inspection method, and acceptance criteria.

# 5. Workmanship

**5.1 General.** All welds produced in accordance with this code 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.

**5.2 Base Metal Preparation**

**5.2.1** 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 code requirements of Clause 7 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.

**5.2.2** 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.

**5.2.3** 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 10 mm (3/8 in) 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 procedures qualified specifically for the repair. The Customer shall be notified before repair commences.

**5.3 Assembly**

**5.3.1 Dry Welding**

**5.3.1.1** Tolerances for the weld preparation and joint fit-up shall be developed during welding procedure qualification. Alternatively, the tolerances given in Figure 5.1 may be applied to groove welds. In either case, the qualified welding procedure shall define the limits.

When the joint includes backing, the separation between faying surfaces of butt joints landing on a backing shall not exceed 1.5 mm (1/16 in). Where irregularities prevent alignment or fit-up to limits qualified in the welding procedure, the methods used to meet those limits shall be subject to the Customer's approval. Welding procedures required to achieve the correct fit shall also be qualified under the rules of this code.

**5.3.1.2** 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. If the root opening is greater than 1.5 mm (1/16 in), the leg(s) of the fillet welds shall be increased by the amount of the root opening.

**5.3.2 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.

**5.4 Confirmation Weld.** Unless otherwise specified by the Customer, the requirements of 5.4.1, 5.4.2, 5.4.3, and 5.4.4 apply.

**5.4.1 General.** Prior to production underwater welding, a confirmation weld test shall be satisfactorily completed at the job site at the depth at which production welding will take place. At least one confirmation weld, excluding automated welding, shall be satisfactorily completed for each welding system to be used during production. The confirmation test weld shall be a fillet break weld conforming to the requirements of 7.10.7 except that the length shall be a minimum of 200 mm (8 in). Unless otherwise specified by the Customer, the requirements of 5.4.2, 5.4.3, and 5.4.4 apply.

**5.4.2 Base Metals.** The base metal for the confirmation weld should be 10 mm (3/8 in) minimum thickness and carbon equivalent within 0.05 of the maximum CE of the base metal welded in production.

**5.4.3 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 position in production in which the majority of welding will be done or as directed by the Customer.

**5.4.4 Examination Requirements.** Each confirmation weld shall undergo visual inspection and fillet break testing. Macroetch testing shall not be required. The test plate may be cut into smaller sections by any convenient means (e.g., thermal cutting) to facilitate breaking. However, cutting shall not interfere with evaluation of the root pass start and stop. Acceptance criteria shall be as specified in Clause 9, 10, or 11 for the class of weld.

**5.5 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 3 mm (1/8 in), whichever is greater. The lengths of the weld shall not exceed the specified length by more than 25 mm (1 in) or 15%, whichever is greater, without the Customer's approval. The location of welds shall not be changed without the approval of the Customer.

**5.6 Weld Profiles.** All welds shall meet the visual acceptance criteria for weld profiles as defined in Part III of Clauses 9 through 11 for Class A through O welds, respectively.

**5.7 Tack Welds and Temporary Welds**

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

**5.7.2** The location and dimensions of temporary welds shall be 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 code for the class of weld selected.

**5.8 Repairs**

**5.8.1** 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.

**5.8.2** 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 thickness shall be restored by welding, using a qualified procedure.

**5.8.3** 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.

**5.8.4** 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 code.

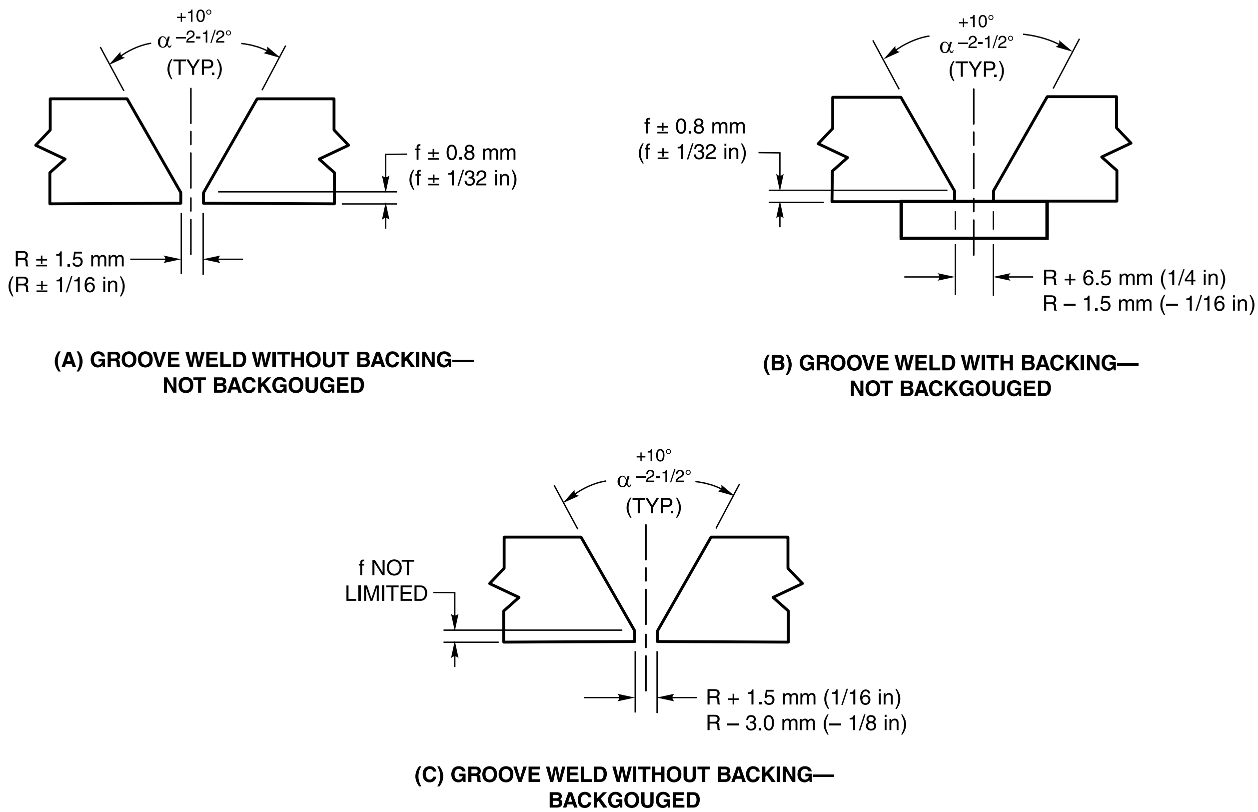
**5.9 Peening.** The root layer shall not be peened. Peening of subsequent beads shall be permitted only with prior approval of the Customer. The operator shall visually inspect the weld surface for slag, overlap, undercut, and cracks prior to peening. If any of these weld defect conditions are present, each should be removed or repaired prior to the application of the peening process. 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 except for austenitic stainless steel and other nonmagnetic materials.

**5.9.1 Ultrasonic Stress Relieving.** When specified by the Customer, the weld shall be ultrasonically stress relieved. Ultrasonic stress relieving shall be done using a device that produces a 25 KHz frequency or greater. The operator shall visually inspect the weld surface for slag, overlap, undercut, and cracks prior to applying ultrasonic stress relieving. If any of these weld defect conditions are present, each should be removed or repaired prior to the application of the ultrasonic stress relieving process. The ultrasonic stress relieving process shall be applied separately to each weld layer, cap, and toes of the finished weld using a pin array as specified by the Customer. Ultrasonic stress relieving shall be preceded by required nondestructive examinations and followed by an additional examination using magnetic particle methods except for austenitic stainless steel and other nonmagnetic materials.

**5.10 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 under the restrictions stated in 5.8.2.

**5.11 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.

**5.11.1 In-process Cleaning.** Before welding over previously deposited metal, all slag shall be removed and the weld and adjacent base metal shall be cleaned by brushing or other suitable means. This requirement shall apply not only to successive layers but also to successive beads and to the crater area when welding is resumed after any interruption.




Notes:
1. α—groove angle
2. R—root opening
3. I—root face
4. The groove configurations shown are for illustration only.

**Figure 5.1—Tolerances in Assembly of Groove Weld Butt Joints—Dry Welding**

# 6. Technique

**6.1 Filler Metal**

**6.1.1** 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.

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

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

**6.2 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 location underwater where the welding is to be performed. If not measured at the weld location, 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.

**6.3 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 260°C (500°F) shall be specified.

# 7. Qualification

## *Part I*
## *General Requirements*

### 7.1 Approved Procedure

**7.1.1 Welding Procedure Specification.** All welding shall be performed in accordance with a welding procedure specification (WPS) which meets the requirements of this clause. The WPS employed shall be qualified prior to production welding in accordance with the requirements of this clause. 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.

**7.1.2 Welding Procedure Qualification.** A welding procedure specification shall be 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 Clauses 9 through 11 for Class A through O welds, respectively.

**7.1.3 Previous Qualification.** Qualifications which were performed to and met the requirements of an earlier edition of AWS D3.6M, while that edition was in effect, are valid and may be used. The use of earlier editions shall be prohibited for new qualifications in lieu of the current edition unless the earlier edition is specified in the contract documents.

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

Welders qualified to deposit Class A welds are also qualified to deposit Class B welds in the same environment qualified.

**7.3 Qualification Responsibility.** Each contractor shall be responsible for the qualification of welding procedures and welders employed in performing work to this standard 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*
## *Welding Procedure Qualification*

### 7.4 Limitation of Variables

**7.4.1 Essential and Nonessential Variables.** Each welding variable described in 7.5 shall be designated as either an essential or nonessential variable for each process.

**7.4.2 Limitations on Essential and Nonessential Variables.** Changes in essential variables beyond the limits specified in Table 7.1 (dry welding variables) and Table 7.2 (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 WPS or by preparing a new WPS.

**7.4.3 Electrical Measurement Accuracy.** Electrical measurements made under qualification and production conditions will involve different levels of accuracy. Accordingly, the electrical ranges discussed in this code shall be considered nominal values.

**7.5 Welding Procedure Qualification Variables.** Variables for welding procedure qualification are listed in Tables 7.1 and 7.2, and described in the following clauses. In general, for Class O welds, the referenced documents take precedence. However, essential variables, and the extent of nondestructive and destructive examination, shall also meet the requirements identified in this document.

**7.5.1 Requirements for Base Metals**

**7.5.1.1** The chemical composition and carbon equivalent (if applicable) of procedure qualification test plates shall be determined through chemical analysis.

**7.5.1.2** 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) Mill Test Reports—The chemical composition of the metal may be based on the maximum values from 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 ISO or 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.

**7.5.1.3** 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:

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

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

$$CE = C + \frac{Mn}{6} + 0.05 \qquad \text{(Equation 2)}$$

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

**7.5.1.4** Procedure qualification testing shall be performed on material with chemical composition and mechanical properties (e.g., equivalent material specification and grades) as close as practical to the production metal, but in no case with a carbon content less than the metal to be welded in production.

**7.5.2 Depth Range**

**7.5.2.1** Welding procedure qualification depth limitations shall be in accordance with Table 7.3.

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

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

**7.6 Types of Tests.** The welded test assemblies required to qualify a welding procedure are described in Part I of Clauses 9 through 11 for Class A through O welds, respectively. The assemblies shall be welded with the procedure that is to be qualified, and shall satisfy all the test requirements for the weld class.

**7.7 Position of Test Welds.** Welding test positions for groove and fillet welds are defined in ISO 6947, *Welding and allied processes—Welding positions* and A3.0M/A3.0, *Standard Welding Terms and Definitions* and depicted in Figures 7.3 and 7.4 for grooves in plate and pipe and Figures 7.5 and 7.6 for fillets in plate and pipe. Figures 7.1 and 7.2 are provided to allow users to differentiate among various production welding positions to determine what welding test position(s) are required for qualification.

**7.7.1** Welding position is an essential variable. Production positions qualified by specific test positions are listed in Table 7.4.

**7.7.2** 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 Clauses 9, 10, and 11 for Class A, B, and O welds, respectively. The Customer shall determine which position shall be used for the first position (i.e., larger test plate).

**7.7.3** 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 Clauses 9, 10, and 11 for Class A, B, and O welds, respectively. Each procedure shall be tested in the manner indicated in 7.7.5.

**7.7.4 Plate Groove Welds.** In making the tests to qualify groove welds, test plates shall be welded in the following positions (see Figure 7.3).

**7.7.4.1 Position PA (1G) Flat.** The plates are placed in an approximately horizontal plane and the weld metal is deposited from the upper side [see Figure 7.3(A)].

**7.7.4.2 Position PC (2G) Horizontal.** The plates are placed in an approximately vertical plane with the groove approximately horizontal [see Figure 7.3(B)].

**7.7.4.3 Position PF (3G up) or PG (3G down).** The plates are placed in an approximately vertical plane with the groove approximately vertical [see Figure 7.3(C) and (D)].

**7.7.4.4 Position PE (4G) Overhead.** The plates are placed in an approximately horizontal plane, and the weld metal is deposited from the underside [see Figure 7.3(E)].

**7.7.5 Pipe Groove Welds.** In making the tests to qualify groove welds, the positions shall be as indicated below (see Figure 7.4).

**7.7.5.1 Position PA (1G) Pipe Horizontal Rolled.** The pipe shall be placed with its axis horizontal and the groove in an approximately vertical plane. The pipe shall be rotated during welding, so the weld metal is deposited from the upper side [see Figure 7.4(A)].

**7.7.5.2 Position PC (2G) Pipe Vertical.** The pipe shall be placed with its axis vertical and the welding groove approximately horizontal. The pipe shall not be rotated during welding [see Figure 7.4(B)].

**7.7.5.3 Position PJ (5G down) or PH (5G up) Pipe Horizontal Fixed.** The pipe shall be placed with its axis horizontal and the groove in an approximately vertical plane. The pipe shall not be rotated during welding [see Figure 7.4(C) and (D)].

**7.7.5.4 Position H-, J-L045 (6G down), or H-L045 (6G up) Pipe Inclined Fixed.** The pipe shall be inclined at 45° with the horizontal. The pipe shall not be rotated during welding [see Figure 7.4(E) and (G)].

**7.7.5.5 Position H-, J-L045 Restricted (6GR).** Test for complete joint penetration groove welds of tubular T-, Y-, and K-connections—the pipe shall be inclined at 45° with the horizontal. The pipe (or tube) shall not be rotated during welding [see Figures 7.4(F) and (H), 9.4 and 10.4].

**7.7.6 Plate Fillet Welds.** In making the tests to qualify fillet welds, the test plate positions shall be as indicated below (see Figure 7.5).

**7.7.6.1 Position PA (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 7.5(A)].

**7.7.6.2 Position PB (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 7.5(B)].

**7.7.6.3 Position PG (3F Down) or PF (3F Up) Vertical.** The plates are placed such that each fillet weld is deposited with its axis approximately vertical [see Figure 7.5(C) and (D)].

**7.7.6.4 Position PD (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 7.5(E)].

**7.7.7 Pipe Fillet Welds.** In making tests to qualify fillet welds, test pipes shall be welded in the positions indicated below (see Figure 7.6).

**7.7.7.1 Position PA (1F) Flat.** The assembly shall be placed with the pipe axis inclined at 45° to horizontal and rotated during welding; the weld metal shall be deposited from above and at the highest point of rotation of the joint. The axis of the weld at that point shall be horizontal and the throat vertical [see Figure 7.6(A)].

**7.7.7.2 Position PB (2F) Horizontal.** The assembly shall be 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 shall be horizontal, and the pipe shall not be rotated during welding [see Figure 7.6(B)].

**7.7.7.3 Position PB (2FR) Horizontal Rotated.** The assembly shall be placed with the pipe axis horizontal and rotated during welding. The weld metal shall be deposited at the highest point of rotation of the pipe, on the upper side of a horizontal surface and against a vertical surface [see Figure 7.6(C)].

**7.7.7.4 Position PD (4F) Overhead.** The assembly shall be 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 shall be horizontal, and the pipe shall not be rotated during welding [see Figure 7.6(D)].

**7.7.7.5 Position PJ (5F down) or PH (5F up) Multiple Positions.** The assembly shall be placed with the pipe axis horizontal and the axis of the deposited weld in a vertical plane. The pipe shall not be rotated during welding [see Figure 7.6(E) and (F)].

### 7.8 Joint Design

**7.8.1** Joint design shall be an essential variable for welding procedure specifications (refer to Tables 7.1 and 7.2).

**7.8.2** A procedure qualified to perform groove welds shall be qualified to perform multiple-pass fillet welds. Single-pass fillet welds are not qualified by groove weld qualification.

**7.8.3** Tolerances for the weld preparation and joint fit-up for dry welding may be developed during welding procedure qualification.

**7.8.4** Joint assembly tolerances for wet welding shall be developed during welding procedure qualification and identified on the welding procedure specification.

**7.9 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 7.7, for one process are summarized in Part I of Clauses 9 through 11 for Class A through O welds, respectively. Specimens shall be removed and tested in accordance with 7.10. Test results shall be in accordance with Part I of Clauses 9 through 11, as applicable.

**7.10 Preparation and Testing of Specimens.** Test assemblies and specimens shall be prepared in accordance with the requirements of Part I of Clauses 9 through 11 for Class A through O welds, respectively. In addition, the following requirements shall apply.

**7.10.1 Reduced-Section Tension Specimens.** Specimens shall be prepared to the dimensions shown in Figure 7.7. 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 tensile strength shall be obtained by dividing the maximum load by the cross-sectional area.

**7.10.2 Macroetch Test.** Specimens shall be removed as shown in Figures 7.8, 7.9, 9.1, 9.2, 10.1, or 10.2, as applicable. 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. (Refer to ISO 4969, *Steel—Etching method for macroscopic examination* or ASTM E340, *Standard Practice for Macroetching Metals and Alloys*.)

**7.10.3 Root-, Face-, and Side-Bend Specimens.** Transverse bend specimens, 10 mm (3/8 in) thick, shall be prepared in accordance with Figures 7.10 or 7.11. Specimens may be machine cut or oxyfuel gas cut from the test plates. If they are oxyfuel gas cut, an additional 3 mm (1/8 in) 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 a full 180° in a guided bend test jig having the contour dimensions shown in Figure 7.12. Bend radius shall be as specified in Part I of Clauses 9 through 11 for Class A through O welds, respectively.

**7.10.3.1** Any convenient means may be used to move the plunger member of the guided bend test jig (Figure 7.12) with relation to the die member. The specimen shall be placed on the die member of the jig with the weld at mid span. 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 be completely within the bent portion of the specimen after testing.

**7.10.3.2** When using the alternate wraparound jig [Figure 7.12(B)], 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° 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 7.12(A).

**7.10.4 All-Weld-Metal Tension Test.** An all-weld-metal tension test specimen shall be prepared as shown in Figures 7.13 and 7.14. If approved by the Customer, the specimen may be machined from the procedure test weld. The test specimen shall be tested in accordance with ISO 6892, *Metallic materials— Tensile testing—Part 1: Method of test at room temperature* or AWS B4.0, *Mechanical Testing of Welds*.

**7.10.5 Charpy Impact Tests.** The location and orientation of Charpy V-notch impact specimens are to be as shown in Figure 7.13. Charpy V-notch specimens shall be machined in accordance with ISO 9016, *Destructive tests on welds in metallic materials—Impact tests—Test specimen location, notch orientation and examination* or ASTM A370, *Standard Methods and Definitions for Mechanical Testing of Steel Products*. For groove weld qualifications, three Charpy V-notch impact specimens shall be machined from the weld metal and three from the heat-affected zone in accordance with Figure 7.15. For qualification of fillet welds, three Charpy V-notch impact specimens shall be machined from the weld metal only. Specimen preparation and testing shall be in accordance with ISO 148, *Metallic materials—Charpy pendulum impact test—Part 1: Test method* or ASTM A370. The test temperature shall be the minimum design service temperature, unless a lower test temperature is specified by the Customer.

When the average value of the three specimens equals or exceeds the minimum value permitted for a single specimen and the value for more than one specimen is below the required average value, or when the value for one specimen is below the minimum value permitted for a single specimen, a retest of three additional specimens shall be made. The value for each of these retest specimens shall equal or exceed the required average value.

**7.10.6 Hardness Test.** The specimens used for macroetch and hardness test shall be prepared in accordance with ISO 9015–2, *Destructive tests on welds in metallic materials—Hardness testing—Part 2: Microhardness testing of welded joints* or ASTM E92, *Standard Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials*. The location of indentations shall be as shown in ISO 9015–2 or as specified by the Customer.

**7.10.7 Fillet Weld Break Test.** The coupon prepared for the fillet weld break test shall conform to Figure 7.8(A) for plate, and 7.8(B) for pipe qualifications. The entire length of the fillet weld shall be examined visually. For plate, one fillet weld break specimen approximately 150 mm (6 in) long, and for pipe, four (4) specimens [each containing approximately 25 mm (1 in) of weld] shall be tested. The specimens shall be loaded in such a way that the root of the weld is in tension until the specimen fractures or bends flat upon itself.

**7.10.8 Fillet Weld Shear Strength Test.** The specimen prepared for the fillet weld shear strength test shall conform to Figures 7.16, 7.17, or 7.18. The specimen type and welding position shall 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.

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.

**7.10.9 Bridge Bend Test.** The weld test coupons shall be made as shown in Figure 7.19. The coupons shall be bent with the weld bead in tension. Bending shall proceed until a minimum angle of 20° 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 shall be unacceptable if a crack is detected.

**7.11 Test Results Required.** Required results for procedure qualification testing are identified in Part I of Clauses 9 through 11 for Class A through O welds, respectively.

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

**7.13 Records.** The procedure qualification record (PQR) shall contain all information necessary to support the essential variables defined in the welding procedure specification (WPS) including the results of examinations and tests performed. The PQRs shall be maintained as long as the WPS is used. Supporting records shall be maintained for a minimum of one year unless otherwise specified by the Customer.

## *Part III*
## *Welder Performance Qualification*

**7.14 General.** All welders employed in executing work in accordance with the requirements of this code shall be qualified prior to production welding in accordance with the requirements of this clause. 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. In general, for Class O welds, the referenced documents take precedence. However, essential variables, and the extent of nondestructive and destructive examination, shall also meet the requirements identified in this document.

**7.15 Limitations of Variables.** Welders shall be qualified to weld with each procedure used for production. A welder shall requalify to weld with an appropriately qualified procedure when there are changes made in the following essential variables:

(1) Change in welding process

(2) Change in welding method (manual, semiautomatic, automatic)

(3) Omission of backing, but not vice versa

(4) Change in diameter or thickness beyond the limits of Tables 7.1, 7.2, or 7.5

(5) Change in electrode classification (e.g., AWS EXX10 to AWS EXX11) or proprietary type, including waterproofing

(6) An increase in electrode diameter for wet welding

(7) Change in position from that qualified in accordance with Table 7.5

(8) Change in depth beyond the limits specified in 7.5.2

(9) Change from a mixed breathing gas to air

(10) Change in shielding gas beyond the limits of Tables 7.1

(11) Change in direction of vertical travel from upward to downward or vice versa

(12) Change from stringer bead to weave technique

(13) Where production welding visibility is less than 150 mm (6 in), unless the welder has already qualified with visibility less than 150 mm (6 in)

In addition to the above-listed performance variables, other factors unique to work in the underwater environment which could affect performance (thermal conditions, diver dress, amount of assistance provided, background gas or breathing gas, etc.) should be considered during welder performance qualification testing.

**7.16 Qualification Tests Required**

**7.16.1** 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.

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

**7.16.3 Groove Welds.** Test assemblies shall be welded for position, thickness, and diameters in accordance with the requirements for variables and positions of 7.15 and Table 7.5, to qualify a welder for groove welding in plate or pipe. The required type and number of specimens are described in Part II of Clauses 9 through 11 for Class A through O welds, respectively.

**7.16.4 T-, Y-, and K-Connections.** To qualify a welder for complete joint penetration groove welds in tubular T-, Y-, and K-connections, a welded H-, J-L045 restricted (6GR) test assembly (refer to Figures 9.4 or 10.4) shall be required in accordance with 7.15. Testing on 13 mm (1/2 in) or greater wall thickness qualifies for welding T-, Y-, and 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 Clauses 9 and 10 for Class A and B welds, respectively.

**7.16.5 Fillet Welds.** The welder shall weld fillet-weld test assemblies in accordance with the requirements of variables and positions of 7.15 and Table 7.5. The required type and number of specimens are described in Part II of Clauses 9 through 11 for Class A through O welds, respectively.

**7.17 Method of Testing**

**7.17.1** Visual, radiographic, or ultrasonic examination of welder qualification coupons shall be accomplished in accordance with Clause 8, Parts II, III, and IV, as applicable.

**7.17.2** Bend specimens shall be tested in accordance with the requirements of 7.10.3.

**7.17.3** Fillet weld specimens shall be tested in accordance with 7.10.7, and 7.10.8, as applicable.

**7.17.4** Macroetch test specimens shall meet the requirements of 7.10.2.

**7.18 Test Results Required.** Required results for welder qualification testing are identified in Part II of Clauses 9 through 11 for Class A through O welds, respectively.

**7.19 Retests.** If a welder fails to satisfy the requirements of this clause 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 clause. If either or both welds are unsatisfactory, the welder must provide evidence of further training prior to retest.

**7.20 Period of Effectiveness.** Qualified welders shall remain qualified for six months from their last qualification, providing acceptable production welds within the range of variables in 7.15 are made within 90 days. When a qualified welder has not welded with the procedure at any time during the previous 90 days, a 200 mm (8 in) 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 radiographic or ultrasonic (for groove welds) inspections meet the acceptance criteria for the class of weld. Macroetch tests may be substituted for radiographic examination as specified in 9.6.1 or 10.6.1. Application of a bead-on-plate or similar “process use” applications are not acceptable for purposes of retaining performance qualifications for underwater welding.

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

## Table 7.1
## 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. Joint Geometry | |
| (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 backing thickness change of 1.5 mm (1/16 in) or 25%, whichever is greater | Essential |
| (e) Groove shape: a decrease in included angle, a decrease in root opening, or an increase in root face beyond the range specified in 7.8.3 | Essential |
| (f) Groove weld to multiple pass fillet weld, subject to paragraph 7.8.2 | Nonessential |
| (g) Fillet weld size: for single-pass fillet welding procedure and welder qualification, the production weld size (leg length) shall be 1.5S, where S is the size of the qualification weld and smaller. For multiple pass fillet welding procedure qualification, the production weld size shall be the qualification size or larger. | Essential |
| 2. Base Metal | |
| (a) Thickness: for groove welding procedure and welder 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 0.5t. Qualification on two different thicknesses of plate or pipe also qualifies all intermediate thicknesses | Essential |
| (b) A change in chemical composition beyond the limits of 7.5.1. | 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) Filler metal classification or type | Essential |
| (b) Procedure for underwater transport and storage, including (but not limited to) change from internally pressurized to unpressurized transfer containers. | Essential |
| (c) Addition or deletion of supplementary coatings | 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 7.4 | 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 |
| 7. Technique | |
| (a) Stringer bead to weave and vice versa | Essential |
| (b) Progression uphill to downhill or vice versa | 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 |
| (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 |
| (k) Addition or deletion of ultrasonic stress relieving | Essential |

(Continued)

## Table 7.1 (Continued) Welding Variables

| | |
|---|---|
| 8. Environment | |
| (a) Change in depth beyond that allowed in 7.5.2 | Essential |
| (b) Back side dry to wet | Essential |
| (c) Change in background gas composition or type or oxygen partial pressure beyond that associated with the depth allowance in 7.5.2 | Essential |
| (d) Back side wet to dry | Nonessential |
| **B. Shielded Metal Arc Welding** | |
| 3. Filler Metal | |
| (a) Manufacturer | Essential |
| (b) Manufacturer's trade name | 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 exceeding +15% of the maximum, or –15% of the minimum of that qualified | Essential |
| **C. Gas Metal Arc Welding** | |
| 3. Filler Metal | |
| (a) Manufacturer | Nonessential |
| (b) Manufacturer's trade name, for ERXXS-G(X) or EXXC-G(X) (AWS A5.18 or A5.28) | Essential |
| (c) Manufacturer's trade name, except classification ERXXS-G | Nonessential |
| (d) 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) Mode of metal transfer (spray, globular, short-circuiting) | Essential |
| 9. Shielding Gas | |
| (a) Nominal percentage composition or classification in AWS A5.32/A5.32M | Essential |
| (b) Flow rate changes exceeding +25% of the maximum, or –25% of the minimum of that qualified | Essential |
| (c) Nozzle orifice diameter (size change) | Essential |
| **D. Flux Cored Arc Welding** | |
| 3. Filler Metal | |
| (a) Manufacturer | Essential |
| (b) Manufacturer's trade name (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) Mode of metal transfer (spray, globular) | Essential |
| 9. Shielding Gas | |
| (a) Addition, or deletion or change in gas or classification in AWS A5.32/A5.32M | Essential |
| (b) Flow rate change exceeding +25% of the maximum, or –10% of the minimum of that qualified | Essential |
| (c) Nozzle orifice diameter (size change) | Essential |
| **E. Gas Tungsten Arc and Plasma Arc Welding** | |
| 3. Filler Metal | |
| (a) Manufacturer | Nonessential |
| (b) Manufacturer's trade name (even if both meet the same AWS Classification) | Nonessential |
| (c) Diameter | Essential |

(Continued)

## Table 7.1 (Continued)
## Welding Variables

| | |
|---|---|
| 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 (nonconsumable) type | Nonessential |
| (e) Electrode (nonconsumable) size | Nonessential |
| 9. Shielding Gas | |
| (a) Gas nominal percentage composition (shielding and orifice) or classification in AWS A5.32/A5.32M | Essential |
| (b) Flow rate change exceeding +25% of the maximum, or –10% of the minimum of that qualified | Essential |
| (c) Nozzle orifice diameter (size change) | Essential |

## Table 7.2
## Welding Variables—Wet Welding by Shielded Metal Arc or Flux Cored Arc Welding

| | |
|---|---|
| **A. Variables Common to All Welding Processes** | |
| 1. Joint Geometry | |
| (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) Groove shape: a decrease in included angle, a decrease in root opening, or an increase in root face beyond the range qualified (refer to 7.8.4) | Essential |
| (e) Groove weld to multiple fillet weld subject to paragraph 7.8.2 | Nonessential |
| (f) Fillet weld size: for single-pass fillet welding procedure and welder qualification, the maximum production weld size (leg length) shall be 1.0S and the minimum production weld size shall be 0.5S, where S is the leg length of the qualification weld. For multiple pass fillet welding procedure qualification, maximum production weld size (leg length) shall be 1.5S, and the minimum production weld size shall be 0.5S, where S is the leg length of the qualification weld. | Essential |
| 2. Base Metal | |
| (a) Thickness: For groove welding procedure and welder qualification with a test plate or pipe thickness t, the maximum production plate or pipe thickness shall be 1.5t. The minimum production plate or pipe wall thickness shall be 0.5t. However, if the production weld thickness is 6 mm (1/4 in) or less, the test weld shall be the same thickness. | Essential |
| (b) An increase in carbon equivalent or percent carbon of the steel above that qualified (not applicable to austenitic stainless steel) | Essential |
| (c) An increase in the specified minimum tensile strength beyond that qualified | Essential |
| (d) A change in chemical composition beyond that qualified in 7.5.1 | Essential |
| 3. Filler Metal | |
| (a) Manufacturer | Essential |
| (b) Manufacturer's trade name (even if both meet the same filler metal 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 7.4 | Essential |
| 5. Weldment Temperature | |
| (a) A change in any heat treatment | Essential |

(Continued)

## Table 7.2 (Continued)
## Welding Variables

| | |
|---|---|
| 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 from uphill to downhill or vice versa | 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 |
| (k) Addition or deletion of ultrasonic stress relieving | Essential |
| 8. Environment | |
| (a) Change in depth beyond that allowed in 7.5.2 | Essential |
| (b) Back side dry to wet if material thickness is 6 mm (1/4 in) or greater | Essential |
| (c) Back side dry to wet and vice versa if material thickness is less than 6 mm (1/4 in) | Essential |
| (d) Pressure differential between back and front side of weld greater than that qualified | Essential |
| (e) Water current | Nonessential |
| (f) Salinity (salt water to fresh water and vice versa) | Nonessential |

## Table 7.3
## Depth Limitations for Qualification Welding

| Type of Welding | Depth of Production Welding | Max. Depth Qualified | Min. Depth Qualified |
|---|---|---|---|
| Dry welding | All | X plus 20 m (66 ft) | X minus the greater of 20 m (66 ft) or 0.2X |
| Wet welding with carbon or low-alloy steel filler metal | Greater than 3 m (10 ft) | X plus 10 m (33 ft) | X minus the greater of 10 m (33 ft) or 0.2X |
| | Equal to or less than 3 m (10 ft) | X plus 10 m (33 ft) | X |
| Wet welding with austenitic stainless steel filler metal | All | X plus 3 m (10 ft) | X minus the greater of 20 m (66 ft) or 0.2X |
| Wet welding with nickel-based and other filler metal | All | X | X minus the greater of 20 m (66 ft) or 0.2X |

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 ±230 mm (9 in).
3. For the minimum depth qualified, depth shall be measured from the upper extremity of the test weldment with a tolerance of ±230 mm (9 in).

## Table 7.4
## Welding Procedure Qualification—Type and Position Limitations

| Qualification Test | | Type of Weld and Position of Welding Qualified[a] | | | |
|---|---|---|---|---|---|
| | | Plate[b] | | Pipe[b] | |
| Weld | Welding Test Position Designators[c] | Groove | Fillet | Groove | Fillet[d] |
| Plate-groove | PA (1G) | F | F | F | F |
| | PC (2G) | H | H | H | H |
| | PG (3G) | V down | V down | | |
| | PF (3G) | V up | V up | | |
| | PE (4G) | OH | OH | | |
| Plate-fillet | PA (1F) | | F | | |
| | PB (2F) | | H | | |
| | PG (3F) | | V down | | |
| | PF (3F) | | V up | | |
| | PD (4F) | | OH | | |
| Pipe-groove | PA (1G) | F | F | F | F |
| | PC (2G) | H | H | H | H |
| | PJ (5G) | V down | V down | F, V, OH | F, V, OH |
| | PF (5G) | V up | V up | F, V, OH | F, V, OH |
| | H-, J-L045 (6G)[e] | F, H, V, OH[e] | F, H, V, OH | F, H, V, OH[e] | F, H, V, OH[e] |
| | H-, J-L045 Restricted (6GR) | All | All | All | All |
| Pipe-fillet | PA (1F) | | F | | F |
| | PB (2F) | | H | | H |
| | PB 2FR | | H | | H |
| | PD (4F) | | OH | | OH |
| | PJ (5F) | | V down | | All |
| | PF (5F) | | V up | | Al |

[a] Positions of welding: F = flat, H = horizontal, V = vertical, OH = overhead.
[b] Plate qualifies for welding pipe or tubing over 600 mm (24 in) in diameter.
[c] Positions as defined in 7.7.
[d] See 7.8.2 and Part I of Clauses 9 through 11 for requirements.
[e] Qualifies for fillet and groove welds in all positions except for complete joint penetration groove welding of T-, Y-, and K-connections.

## Table 7.5
## Positions for Welder Performance Qualification

| Qualification Test | | Type of Weld and Position of Welding Qualified[a] | | | |
|---|---|---|---|---|---|
| | | Plate | | Pipe[b] | |
| Weld | Welding Test Position Designators[c] | Groove | Fillet | Groove | Fillet |
| Plate—groove | PA (1G) | F | F, H | F | F, H |
| | PC (2G) | F, H | F, H | F, H | F, H |
| | PG (3G) | F, V down | F, H, V down | | F, H, V down |
| | PF (3G) | F, V up | F, H, V up | | F, H, V up |
| | PE (4G) | F, OH | F, H, OH | | F, H, OH |
| | PG or PF, & PE (3G & 4G) | F, V, OH | All | | All |
| Plate—fillet | PA (1F) | | F | | F |
| | PB (2F) | | F, H | | F, H |
| | PG (3F) | | F, V down | | F, V down |
| | PF (3F) | | F, V up | | F, V up |
| | PD (4F) | | F, H, OH | | F, H, OH |
| | PG or PF, & PD (3F & 4F) | | F, V, H, OH | | F, V, H, OH |
| Pipe—groove | PA (1G) | F | F, H | F | F, H |
| | PC (2G) | F, H | F, H | F, H | F, H |
| | PJ (5G) | F, OH, V down | F, OH, V down | F, V, down, OH | F, V down, OH |
| | PF (5G) | F, OH, V up | F, OH, V up | F, V up, OH | F, V up, OH |
| | H-L045, J-L045 (6G) | All | All | All[d] | All |
| | PG or PF, & PC (2G & 5G) | All | All | All[d] | All |
| | (6GR) | All | All | All | All |
| Pipe—fillet | PA (1F) | | F | | F |
| | PB (2F or 2FR) | | F, H | | F, H |
| | PD (4F) | | F, H, OH | | OH |
| | PJ (5F) | | F, H, OH, V down | | F, H, V down, OH |
| | PF (5F) | | F, H, OH, V up | | F, H, V up, OH |

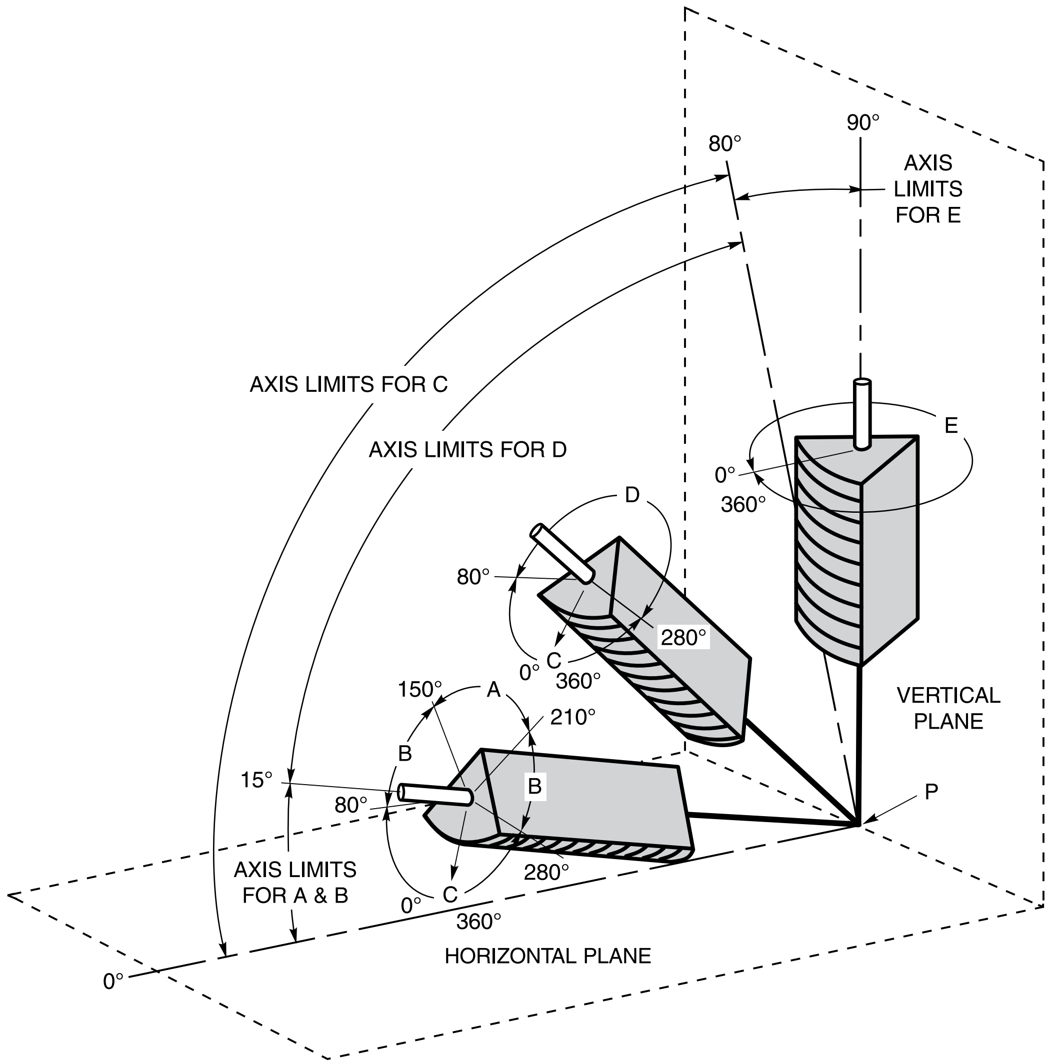
a Position of welding: F-flat, H-horizontal, V-vertical, OH-overhead.
b Plate qualifies pipe or tubing over 600 mm (24 in) in diameter.
c Positions as defined in 7.7.
d Except complete joint penetration groove welds in tubular T-, Y-, and K-connections.

## Table 7.6
## Pipe Diameter Groups for Welder Performance Qualification

| Test Pipe Diameter, D, mm (in) | Diameter of Production Pipe Qualified |
|---|---|
| 100 (4) and under | 0.7D to 2D |
| Over 100 (4) up to 300 (12) | 0.5D to 2D |
| 300 (12) and over | 0.5D and above |

Notes:
1. See Tables 7.1 and 7.2 for range of thickness qualified.
2. See 7.15 for other welder qualification variables.
3. See Figures 9.3 and 10.3 for the bend test type and location of test specimens.

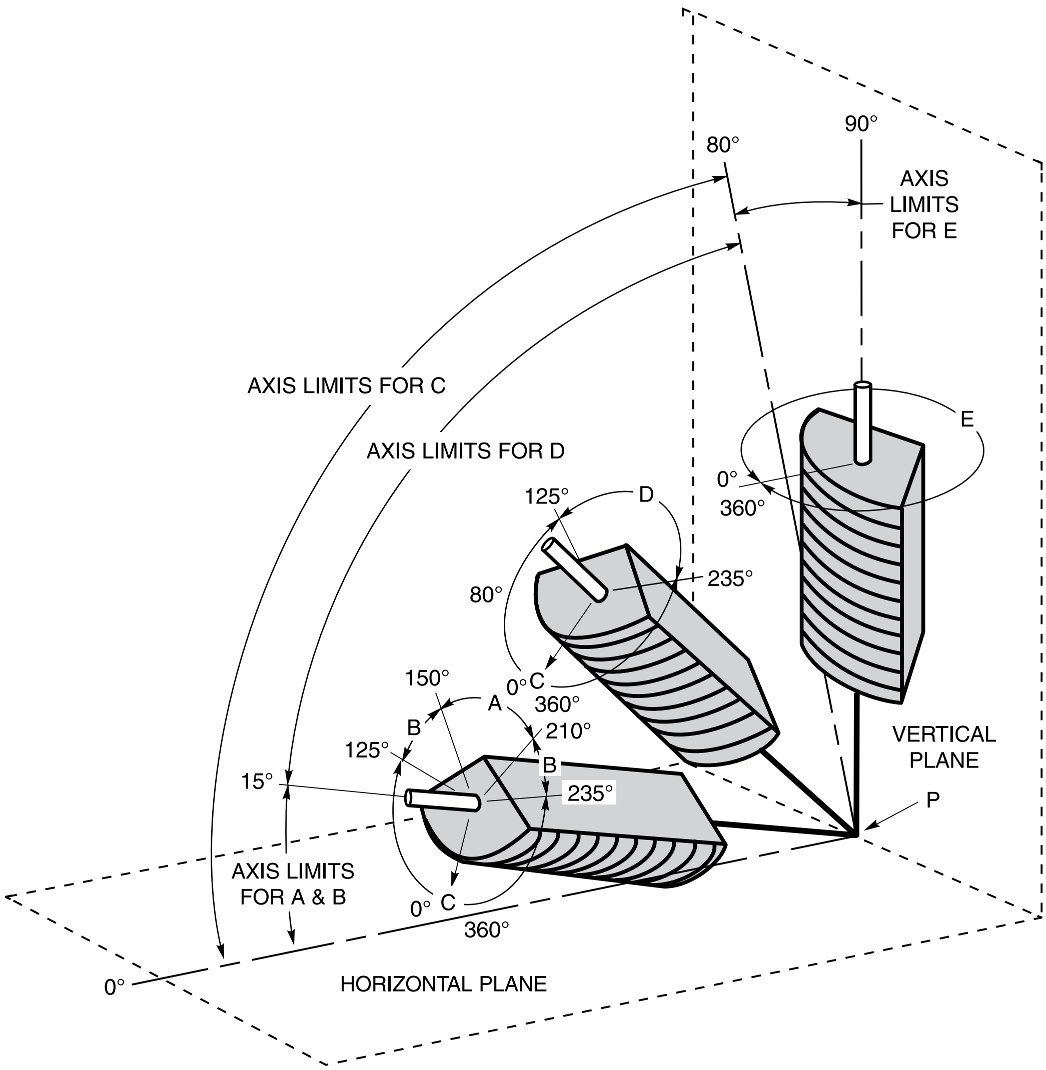
| Tabulation of Positions of Groove Welds | | | |
|---|---|---|---|
| Position | Diagram Reference | Inclination of Axis | Rotation of Face |
| Flat | A | 0° to 15° | 150° to 210° |
| | | | 80° to 150° |
| Horizontal | B | 0° to 15° | 210° to 280° |
| | | | 0° to 80° |
| Overhead | C | 0° to 80° | 280° 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 7.1—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° |




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 7.2—Positions of Fillet Welds**

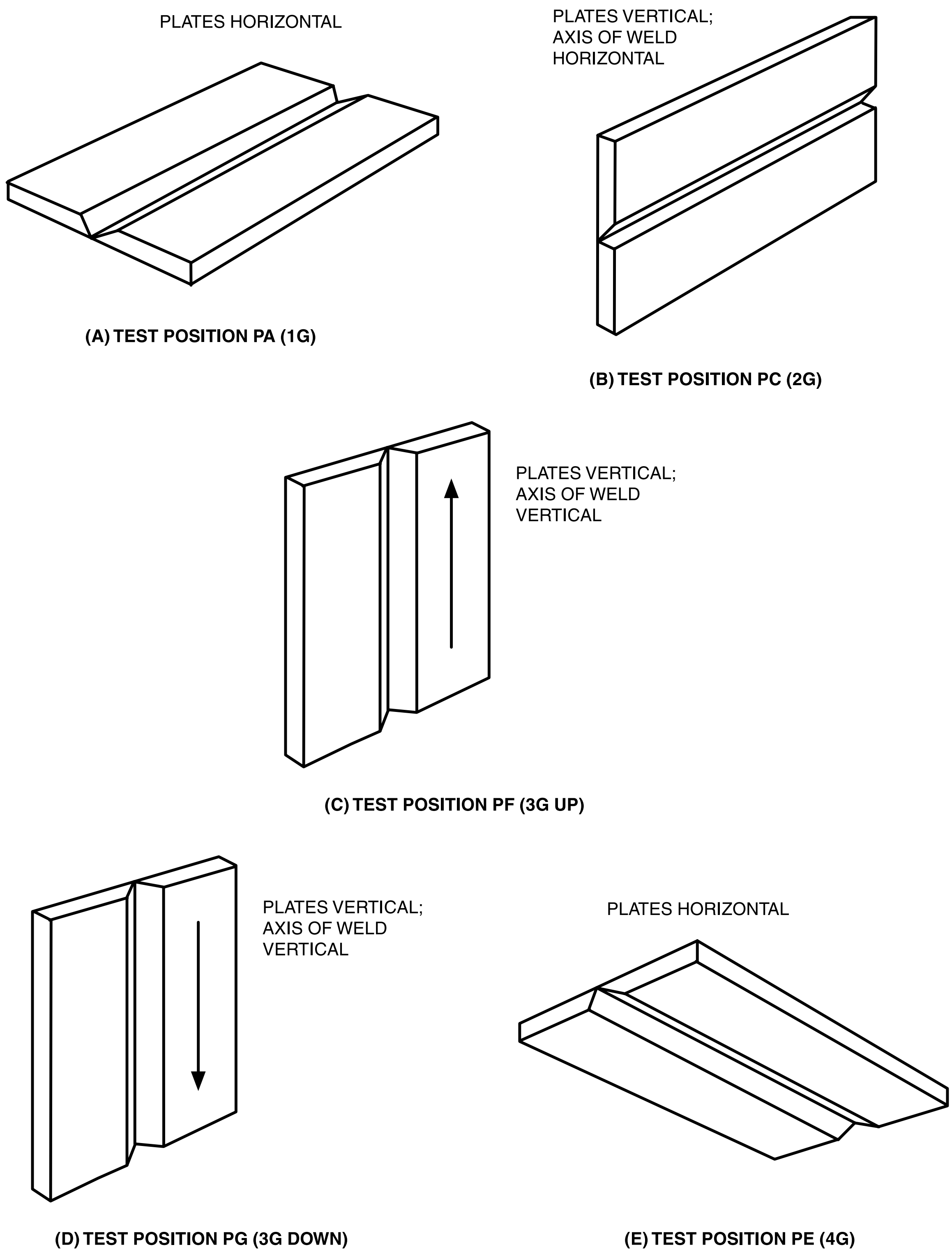



**Figure 7.3—Welding Test Positions for Groove Welds in Plate**

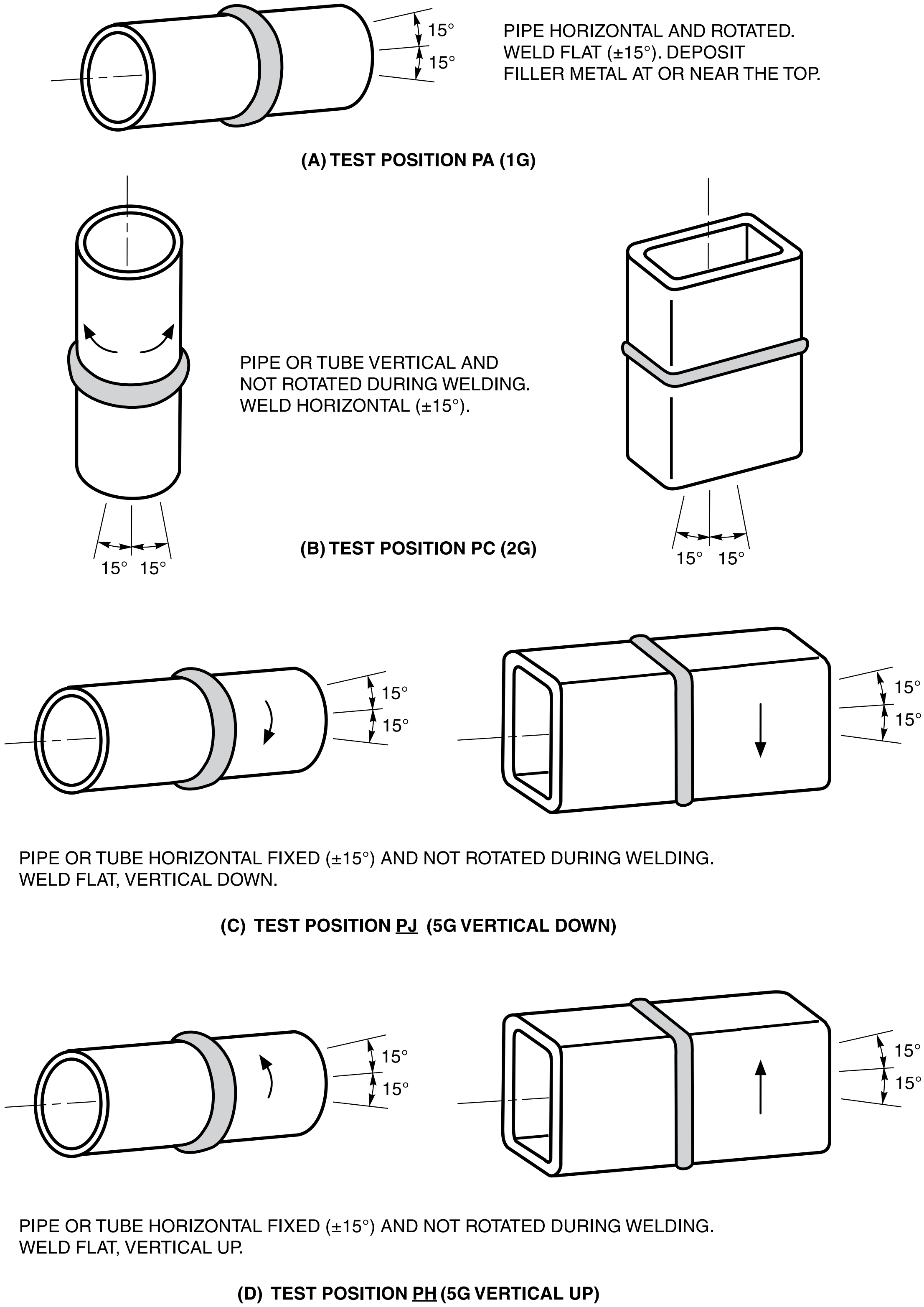



**Figure 7.4—Welding Test Positions for Groove Welds in Pipe or Tubing**

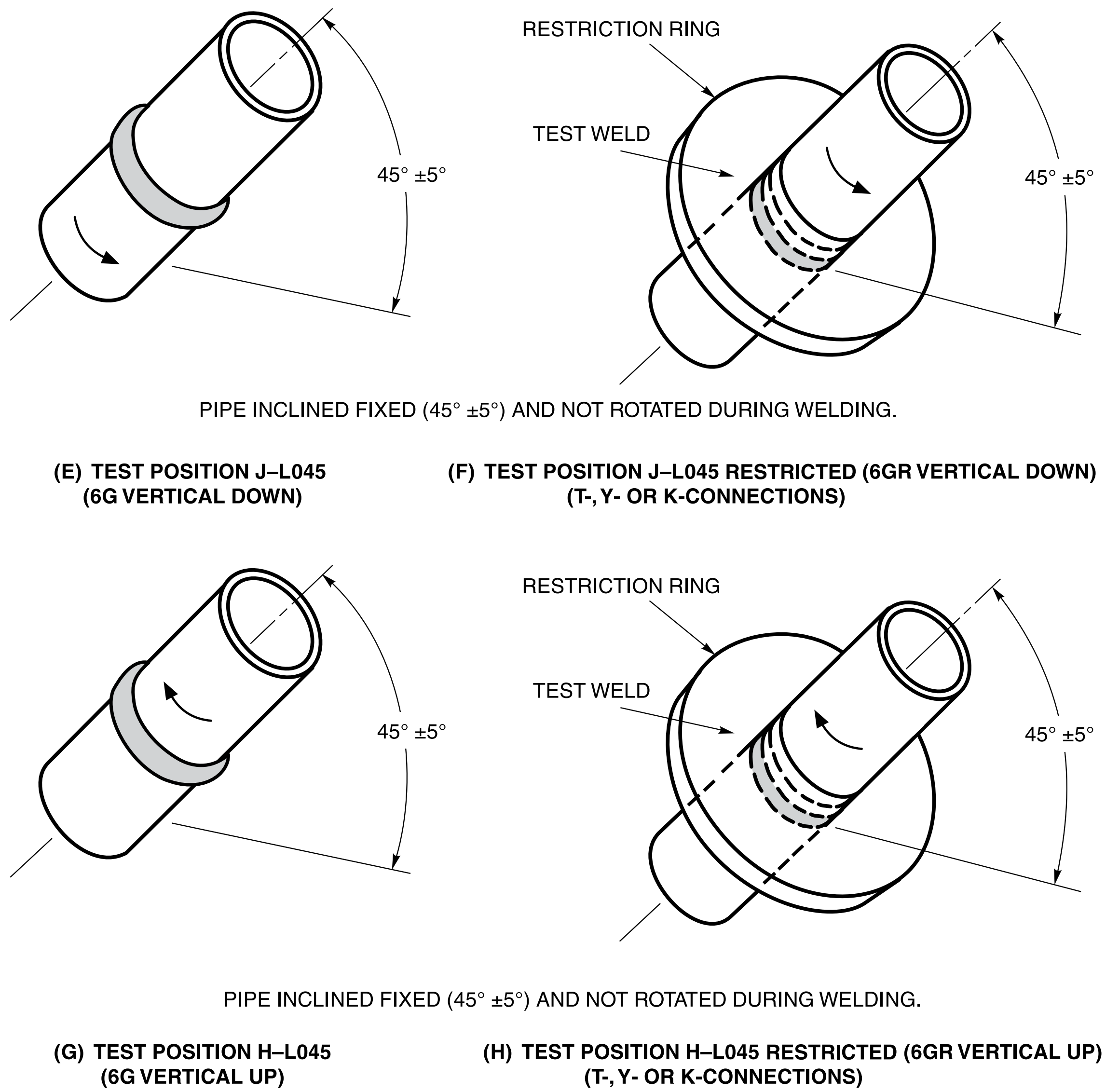



**Figure 7.4 (Continued)—Welding Test Positions for Groove Welds in Pipe or Tubing**

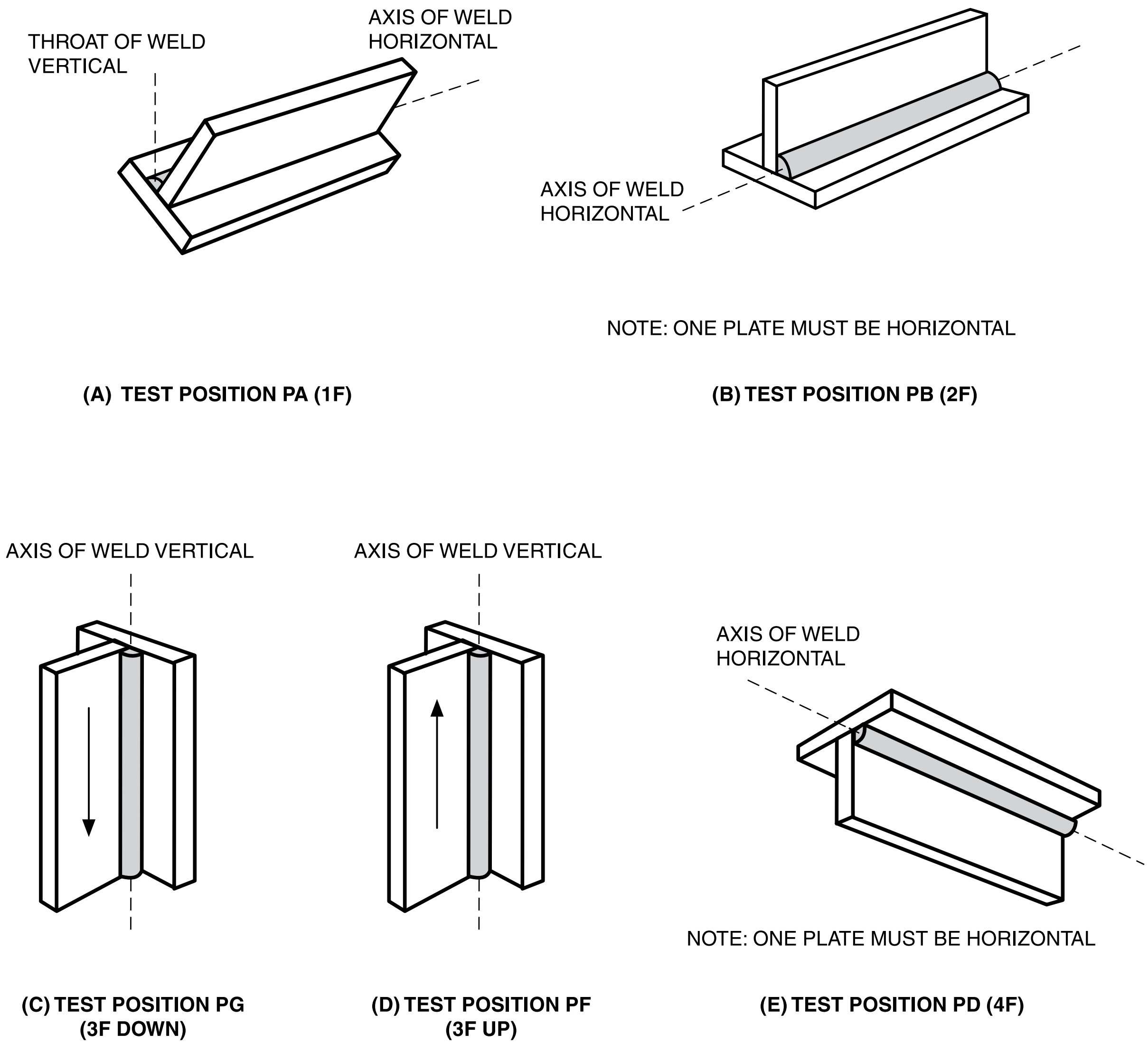
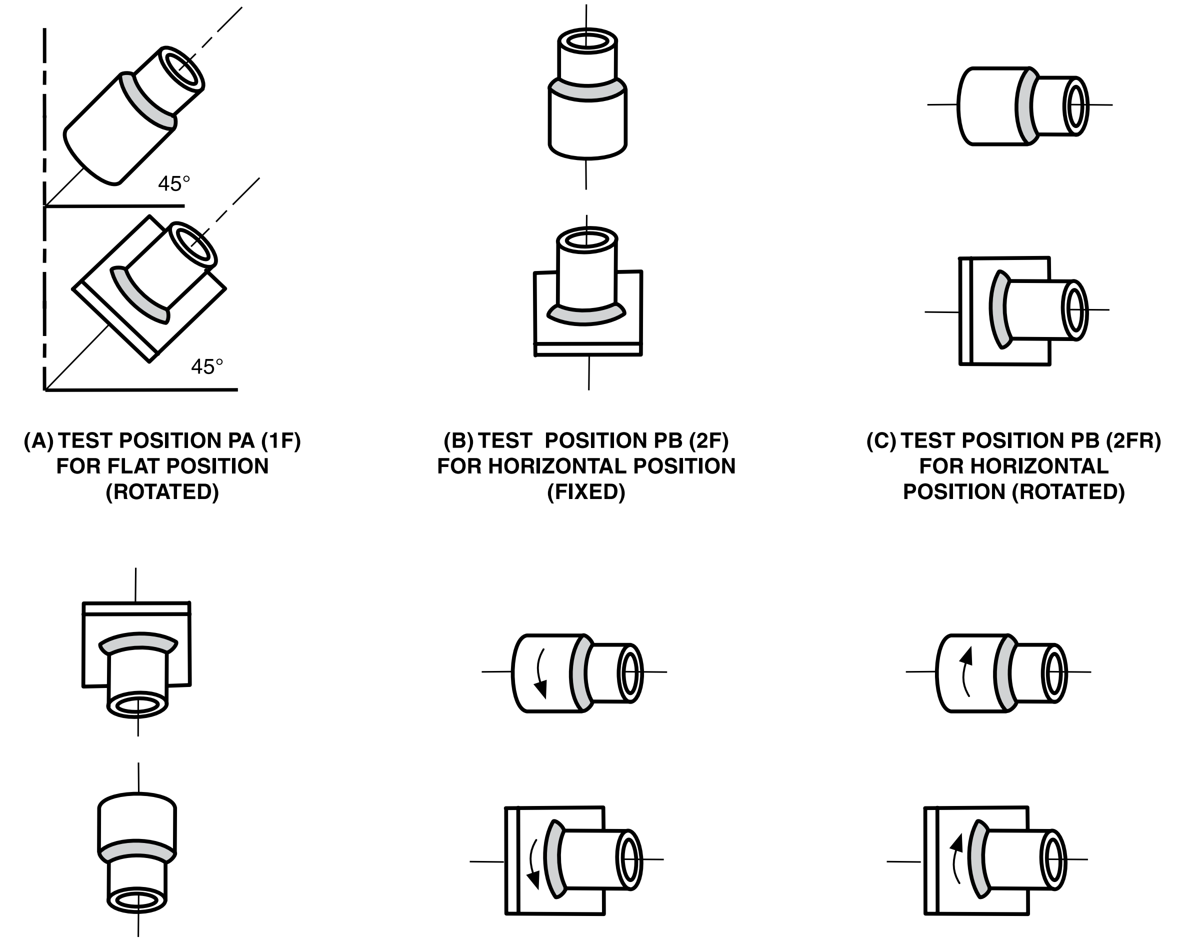



**Figure 7.5—Welding Test Positions for Fillet Welds in Plate**




**(A) TEST POSITION PA (1F) FOR FLAT POSITION (ROTATED)**

**(B) TEST POSITION PB (2F) FOR HORIZONTAL POSITION (FIXED)**

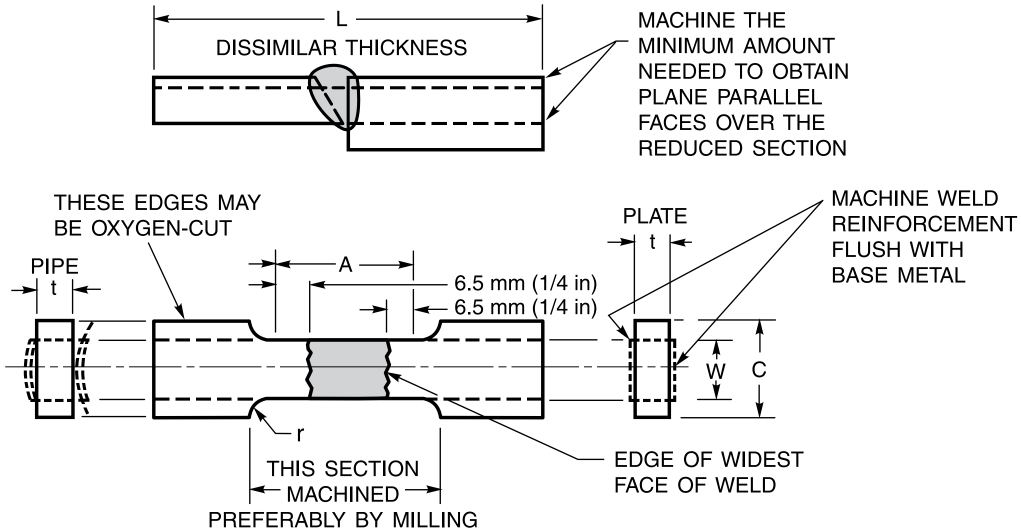
**(C) TEST POSITION PB (2FR) FOR HORIZONTAL POSITION (ROTATED)**

**(D) TEST POSITION PD (4F) FOR OVERHEAD POSITION (FIXED)**

**(E) TEST POSITION <u>PJ</u> (5F) FOR MULTIPLE POSITION DOWN (FIXED)**

**(F) TEST POSITION <u>PH</u> (5F) FOR MULTIPLE POSITION UP (FIXED)**

**Figure 7.6—Welding Test Positions for Fillet Welds in Pipe or Tubing**




| | Test Plate | | Test Pipe | |
|---|---|---|---|---|
| | Tp[a] ≤ 40 mm (1–1/2 in) | Tp ≥ 40 mm (1–1/2 in) | Less than 150 mm (6.625 in) (nominal) Outside Diameter | 150 mm (6.625 in) (nominal) and Greater Outside Diameter |
| A—Length of reduced section | Widest face of weld + 12 mm (1/2 in), 60 mm (2–1/4 in) min | | Widest face of weld + 12 mm (1/2 in), 60 mm (2–1/4 in) min | |
| L—Overall length, min[b] | As required by testing equipment | | As required by testing equipment | |
| W—Width of reduced section[c, d] | 20 mm (3/4 in) min | 20 mm (3/4 in) min | 12 mm (1/2 ± 0.01) | 20 mm (3/4 in) min) |
| C—Width of grip section[d, e] | W + 12 mm (1/2 in) min | W + 12 mm (1/2 in) min | W + 12 mm (1/2 in) min | W + 12 mm (1/2 in) min |
| t—Specimen thickness[f] | Tp | Tp/n[f] | Maximum possible with plane parallel laces within length A | |
| r—Radius of fillet, min | 12 mm (1/2 in) | 12 mm (1/2 in) | 25 mm (1 in) | 25 mm (1 in) |

[a] Tp = Nominal thickness of plate. Metric specimens may be produced in accordance with ISO 4136, *Destructive tests on welds in metallic materials—Transverse tensile test.*

[b] 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.

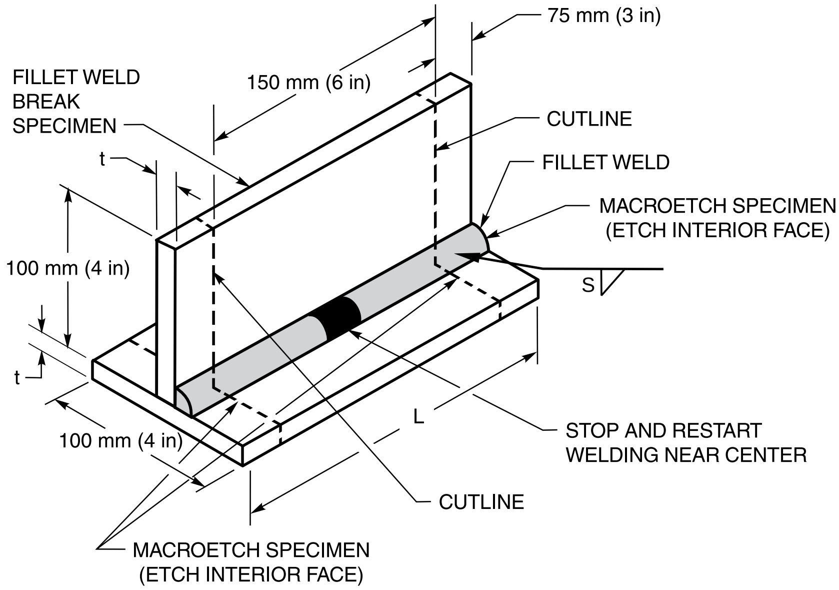
[c] The ends of the reduced section shall not differ in width by more than 0.1 mm (0.004 in). Also, there may be a gradual decrease in width from the ends to the center, but the width of either end shall not be more than 0.4 mm (0.015 in) larger than the width at the center.

[d] 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.

[e] For standard plate-type specimens, the ends of the specimen shall be symmetrical with the centerline of the reduced section within 6.5 mm (1/4 in).

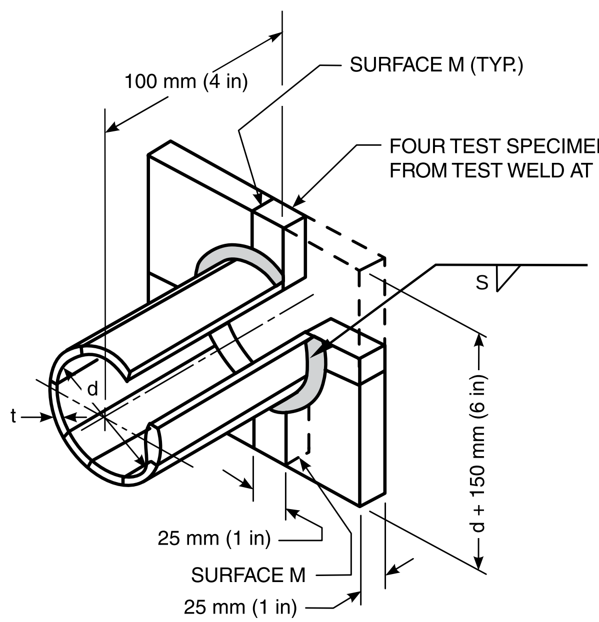
[f] For plates over 40 mm (1.5 in) thick, specimens may be cut into “n” approximately equal strips. Each strip shall be at least 20 mm (3/4 in) thick. The test results of each strip shall meet the minimum requirements.

**Figure 7.7—Reduced-Section Tension Specimens**




**(A) FOR PLATE QUALIFICATION**

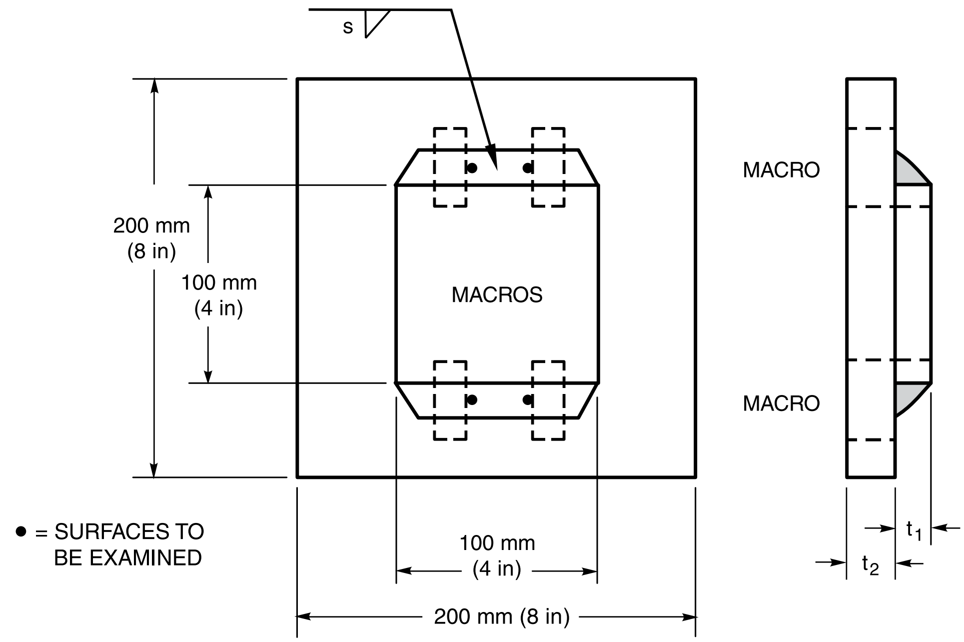
Notes:
1. S in accordance with Tables 7.1 [Item A, 1(g)] and 7.2 [Item A. 1(f)].
2. As a minimum, t = S + 3 mm (1/8 in).
3. L—equal to 300 mm (12 in) min, for welder performance qualification and for welding procedure qualification.
4. Fillet weld break specimen may be cut in sections to facilitate breaking.




**(B) FOR PIPE QUALIFICATION**

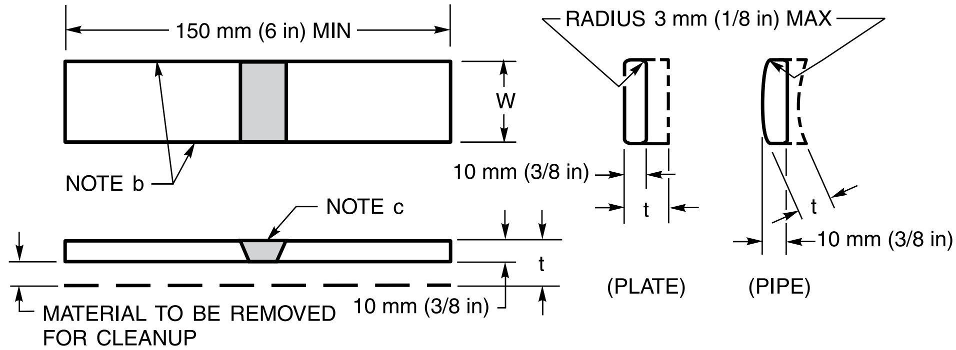
Notes:
1. Diameter of d selected from Table 7.6 to quality for production pipe sizes (welder qualification only).
2. S in accordance with Tables 7.1 [Item A. 1(g)] and 7.2 [Item A. 1(f)] for procedure qualification and Clause 7, Part III for performance qualification.
3. As a minimum, t = S + 3 mm (1/8 in).
4. 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 7.8—Fillet Weld Break and Macroetch Test Specimens**

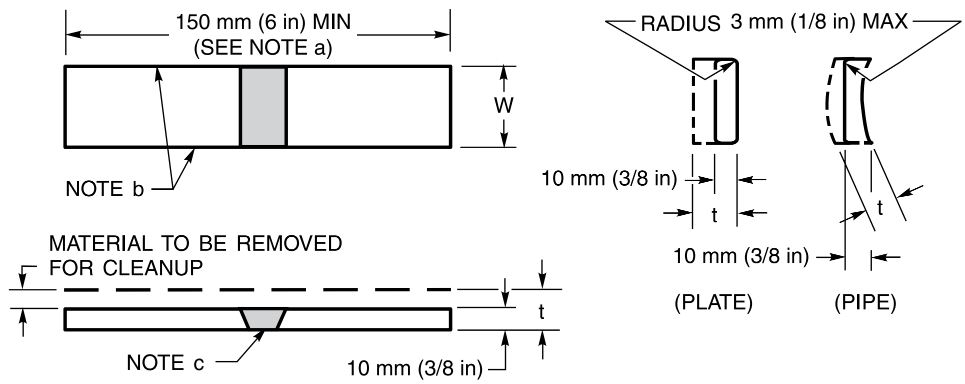



Note: Thickness $t_1$ and $t_2$ are to be in accordance with Tables 7.1 and 7.2 for welding procedure qualification and Clause 7, Part III for performance qualification

**Figure 7.9—Lap Joint Fillet Macroetch Test Assembly and Specimen Location**




**(A) FACE BEND SPECIMEN**

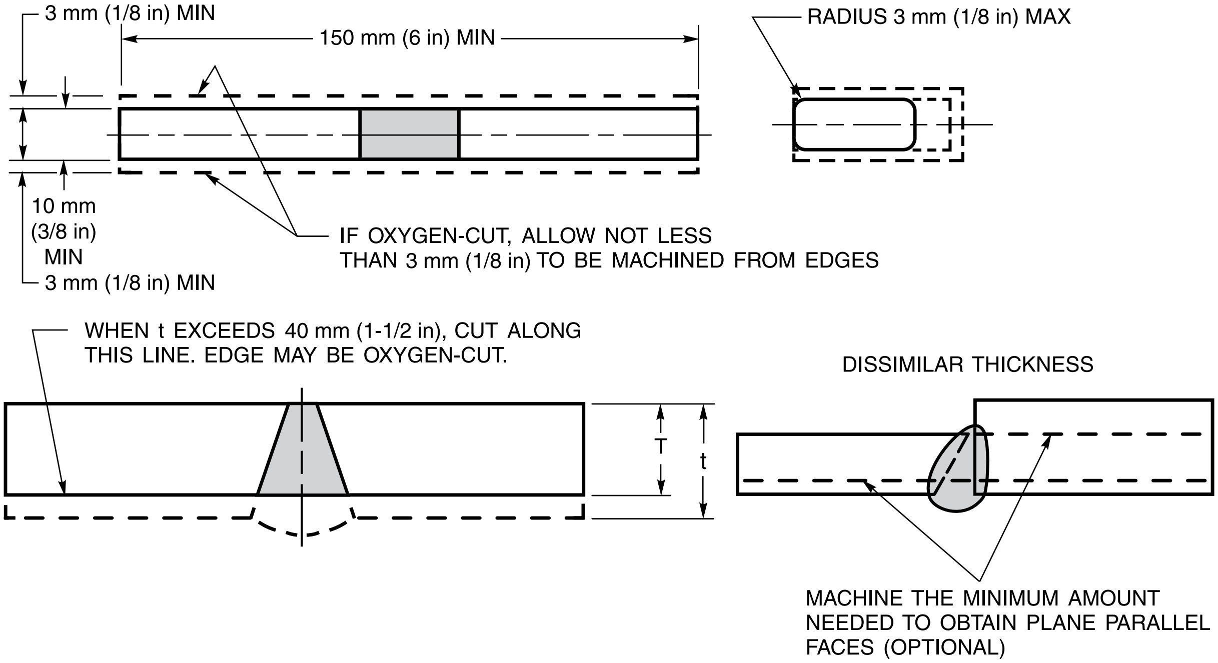



**(B) ROOT BEND SPECIMEN**

| Dimensions | |
|---|---|
| Test Weldment | Test Specimen Width (W) |
| Plate | 40 mm (1–1/2 in) |
| Test pipe smaller than 150 mm (6 in) (nominal) | 25 mm (1 in) |
| Test pipe 150 mm (6 in) (nominal) or greater | 40 mm (1–1/2 in) |

[a] A longer specimen length may be necessary when using a wraparound-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 a 6T bend radius.
[b] These edges may be oxygen cut and may or may not be machined.
[c] 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.

**Figure 7.10—Face- and Root-Bend Specimens**

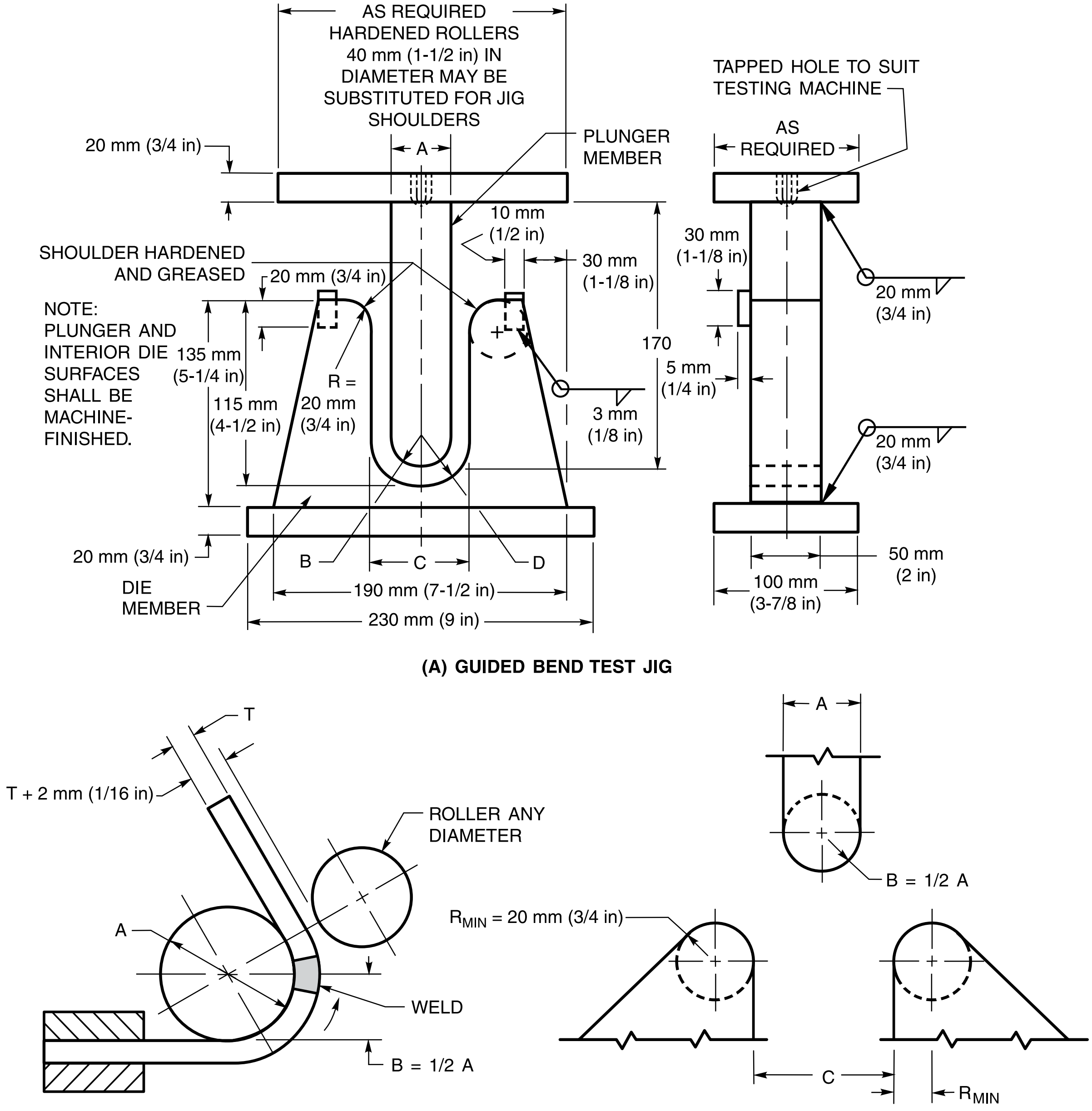



| t, mm | T, mm |
|---|---|
| 10 mm to 40 mm (3/8 in to 1-1/2 in) | 25 mm (1 in) |
| >40 mm (1-1/2 in) | see Note[a] |

[a] For plates over 40 mm (1–1/2 in) thick, cut the specimen into approximately equal strips with T between 20 mm (3/4 in) and 40 mm (1–1/2 in) and test each strip.

Notes:
1. A longer specimen length may be necessary when using a wraparound-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 a 6T bend radius.
2. t = plate or pipe thickness.

**Figure 7.11—Side-Bend Specimens**




**(A) GUIDED BEND TEST JIG**

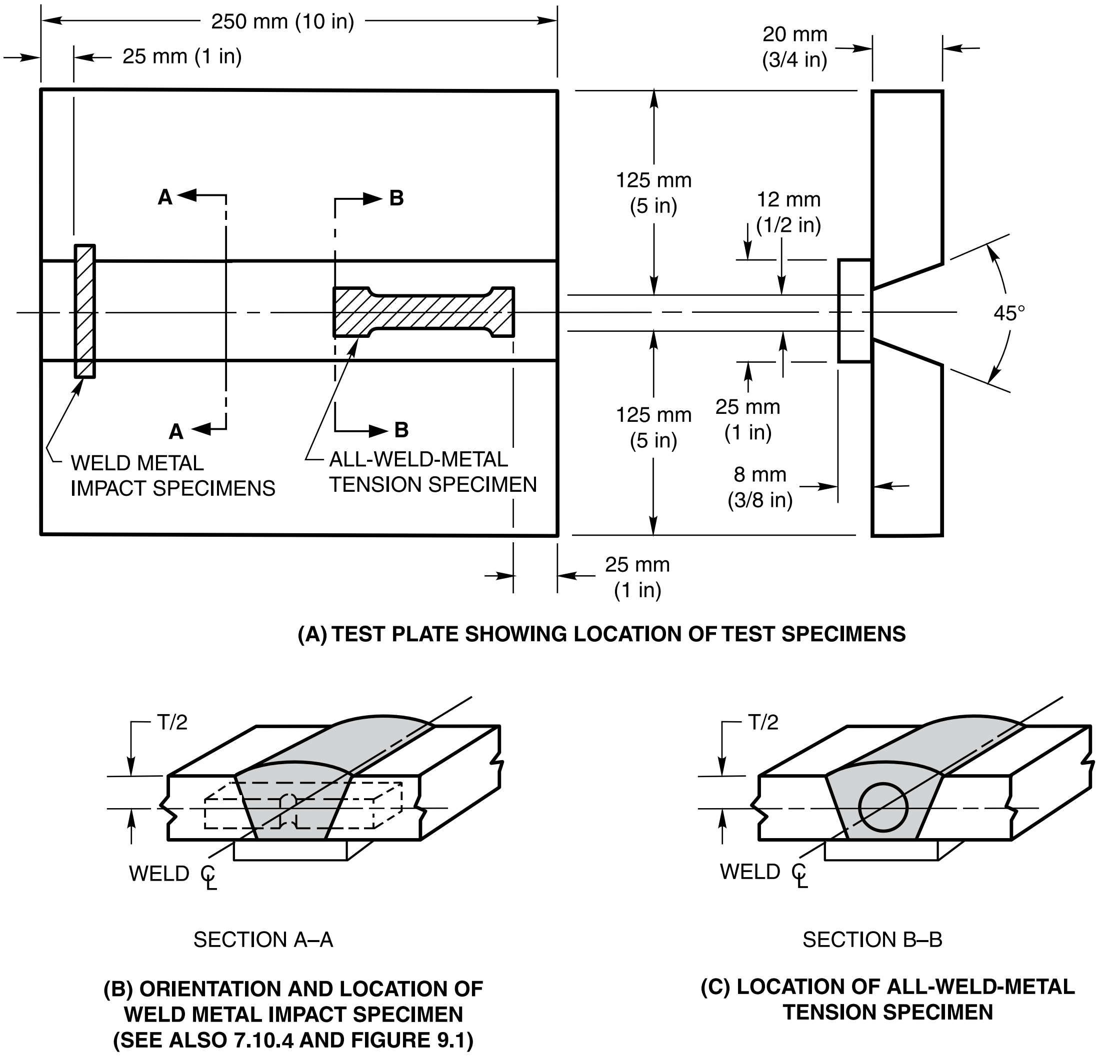
**(B) ALTERNATIVE WRAPAROUND GUIDED BEND TEST JIG**

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

| | Dimensions | | | |
|---|---|---|---|---|
| Bend Radius (B) | A | B | C | D |
| 2T | 40 mm (1–1/2 in) | 20 mm (3/4 in) | 63 mm (2–3/8 in) | 32 mm (1–3/16 in) |
| 2–2/3T | 53 mm (2 in) | 27 mm (1 in) | 76 mm (2–7/8 in) | 38 mm (1–7/16 in) |
| 3–1/3T | 67 mm (2–1/2 in) | 33 mm (1–1/4 in) | 90 mm (3–3/8 in) | 45 mm (1–11/16 in) |
| 6T | 120 mm (4–1/2 in) | 60 mm (2–1/4 in) | 143 mm (5–3/8 in) | 72 mm (2–11/16 in) |

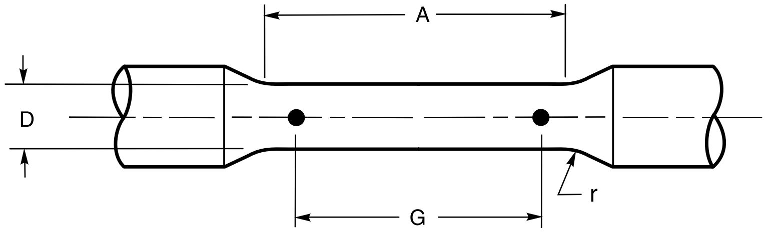
Note: For required radius, refer to Parts I and II of Clauses 9 through 11 for Class A through O welds, respectively. Bending fixture dimensions are for specimen radius bends on 10 mm (3/8 in) thick specimens. If qualification welds are required on thinner material, fixture dimensions may be altered so bending radius remains as specified. T equals thickness of bend specimen. Weld sizes are recommendations. The actual fillet weld size is the responsibility of the user to ensure rigidity and design adequacy.

**Figure 7.12—Bend Test Jigs**




Notes:
1. Test plate length—for Class B Welds, where only weld metal impact specimens are required, a shortened plate length of 150 mm (6 in) may be welded.
2. Plate material for the weld metal impact specimens and the all-weld-metal tension specimen may be from any material that is within the limits of the welding procedure specification.

**Figure 7.13—All-Weld-Metal Tension and Impact Specimen Test Plate Design and Specimen Locations**




| Dimensions, mm | Standard Specimen | Small Size Specimens | Proportional to Standard |
|---|---|---|---|
| G—Gauge length (5:1) | 100 ± 1.0 | 50 ± 0.5 | 25 ± 0.25 |
| D—Diameter[a, b] | 20 ± 0.150 | 10 ± 0.075 | 5 ± 0.040 |
| r—Radius of fillet, min | 10 | 5 | 3 |
| A—Length of reduced section, min[c] | 110 | 55 | 28 |

| Dimensions, in | Standard Specimen | Small Size Specimens | Proportional to Standard |
|---|---|---|---|
| Nominal Diameter | 0.500 in round | 0.350 in round | 0.250 in round |
| G—Gauge length | 2.000 ± 0.005 | 1.400 ± 0.005 | 1.000 ± 0.005 |
| D—Diameter[a] | 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, min[c] | 2–1/4 | 1–3/4 | 1–1/4 |

[a] Preferred ISO 6892 sizes are as shown. Other sizes may be used, provided the gauge length to diameter ratio of 5 is maintained, that is, G/D = 5, and r ≥ D/2.
[b] Metric specimens may be prepared in accordance with ASTM E8M.
[c] If desired, the length of the reduced section may be increased to accommodate an extensometer of any convenient gauge length. Reference marks for the measurement of elongation shall be spaced at the indicated gauge length.

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 than the center (controlling dimension).
2. The gauge 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 is 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.
3. The surface finish with the A dimension shall be no rougher than 1.5 µm (63 µin).
4. The weld coupon for the all-weld-metal tension coupon may be welded in the PA (1G) position.
5. If necessary, a subsize specimen, as shown in the filler metal specification, may be used.
6. Percent elongation results will be lower with a 5:1 gauge length to diameter ratio specimen.

**Figure 7.14—All-Weld-Metal Tension Test Specimen Design**

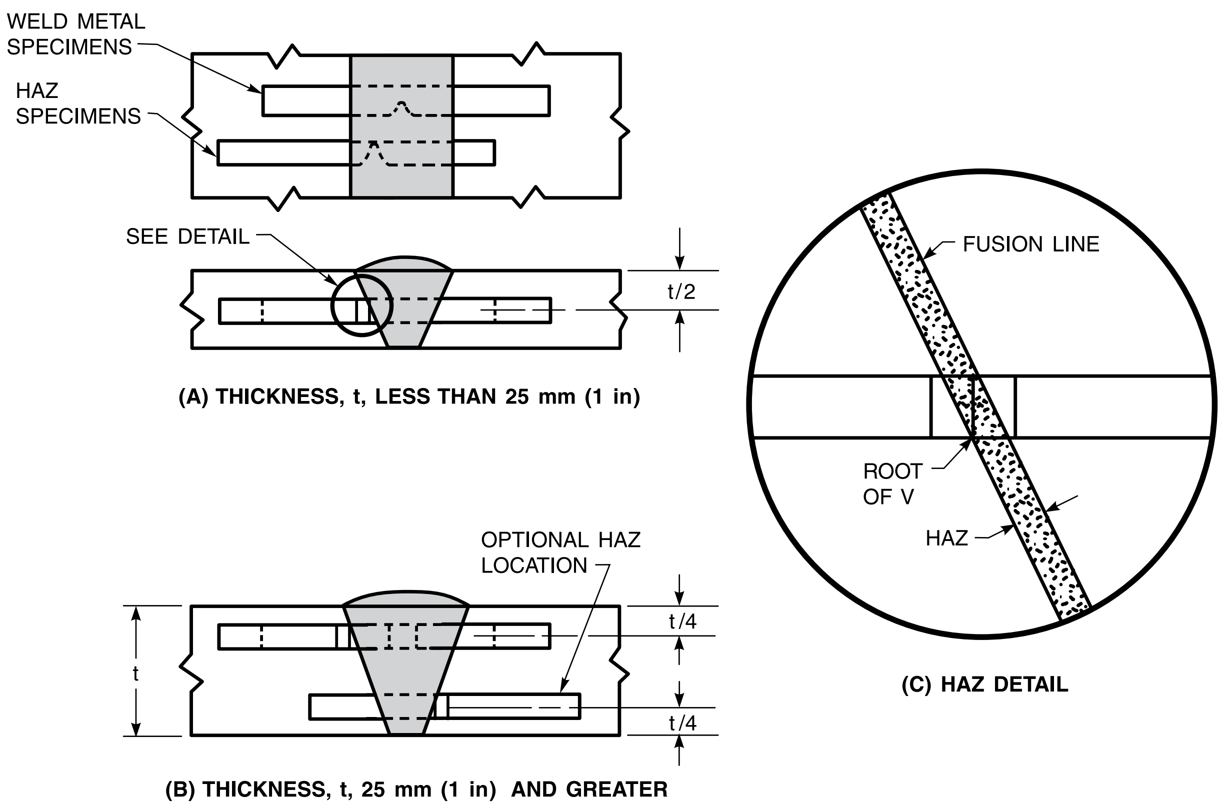
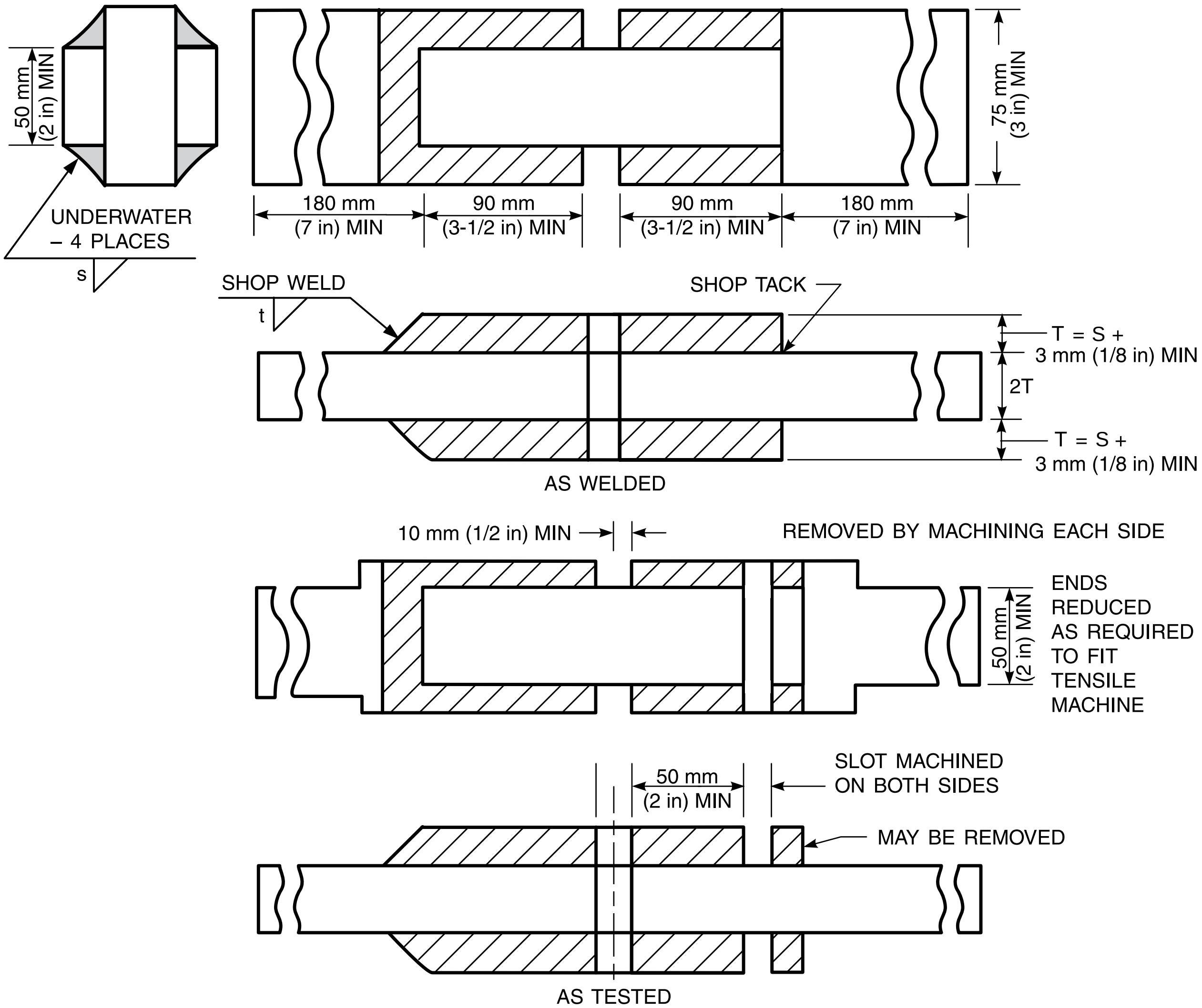
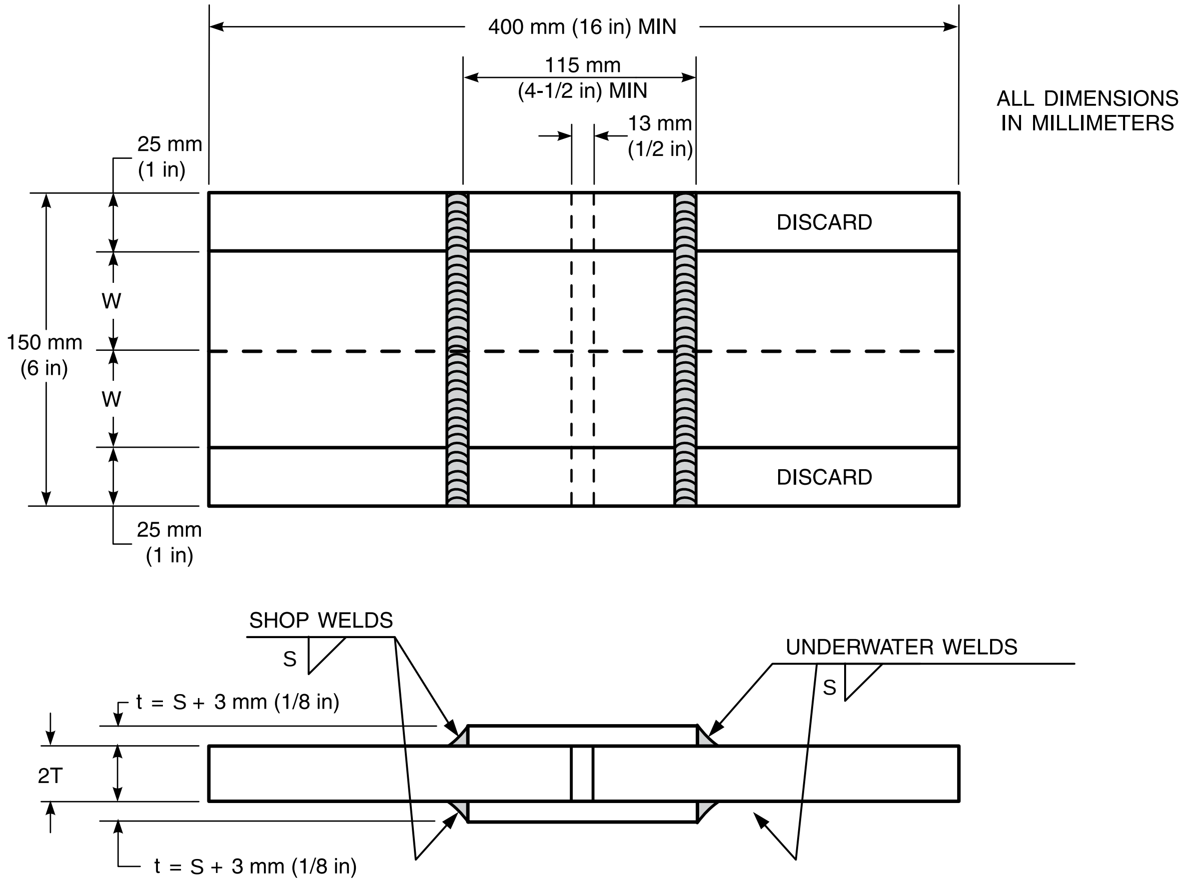



**Figure 7.15—Location of Charpy V-Notch Impact Test Specimen in Test Weld**



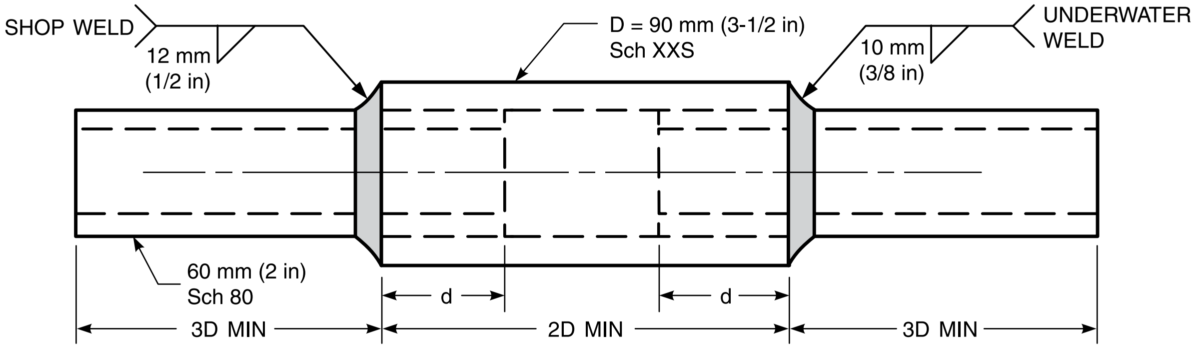

Notes:
1. Test fillet weld size S=10 mm (3/8 in) except for single-pass fillet welds.
2. Other plate thicknesses and fillet weld sizes may be used by agreement.
3. Total length of fillet weld tested in shear shall not exceed the total length of the shop fillet weld. The test length is determined by the distance between the machined slots. Minimum length of underwater fillet weld to be tested is 200 mm (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 7.16—Fillet Weld Shear Strength Specimens—Longitudinal from Plate**



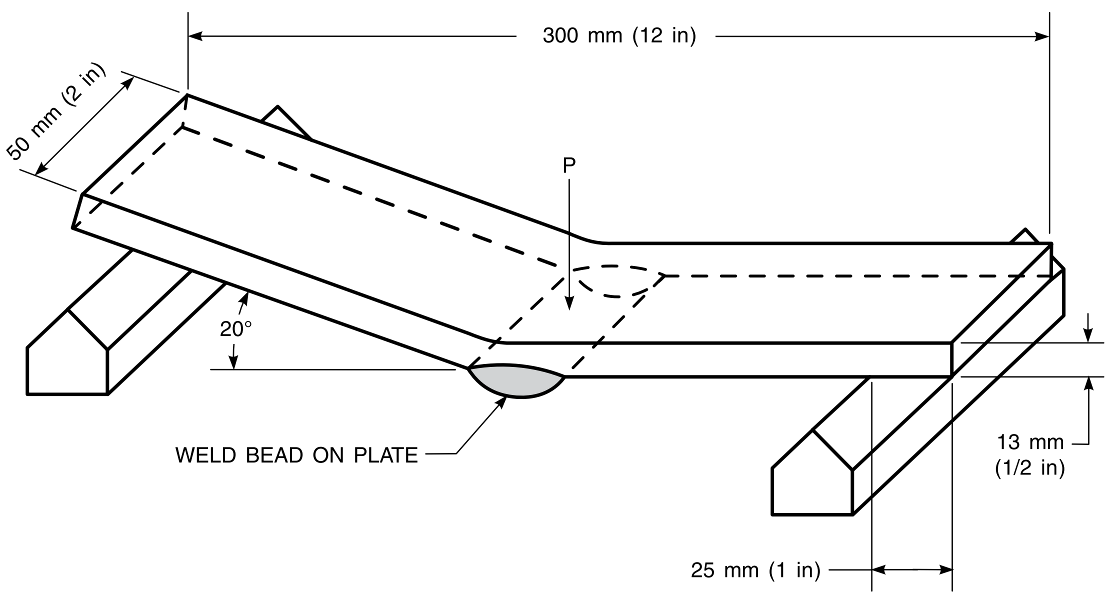

Notes:
1. Test fillet weld size S = 10 mm (3/8 in) except for single-pass fillet welds.
2. Other plate thicknesses and fillet weld sizes may be used by agreement.
3. The number of specimens (straps) cut from the coupon, and their width, W, may be controlled by testing machine capacity. The minimum total length of underwater weld to be tested is 200 mm (8 in), i.e., 100 mm (4 in) on top and 100 mm (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 average 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 7.17—Fillet Weld Shear Strength Specimens—Transverse from Plate**




Notes:
1. d=60 mm (2.375 in or 2 in nominal pipe size). Larger pipe sizes may result in breaking strengths exceeding usual testing machine capabilities.
2. Other pipe and fillet weld sizes may be used by agreement.
3. Pipe I.D. may be machined for joint fitup.
4. The coupon length shall be sufficient to accommodate the plug and testing machine jaws as shown in ASTM A370 or AWS B4.0.
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 shall 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 7.18—Transverse Weld Shear Strength Test Coupon for Pipe**




Notes:
1. Test weld to be made with a single pass.
2. Sample to be bent with the face in tension.
3. Sample is to be supported at each end with a slowly applied force (P) applied of the center (three point bending).
4. Bending is to proceed until the sample has a permanent bend angle of 20° minimum.

**Figure 7.19—Bridge Bend Test**

# 8. Inspection

## *Part I*
## *General Requirements*

### 8.1 General

**8.1.1** The contractor shall ensure that materials, fabrication, and examination procedures conform to this code. The Customer should verify this conformance.

**8.1.2** All weld classes shall, as a minimum, receive visual examination in accordance with the requirements of Part II of this clause. Welds shall meet the inspection requirements and acceptance criteria specified in Part III of Clauses 9 through 11 for Class A through O welds, respectively.

**8.1.3** Drawings or other documents 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. When supplemental nondestructive examination is required, the Customer shall designate the welds to be examined, extent of examination of each weld, method of examination, and acceptance standards. When random or partial examinations are required, the Customer shall designate the weld(s) to be inspected.

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

**8.2 Inspection of Materials.** 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. The Customer may not have access to the worksite in some operations; therefore, special consideration for the collection and recording of data will be necessary.

**8.3 Inspection of Equipment.** The Customer shall have the right to examine the equipment to verify that it is suitable for use in production welding.

### 8.4 Verification of Procedure and Performance Qualification

**8.4.1** 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.

**8.4.2** The contractor shall furnish the Customer with evidence that all welders are qualified in accordance with the requirements of Clause 7. Evidence of previous qualification may be accepted by the Customer if the qualification meets all applicable criteria of this code. 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.

**8.4.3** The contractor shall have sufficient evidence submitted to and approved by the Customer to verify that the confirmation weld meets the requirements of 5.4.

**8.4.4** If there is specific reason to question the welder's ability to produce welds that meet the quality requirements of this code, the welder shall weld a requalification test in accordance with Clause 7, Part III of this code. At the Customer's discretion, an alternate test suitable for the type of welding involved (e.g., fillet weld break test) may be performed.

### 8.5 Inspection of Work and Records

**8.5.1** All welds, including repair welds, shall be examined. The examination procedures for Visual Examination (Part II), Radiographic Examination (Part III), Ultrasonic Examination (Part IV), Magnetic Particle Examination (Part V), and Eddy Current Examination (Part VI) are described in this clause. Acceptance standards are described in Part III of Clauses 9 through 11 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.

**8.5.2** 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.

**8.5.3** 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. Inspections may be performed during the welding operations and/or after the welding has been completed.

**8.5.4** If nondestructive examination other than visual is not specified herein but is requested by the Customer, the contractor shall perform such requested examination or permit the examination to be performed in accordance with 8.7 of this code.

**8.5.5** Welds examined nondestructively that do not meet the acceptance criteria of this code shall be repaired by the methods permitted by Clause 5.8.

**8.6 Obligations of Contractor**

**8.6.1** The contractor shall be responsible for initial visual examination of all welds. The contractor shall correct nonconforming welds in accordance with the welding procedure specification and the requirements of this code.

**8.6.2** In the event that nonconforming welds, or the removal of nonconforming welds, damage the base metal and retention of the base metal is not in accordance with 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.

**8.6.3** When nondestructive examination other than visual is specified in the contract documents, it shall be the contractor's responsibility to ensure that all specified welds meet the acceptance criteria specified in Part III of Clauses 9 through 11 for Class A through O welds, respectively.

**8.7 Inspection Methods**

**8.7.1** When visual inspection is required, the procedures and techniques shall be in accordance with Part II of this clause.

**8.7.2** When radiographic examination is required, the procedures and techniques shall be in accordance with Part III of this clause.

**8.7.3** When ultrasonic examination is required, the procedures and techniques shall be in accordance with Part IV of this clause.

**8.7.4** When magnetic particle examination is required, the procedures and techniques shall be in accordance with Part V of this clause.

**8.7.5** 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 ISO 3452, *Nondestructive testing—Penetrant testing—General principles* or ASTM E165/E165M, *Standard Practice for Liquid Penetrant Examination for General Industry* shall be used for dye penetrant examination. This method is not generally suitable for examination of welds in an underwater wet environment.

**8.7.6** When electromagnetic technique examination is required, the procedures and techniques shall be in accordance with Part VI of this clause.

**8.8 Inspection Personnel Qualification**

**8.8.1** When inspection is to be conducted in an underwater environment, the nondestructive examination operators and technician/divers shall provide 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 as NDT Level II or III in accordance with the current edition of American Society for Nondestructive Testing, *Recommended Practice No. SNT-TC–1A* or as specified by the Customer. Individuals qualified as AWS Certified Radiographic Interpreter (CRI) or AWS Certified Welding Inspector (CWI) as determined by the Customer may also interpret nondestructive testing results. Third party surveillance should be in accordance with the recommended requirements of Annex E, Marine Welding Inspectors or equivalent standard as approved by the Customer.

**8.8.2 Additional Ultrasonic Qualification Requirements.** In addition to the requirements of 8.8.1, when ultrasonic examinations of T-, Y-, and K-connections are to be performed, the UT operator shall be required to demonstrate ability to apply the special techniques required for such examination. Practical tests for this purpose shall be performed as specified in API RP2X, *Recommended Practice for Ultrasonic Examination of Offshore Structural Fabrication and Guidelines for Qualification of Ultrasonic Technicians* using mock-up welds similar to the welds to be inspected. The mock-up welds should contain a representative range of dihedral angles and thicknesses to be encountered in production. The inspection procedure shall be qualified and approved for use.

Each mock-up shall contain natural or artificial discontinuities that yield ultrasonic indications above and below the rejection criteria specified in the approved procedure to be used. Performance shall be judged based upon the ability of the UT 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.

**8.8.3 Additional Electromagnetic Technique Qualification Requirements.** For either the wet or dry environment, operators manipulating the probe shall be qualified to the minimum level outlined in SNT-TC-1A-ET1. 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*

### 8.9 General

**8.9.1** The procedures described herein shall govern the visual examination of welds in both dry and wet environments.

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

**8.9.3** Welds that do not meet the visual acceptance criteria specified in Part III of Clauses 9 through 11, as applicable for the class of weld inspected, shall be corrected in accordance with 5.8.

### 8.10 Procedure

**8.10.1** The Customer may verify that the visual inspection performed meets the requirements, and that the inspected welds meet the visual acceptance criteria of Part III of Clauses 9 through 11 for the class of weld inspected.

**8.10.2** Visual examination techniques shall employ aids as necessary 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.

**8.10.3** Each weld shall be uniquely identified on all visual examination reports.

**8.10.4** All media and supporting documentation and a report interpreting the inspection results shall be submitted to the Customer. The submitted documents shall identify the nonconforming conditions prior to and subsequent to the 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*

### 8.11 General

**8.11.1** The requirements 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.

**8.11.2** 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.

**8.11.3** 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 specified by the customer. Each spot examined shall cover at least 100 mm (4 in) of the weld length. When spot examination reveals discontinuities that require repair, two additional spots selected by the customer 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.

**8.11.4** When radiography is required, welds that do not meet the radiographic acceptance criteria of Part III in Clauses 9 through 11, as applicable for the class of weld inspected, shall be corrected in accordance with Clause 5.

**8.12 Procedure**

**8.12.1** All radiographic examinations (RT) shall be performed in accordance with a procedure complying with the requirements of this code and which has been prepared or approved by an individual qualified to SNT-TC-1A Level III, or equivalent as approved by the Customer. 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.

**8.12.2** The size of discontinuities, as a percentage of the thickness of the weld, to 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 the required resolution.

**8.12.3** If, in the Customer's judgment, film processing defects may have obscured defects, the weld shall be reexamined.

**8.12.4** If, in the Customer's judgment, weld surface irregularities may obscure defects, the surface shall be smoothed by a procedure submitted to and approved by the Customer.

**8.12.5** Radiographs shall have an H & D (Hurter and Driffield) density of not less than 1.8 and not more than 4.0. Densities within the range of 2.5 to 3.5 are preferred.

**8.12.6** The source of radiation shall be approximately centered with respect to the length being examined. An IQI shall be located within 25 mm (1 in) 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° 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.

**8.12.7** 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

**8.12.8** 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 shall be changed (x ray, gamma ray, etc.).

(4) The type or grade of film shall be changed.

**8.12.9** A viewer with suitable high-intensity and sufficient capacity to illuminate radiographs with an H & D density of 4.0 without difficulty shall be used.

**8.12.10** 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 inspected welds.

## *Part IV*
## *Ultrasonic Examination*

**8.13 General.** Procedure requirements described herein are conventional contact methods only.

**8.14 UT Operator and Equipment.** The UT operator shall demonstrate ability to use the written procedure, including all special techniques required and, when discontinuity height and length are required, shall establish ability and accuracy for determining these dimensions. Alternate equipment which utilizes computerization, imaging systems, mechanized scanning, and recording devices, may be used, when approved by the customer. Transducers with frequencies up to 6 MHz, with sizes down to 6 mm (1/4 in) and of any shape may be used, provided they are included in the procedure and properly qualified.

**8.15 Procedure.** All ultrasonic examinations (UT) shall be in accordance with procedures written in compliance with the requirements of this code and which have been prepared and/or approved by a Level III experienced in UT of welded structures. Prior to use on production welds, the procedure and acceptance criteria shall be approved by the Customer. UT personnel shall have been qualified per 8.8. When T-, Y-, and K-connections are to be examined, the UT technician shall also be experienced in examination of those types of weldment.

**8.15.1 Communications.** During examinations in the wet or dry environment, communications between the probe manipulator and the interpreter (see 8.8.3) shall be continuous and clear in nature, utilizing a dedicated system.

**8.15.2 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 angle)[1]

(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 probes[2]

(6) Functions to be performed by and information displays available to the UT diver technician performing the scanning and/or the top side UT 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 8.15.4) and for establishing weld geometry as a function of local dihedral angle and thickness

(12) Scanning pattern and sensitivity (see 8.15.5)

(13) Adjustment for depth (pressure) effects

(14) Transfer correction for surface curvature and roughness, where amplitude methods are used [see 8.15.3.4 (3)]

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

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[1] Conventional techniques are limited to diameters of 320 mm (12.75 in) and above, thicknesses of 13 mm (1/2 in) and above, and local dihedral angles of 30° 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 6 mm (1/4 in), and various geometric shapes may be used, provided they are also used during the procedure qualification.

(16) Method of determining discontinuity length and width

(17) Method of verification that a defect has been identified prior to excavation.

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

**8.15.3.1 Reference Standard.** The standard reflector shall be a 1.5 mm (0.060 in) diameter side-drilled hole or equivalent. The reflector may be placed in any design of calibration block, weld mock-up, or actual production part at the option of the user. Orientation and tolerances for placement of the reflector are shown in Figure 8.1. A recommended calibration block is shown in Figure 8.2. Alternate possible uses of the reflector are shown in Figure 8.3. When placed in weld mock-ups and sections of production weldments, the reflector should be in locations where it is difficult to direct sound beams, thereby ensuring detection of discontinuities in all areas of interest.

**8.15.3.2 Calibration Methods.** The code recognizes that other calibration methods may be preferred by the individual user, or required by different codes/project specifications. If other methods are used, they should produce results which can be shown to be at least equal to the methods recommended herein. The standard reflector described in 8.15.3.1 should be considered the standard reflector for these and for all other methods which might be used.

**8.15.3.3 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. See Figures 8.4 and 8.5.

**8.15.3.4 Sensitivity Calibration.** Standard sensitivity amplitude reject level (ARL) for examination of production welds using amplitude techniques shall be the sum of the basic sensitivity, the distance amplitude correction, and the transfer correction. See Figures 8.5 and 8.6.

(1) Basic sensitivity—Reference level screen height shall be obtained using maximum reflection from the 1.5 mm (0.060 in) 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 receiver (e.g., a second search unit acting as a reflector) in both situations, after correcting for distance as described above. See Figure 8.7.

**8.15.3.5** As an alternative, the dB rating system as described in AWS D1.1/D1.1M, *Structural Welding Code—Steel* may be used.

**8.15.4 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.

**8.15.5 Weld Scanning.** Scanning of normal groove welds shall be in accordance with the requirements of Figures 8.8 and 8.9 (A), or as established in the approved procedure. Scanning of T-, Y-, and K-connections shall be performed from the attachment surface [see Figures 8.8 and 8.9 (B)], 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 ARL established in 8.15.3.4 at the maximum sound path. Indication evaluation shall be performed with reference to the standard sensitivity.

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

**8.15.7 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 Figures 8.10 through 8.15 to determine characteristics and dimensions of various discontinuities and Figure 8.16 for additional evaluation requirements.

**8.15.8 Acceptance Criteria.** Refer to 9.11.

**8.15.9 Reporting**

**8.15.9.1** A report clearly defining the environment (depth, etc.) and identifying the part and the area of inspection shall be completed by the ultrasonic 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 rejectable indications are found. A recommended form is included in Annex A. Report forms shall be submitted to the Customer upon completion of the work.

**8.15.9.2** When specified, discontinuities approaching rejectable size and are questionable in their evaluation, shall also be noted on the report form.

**8.15.9.3** Areas of any part for which complete inspection was not accessible shall also be explained in the report.

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

## *Part V*
## *Magnetic Particle Examination*

### 8.16 General

**8.16.1** The procedure and standards described herein shall govern magnetic particle examination, when such an examination is required. This method is used to detect the presence of surface and near-surface discontinuities in materials that can be magnetized (ferromagnetic).

**8.16.2** 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.

**8.16.3** When magnetic particle examination is required, welds that do not meet the visual acceptance criteria of Part III in Clauses 9 through 11, as applicable for the class of welds inspected, shall be corrected in accordance with Clause 5.8. Light grinding may be employed to determine relevancy of indications.

### 8.17 Procedure

**8.17.1 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 E709, *Standard Guide for Magnetic Particle Testing* (Dry and Wet Powder).

**8.17.2 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 if the continuous or residual magnetization method is to be applied.

**8.17.3 Particles.** The ferromagnetic particles shall be of a color that best contrasts with the test surface. Fluorescent magnetic particles may be used with a black light.

**8.17.4 Preparation and Disposition of Reports**

**8.17.4.1** 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), printed name, date and NDE Level, examination variables, and the acceptability of the weld. When specified by the Customer, indications of defects shall be documented by video, photographs, or other positive means (but not limited to tape and magnetic rubber). Reports shall be submitted to the Customer upon completion of the work.

**8.17.4.2** 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*
## *Electromagnetic Technique Examination*

**8.18 General** There are a variety of electromagnetic techniques available as well as an assortment of coils and probes for this equipment. A number of variables in the size and shape of the coils have a significant effect on the detection and sizing capability of the selected equipment. The Customer shall approve the technique to be used for probability of detection (POD) and sizing requirements for the application.

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

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

**8.18.3** When electromagnetic technique examination is required, welds or other materials which do not meet the visual acceptance criteria of Part III in Clauses 9 through 11, as applicable for the class of weld inspected, shall be corrected in accordance with Clause 5.8. Light grinding may be employed to determine relevancy of indications.

**8.19 Procedure**

**8.19.1 Technique**. When using ET examination in wet or dry environment, the procedure and technique shall be in accordance with ASTM E309, *Standard Practice for Eddy Current Examination of Steel Tubular Products Using Magnetic Saturation* or ASTM E426. ET examination techniques found in ASTM E309 and ASTM E426, *Standard Practice for Electromagnetic (Eddy Current) Examination of Seamless and Welded Tubular Products, Titanium, Austenitic Stainless Steel and Similar Alloys*, which refer to tubular material, may also apply to nontubular materials.

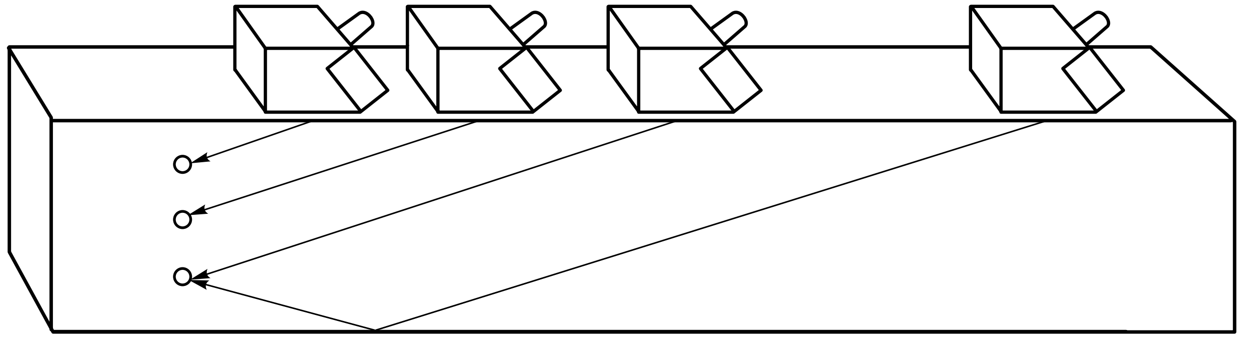
**8.19.2 Supplemental Examination.** When indications of defects are found in magnetic materials using ET examination, those areas may also be examined with the magnetic particle method, in accordance with Part V of this clause, for purposes of verification.

**8.19.3 Communications.** During examinations in the wet or dry environment, communications between the probe manipulator and the interpreter (see 8.8.3) shall be continuous and clear in nature, utilizing a dedicated system.

**8.19.4 Preparation and Disposition of Reports**

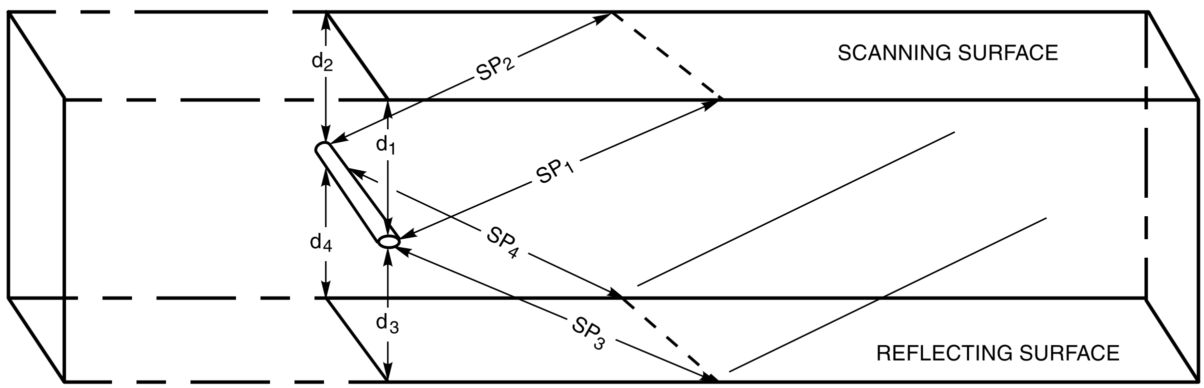
**8.19.4.1** A report clearly identifying the work and the area of examination shall be completed by the ET interpreter at the time of the examination. Reports for acceptable welds need only contain sufficient information to identify the weld, the segment inspected, the interpreter (signature), printed name, date and NDE level, 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.

**8.19.4.2** Before a weld subject to ET examination is accepted, all reports pertaining to the weld, including any identifying nonconforming 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.



Notes:
1. $d_1$=$d_2$ ± 0.5 mm, $d_3$=$d_4$ ± 0.5 mm, $SP_1$=$SP_2$ ± 1 mm, $SP_3$=$SP_4$ ± 1 mm.
2. The above tolerances should be considered as appropriate. The reflector should, in all cases, be placed in a manner to allow maximizing the reflection and UT indication. (This is a general comment for all notes for the figures in Clause 8.)

**Figure 8.1—Standard Reference Reflector**




Note: Dimensions should be required to accommodate search units for the sound path distances required.

**Figure 8.2—Recommended Calibration Block**

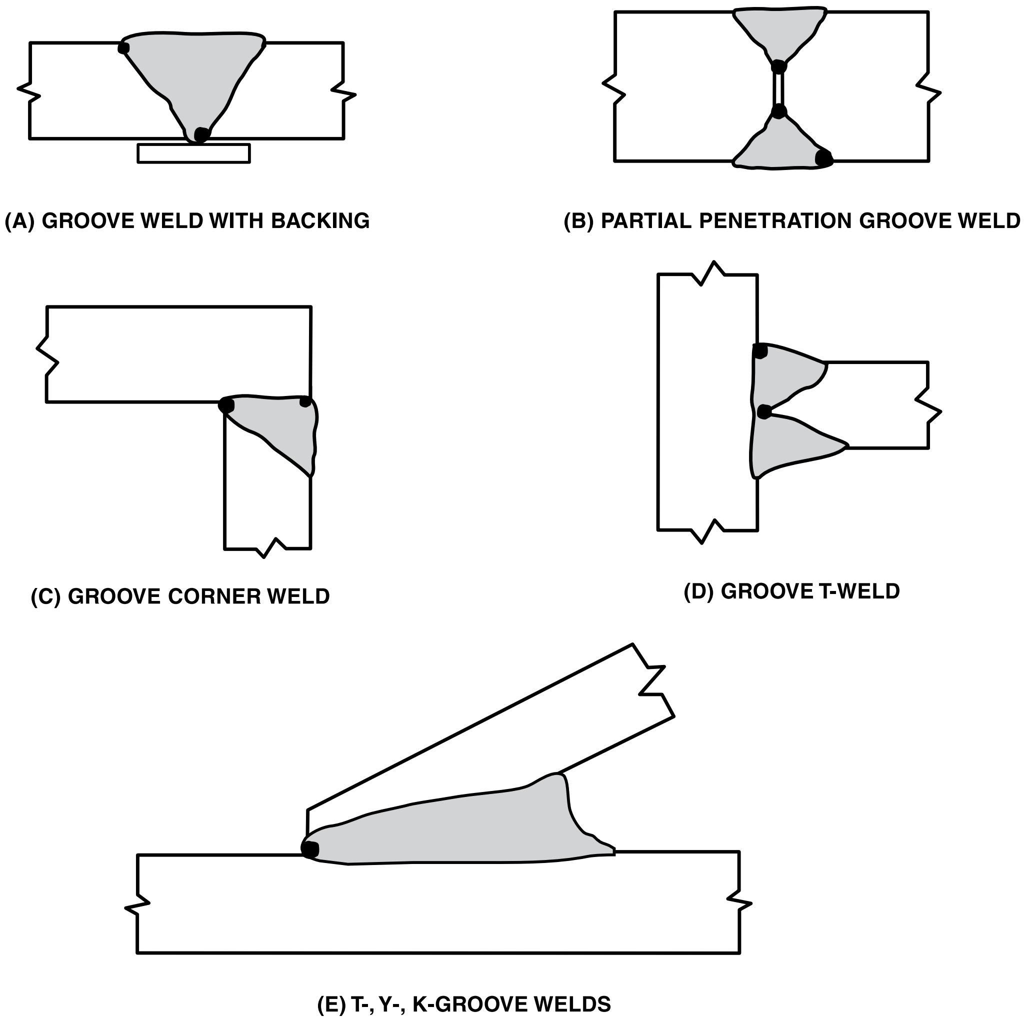



**Figure 8.3—Typical Standard Reflector (Located in Weld Mock-Ups and Production Welds)**

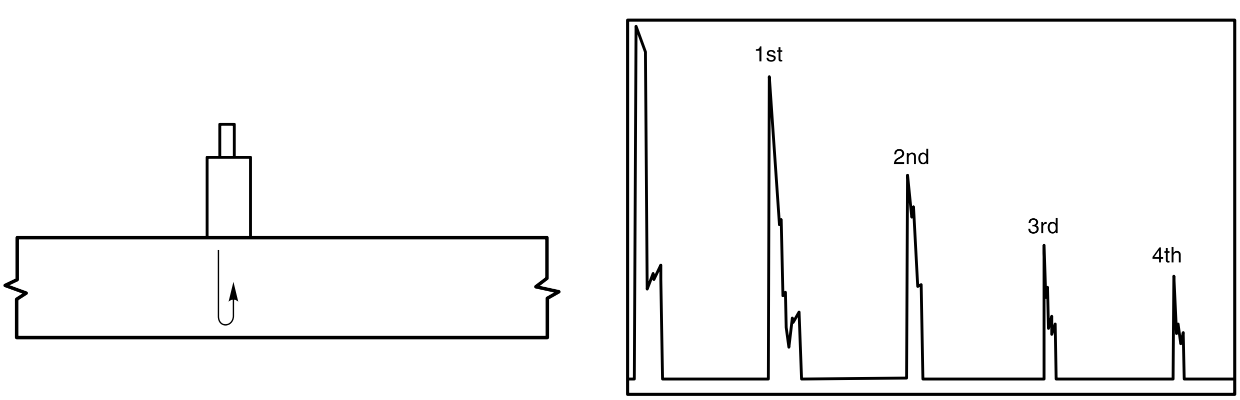



**Figure 8.4—Compression Wave Depth (Horizontal Sweep Calibration)**

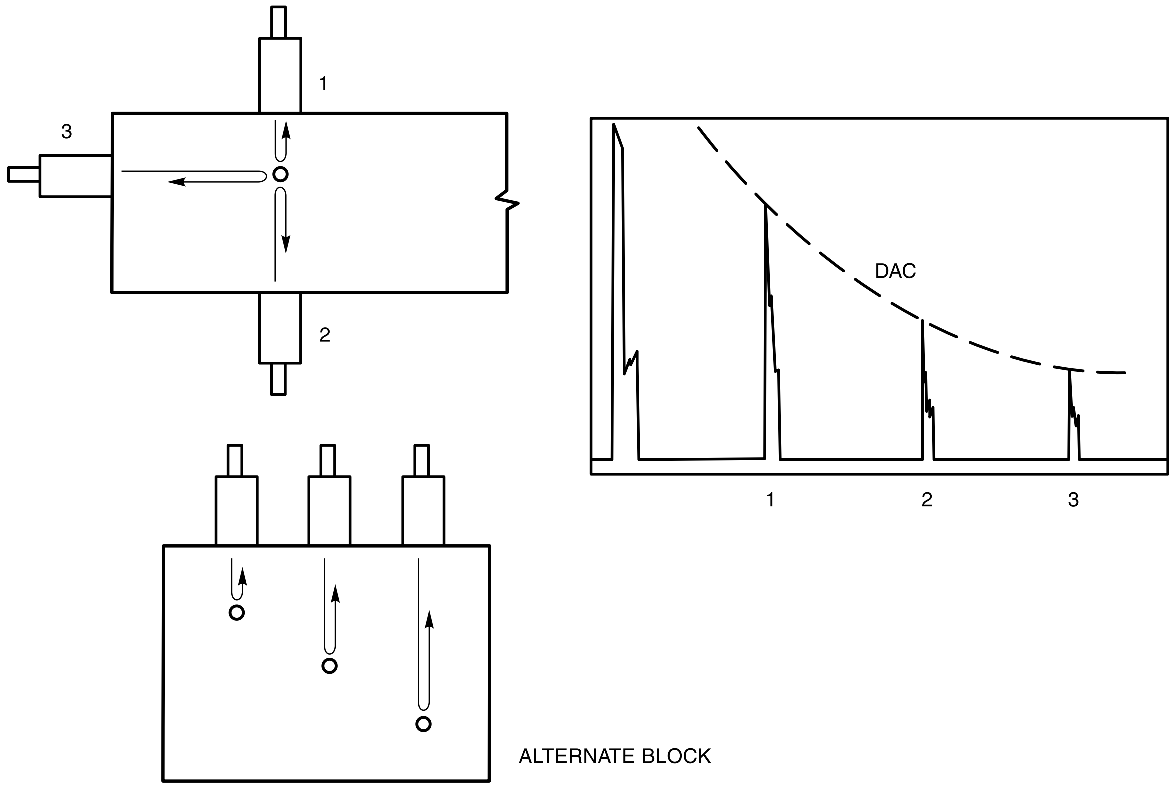



**Figure 8.5—Compression Wave Sensitivity Calibration**

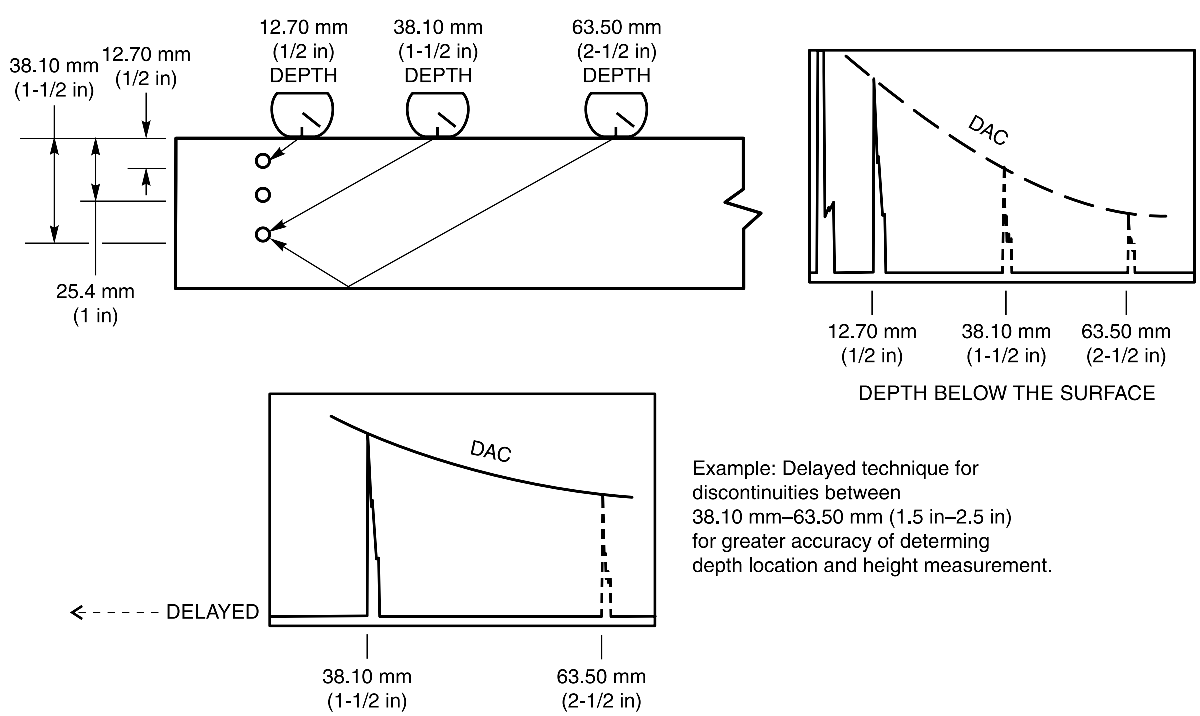
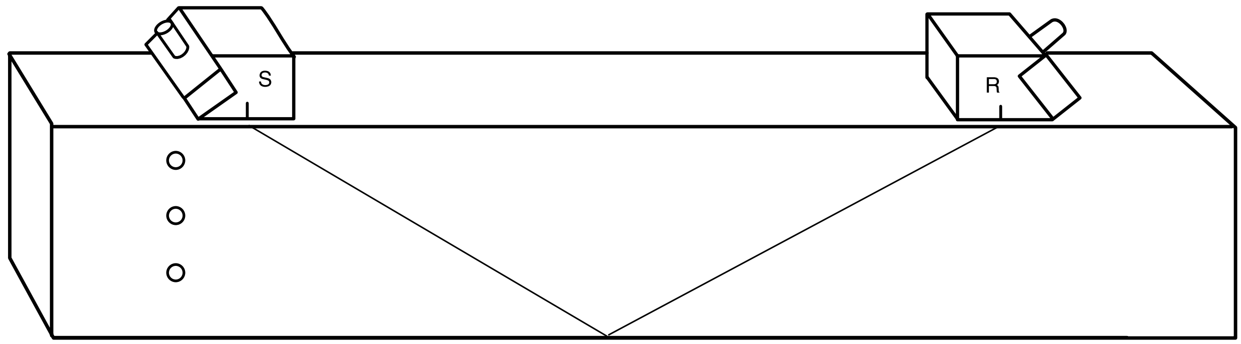
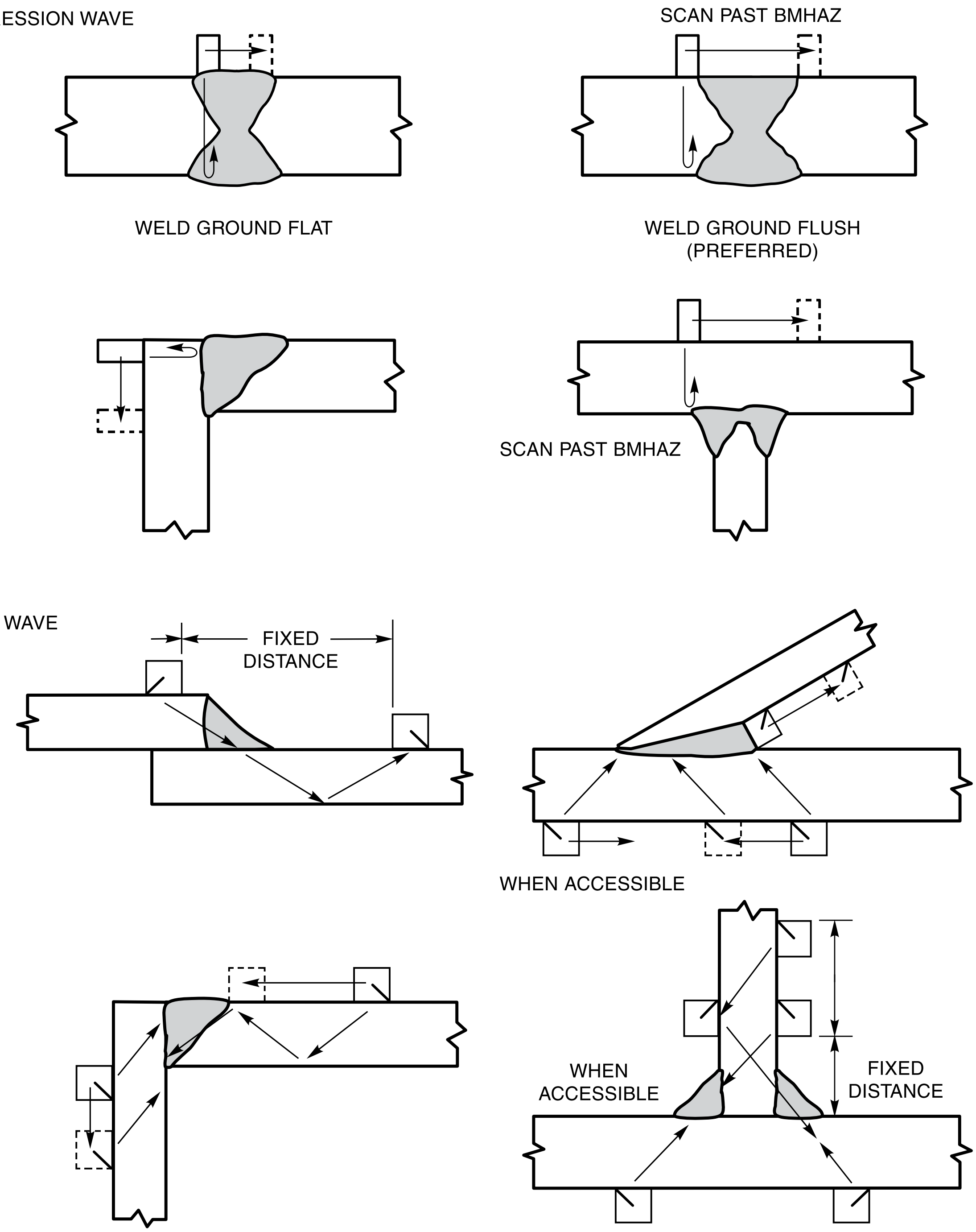



**Figure 8.6—Shear Wave Distance and Sensitivity Calibration**




Notes:
1. Procedure:
   a. Place two similar angle beam search units on the calibration block or mock-up to be used in the position shown above.
   b. Using through transmission methods, maximize the indication obtained and obtain a dB value of the indication.
   c. Transfer the same two search units to the part to be examined, orient in the same direction in which scanning will be performed, and obtain a dB value of indications as explained above from the least three locations.
   d. The difference in dB between the calibration block or mock-up and the average of that obtained from the part to be examined should be recorded and used to adjust the standard sensitivity.

**Figure 8.7—Transfer Correction**




Notes:

1. Denotes scanning, otherwise search unit should be at a fixed distance from the weld while scanning down the weld.
2. Cross-section scanning is shown. It is assumed that scanning will also be performed completely down the length of the weld with a minimum of 25% overlap to ensure 100% coverage. All scanning positions shown may not be required for full coverage. Optional positions are given in case that inaccessibility prevents use of some positions.

**Figure 8.8—Scanning Methods**

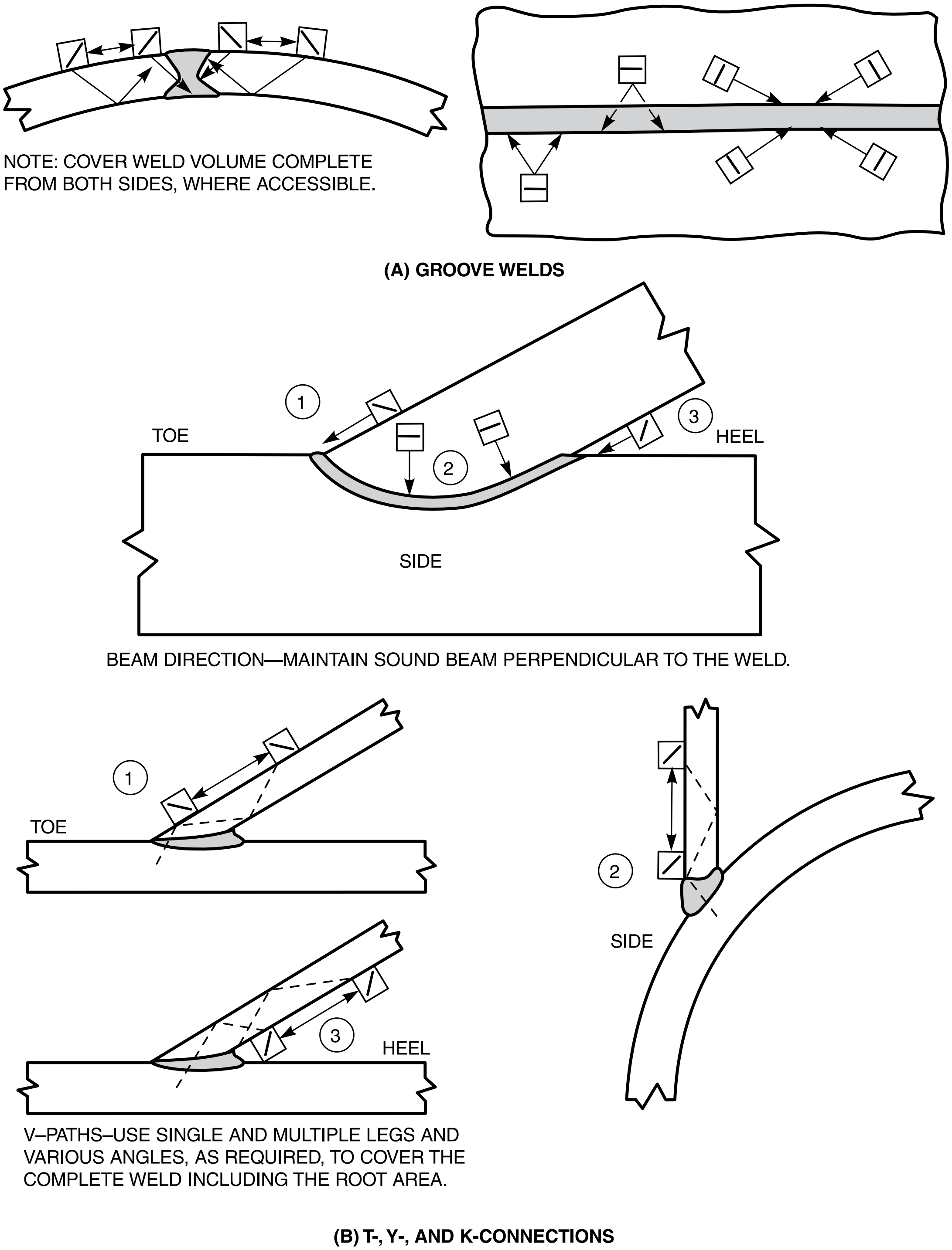



**Figure 8.9—Ultrasonic Scanning Techniques**

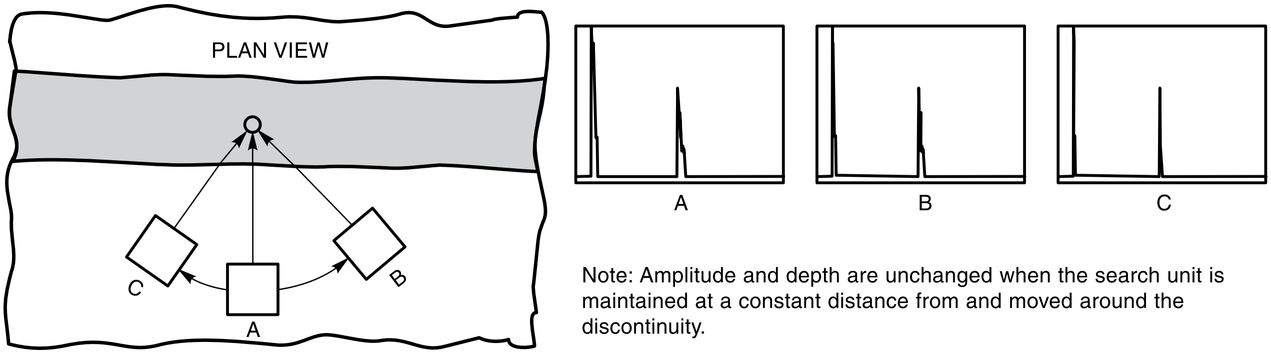



**Figure 8.10—Spherical Discontinuity Characteristics**

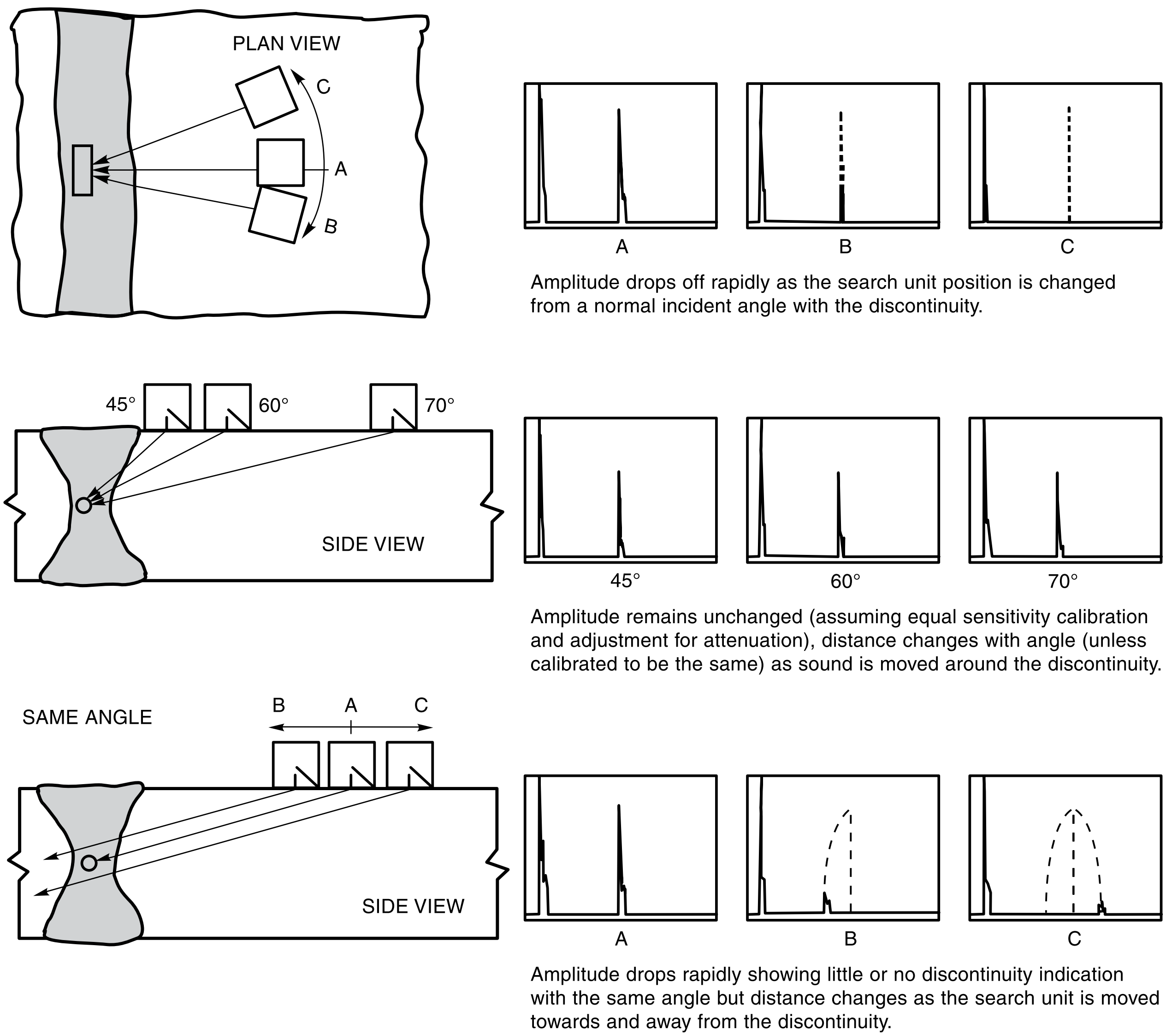



**Figure 8.11—Cylindrical Discontinuity Characteristics**

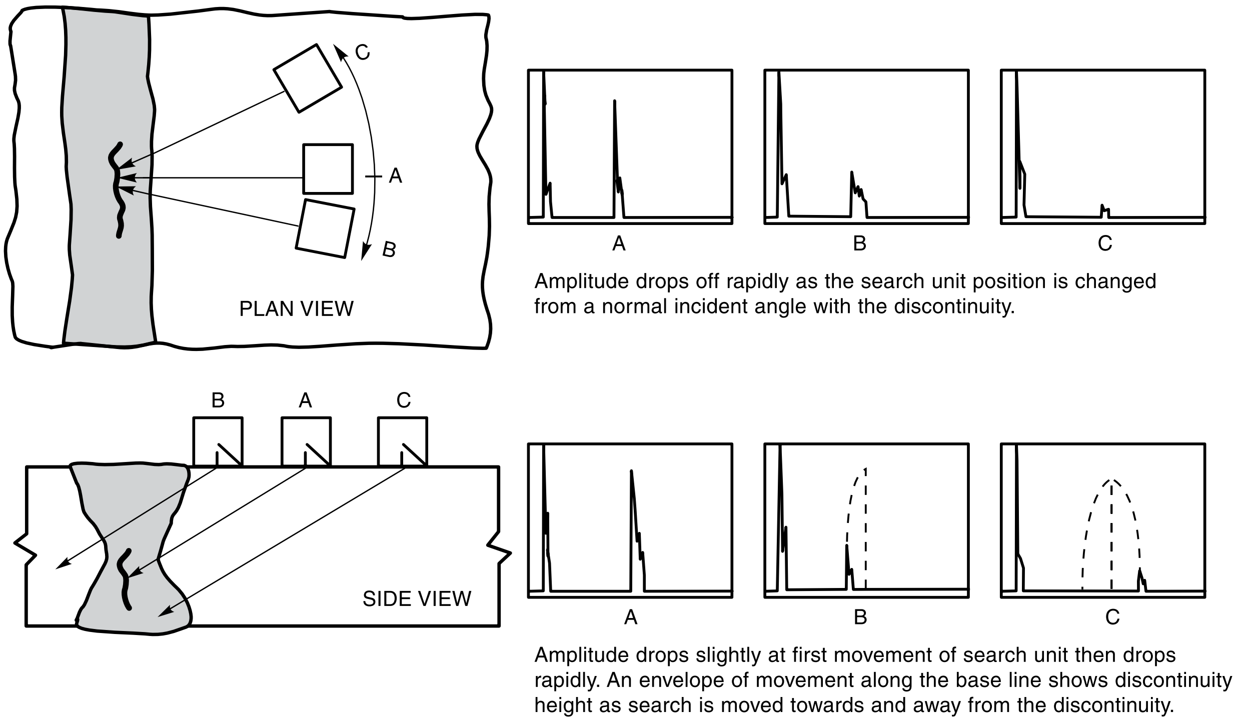



**Figure 8.12—Planar Discontinuity Characteristics**

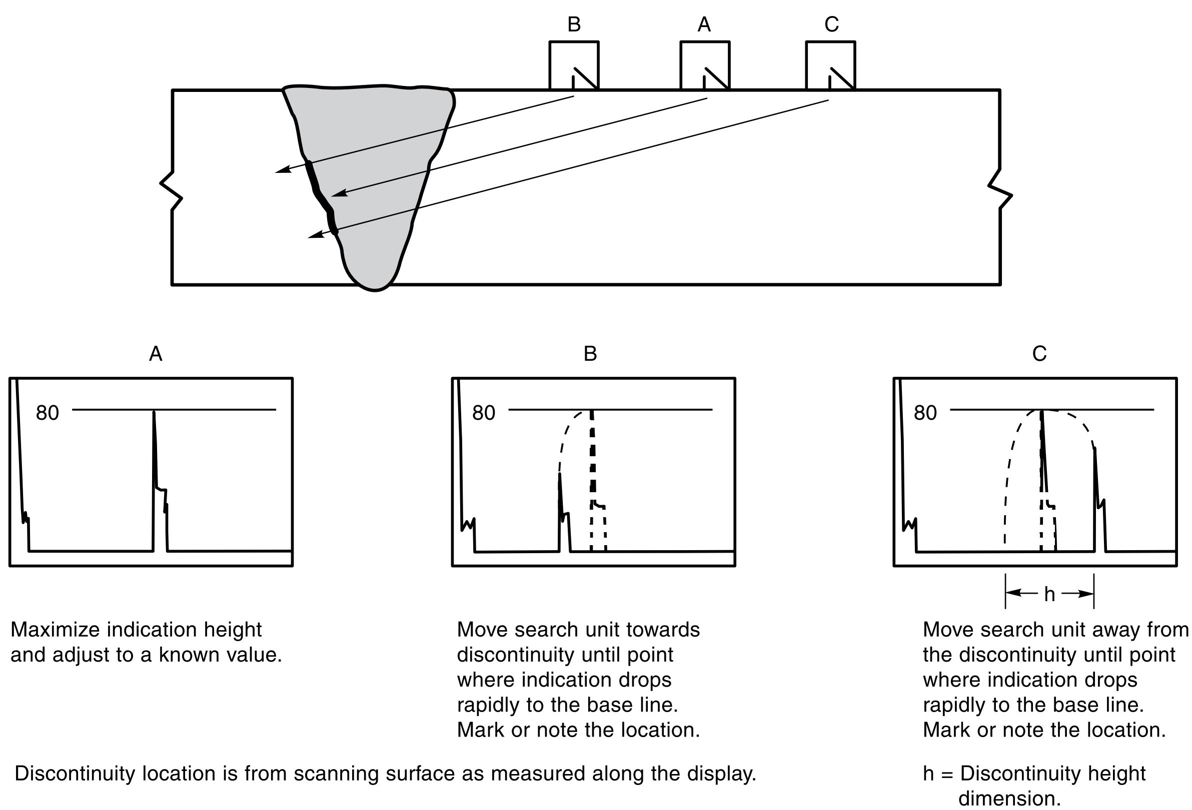



**Figure 8.13—Discontinuity Height Dimension**

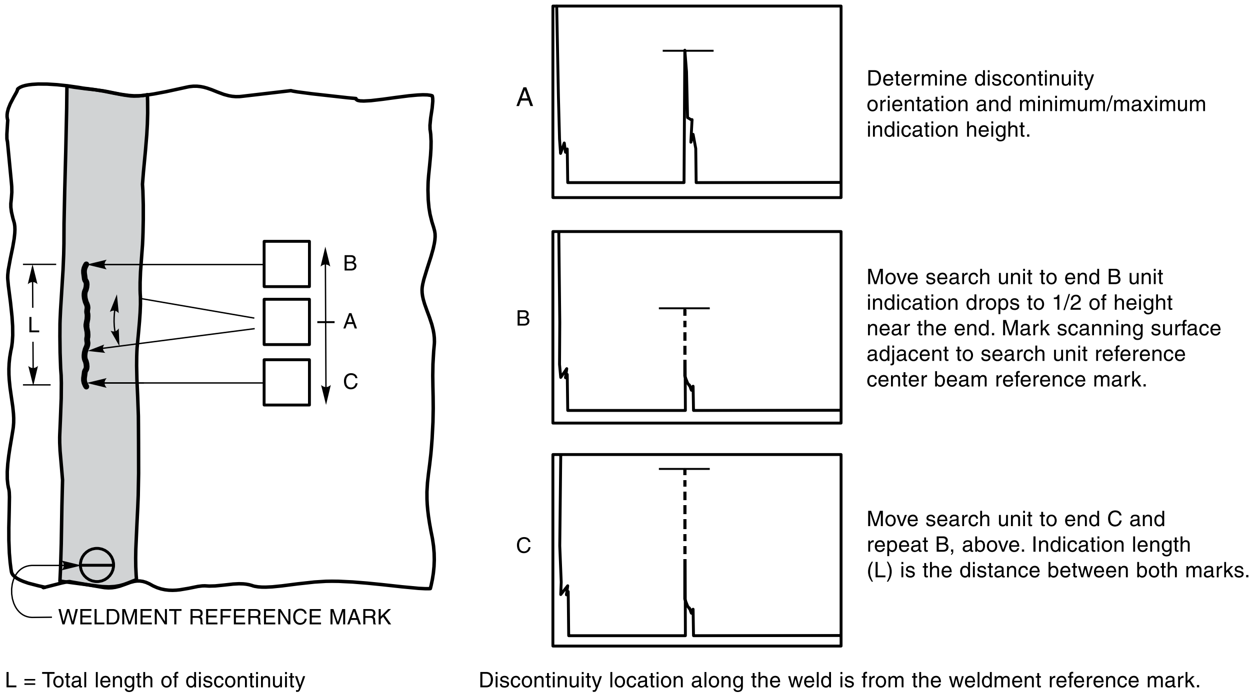
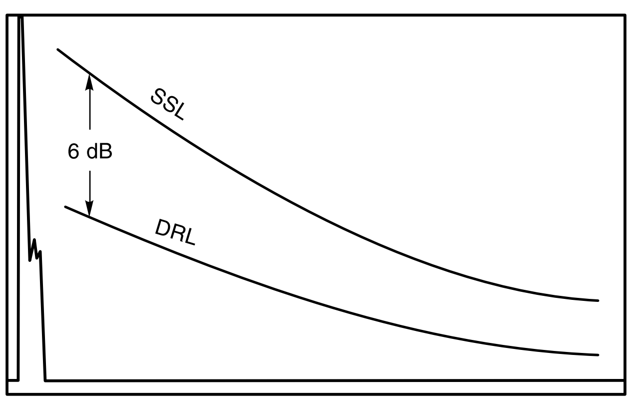
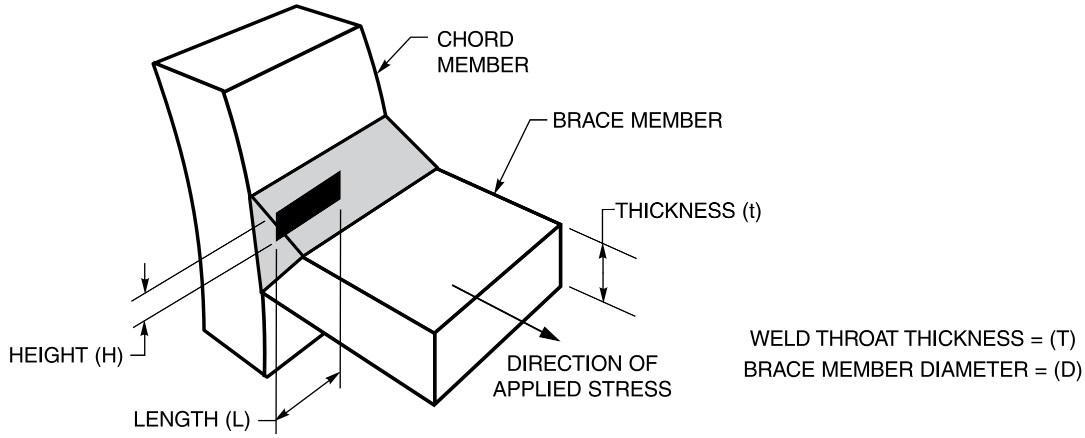



**Figure 8.14—Discontinuity Length Dimension**




Note: The display screen may be marked to show SSL established during sensitivity calibration with the DRL located 6 dB below.

**Figure 8.15—Display Screen Marking**




Notes:
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 150 mm (6 in) or D/2 length of weld, whichever is less.
7. Root area shall be defined as that lying within 6 mm (1/4 in) 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 8.16—Discontinuity Evaluation**

# 9. Class A Welds

**9.1 Application.** The requirements of this clause 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 code for Class A welds.

**9.1.1** Welding procedure specifications for Class A welds shall be qualified in accordance with the general requirements of Clause 7, Parts I and II, and the specific requirements of Part I of this clause.

**9.1.2** All welders, including tack welders, making Class A welds shall be qualified prior to production welding in accordance with the general requirements of Clause 7, Parts I and III, and with the specific requirements of Part II of this clause.

**9.1.3** 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 clause.

## *Part I*
## *Welding Procedure Qualification*

**9.2 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 9.1. The specimen type and welding position shall 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.

**9.3 Groove Welds**

**9.3.1 Test Specimens.** Test specimens for Class A groove welds shall be located in accordance with Figures 9.1 and 9.2. All-weld-metal specimens shall be prepared and located in accordance with 7.10.4 and Figures 7.13 and 7.14. As an option, the length of the procedure qualification test assembly (Figure 9.1) may be increased, and the all-weld-metal tension specimen may be removed from the procedure qualification test assembly.

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

**9.3.2.1 Visual Examination.** The welds shall meet the visual acceptance criteria of 9.9.

**9.3.2.2 Radiographic Examination.** The welds shall meet the acceptance criteria of 9.10.

**9.3.2.3 Reduced-Section Tension Test.** The tensile strength shall be equal to or exceed the specified minimum tensile strength of the base metal for each sample.

**9.3.2.4 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 indicated in Table 9.2.

**9.3.2.5 Bend Tests.** The bending fixture shall conform to Figure 7.12. Bend radius (B) for testing shall be in accordance with Table 9.2. Four samples shall be tested, and they shall not reveal tears or other defects exceeding 3 mm (1/8 in) in the weld metal or fusion zone after bending. A single replacement test specimen adjacent to the original specimen shall be tested if one out of the four specimens contains a corner crack(s) exceeding 6 mm (1/4 in) long. A crack shall not be cause for rejection unless it is associated with a defect. Only one replacement specimen shall be permitted.

**9.3.2.6 Macroetch.** Macroetch test specimens shall reveal no cracks at 5× magnification and shall meet the requirements 9.12. Vickers HV10 measurements shall not exceed 325 HV10 (see Table 9.2).

**9.3.2.7 Charpy Impact Test.** The average and minimum Charpy energy values of the three specimens shall satisfy the requirements of Table 9.2B when tested at a minimum design service temperature (see 7.10.5) unless other requirements are specified by the Customer.

**9.4 Fillet Welds**

**9.4.1 Test Specimens.** A groove weld for the all-weld-metal tension specimen and Charpy V-notch impact specimens shall be produced in accordance with 7.10.4 and 7.10.5. Fillet weld shear specimens shall be produced in accordance with the requirements of 7.10.8 (refer to Figures 7.16 or 7.17 for plate qualification and Figure 7.18 for pipe qualification). Fillet weld break test coupons shall be produced in accordance with the requirements of 7.10.7 (refer to Figure 7.8 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 7.8.2.

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

**9.4.2.1 Visual Examination.** All test welds shall meet the visual acceptance criteria of 9.9.

**9.4.2.2 Radiographic Examination.** The groove weld for the all-weld-metal tension and Charpy V-notch impact specimens shall meet the acceptance criteria of 9.10.

**9.4.2.3 Fillet Weld Shear Strength Test.** The minimum acceptable shear strength of the weld shall be 60% of the minimum tensile strength of the weld metal measured in the all-weld-metal tension test.

**9.4.2.4 All-Weld-Metal Tension Test.** The test specimen machined from the groove weld, as described in 7.10.4, shall be tested in accordance with ISO 6892 or ASTM A370. The yield strength and tensile strength shall exceed the minimum values specified for the base metal. The minimum elongation shall meet the requirements of Table 9.2.

**9.4.2.5 Fillet Weld Break Test.** The specimen shall pass if it bends flat upon itself. If the fillet weld fractures, it shall show fusion to the root of the joint but not necessarily beyond. The fracture surface shall exhibit no inclusion or porosity greater than 2.5 mm (3/32 in) in the greatest dimension. The sum of the greatest dimensions of all inclusions and porosity shall not exceed 10 mm (3/8 in) in any 150 mm (6 in) of weld.

**9.4.2.6 Macroetch.** Macroetch test specimens shall reveal no cracks at 5× magnification and shall meet the requirements of 9.12. Hardness tests on the surfaces shall not exceed 325 HV10 (see Table 9.2).

**9.4.2.7 Charpy Impact Test.** Charpy impact test specimens shall be prepared and tested as described in 7.10.5. They shall meet the impact requirements for Class A welds listed in 9.3.2.7.

## *Part II*

## *Welder Performance Qualification*

**9.5 Testing Requirements.** The number and type of test specimens required for welder qualification for Class A welds are summarized in Table 9.3.

**9.6 Groove Welds**

**9.6.1 Test Specimens.** Test specimens for welder qualification shall be prepared and located in accordance with Figure 9.3 for groove welds, and Figure 9.4 for T-, Y-, and K-connections on pipe or tubing. Four bend specimens shall be removed from each weld coupon. Radiographic inspection may be substituted by ultrasonic inspection or three macroetch test specimens removed from the weld adjacent to the required bend specimens; such specimens shall be prepared and etched in accordance with 7.10.2 and shall meet the requirements of 9.12.

**9.6.2 Test Results.** Welder qualification test results for Class A groove welds shall meet the following requirements as applicable.

**9.6.2.1 Visual Examination.** The welds shall meet the visual acceptance criteria of 9.9.

**9.6.2.2 Radiographic.** The welds shall meet the acceptance criteria of 9.10.

**9.6.2.3 Ultrasonic Examination.** The welds shall meet the acceptance criteria of 9.11.

**9.6.2.4 Macroetch.** The welds shall meet the acceptance criteria of 9.12.

**9.6.2.5 Bend Tests.** The bending fixture shall conform to Figure 7.12 with the bend radius as specified in 9.3.2.5. Four samples shall be tested, and they shall not reveal cracks or other defects exceeding 3 mm (1/8 in) in the weld metal or fusion zone after bending. A single replacement test specimen adjacent to the original specimen shall be tested if one out of the four specimens contains a corner crack(s) exceeding 6 mm (1/4 in) long. A crack shall not be cause for rejection unless it is associated with a defect. Only one replacement specimen shall be permitted.

### 9.7 Fillet Welds

**9.7.1 Test Specimen.** The welder shall weld fillet-weld break and macroetch test assemblies as shown in Figure 7.8 in accordance with the requirements of variables and positions of 7.15 and Table 7.5. The number and type of specimens required to qualify from each assembly are shown in Table 9.3.

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

**9.7.2.1 Visual Examination.** All test welds shall meet the visual acceptance criteria of 9.9

**9.7.2.2 Macroetch.** Macroetch test specimens shall reveal no cracks at 5× magnification and shall meet the acceptance criteria of 9.12.

**9.7.2.3 Fillet Weld Break Test.** The entire length of the fillet weld shall be examined visually, and then a 150 mm (6 in) long center specimen (see Figure 7.8) of an eighth section of the pipe fillet weld assembly shall be loaded in such a way that the root of the weld is in tension. At least one welding start and stop shall be located within the test specimen. The load shall be increased or repeated until the specimen fractures or bends flat upon itself.

**9.7.2.4 Acceptance Criteria for Fillet Weld Break Test.** To pass the visual examination prior to the break test, the weld shall present a reasonably uniform appearance and shall be free of overlap, cracks, and undercut in excess of the requirements of 9.9. There shall be no porosity visible on the weld surface.

The broken specimen shall pass if:

(1) The specimen bends flat upon itself, or

(2) The fillet weld, if fractured, has a fracture surface showing complete fusion to the root of the joint but not necessarily beyond with no inclusion or porosity larger than 2.5 mm (3/32 in) in greatest dimension, and

(3) The sum of the greatest dimensions of all inclusions and porosity shall not exceed 10 mm (3/8 in) in the 150 mm (6 in) long specimen.

## *Part III*

## *Examination*

**9.8 Examination Requirements.** All Class A production welds shall be visually examined in accordance with Clause 8, Part II. In addition, unless otherwise specified by the Customer, complete joint-penetration welds shall be either radiographed (Clause 8, Part III) or ultrasonically examined (Clause 8, Part IV); partial penetration and fillet welds shall be examined by the magnetic particle method (Clause 8, Part V) except for austenitic stainless steel and other nonmagnetic materials. 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 Clause 8, 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 as identified by the unaided eye.

(2) Complete fusion shall exist between adjacent weld beads, and between weld metal and base metal.

(3) All craters shall be filled to provide the specified weld size, except for the ends of intermittent fillet welds outside their effective length.

(4) Weld profiles shall be in accordance with Figure 9.5(A), (B), or (D).

(5) Undercut shall be restricted for base metals of thickness t as follows:
  (a) t > 25 mm (1 in): Undercut shall not exceed 1.5 mm (1/16 in) in depth, and the length of any undercut is not restricted.

(b) 6 mm (1/4 in) ≤ t ≤ 25 mm (1 in): Undercut shall not exceed 0.8 mm (1/32 in) in depth, and the length of any undercut exceeding 0.4 mm (1/64 in) in depth shall not exceed 50 mm (2 in) in length in any continuous 300 mm (12 in) of weld.

(c) t < 6 mm (1/4 in): Undercut shall not exceed 0.4 mm (1/64 in) in depth, and the length of any undercut shall not be restricted.

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

**9.10 Radiographic Test 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 6 mm (1/4 in) or less, the greatest dimension of any individual discontinuity shall be less than 3 mm (1/8 in). If t is more than 6 mm (1/4 in) but less than or equal to 30 mm (1–3/32 in), 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 30 mm (1–3/32 in), the greatest dimension of any discontinuity shall not exceed 20 mm (3/4 in).

(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., l/6× 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 9.10(2) through 9.10(5), the sum of the greatest dimensions of all discontinuities with a greatest dimension of less than 3 mm (1/8 in) shall not exceed 10 mm (3/8 in) in any continuous 25 mm (1 in) of weld.

**9.11 Ultrasonic Examination Acceptance Criteria.** The Customer shall designate the class, X or R, which applies to all welds to be examined.

**9.11.1** Disregard all disregard level (DRL) indications having half (6 dB) or less amplitude compared to the standard sensitivity level (with due regard for 8.15.7).

**9.11.2** Indications exceeding the DRL shall be evaluated as follows.

(1) Class X (applicable to T-, Y-, and 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 9.6 for linear or planar reflectors shall be acceptable.

(b) Linear or planar reflectors shall be evaluated using beam boundary techniques, and those that have dimensions exceeding the limits of Figure 9.6 shall be retested. Discontinuities in the backup weld[3] shall be disregarded.

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

(a) Isolated, random spherical reflectors, with 25 mm (1 in) 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.

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

(c) Clustered spherical reflectors having a density of more than one per 650 $mm^2$ (one per square inch) with indications above the disregard level [projected area normal to the direction of applied stress, averaged over a 150 mm (6 in) length of weld] shall be rejected.

(d) Linear or planar reflectors, whose lengths (extent) exceed the limits of Figure 9.6 or 9.9 shall be rejected.

**9.12 Macroetch Test Acceptance Criteria.** The weld shall be free of cracks. Slag, porosity, or other defects exceeding 1.5 mm (1/16 in) or 10% of the throat thickness in height or width shall be cause for rejection. However, linear indications associated with the root of partial penetration joints and groove welds with backing bars are acceptable, provided such linear indications do not exceed 1.0 mm (1/32 in), and provided such adjacent linear indications are separated by at least 3 mm (1/8 in).

## Table 9.1
## Welding Procedure Qualification—Number and Type of Test Specimens for Class A Welds[a]

| Coupon | Joint Type | Thickness Tested mm (in) | Visual (See 8.9 and 8.10) | Radio-graphic (See 8.11 and 8.12) | Reduced Section Tension (See 7.10.1) | Fillet Weld Shear (See 7.10.8) | All-Weld-Metal Tension (See 7.10.4) | Bends[b] (See 7.10.3) Root and Face | Bends[b] (See 7.10.3) Side | Macroetch Test (See 7.10.2) | Vickers Hardness (See 7.10.6)[c] | Charpy Impact (See 7.10.5)[d] | Fillet Weld Break (See 7.10.7) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | T ≤ 10 (3/8) | Yes | Yes | 2 | 0 | 1 | 2 each | 0 | 1 | 1 | WM and HAZ | 0 |
| Plate | Groove | 10 (3/8) < T < 20 (3/4) | Yes | Yes | 2 | 0 | 1 | 2 each or | 4 | 1 | 1 | WM and HAZ | 0 |
| | | T ≥ 20 (3/4) | Yes | Yes | 2 | 0 | 1 | 0 | 4 | 1 | 1 | WM and HAZ | 0 |
| | | T ≤ 10 (3/8) | Yes | Yes | 2 | 0 | 1 | 2 each | 0 | 1 | 1 | WM and HAZ | 0 |
| Pipe | Groove | 10 (3/8) < T < 20 (3/4) | Yes | Yes | 2 | 0 | 1 | 2 each or | 4 | 1 | 1 | WM and HAZ | 0 |
| | | T ≥ 20 (3/4) | Yes | Yes | 2 | 0 | 1 | 0 | 4 | 1 | 1 | WM and HAZ | 0 |
| Plate | Fillet | All[d] | Yes | No | 0 | 1 | 1 | 0 | 0 | 2[e] | 1 | WM | 1[e] |
| Pipe | Fillet | All[d] | Yes | No | 0 | 1 | 1 | 0 | 0 | 4[e] | 1 | WM | 4[e] |

[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 10 mm (3/8 in) and 20 mm (3/4 in) thick, the Customer may specify either two root and two face-bend tests or four side-bend tests.
[c] Vickers Hardness and Charpy impact tests not applicable for austenitic stainless steel base metals.
[d] Multiple pass fillet welds are considered qualified by groove weld qualification (7.8.2).
[e] For single-pass welds the qualification weld size shall be the maximum size to be performed in production. For multipass welds, the qualification weld size shall be the minimum size to be welded in production.

Note: WM = Weld metal; HAZ = Heat-affected-zone.

## Table 9.2
## Welding Procedure Qualification—Mechanical Test Acceptance Criteria for Class A Welds

**A. Tensile and Bend Test Acceptance Criteria[a]**

| Base Metal Minimum Specified Yield Strength | All-Weld-Metal Tensile (Figure 7.14)/Minimum Percent Elongation: GL/D = 5[b] | All-Weld-Metal Tensile (Figure 7.14)/Minimum Percent Elongation: GL/D = 4[b] | Bend Specimen: Maximum Bend Test Radius[c, d] |
|---|---|---|---|
| 350 MPs (50 ksi) and below | 18 | 20 | 2T |
| Over 350 MPa to but not including 600 MPa | 14 | 16 | 2–2/3T |
| 600 MPa and Over (90 ksi) | As specified by Customer | As specified by Customer | 3–1/3T |

**B. Charpy V-Notch and Vickers HV10 Acceptance Criteria[e]**

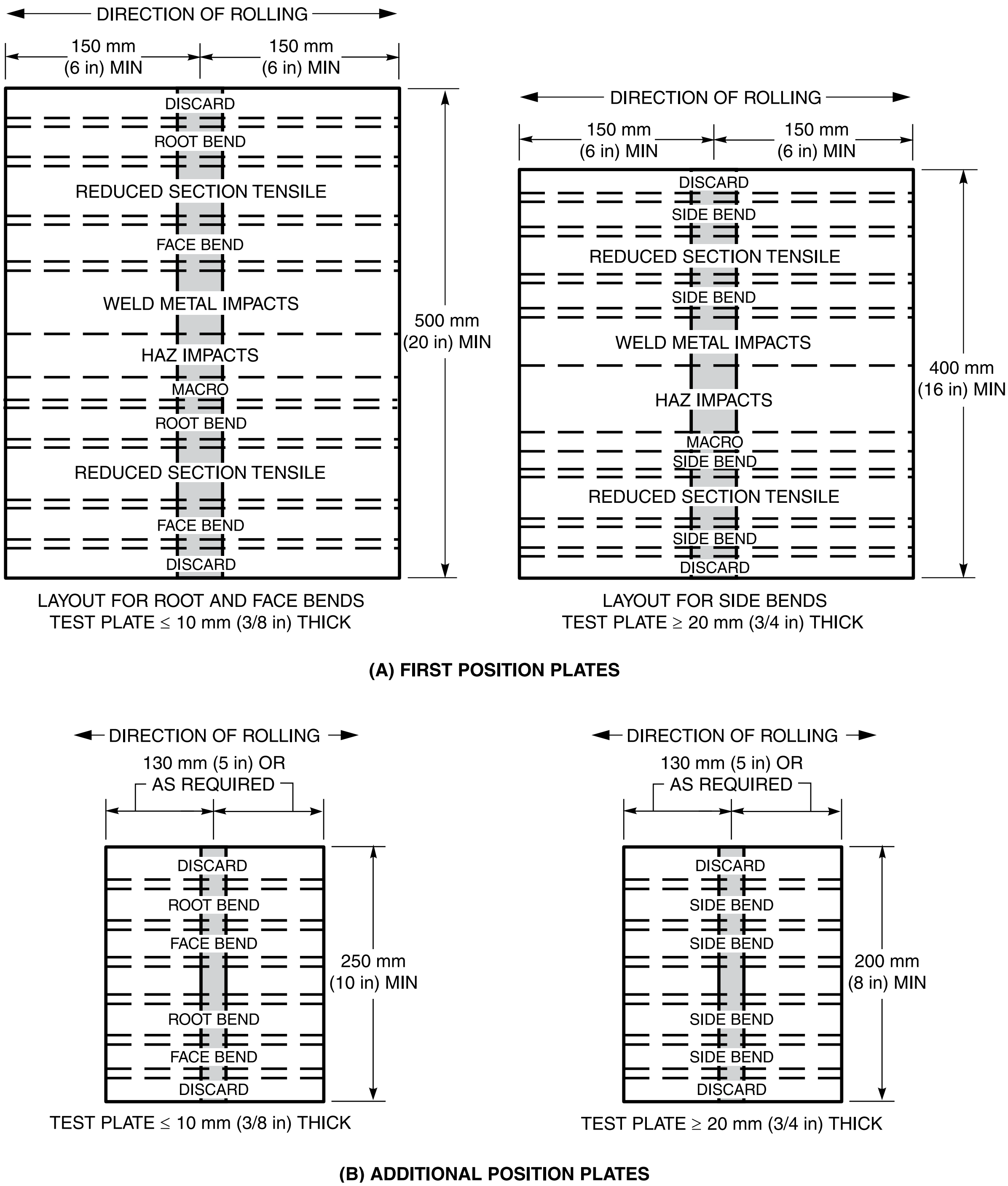
| Base Metal Minimum Specified Tensile Strength | Weld-Metal and HAZ/Charpy V-Notch: Average Energy | Weld-Metal and HAZ/Charpy V-Notch: Minimum Energy | Maximum Vickers HV10 |
|---|---|---|---|
| 485 MPa (70 ksi) and below | 26 J (15 ft-lb) | 14 J (10 ft-lb) | 325 HV10 |
| Over 485 MPa to 550 MPa | 27 J (20 ft-lb | 19 J (14 ft-lb) | 325 HV10 |
| Over 550 MPa (80 ksi) | 34 J (25 ft-lb) | 23 J (17 ft-lb) | 325 HV10 |

[a] Values apply to carbon, low alloy, and austenitic stainless steel.
[b] GL = Gauge Length; D = Machined Diameter.
[c] T is the specimen thickness, i.e., 10 mm (3/8 in) for side bends.
[d] Use 2T for all grades of austenitic stainless steel.
[e] Vickers Hardness and Charpy impact tests are not applicable for austenitic stainless steel base metals.

## Table 9.3
## Welder Performance Qualification—Number and Type of Test Specimens for Class A Welds (Per Welder)

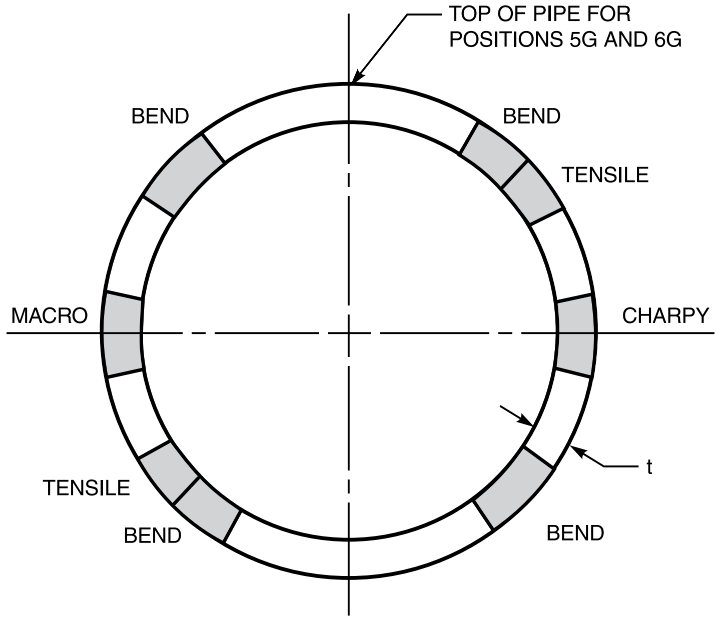
| Coupon | Joint Type | Thickness Tested mm (in) | Visual[b] (see 8.9 and 8.10) | Radiographic[b] (see 8.11 and 8.12) | Bends[a] (see 7.10.3): Root and Face | | Bends[a] (see 7.10.3): Side | Macro[c] | Fillet Weld Break (See Figure 7.8) |
|---|---|---|---|---|---|---|---|---|---|
| Plate | Groove | $T \leq 10$ (3/8) | Yes | Yes[d] | 2 each | | – | – | – |
| | | $10 (3/8) < T < 20 (3/4)$ | Yes | Yes[d] | 2 each | or | 4 | – | – |
| | | $T \geq 20$ (3/4) | Yes | Yes[d] | – | | 4 | – | – |
| Pipe | Groove | $T \leq 10$ (3/8) | Yes | Yes[d] | 2 each | | | – | – |
| | | $10 (3/8) < T < 20 (3/4)$ | Yes | Yes[d] | 2 each | or | 4 | – | – |
| | | $T \geq 20$ (3/4) | Yes | Yes[d] | – | | 4 | – | – |
| Plate | Fillet | All | Yes | – | – | | – | 2 | 1 |
| Pipe | Fillet | All | Yes | – | – | | – | 4 | 4 |

[a] For plate and pipe between 10 mm (3/8 in) and 20 mm (3/4 in) thick, Customer may specify either root and face bends or side bends.
[b] See Clause 8, Part II for visual examination, Part III for radiographic examination.
[d] Ultrasonic or three macros may be substituted. See 9.6.1.
[c] See 7.10.2, 9.7, and Figure 7.8. Hardness tests not required.
[d] Ultrasonic or three macros may be substituted. See 9.6.1.




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 9.3.1 when the plate thickness is ≥20 mm (3/4 in). For plates between 10 mm (3/8 in) and 20 mm (3/4 in), the Customer may specify root and face bends or side bends for the first and additional position plates.

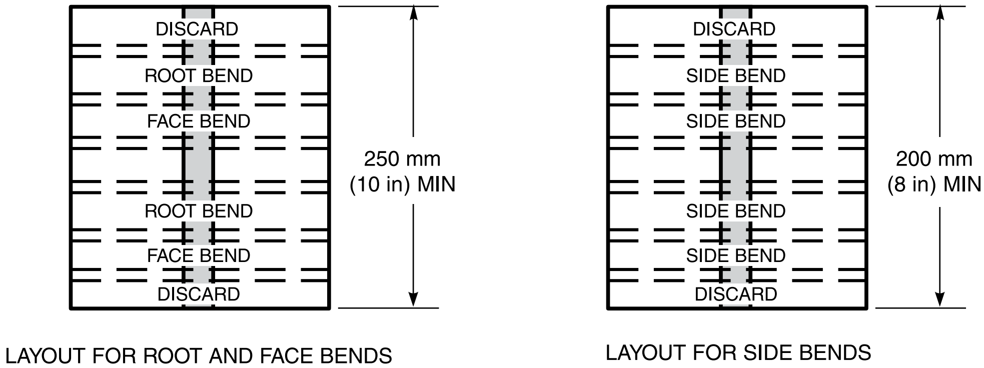
**Figure 9.1—Location and Type of Test Specimens on Welded Plate Test Procedure Qualification Assembly, Class A Groove Welds**



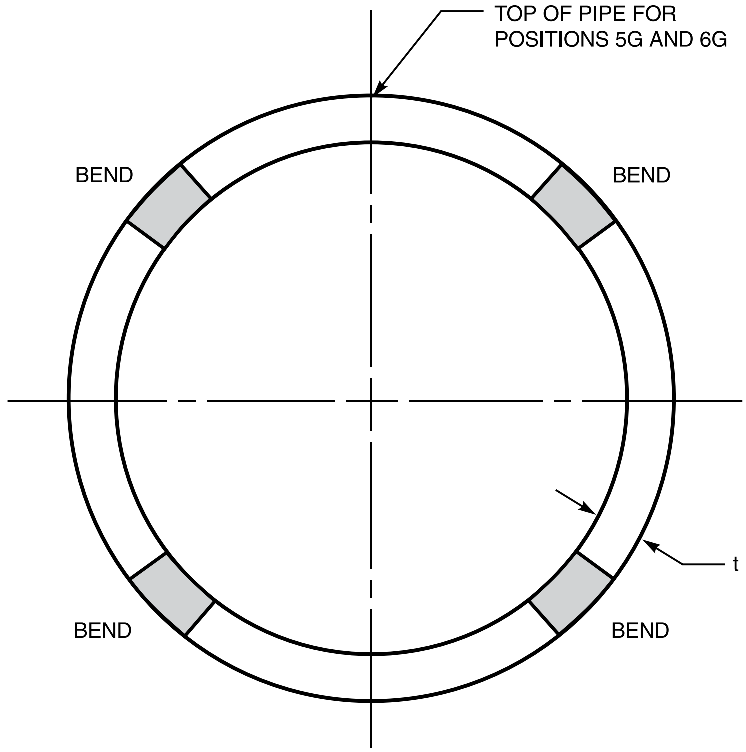

Notes:

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 testing.
2. First position weld, test all specimens shown. Additional position welds, test bend specimens only.
   a. t ≤ 10 mm (3/8 in)—Two root and two face bends.
   b. t ≥ 20 mm (3/4 in)—Four side bends.
   c. t between 10 mm (3/8 in) and 20 mm (3/4 in), Customer may specify root and face or side bends.
   d. Specimen geometry as described in Figures 7.7, 7.10, and 7.11.

**Figure 9.2—Location and Types of Test Specimens on Welded Pipe Test Procedure Qualification Assembly, Class A Groove Welds in Pipe**




**(A) FOR PLATE**




**(B) FOR PIPE**

Notes:
1. t ≤ 10 mm (3/8 in)—Two root and two face bends.
2. t ≥ 20 mm (3/4 in)—Four side bends.
3. t between 10 mm (3/8 in) and 20 mm (3/4 in), Customer may specify root and face or side bends.
4. Specimen geometry as described in Figures 7.7, 7.10, and 7.11.
5. For plates between 10 mm (3/8 in) and 20 mm (3/4 in) thick, Customer may specify root and face bends or side bends (for pipe).

**Figure 9.3—Type and Location of Bend Test Specimens for Welder Performance Qualification, Class A Groove Welds**

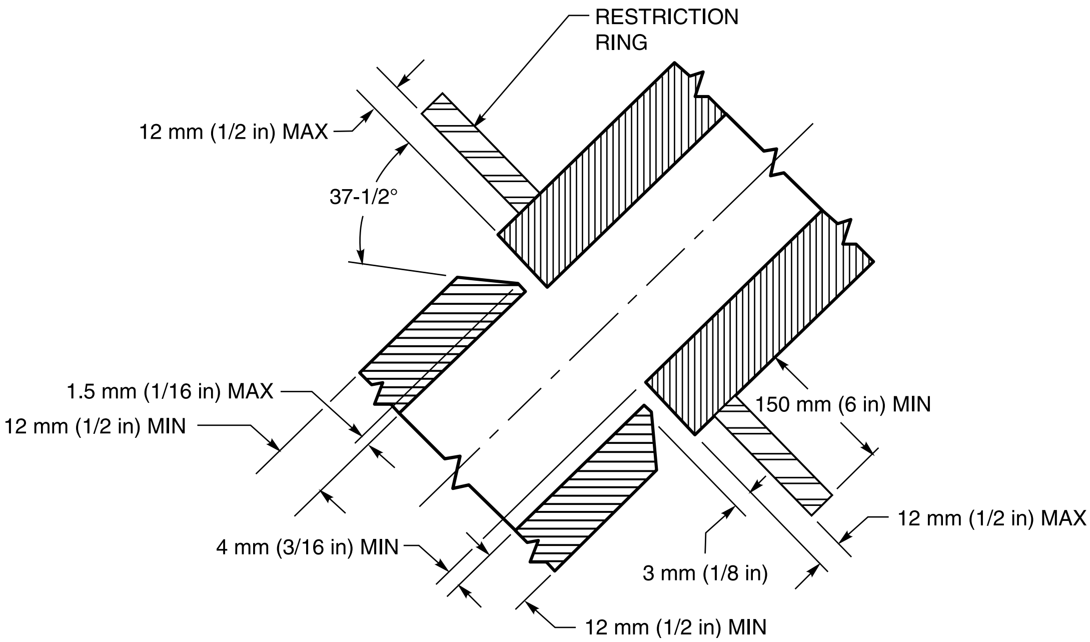



**Figure 9.4—Test Assembly for T-, Y-, and K-Connections on Pipe or Square or Rectangular Tubing—Welding Procedure and Welder Performance Qualification, Class A Welds**

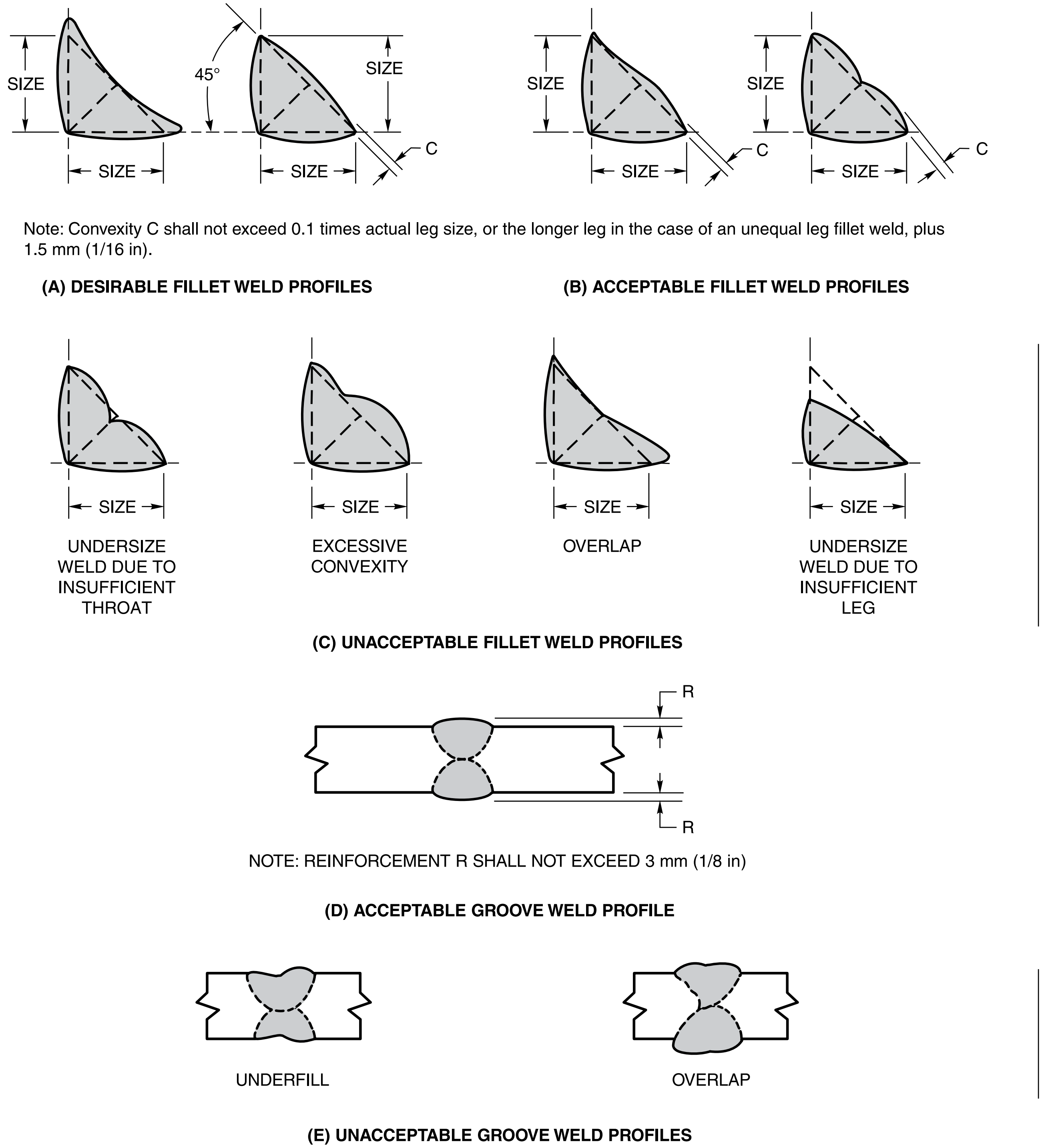
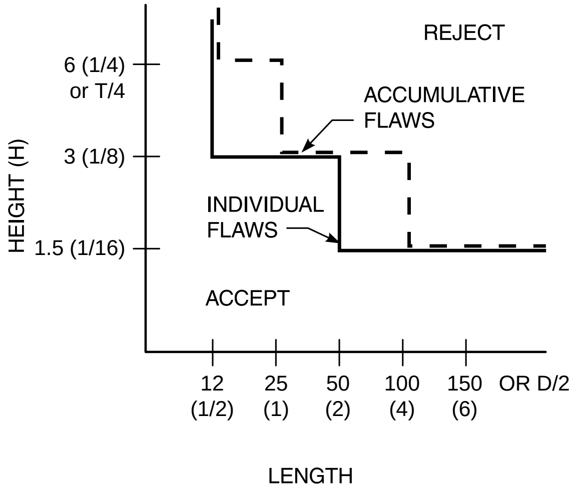



**Figure 9.5—Acceptable and Unacceptable Weld Profiles for Class A Welds**

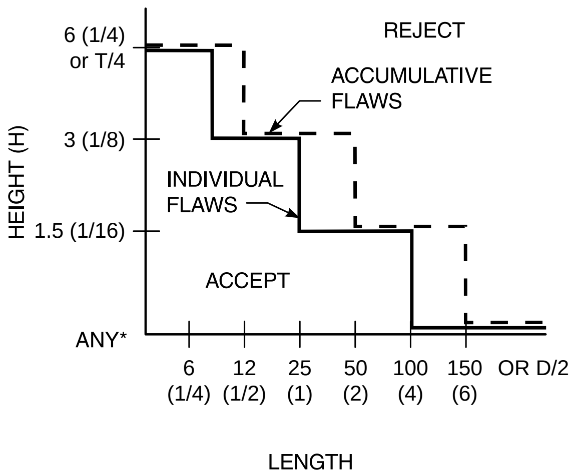
DIMENSIONS IN MILLIMETERS (INCHES)




T-, Y-, AND 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.



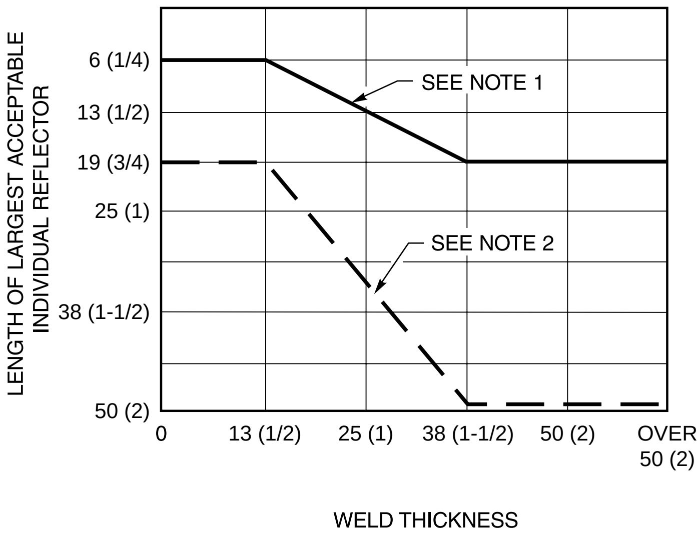

INTERNAL REFLECTORS AND ALL OTHER WELDS

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 (SEE CLAUSE 9.12.2) ARE TO BE DISREGARDED.

**(A) CLASS X INDICATIONS**

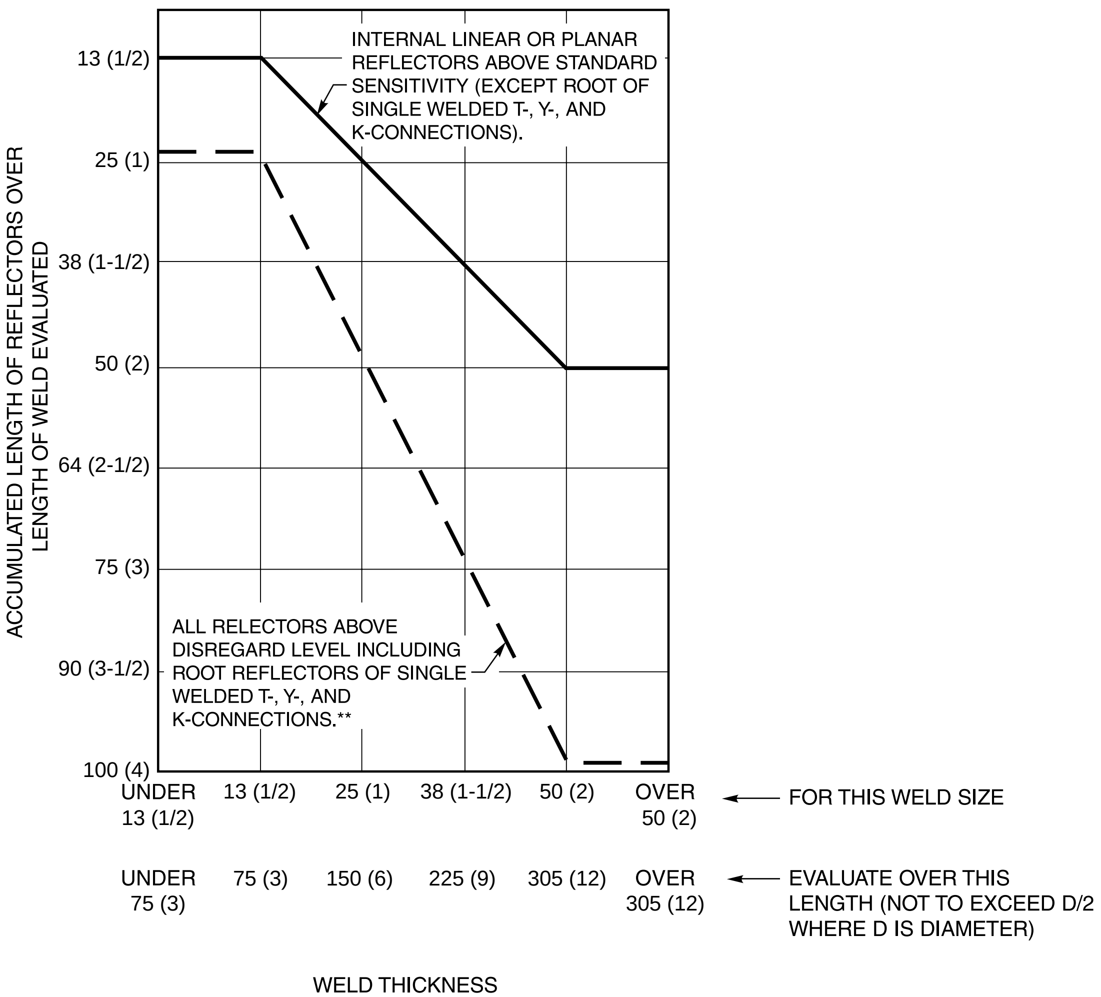
**Figure 9.6—Ultrasonic Inspection Acceptance Criteria**




DIMENSIONS IN MILLIMETERS (INCHES)

NOTES:
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 9.6 (Continued)—Ultrasonic Inspection Acceptance Criteria**

# 10. Class B Welds

**10.1 Application.** The requirements of this clause apply to Class B welds. Class B underwater welds are intended for applications that are less critical than Class A. This class of weld shall meet the requirements of this code for Class B welds, and shall satisfy the Customer's requirements for a particular application.

**10.1.1** Welding procedure specifications for Class B welds shall be qualified in accordance with the general requirements of Clause 7, Parts I and II, and the specific requirements of Part I of this clause.

**10.1.2** All welders, including tack welders, making Class B welds shall be qualified prior to production welding in accordance with the general requirements of Clause 7, Part I and III, and the specific requirements of Part II of this clause.

**10.1.3** 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 clause.

## *Part I*
## *Welding 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 B welds are summarized in Table 10.1. The specimen type and welding position shall 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.

**10.3 Groove Welds**

**10.3.1 Test Specimens.** Test specimens for Class B welds shall be located in accordance with Figures 10.1 or 10.2.

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

**10.3.2.1 Visual Examination.** The weld shall meet the visual acceptance criteria of 10.9.

**10.3.2.2 Radiographic Examination.** The weld shall meet the radiographic acceptance criteria of 10.10.

**10.3.2.3 Reduced-Section Tension Tests.** The tensile strength shall equal or exceed the specified minimum tensile strength of the base metal for each sample.

**10.3.2.4 Bend Tests.** The bending fixture shall conform to Figure 7.12 of Clause 7, Part II. Maximum bend radius for testing shall be 6T unless a smaller radius is specified by the Customer. Four samples shall be tested, and none shall reveal tears or other defects exceeding 3 mm (1/8 in) in the weld metal or fusion zone after the bending. A single replacement test specimen adjacent to the original specimen shall be tested if one out of the four specimens contains a corner crack(s) exceeding 6 mm (1/4 in) long. A crack shall not be cause for rejection unless it is associated with a defect. Only one replacement specimen shall be permitted.

**10.3.2.5 Macroetch.** Macroetch test specimens shall contain no cracks at 5× magnification and shall meet the acceptance criteria of 10.11. Vickers HV10 measurements shall not exceed 375 HV10 (see Table 10.2) unless otherwise specified by the Customer.

**10.3.2.6 Charpy Impact Test.** The average and minimum Charpy energy values shall satisfy the requirements of Table 10.2, unless other requirements are specified by the Customer.

**10.4 Fillet Welds**

**10.4.1 Test Specimens.** Fillet weld shear strength specimens shall be produced in accordance with the requirements of 7.10.8 (refer to Figures 7.16 or 7.17 for plate qualification and Figure 7.18 for pipe qualification). Fillet weld break test coupons shall be produced in accordance with the requirements of 7.10.7 (refer to Figure 7.8 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 7.8.2.

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

**10.4.2.1 Visual Examination.** All test welds shall meet the visual acceptance criteria of 10.9.

**10.4.2.2 Fillet Weld Shear Test.** The minimum acceptable shear strength of the weld shall be 60% of the specified minimum tensile strength of the base metal to be welded in production.

**10.4.2.3 Fillet Weld Break Tests.** To pass the visual examination prior to the break test, the weld shall present a reasonably uniform appearance and shall be free of cracks and undercut in excess of the requirements of 10.9.

The broken specimen shall pass if:

(1) The specimen bends flat upon itself, or

(2) The fillet weld, if fractured, has a fracture surface showing complete fusion to the root of the joint but not necessarily beyond with for at least 90% of the joint length with no inclusion or porosity (including piping porosity) exceeding 5 mm (3/16 in) in greatest dimension, and

(3) The sum of these discontinuities up to 5 mm (3/16 in) in the greatest dimension shall not exceed two (2) per 25 mm [1 in] of weld length nor eight (8) per 150 mm (6 in).

(4) Discontinuities less than 1.5 mm (1/16 in) shall be ignored.

**10.4.2.4 Macroetch.** Macroetch test sections transverse to the weld shall reveal no cracks at 5× magnification and shall meet the requirements of 10.11.

## *Part II*
## *Welder Performance Qualification*

**10.5 Testing Requirements.** The number and type of test specimens required for welder qualification for Class B welds are summarized in Table 10.3.

**10.6 Groove Welds**

**10.6.1 Test Specimens.** Test specimens for welder qualification shall be located in accordance with Figure 10.3 for groove welds and Figure 10.4 for T-, Y-, and K-connections on pipe or tubing. Four bend specimens shall be removed from each weld coupon. In lieu of radiographic inspection, three macroetch test specimens may be removed from the weld adjacent to the required bend specimens; such specimens shall be prepared and etched in accordance with 7.10, and meet the requirements of 10.6.

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

**10.6.2.1 Visual Examination.** The weld shall meet the visual acceptance criteria of 10.9.

**10.6.2.2 Radiographic Examination.** The weld shall meet the acceptance criteria of 10.10.

**10.6.2.3 Macroetch.** The weld shall meet the acceptance criteria of 10.11.

**10.6.2.4 Bend Tests.** The bending fixture shall conform to Figure 7.12. Maximum bend radius for testing shall be 6T. Four samples shall be tested, and none shall reveal tears or other defects exceeding 3 mm (1/8 in) in the weld metal or fusion zone after the bending. A single replacement test specimen adjacent to the original specimen shall be tested if one out of the four specimens contains a corner crack(s) exceeding 6 mm (1/4 in) long. A crack shall not be cause for rejection unless it is associated with a defect. Only one replacement specimen shall be permitted.

**10.7 Fillet Welds**

**10.7.1 Test Specimens.** The welder shall weld fillet-weld-break and macroetch test assemblies as shown in Figure 7.8 in accordance with the requirements of variables and positions of 7.15 and Table 7.5. The number and type of specimens required to qualify from each assembly are shown in Table 10.3.

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

**10.7.2.1 Visual Examination.** All test welds shall meet the visual acceptance criteria of 10.9.

**10.7.2.2 Macroetch Test.** Macroetch test sections shall reveal no cracks at 5× magnification and shall meet the acceptance criteria of 10.11.

**10.7.2.3 Fillet Weld Break Tests.** A fillet weld break test shall pass if it meets the acceptance criteria of 10.12.

## *Part III*
## *Examination*

**10.8 Examination Requirements.** All Class B production welds shall, as a minimum, be visually examined in accordance with Clause 8, Part II. Any additional examination shall be as specified by the Customer, and performed in accordance with the requirements of Clause 8, as applicable. Acceptance criteria shall be in accordance with the following.

**10.9 Visual Acceptance Criteria.** The following acceptance criteria, in accordance with the procedures and standards of Clause 8, 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.

(3) All craters shall be filled to provide the specified weld size, except for the ends of intermittent fillet welds outside their effective length.

(4) Weld profiles shall be in accordance with Figure 10.5(A), (B), or (D).

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

(6) Undercut shall not exceed 1.5 mm (1/16 in) in depth with the following exception. Isolated undercut over 1.5 mm (1/16 in) but not more than 3 mm (1/8 in) or 20% of the base metal thickness in depth, whichever is less, shall be permitted, provided it does not exceed 10 mm (3/8 in) in length and it shall be separated by a minimum of 150 mm (6 in) from adjacent undercut that is deeper than 1.5 mm (1/16 in). The maximum length of undercut between 0.8 mm (1/32 in) and 1.5 mm (1/16 in) in depth shall not exceed 100 mm (4 in) in any continuous 300 mm (12 in) of weld. Undercut less than 0.8 mm (1/32 in) in depth shall be acceptable without restrictions.

(7) When root surfaces are present and accessible, for one-sided welds, incomplete joint penetration or drop-through shall be limited to 3 mm (1/8 in) maximum depth and 100 mm (4 in) maximum length in any 300 mm (12 in) 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) For the case of unequal leg length fillet welds, the tolerance on leg length shall be 3 mm (1/8 in).

**10.10 Radiographic Test Acceptance Criteria.** The following acceptance criteria for Class B production and qualification welds, as applicable, shall be satisfied. Discontinuities found by radiographic examination shall not exceed the dimensions specified.

**10.10.1 Cracks.** The welds shall have no cracks.

**10.10.2 Porosity.** Dispersed pores in a size range of 1.5 mm (1/16 in) diameter to 5 mm (3/16 in) diameter shall not exceed 7 per linear 25 mm (1 in) of weld per 25 mm (1 in) of weld thickness. The maximum pore size shall not exceed 5 mm (3/16 in). Pores smaller than 1.5 mm (1/16 in) in diameter shall not be restricted in number.

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

**10.10.4 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 3 mm (1/8 in), unless specifically approved by the Customer.

**10.10.5 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 100 mm (4 in) in any 300 mm (12 in) of weld. Incomplete fusion defects that appear to be continuous from one bead or layer to the next shall be unacceptable regardless of length.

**10.10.6 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 3 mm (1/8 in), unless specifically approved by the Customer.

**10.10.7 Melt-Through.** The length of any unrepaired excessive melt-through shall not exceed the base metal thickness.

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

**10.11 Macroetch Test Acceptance Criteria.** Slag and porosity shall not exceed 5% of the surface area, and the maximum dimension of any discontinuity shall not exceed 2 mm (3/32 in). Linear indications of 1.5 mm (1/16 in) and less shall be acceptable when associated with the root of partial penetration and backing bar groove welds, provided such adjacent linear indications are separated by at least 3 mm (1/8 in).

**10.12 Fillet Weld Break Test Acceptance Criteria.** To pass the visual examination prior to the break test, the weld shall present a reasonably uniform appearance and shall be free of cracks and undercut in excess of the requirements of 10.9.

The broken specimen shall pass if:

(1) The specimen bends flat upon itself, or

(2) The fillet weld, if fractured, has a fracture surface showing complete fusion to the root of the joint, but not necessarily beyond, with at least 90% of the joint length with no inclusion or porosity (including piping porosity) exceeding 5 mm (3/16 in) in greatest dimension, and

(3) The sum of these discontinuities up to 5 mm (3/16 in) in the greatest dimension shall not exceed two (2) per 25 mm (1 in) of weld length nor eight (8) per 150 mm (6 in).

(4) Discontinuities less than 1.5 mm (1/16 in) shall be ignored.

## Table 10.1
## Welding Procedure Qualification—Number and Type of Test Specimens for Class B Welds[a]

| Coupon | Joint Type | Coupon Thickness, mm (in) | Visual (See 8.9 and 8.10) | Radiographic (See 8.11 and 8.12) | Reduced Section Tension (See 7.10.1) | Fillet-Weld-Shear (See 7.10.8) | Bends[b] (See 7.11.3) Root and Face | | Bends[b] (See 7.11.3) Side | Macroetch Test (See 7.10.2) | Vickers Hardness (See 7.10.6)[c] | Charpy Impact[c] (See 7.10.5) | Fillet Weld Break (See 7.10.7) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plate | Groove[d] | T ≤ 10 (3/8) | Yes | Yes | 2 | 0 | 2 each | | 0 | 1 | 1 | WM and HAZ | 0 |
| | | 10 (3/8) < T < 20 (3/4) | Yes | Yes | 2 | 0 | 2 each | or | 4 | 1 | 1 | WM and HAZ | 0 |
| | | T ≥ 20 (3/4) | Yes | Yes | 2 | 0 | 0 | | 4 | 1 | 1 | WM and HAZ | 0 |
| Pipe | Groove[d] | T ≤ 10 (3/8) | Yes | Yes | 2 | 0 | 2 each | | 0 | 1 | 1 | WM and HAZ | 0 |
| | | 10 (3/8) < T < 20 (3/4) | Yes | Yes | 2 | 0 | 2 each | or | 4 | 1 | 1 | WM and HAZ | 0 |
| | | T ≥ 20 (3/4) | Yes | Yes | 2 | 0 | 0 | | 4 | 1 | 1 | WM and HAZ | 0 |
| Plate | Fillet | All[e] | Yes | No | 0 | 1 | 0 | | 0 | 2[f] | 1 | WM | 1[f] |
| Pipe | Fillet | All[e] | Yes | No | 0 | 1 | 0 | | 0 | 4[f] | 1 | WM | 4[f] |

a First position only. Qualification for additional positions will omit groove weld tension, Vickers HV10, Charpy tests, and fillet weld shear strength 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 10 mm (3/8 in) and 20 mm (3/4 in) thick, the Customer may specify either two root and two face-bend tests or four side-bend tests.
c Vickers Hardness and Charpy Impact tests are not applicable to austenitic stainless steel base metal.
d Only groove welds require radiography.
e Multiple-pass fillet welds are considered qualified by groove weld qualification (7.8.2).
f For single-pass welds, the qualification weld size shall be the maximum size to be performed in production. For multiple-pass welds, the qualification shall be the minimum to be welded in production.

Note: HAZ Charpy impact testing is not required for qualification of wet welding procedures. WM = weld metal; HAZ = heat-affected-zone.

## Table 10.2
## Welding Procedure Qualification—Mechanical Test Acceptance Criteria for Class B Welds

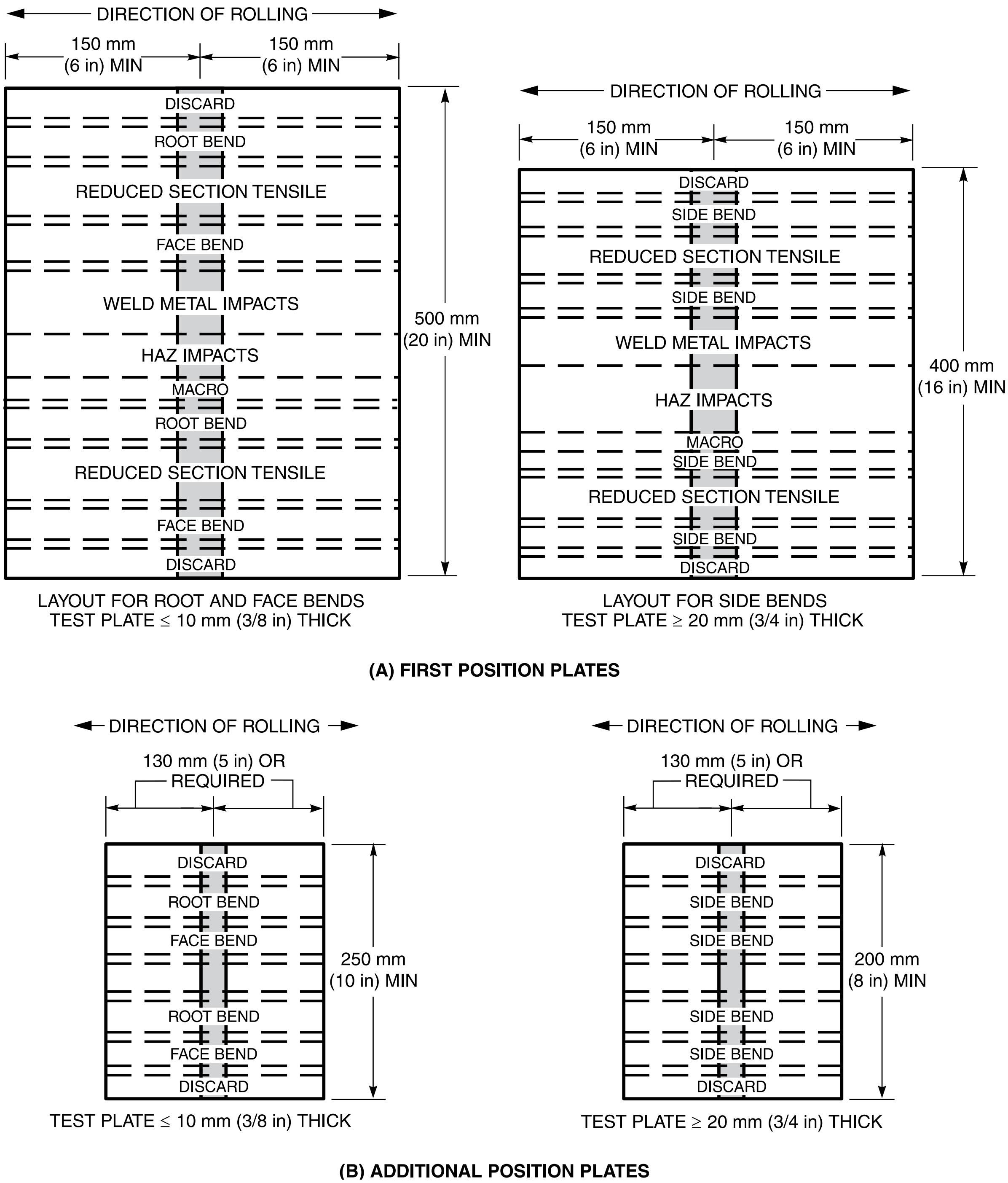
| Base Metal Minimum Specified Tensile Strength | Bend Specimen Maximum Bend Radius[a] | Weld Metal and HAZ Charpy V-Notch Impact Test | | Maximum Vickers HV10[b] |
|---|---|---|---|---|
| | Figure 7.12 | Average Energy | Minimum Energy | |
| 485 MPA (70 ksi) and below | 6T | 20J (15 ft-lb) | 14J (10 ft-lb) | 375 HV10 |
| Over 485 MPA to 550 MPA | 6T | 27J (20 ft-lb) | 19J (14 ft-lb) | 375 HV10 |
| Over 550 MPA (80 ksi) | 6T | 34J (25 ft-lb) | 23J (17 ft-lb) | 375 HV10 |

[a] See also 10.3.2.4.
[b] See 10.3.2.5.

## Table 10.3
## Welder Performance Qualification—Number and Type of Test Specimens for Class B Welds (Per Welder)

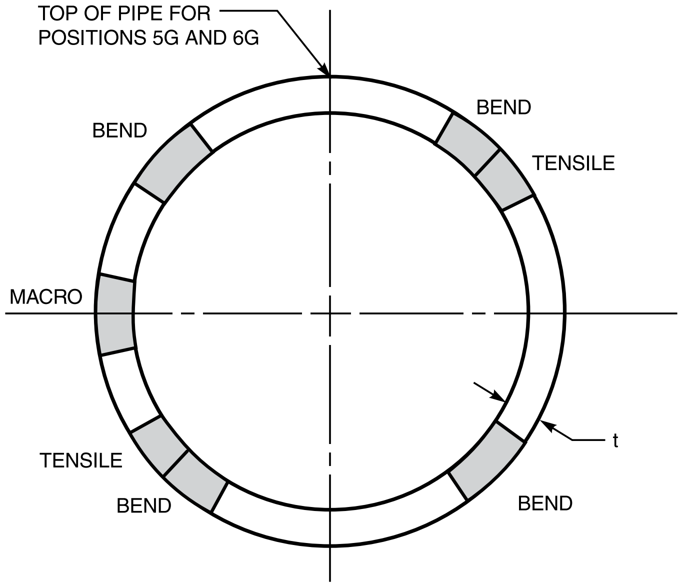
| Coupon | Joint Type | Thickness Tested, mm (in) | Visual (See 8.9 and 8.10) | Radiographic (See 8.11 and 8.12) | Bends[a] (See 7.10.3) Root and Face | | Bends[a] (See 7.10.3) Side | Macro[b] | Fillet Weld Break (See Figure 7.8) |
|---|---|---|---|---|---|---|---|---|---|
| Plate | Groove | T ≤ 10 (3/8) | Yes | Yes[c] | 2 each | | – | – | – |
| | | 10 (3/8) < T < 20 (3/4) | Yes | Yes[c] | 2 each | or | 4 | – | – |
| | | T ≥ 20 (3/4) | Yes | Yes[c] | – | | 4 | – | – |
| Pipe | Groove | T ≤ 10 (3/8) | Yes | Yes[c] | 2 each | | – | – | – |
| | | 10 (3/8) < T < 20 (3/4) | Yes | Yes[c] | 2 each | or | 4 | – | – |
| | | T ≥ 20 (3/4) | Yes | Yes[c] | – | | 4 | – | – |
| Plate | Fillet | All | Yes | – | – | | – | 2 | 1 |
| Pipe | Fillet | All | Yes | – | – | | – | 4 | 4 |

[a] For plate and pipe between 10 mm (3/8 in) and 20 mm (3/4 in) thick, the Customer may specify either root and face bends or side bends.
[b] See 7.10.2, 10.7 and Figures 7.8, 10.1, or 10.2. Hardness tests not required.
[c] Three macros may be substituted (see 10.6.1).



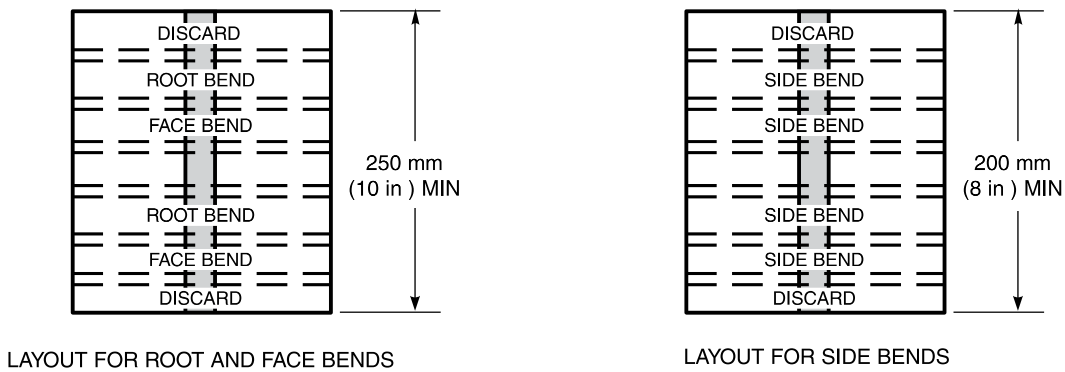

Note: For plates between 10 mm (3/8 in) and 20 mm (3/4 in) thick, the Customer may specify root and face bends or side bends.

**Figure 10.1—Location and Types of Test Specimens on Welded Plate Test Procedure Qualification Assembly, Class B Groove Welds**

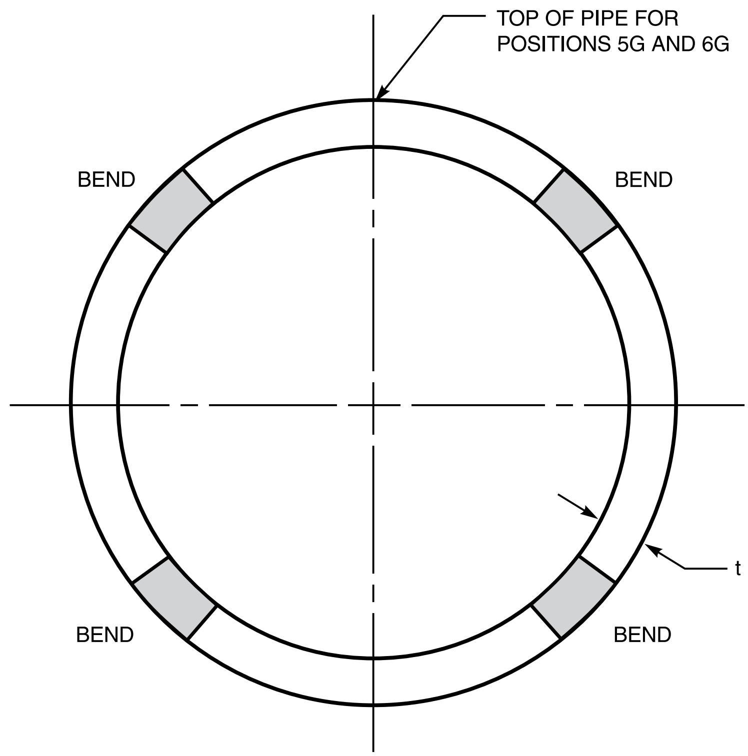



Notes:
1. If the pipe diameter is too small to permit all specimens to be machined from a single weld, additional welds shall be made to provide sufficient material for testing.
2. First position weld: test all specimens shown. Additional position welds: use bend specimens only.
3. Type of bend specimens to be used:
   a. t ≤ 10 mm (3/8 in)—Two root and two face bends.
   b. t ≥ 20 mm (3/4 in)—Four side bends.
   c. T between 10 mm (3/8 in) and 20 mm (3/4 in), the Customer may specify root and face or side bends.
   d. Specimen geometry as described in Figures 7.7, 7.10, and 7.11.

**Figure 10.2—Location and Types of Test Specimens on Welded Pipe Test Procedure Qualification Assembly, Class B Groove Welds in Pipe**




**(A) FOR PLATE**




**(B) FOR PIPE**

Notes:
1. t ≤ 10 mm (3/8 in)—Two root and two face bends.
2. t ≥ 20 mm (3/4 in)—Four side bends.
3. t between 10 mm (3/8 in) and 20 mm (3/4 in), the Customer may specify root and face or side bends.
4. Specimen geometry as described in Figures 7.7, 7.10, and 7.11.
5. For rectangular tubing, rotate the location of the bend and tensile specimens approximately so that they are centrally located on the flat faces.
6. For plates between 10-mm (3/8-in) and 20-mm (3/4-in) thick, the Customer may specify root and face bends or side bends (for pipe).

**Figure 10.3—Type and Location of Bend Test Specimens for Welder Performance Qualification, Class B Groove Welds**

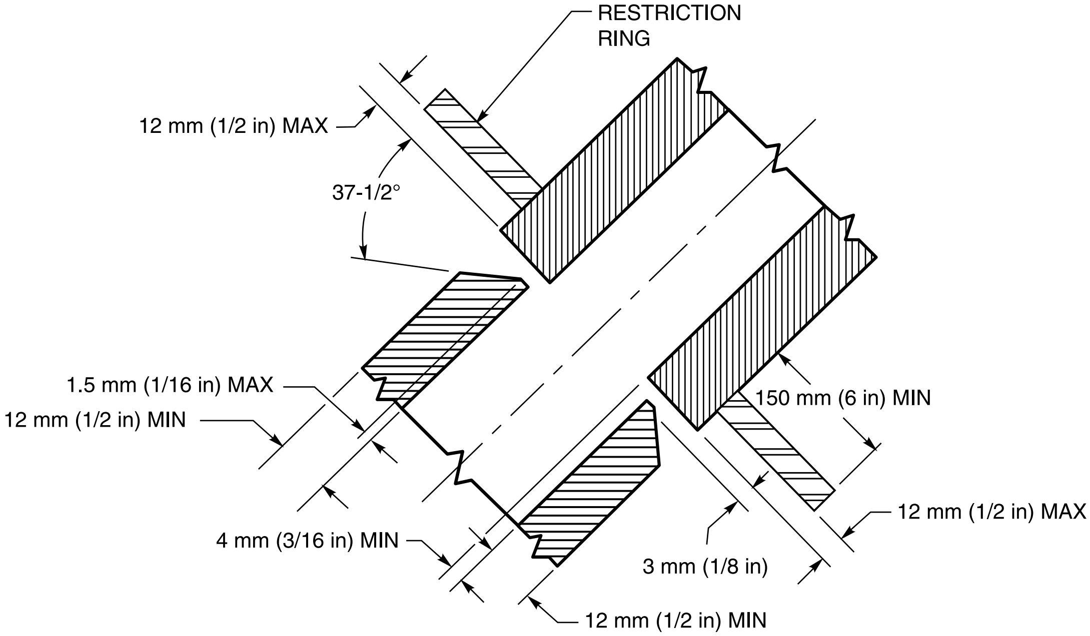



**Figure 10.4—Test Assembly for T-, Y-, and K-Connections on Pipe or Square or Rectangular Tubing—Welding Procedure and Welder Performance Qualification, Class B Welds**

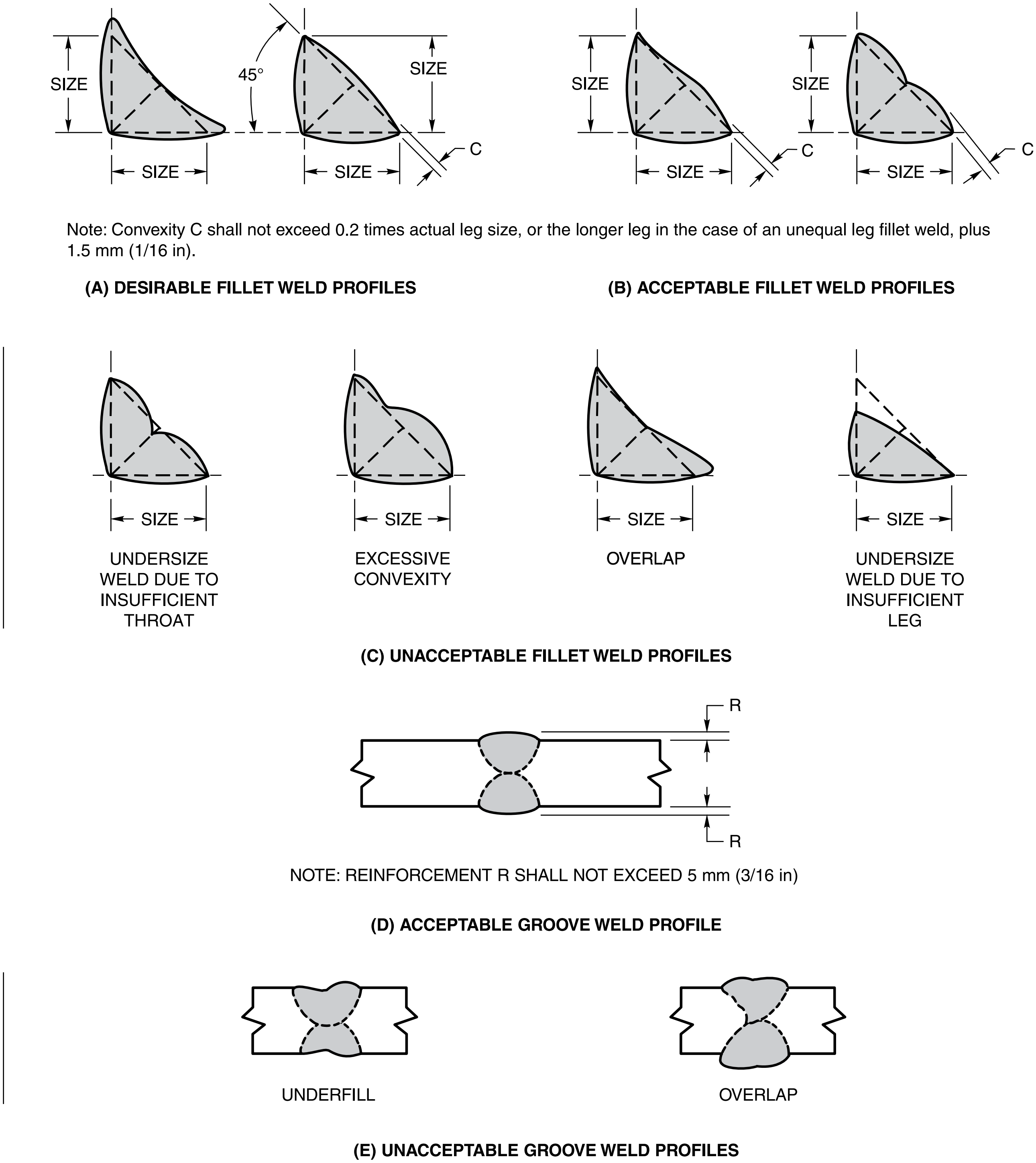



**Figure 10.5—Acceptable and Unacceptable Weld Profiles for Class B Welds**

# 11. Class O Welds

**11.1 Application.** The requirements of this clause 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. Class O welds shall also meet the requirements identified in this clause.

**11.1.1** Welding procedure specifications for Class O welds shall be qualified in accordance with the general requirements of Clause 7, Parts I and II, and the specific requirements of Part I of this clause.

**11.1.2** All welders, including tack welders, making Class O welds shall be qualified prior to production welding in accordance with the general requirements of Clause 7, Parts I and III, and the specific requirements of Part II of this clause.

**11.1.3** 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 clause.

## *Part I*
## *Welding Procedure Qualification*

**11.2 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 11.1. (Refer also to 7.5.)

**11.3 Groove Welds**

**11.3.1 Test Specimens.** Welded test assemblies shall satisfy the dimensional requirements of the standard designated by the Customer. Provision should be made to remove a macroetch test specimen 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 Figures 7.13 and 7.14. (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. When specified by the Customer, a bridge bend test shall be required for nonstructural welds or weld overlays. Refer to 7.10.9 and Figure 7.19.

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

**11.3.2.1** The visual and nondestructive examination acceptance criteria and mechanical property requirements shall satisfy the standard designated by the Customer.

**11.3.2.2 Radiography.** Radiographic examination is to be required for groove welds and shall satisfy the designated standard for production welds.

**11.3.2.3 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 elongation requirement for Class A shall apply.

**11.3.2.4 Macroetch Test.** Macroetch test specimen transverse to the weld shall reveal no cracks at 5× 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 clause).

**11.3.2.5 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 as specified by the referenced standard or by the Customer.

**11.4 Fillet Welds**

**11.4.1 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 test specimen. A groove weld shall be produced in accordance with Figure 7.13 for the all-weld-metal tensile and the Charpy V-notch weld-metal tests.

**11.4.2 Test Results.** The provisions of 11.3.2.1 and 11.3.2.3 through 11.3.2.5 shall apply to fillet weld test results.

## *Part II*
## *Welder Performance Qualification*

**11.5 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 7.14.

## *Part III*
## *Examination*

**11.6 Examination Requirements.** All Class O welds shall, as a minimum, be visually examined in accordance with Clause 8, 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.

**11.7 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.

## Table 11.1
## Welding Procedure Qualification—Number and Type of Test Specimens for Class O Welds[a]

| Coupon | Thickness mm (in) | Visual (See 8.9 and 8.10) | Radiographic (See 8.11 and 8.12) | Reduced Section Tension (See 7.10.1) | Fillet Weld Shear[b] (See 7.10.8) | All-Weld-Metal Tension (See 7.10.4) | Root, Face, and Side Bends | Macroetch Test (See 7.10.2) | Vickers Hardness[c] (See 7.10.6) | Charpy[c] (See 7.10.5) | Fillet Weld Break[b] (7.10.7) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| All | All | Yes | Note[d] | Note[e] | 0 | 1 | Note[e] | 1 | 1 | Note[e] | Note[e] |

[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 7.8.2.)
[c] Vickers Hardness and Charpy Impact tests are not applicable to austenitic stainless steel.
[d] Groove welds only are radiographed.
[e] 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.

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# Annex A (Informative)
# Sample Forms

This annex is not part of this standard but is included for informational purposes only.

This annex contains four (4) forms that the D3 Committee has approved for the recording of procedure and welder performance qualification data required by this code. References in parentheses identify applicable clause or tables of D3.6M concerning the variables. Also included are laboratory report forms for recording the results of ultrasonic examination of welds.

A–1 Welding Procedure Specification—Wet Welding and Dry Hyperbaric Welding

A–2 Procedure Qualification Record

A-3 Ultrasonic Examination Report Form

A-3A Ultrasonic Examination Report Form (U.S. Customary Units)

| | |
|---|---|
| Customer | Job No. |
| Procedure No. | Date |
| Revision No. | Date |
| Welding Process(es) | |
| Contract No. | |
| | |

**Form A–1—Welding Procedure Specification—Wet Welding and Dry Hyperbaric Welding**

| GENERAL DATA | |
|---|---|
| Client | |
| Location | |
| Certifying Authority | |
| Welding Code | |
| Weld Class | |

| ENVIRONMENTAL DATA | |
|---|---|
| Water Depth | |
| D.W.C. Gas | |
| D.W.C. Pressure | |
| D.W.C. Temp. (est) | |
| D.W.C. Humidity | |

| JOINT DETAILS | |
|---|---|
| Design | |
| Backing | |
| Position | |
| Alignment Clamp | |

| JOINT DESIGN SKETCH |
|---|
| |

| JOINT DETAILS | |
|---|---|
| Material Spec. | |
| Wall Thickness | |
| Carbon Equiv. | |

| WELDING CONSUMABLES | | |
|---|---|---|
| Process | Type | Size |
| FCAW | | |
| GTAW | | |
| SMAW | | |

| DOUBLER PLATE MATERIAL | |
|---|---|
| Material Spec. | |
| Wall Thickness | |
| Carbon Equiv. | |

| PRE-HEAT | | |
|---|---|---|
| Temp. °C (Min) | Interpass Temp. (Max) | Heater Type |
| | | |

| TECHNIQUE |
|---|
| |
| |
| |

**Form A–1 (Continued)—Welding Procedure Specification—Wet Welding and Dry Hyperbaric Welding**

| OTHER PROCESS DATA | | | |
|---|---|---|---|
| Item | FCAW | GTAW | GMAW |
| Torch | | | |
| Gas Shroud | | | |
| Electrode | | | |
| Arc Length | | | |

| WELD PASS SEQUENCE | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |
| Pass | Progress | DC Polarity | Volts | Amps | Speed | Oscillation |
| | | | | | | |

| TESTING/INSPECTION REQUIREMENT | | |
|---|---|---|
| Procedure Qual. | Welder Qual. | Operational |
| | | |
| | | |
| | | |
| | | |
| | | |

**Form A–1 (Continued)—Welding Procedure Specification—Wet Welding and Dry Hyperbaric Welding**

| ANY OTHER RELEVANT SPECIAL DATA |
| --- |
| |

| APPLICABLE PROCEDURE SPECIFICATION APPENDIX SHEETS |
| --- |
| |
| |
| |
| |
| |
| |
| |
| |
| |
| |
| |
| |

**Form A–1 (Continued)—Welding Procedure Specification—Wet Welding and Dry Hyperbaric Welding**

| **PQR Number:** | **Procedure Qualification Record** | **Page 1 of 3** |
|---|---|---|
| Contractor: | | |
| WPS# | Code/Standard | |
| Process: | Welding Positions Qualified: | Weld Class: |
| Manual | Description Of Welding Qualified - Scope: | Date: |
| Machine | | |
| Auto | | Depth: |
| Semi-Auto | Reference Documents: | |

| **Base Materials** | | | |
|---|---|---|---|
| Thickness: | Material: | Heat#: | Grade: |
| C%: C.E.: | Min. Tensile Strength: | | Spec: |
| Material Fabrication Method: | | | |
| Range Of Material Qualified: | | | |
| Nominal O.D. & W.T. Welded: | | | |
| Range Qualified: | | | |
| Nominal I.D.: | | | |
| Chemistry/Range Qualified: | | | |

| **Joint Design** | **Bead Sequence** |
|---|---|
| | |

**Welding Parameters**

| **Layer** | **Root** | **Hot Pass** | **Fill 1** | **Fill(s)** | **Cap Passes** |
|---|---|---|---|---|---|
| Travel Direction | | | | | |
| Weld Process | | | | | |
| Filler Wire/Rod | | | | | |
| Trade Name | | | | | |
| Country of Origin | | | | | |
| Batch # | | | | | |
| Filler Diameter | | | | | |
| Added Coatings | | | | | |
| Chemical Analysis | | | | | |
| AWS Spec. | | | | | |
| AWS Class. | | | | | |

**Approvals - Name - Signature - Date**

| | | | | | |
|---|---|---|---|---|---|
| | | | | | |

**Form A–2—Procedure Qualification Record**

| PQR# | Welding Parameters Cont'd | | | Page 2 of 3 | |
|---|---|---|---|---|---|
| | **Root** | **Hot Pass** | **Fill 1** | **Fill(s)** | **Cap Passes** |
| Power Source | | | | | |
| Polarity | | | | | |
| Arc Voltage | | | | | |
| Amperage | | | | | |
| Travel Speed | | | | | |
| Heat Input Range | | | | | |
| Interpass Temp. | | | | | |
| Stringer/Weave | | | | | |
| Shielding Gas | | | | | |
| Gas Flow Rate | | | | | |
| **Technique** | | | | | |
| Time Between Root & Hot Pass | | | | | |
| Time Between Hot Pass & 1st fill | | | | | |
| Exposure Time Of Filler Metals | | | | | |
| Temper Beads | | | | | |
| Water Barrier | | | | | |
| Part Of Root To Be Left Open | | | | | |
| Clamp Type | | | | | |
| Clamp Release | | | | | |
| Electrical Parameter Monitoring | | | | | |
| Number Of Welders | | | | | |
| Method of u/w Transport | | | | | |
| Interpass Cleaning Method | | | | | |
| Final Cleaning Method | | | | | |
| Preheat Method & Temp. | | | | | |
| Postheat Method & Temp. | | | | | |
| Temp. Monitoring Method | | | | | |
| **Environment** | | | | | |
| Water Depth | | | | | |
| Water Current/Visibility | | | | | |
| Depth Range Qualified | | | | | |
| Length/Type Of Welding Umbilical | | | | | |
| Joint Backside/Pressure Diff. | | | | | |
| Background Gas | | | | | |
| **General** | | | | | |
| Welder(s) Name(s)/Number(s) | | | | | |
| Location of Qualification Test | | | | | |
| Coupon(s) I.D. / Witnessed By | | | | | |
| **Approvals - Name - Signature - Date** | | | | | |
| | | | | | |

**Form A–2 (Continued)—Procedure Qualification Record**

| PQR # | Testing Results | Page 3 of 3 |
|---|---|---|

| Specimen # | Width | Thickness | Area | Ult. Tensile | Ult. Unit Stress | Failure & Location |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

**Guided Bend Tests**

| Specimen # | Type Of Bend | Result | Remarks |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

**Visual Inspection**

| Coupon I.D. | Test Date | Undercut | Porosity | Weld Profile | Appearance | Witnessed By |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

**Fillet Weld Test Results**

| Coupon I.D. | | Fillet Weld Shear | | Fillet Weld Break | | Macroetch |
|---|---|---|---|---|---|---|
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

| | |
|---|---|
| Tensile strength: | Yield Point/Strength: |
| Elongation in 2 in. % values: Gauge Length:<br>Diameter: | |
| Attach Sheets For Any Vickers Hardness Tests | Attach Sheets For Any Charpy Tests |
| Welder's Name(s) | |

**Approvals - Name - Signature - Date**

| | | | | |
|---|---|---|---|---|
| | | | | |

**Form A–2 (Continued)—Procedure Qualification Record**

ALL DIMENSIONS
IN MILLIMETERS

NDT COMPANY NAME

NONDESTRUCTIVE EXAMINATION REPORT

| | |
|---|---|
| JOB NO. | |
| WELD NO. | |
| DATE | |

PART IDENTIFICATION

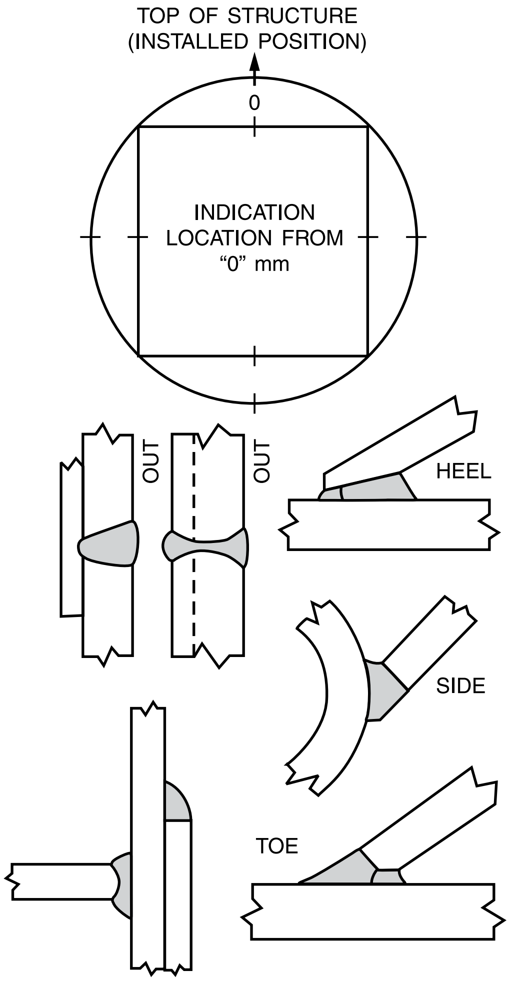
ENVIRONMENT

NDE METHOD: ☐ UT ☐ MT ☐ PT ☐ RT ☐ ______________

NDE PROCEDURE NO.: TECHNIQUE:

EQUIPMENT USED:


INDICATION LOCATION AND EVALUATION




| INDICATION NO. | LENGTH | UT ONLY: HEIGHT | UT ONLY: AMP CAT. | LOCATION FROM “0” | ACCEPT | REJECT | COMMENTS |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

| UT AMPLITUDE CATEGORY | 2 DRL–ARL | 3 OVER ARL |
|---|---|---|

NDE TECH. ______________________

NDE CO. ______________________

______________________
INSPECTOR

**FORM A-3–Ultrasonic Examination Report Form**

DIMENSIONS
ARE IN INCHES

NDT COMPANY NAME

NONDESTRUCTIVE EXAMINATION REPORT

JOB NO.
WELD NO.
DATE

PART IDENTIFICATION

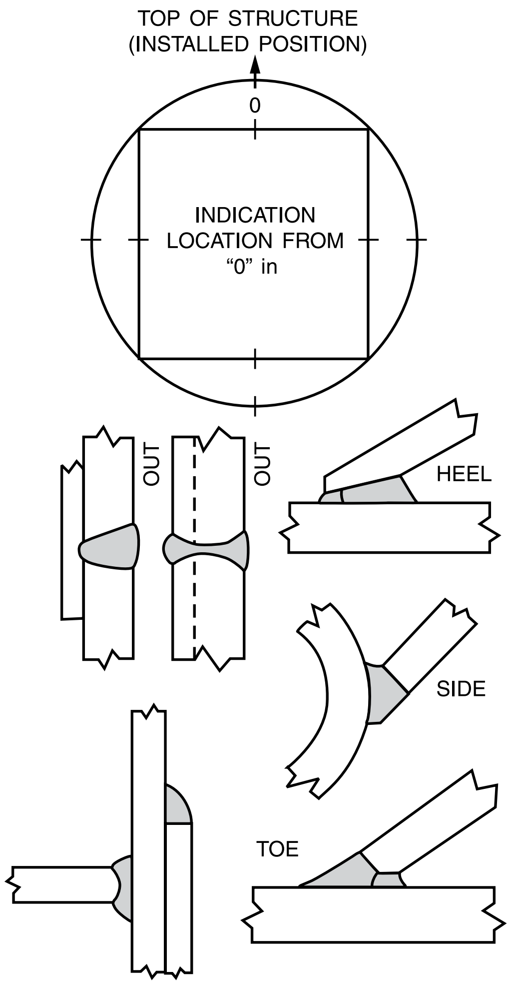
ENVIRONMENT

NDE METHOD: ☐ UT ☐ MT ☐ PT ☐ RT ☐ ____________

NDE PROCEDURE NO.: TECHNIQUE:

EQUIPMENT USED:


INDICATION LOCATION AND EVALUATION




| INDICATION NO. | LENGTH | UT ONLY | | LOCATION FROM "0" | ACCEPT | REJECT | COMMENTS |
|---|---|---|---|---|---|---|---|
| | | HEIGHT | AMP CAT. | | | | |
| | | | | | | | |

| UT AMPLITUDE CATEGORY | 2 DRL–ARL | 3 OVER ARL |
|---|---|---|

NDE TECH. ____________

NDE CO. ____________

____________
INSPECTOR

**FORM A-3A–Ultrasonic Examination Report Form (U.S. Customary Units)**

# Annex B (Informative)
# Recommended Guidelines for Safety in Underwater Welding

This annex is not part of this standard but is included for informational purposes only.

## B1. Scope

This annex is limited to recommended safe practices specifically related to underwater welding and associated work activities performed in either a dry (hyperbaric) or a wet environment. There are no assurances regarding accuracy, completeness, or thoroughness of these recommendations. Users should make an independent determination as to the appropriateness of these recommendations, both generally and as applied to a specific situation. Although these guidelines are presented as recommendations, many of their provisions are mandatory, depending on the legal jurisdiction applicable at the work location. For additional recommendations applicable to safety in underwater welding, and for requirements and recommendations applicable to diving and diver safety, see the references at the end of this annex.

## B2. Safe Practices/Operations Manual

Each contractor involved in diving activities involving underwater welding should develop and maintain a safe practices/operations manual which reflects, as a minimum, all legal regulations applicable to the specific work location. This manual should be made available at the dive location to each dive team member. The operations manual should include, in addition to diving safety procedures, procedures dealing with the use of hand-held power tools and welding and thermal cutting equipment.

## B3. Communications

Two-way communications should be available and accessible at any diving or hyperbaric work site in order to engage emergency services as required. In addition, when underwater welding or cutting is to be performed, constant two-way voice communications should be maintained between the diver and a topside supervisor or tender in control of the welding or cutting equipment.

## B4. Electrical Equipment

All underwater electrical equipment powered from topside should be equipped with a ground fault interrupter (GFI), between the power source and the tool. Alternating current (ac) circuits should never be used for manual or diver-assisted welding or cutting activities beneath the surface of the water.

Welding machine frames should be securely grounded. Welding and cutting cables, electrode holders, and connections should be properly insulated and capable of carrying the maximum current required for the work.

Welding and thermal cutting electrical circuits should have a positive disconnect switch. The switch should remain open at all times except during actual welding or cutting. When an electronically actuated switch is used for routine circuit activation, a manual emergency disconnect should be within easy reach of the person tending the switch.

## B5. Hand-Held Power Tools

All hand-held electric power tools should comply with the requirements of B4. All hand-held hydraulic and pneumatic power tools should have a constant pressure switch or control which causes the tool to stop upon release.

## B6. Preparation for Work

A job hazard analysis, or tailboard, should be held prior to each diving task, before any hand-held power tools are used, and before any welding or thermal cutting is performed.

A predefined method for welder direction to energize and de-energize the welding or cutting circuits, including supervisor or tender acknowledgment of action taken, should be established and agreed upon prior to any underwater welding or electrode-thermal cutting. It should be emphasized to the welder that the circuit must be opened prior to touching or changing any electrode.

All required equipment should be inspected prior to use to ensure that it is in safe operating order. All electrical devices and umbilicals should be inspected carefully before all operations, and prevented from becoming abraded or cut over sharp edges. GFI circuits should be tested prior to, and at regular intervals throughout, the operation.

All hand-held electrical tools and equipment, including hand-held electrical equipment inside bells and habitats, should be de-energized at the surface before being placed into or retrieved from the water.

Insulated gloves should be worn by the diver while engaged in underwater welding and cutting. Insulated gloves should also be worn whenever handling any electrical equipment or cables underwater—including de-energized components.

Prior to thermal cutting or welding on closed compartments, structures or pipes which contain a flammable vapor or in which a flammable vapor may be generated by the work, should be vented, flooded, or purged with a mixture of gases which will not support combustion. (This is not mandatory for “hot-tapping” operations.)

Underwater habitats should be continuously monitored for the presence of excessive amounts of toxic, asphyxiating, narcotic, and explosive gases. For example, these include, argon and carbon dioxide (used by the welding procedure), helium (from mixed breathing gas), nitrogen (when used to offset partial pressure in the habitat), welding fumes including carbon monoxide (from the welding process), and hydrogen and oxygen (due to possible explosion).

## B7. Performance of Work

Hand-held power tools should only be supplied with power from the dive location when requested by the diver.

A current supply switch to interrupt the current flow to the welding or thermal cutting electrode should be tended by a dive team member in voice communication with the diver performing the welding or cutting, and kept in the open position except when the diver directs its closure for performance of welding or cutting.

## B8. Inspections and Examinations

Radiographic examination procedures should address the safety aspects of controlling and using radioactive sources. Equipment used to contain the sources should be designed and constructed in accordance with applicable regulatory standards for use in the underwater environment.

Use of alternating current (ac) for performance of diver-assisted examinations should be avoided. Where they are used, ac circuits should be totally isolated to prevent the possibility of electrocution.

## B9. References

(1) AWS *Welding Handbook*, 8th ed., Vol. 3, Chapter 10.

(2) *International Consensus Standards for Commercial Diving and Underwater Operations*,Latest ed., Houston, TX: Association of Diving Contractors International.

(3) OSHA 1910 (Subpart T)—Occupational Safety and Health Act. (Also issued as 29CFR Chapter XVII.)

(4) 46CFR Chapter 1, Subchapter V—Marine Occupational Safety and Health Standards, Part 197—Code of Federal Regulations.

(5) IMCA D045/IMCA R015—Code of Practice for the Safe use of Electricity Underwater.

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# Annex C (Informative)
# Commentary on AWS D3.6M:2017, Underwater Welding Code

This annex is not part of this standard but is included for informational purposes only.

## Foreword

This commentary on AWS D3.6M:2017, *Underwater Welding Code*, is primarily intended to provide clarification of its provisions, requirements, and intended applications. In addition, the commentary provides background information, where appropriate, to explain the rationale behind its unique requirements—especially those which differ from the common codes and specifications dealing with conventional surface, or "in-air" welding. In so doing, an attempt is made to reflect the bases for the requirements as discussed in D3B Subcommittee meetings and as substantiated by related research and development or practical application of the code.

This commentary is not intended to supplement the requirements of AWS D3.6M, but rather to provide an informative document for explanation, interpretation, and application of the code; as such, none of its provisions are binding. Comments or inquiries pertaining to this commentary are welcome and should be addressed to the Secretary, D3B Subcommittee, as indicated in the foreword to this code.

## Preface

It is the intention of the D3B Subcommittee on Underwater Welding to revise this commentary with each revision of the code. In this manner, the bases for all substantive changes will be provided concurrent with the changes.

## C1. General Requirements

**C1.2 Units of Measurement** In this code, a "hard" conversion between United States Customary and SI Units is generally reflected in the text—as well as in figures which do not have an ISO counterpart—in order to make the document more user-friendly. The hard conversion utilizes metric or U.S. integers and sizes wherever exact conversion is not technically necessary.

The metric figures incorporate, where applicable, equivalent standard metric coupon/specimen shapes and dimensions when provided by applicable ISO standards. In such cases, related test acceptance criteria have been adjusted to reflect disproportionate differences. Where a more appropriate metric standard detail exists, the customer is at liberty to utilize it—provided, of course, the test data is properly reconciled with the results stipulated in the code. In such cases, the subcommittee requests that the more appropriate metric standard be brought to its attention for future incorporation into the code.

### C1.4 Application

**C1.4.1** The early editions of the code contained various references to "Owner," "Customer," and "Inspector." These terms were intended to (respectively) relate to: (1) contractual, (2) engineering, design and approval, and (3) inspection aspects of the work. The subcommittee decided that all responsibilities should be under the auspices of one party—termed the Customer—who is responsible for formally delegating defined scopes of responsibility to those whom the

Customer selects. To assist the user of this code in identifying the nature and scope of individual responsibilities assigned to the Customer, a detailed listing of reference paragraphs has been provided in the Index under the heading "Customer."

**C1.6 Welding Process**

**C1.6.1** The five welding processes covered by this code are all suitable (under certain conditions) for dry underwater welding; however, only two have had substantial success in wet underwater applications—shielded metal arc welding (SMAW) and flux cored arc welding (FCAW).

# C4. Classification and Design of Welded Connections

**C4.1 Classification of Welds** The categorization of welds for underwater welding posed several questions for the D3B Subcommittee on Underwater Welding, including whether to categorize welding by the different processes or procedures used to produce the weld or to establish levels of quality reflecting the mechanical and physical properties achievable with underwater welding processes. The subcommittee ultimately chose the latter criterion as having the most meaning to the user community.

For the majority of underwater welding, it was decided to specify three types of welds representing three levels of quality: Class A, Class B, and Class O welds. It was also decided to provide the user with all of the qualification, installation, and examination requirements pertinent to these three types of welds in one stand-alone set of requirements, or code. In addition, it was recognized that in some situations the user would require a weld that met all of the obligatory codes and standards applicable to a weld made on the surface. Class O was created for these welds and was intended to imply that "other" requirements applied in addition to the unique requirements pertinent to the underwater environment. Since these three categories generally reflected levels of quality, the term was changed in the 1993 edition of AWS D3.6M from *type* to *class*.

**C4.1.4 Class A Welds.** Class A defines a stand-alone set of requirements for underwater welds intended to be comparable to welds produced above water in accordance with AWS D1.1 or ASME Section IX. This class of groove weld is qualified on the basis of visual and radiographic examination, reduced-section tension, all-weld-metal tension, 2T to 3–1/3T bends, macroetch, hardness and impact tests. Testing for fillet welds include fillet-weld-break and fillet-weld-shear tests. The acceptance criteria for all qualification testing, nondestructive examination, and inspection is very similar to the codes covering above-water welding.

Class A welding procedures are generally specified for most dry hyperbaric welding of ferritic and austenitic base metals [routinely for depths to 150 m (500 ft) and in some cases to 600 m (2000 ft)] and for shallow [less than 15 m (50 ft)] *wet* shielded metal arc or flux-cored arc welding of austenitic stainless steels. However some success has been achieved in qualifying wet SMAW welding for ferritic steel base metals to the requirements of Class A including bend test criteria. Conversely, wet flux cored arc welding of mild steel base metals has had limited success in meeting Class A requirements.

**C4.1.5 Class B Welds.** Class B defines an intermediate set of mechanical and examination requirements representing a slightly lower level of quality, but still resulting in a weld of predictable strength. Class B welds are intended for less critical applications where reduced ductility and increased porosity can be tolerated. The suitability of Class B welds for a particular application is intended to be evaluated on a fitness-for-purpose basis. Class B welds are qualified similarly to Class A, except that a larger bend radius (typically 6t) is used for qualification testing, and the acceptance limits of porosity for visual and radiographic tests are expanded. Class B requirements are generally applied for most *wet* welding of ferritic steel base metals at depths of from 0 to 50 m (150 ft.), with occasional applications to depths of 100 m (325 ft.). Class B is also used for welding of austenitic stainless steels at depths to about 25 m (75 ft.).

**C4.1.6 Class O Welds.** Class O invokes the qualification, installation, and examination requirements, including acceptance criteria, of some "other" code or standard applicable to above-water welding such as API–1104, as specified by the Customer. However, since the essential variables that must be incorporated into an underwater welding procedure are much more extensive than for a surface weld, this code takes precedence relative to essential variables for procedure and performance qualification.

Class O welding procedures are generally applicable to the same underwater welding conditions as noted above for Class A welds.

# C5. Workmanship

### C5.3 Assembly

**C5.3.1 Dry Welding.** The standard tolerances for joint preparation and fit-up provided in Figure 5.1 may be applied to dry welding. Alternatively, during development of dry welding procedures, the most restrictive groove angle, root opening, and root face may be tested [see A.1(f) of Table 7.1].

**C5.3.2 Wet Welding.** Joint designs typically utilized in the performance of underwater wet welding are generally more restrictive in nature, due to the limitations of the process. Position, steaming, bubbling effects, arc pressure, electrode diameter, deposition rates, and many other variables significantly affect the ability to make sound weldments in this environment. Consequently, joint designs should be as simple as possible, minimizing use of the overhead position. This code does not require that the extremes be tested, only that the most restrictive configuration be tested and qualified [see A.1(e) of Table 7.2]. However, the range or limits must be specified in the WPS (see 7.8.4).

### C5.4 Confirmation Weld

The purpose of the confirmation weld is to confirm that the welding system to be utilized at the underwater work site is functioning properly. It is not intended to be a retest of the procedure nor of welders who have already been qualified.

### C5.5 Dimensional Tolerances

Minimum specified size and length of welds must be satisfied to ensure that required design strengths are achieved. Limitations are imposed on the size of fillet welds and lengths of all welds for purposes of avoiding excessive distortion of the welded members.

### C5.7 Tack Welds and Temporary Welds

**C5.7.1** Tack welds are made with a fully qualified procedure since it is difficult, especially in wet welding, to completely remelt tack welds. Cracked tack welds should never be welded over since they can be generating points for faults and progressive cracking.

### C5.8 Repairs

For weldments requiring repair underwater, proper and careful excavation and subsequent preparation for welding can ensure that the remaining weld metal or base metal is not damaged. Excessive excavation for wet welded repairs can result in burnthrough which may be impossible to repair properly. In some cases, use of a mock-up sample may be necessary to pre-qualify a repair procedure. By using a properly developed and qualified repair procedure, most problems associated with the repair of weldments can be avoided, with the integrity of the finished product ensured.

#### C5.9.1 Ultrasonic Stress Relieving

The ultrasonic stress relieving process is used to reduce stress created during the welding process and improve fatigue properties of welded structures. The process plastically deforms the surface, mitigating harmful tensile stress and imparting beneficial residual compressive stress. The process is capable of driving compressive residual stress to depths of 0.250 in (6.3 mm) into thick fabrications and base material, an order of magnitude deeper than conventional shot peening. The application methods and techniques can be used to stress relieve weldments, reducing and/or eliminating surface tension and improving life of fatigue prone joints.

### C5.10 Arc Strikes

Arc strikes occurring outside of the weld area can result in untempered hardened and embrittled areas having a potential for micro-fissures which can cause crack-initiation and propagation, therefore all arc strikes encountered during underwater welding are removed with light grinding or filing in accordance with 5.8.2.

# C6. Technique

### C6.1 Filler Metal

Historically, the two most widely used electrode formulations for wet welding of carbon steel are derived from rutile (E6013 and E7014) electrodes. More recently, austenitic stainless steel electrodes are being used for wet welding stainless steel. The austenitic stainless steel electrodes and nickel-based electrodes are also being used for welding higher carbon equivalent steel; however, use of the austenitic stainless steel electrode is limited due to the tendency for diffusion zone cracking when the weld size or thickness exceeds 3/8 in (9.5 mm). For this dissimilar metal welding, the potential for galvanic corrosion should be considered. For dry hyperbaric welding, some low-hydrogen electrodes such as E7018M, are produced with improved moisture-resistant flux coatings. However, just meeting the AWS requirements for these classifications does not mean that a particular filler metal will be capable of producing the desired results underwater. Even a single manufacturer can produce several different types of filler metal fulfilling the requirements for a single AWS classification, and only one—or even none—may be suitable for underwater use.

Even for dry hyperbaric welding, moisture resistance of the flux coating can have a significant effect on the electrode's ability to resist humidity, such as that found in the underwater habitat. For these reasons, the code requires any change in electrode (AWS classification, manufacturer, manufacturer's trade name) to be an essential variable (reference Tables 7.1 and 7.2).

**C6.1.2** Waterproofing of electrodes, particularly for wet welding, is common practice. There are many different types and methods of waterproofing, and the different types or methods of coatings react in various ways on different electrodes. For example, one type of coating may work well on a mild steel electrode and not work at all on stainless steel. Even different coating thicknesses will cause a change in the way an electrode performs; a heavy coating will cause the arc to elongate, resulting in an increase in the arc voltage.

**C6.1.3** Transporting of electrodes for dry underwater welding is an essential variable due to the fact that getting the electrode to the work site could adversely affect the quality of the rod. Also, when a pressurized container is used for transport in either wet or dry underwater welding, the media used to pressurize the container should be the same as used during qualification, including moisture content of the pressurizing media. Once the rod is at the work site, it is important that the storage of the electrodes be consistent with that utilized during qualification testing, since once an exposure and storage method has been established, any variation in that process creates unknown variables that can have adverse effects on the mechanical properties of the production welds.

Standard electrode coatings and supplemental coatings (particularly those used for waterproofing purposes) have been found to deteriorate after lengthy submergence in the wet environment or high-humidity atmospheres associated with dry underwater welding. Since such deterioration adversely impacts the weldability of the filler metal, the time of exposure underwater is also considered an essential variable and is required to be established during qualification testing and defined in the WPS.

**Austenitic Stainless Filler Metal.** Because of the influence of ferrite in preventing hot-cracking in austenitic materials, average delta ferrite content of austenitic filler metal is often considered an important factor in wet underwater welding of stainless steel, and even when stainless filler metal is used on carbon or alloy steel base metals. Use of austenitic filler metal with average ferrite content of 7FN or greater has proven to significantly reduce the potential for hot-cracking. The amount of undiluted delta ferrite, or ferrite number, can be determined from an analysis of the chemical composition of the weld metal using the latest WRC constitution diagrams or from direct ferrite measurement of weld metal in accordance with AWS A5.4/A5.4M, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*.

# C7. Qualification—Procedure and Performance

## *Part I*
## *General Requirements*

Underwater welding procedure and performance qualification requirements must take into consideration factors which are not applicable to surface welding qualification testing. Such factors as increased weldment cooling rate, arc constriction due to pressures at depth, and high-hydrogen arc atmospheres, among others, require some degree of additional qualification testing as compared with surface welding.

The qualification requirements of this code consider the fact that the final welded fabrication will not be as accessible for subsequent inspection as a fabrication welded on the surface. Accordingly, these requirements are intended to provide a reasonable degree of confidence in the lifetime structural integrity of weldments produced using the procedures and personnel qualified in accordance with this code.

**C7.1.3 Previous Qualification**

It is up to the Customer to ensure that all of the applicable essential variables (for both procedure and performance qualifications) are met. The review and approval of previous qualification documents should be carried out by someone who is familiar with reviewing welding documents and with the requirements of this code.

**C7.2 Welder Performance Qualification**

If a welder/diver qualifies to a Class A procedure and all essential variables from Table 7.2 are the same the welder/diver is also qualified to weld production welds that are designated Class B.

**C7.4.2 Limitations on Essential and Nonessential Variables.** The number and type of essential variables are quite different for underwater welding than for surface welding. This is necessary because of differences in welding in the underwater environment and the effects of changes (i.e., depth, diving mode) in the underwater environment. It will be noted that filler metal manufacturer is an essential variable; this is because filler metals from different manufacturers, although of the same AWS classification, may produce different results underwater (see Commentary, C6.1). It will also be noted that base metal chemical composition controls are generally tighter with respect to the essential variables; this is due to the higher propensity for base metal cracking as cooling rates are increased (see C7.5.1.3).

Almost every variable that can have an influence on heat input is essential for wet welding. Better welding quality is typically achieved using small diameter electrodes in a stringer-bead technique. Multi-layer beads—especially using promptly applied temper-bead techniques—are also very beneficial in wet ferritic applications, as are quickly applied postweld heat treatments. Such methods can reduce the amount of absorbed hydrogen, as well as reduce hardness in the heat-affected zones of the base metal.

**C7.5 Procedure Qualification Variables**

**C7.5.1 Requirements for Base Metals**

**C7.5.1.3** Carbon steels preferred for general-purpose wet welding are those with a carbon content of less than 0.10% and a carbon equivalent (CE) of less than 0.37%. Steels with CE greater than 0.37% have a tendency for hydrogen-induced cold cracking (HICC), depending on the carbon content, and may require utilization of special materials and/or techniques. Carbon steels with a carbon equivalent approaching 0.40 have been successfully wet welded with ferritic electrodes where the carbon content was less than 0.10. Since the carbon is the strongest factor in influencing HICC in the carbon equivalent formula, a low carbon content can justify a higher carbon equivalent. Based on these observations, the importance of the use of qualification test base material, with a carbon content and carbon equivalent at least as high as that of the material to be welded in production, cannot be overemphasized.

The cracking effect due to hydrogen contamination can be reduced by application of the stringer bead technique or use of temper beads. In the latter case, it is essential that the tempering layer be applied very soon (typically less than one minute) after deposition of the previous bead. Another approach in the elimination of HICC is the use of nickel-based electrodes. The nickel can hold more hydrogen in solution than ferritic weld metal, greatly reducing the hydrogen in the heat-affected zone of the carbon steel base metal. Nickel-based electrodes have been successfully used on carbon steels and low alloy quenched and tempered steels with carbon equivalents over 0.50.

With respect to underwater dry chamber or dry habitat welding, preheating and/or postheat treatment can eliminate the potential effects of a high carbon equivalent. Again, qualification testing using a base material, with a carbon content and carbon equivalent at least as high as that of the material to be welded in production, is important.

**C7.5.1.4** When the following elements are known to exist in the base metal in amounts exceeding the indicated weight percentages, consideration should be given to requiring similar percentages of those elements in the welding procedure qualification test plates.

(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) niobium (columbium), 0.05%

(8) phosphorous, 0.05%

(9) sulfur, 0.05%

(10) titanium, 0.05%

(11) vanadium, 0.12%

The presence of elements above these percentages is generally indicative of a special alloy or nonferritic base metal.

**C7.5.2 Depth Range**

**C7.5.2.1** The gas absorption of molten material is directly related to the surrounding pressure and the temperature of the molten material. The higher the surrounding pressure or temperature of the liquefied materials, the more the gas that can be absorbed. This is a reversible process. High cooling rates can therefore lead to entrapped gas due to a reduced solubility in solidified material. During solidification, the entrapped gas cannot evaporate from the warmer inner part through the rigid shell. This will then lead to a gas bubble (pore) in the cooled weldment. The deeper the operational depth in which the welding process is applied, the higher will be the pore formation.

Because different filler metals have different levels of sensitivity to water depth/pressure, Table 7.3 has different depth limitations for mild steel, austenitic stainless steel, and nickel-based or other filler metals. The limitations are based on the experience that wet welding procedures have been qualified with carbon and low alloy steel electrodes down to 100 m (325 ft).

The maximum qualification depth for nickel-based wet welding electrodes is yet to be established. All-position fillet welding has been qualified to a depth of 14 m (45 ft.). All-position groove welding has been qualified to a depth of 10 m (33 ft). Testing to date indicates that 10 m (33 ft.) will be the maximum qualification depth for overhead groove welding due to propensity for excess porosity. Maximum qualification depth for austenitic stainless steel filler metal is reported to be 30 m (90 ft).

**C7.7 Position of Test Welds**

The International Standard Organization (ISO) welding position designations (reference ISO 6947) are used in this document. There presently are no ISO designations for 6GR (for T-, Y-, K-connection full-penetration groove joints).

In wet welding, the flat and horizontal positions are usually the simplest with which to weld in the underwater environment. Vertical-down, because of the rapid cooling effects of water, is usually the preferred direction for wet underwater welding, resulting in good welder visibility and a bead with soft, smooth shape. Uphill welding typically results in increased undercut and rough bead transitions with a propensity for slag inclusions. Overhead is the most difficult position in wet welding, due to presence of gas bubbles which can obstruct the visibility of the arc and weld puddle, causing the welder to utilize an increased arc length.

**C7.8 Joint Design**

Table 7.1 (dry welding) and Table 7.2 (wet welding) include joint configurations as essential variables. Joints that may be welded underwater can vary from simple to complex. Joint design is included as an essential variable due to the effects of groove shape on the quality of the weld that is produced.

**C7.10 Preparation and Testing of Specimens**

**C7.10.1 Reduced-Section Tension Specimens.** Reduced-section tension specimens are used to confirm the tensile strength suitability of the underwater weldment for the intended application. The dimensions of the reduced-section tensile specimens are identical to those required by AWS D1.1/D1.1M. To comply with the requirements of ISO 4136, the width of the tensile specimens for metric plate tests was increased to 25 mm (1 in).

**C7.10.2 Macroetch Test.** Macroscopic examinations ensure, in addition to overall weld quality, the absence of cracking in the weld metal and adjacent base metal. Hydrogen-induced underbead cracking can be a problem, especially when wet welding the higher carbon equivalent base metals.

Suitable etchants may include those described by ASTM E340, *Standard Test Method for Macroetching Metals and Alloys*, ISO 4969, *Etching method for macroscopic examination*, AWS B2.1/B2.1M, *Specification for Welding Procedure and Performance Qualification*—Annex F, or *ASME Boiler and Pressure Vessel Code, Section IX* QW–470.

Macroetch specimens may also be used for hardness testing. It is important that the two machined surfaces are parallel in order to produce meaningful results.

**C7.10.3 Root-, Face-, and Side-Bend Specimens.** Transverse bend tests are performed to verify the soundness and ductility of the weld metal, weld/base metal interface, and heat-affected zones (HAZ) of the underwater weldment. Since even minute surface impressions can drastically influence bend test results, consideration should be given to the final finish of the tested surface. Also, the direction of any surface finishing or polishing should be aligned along the longitudinal axis of the specimen.

**C7.10.3.2** The wraparound jig has been found to be particularly beneficial when the test assembly consists of two different plate or pipe materials having significantly different yield strengths, or when the deposited weld metal has significantly different as-deposited yield strength from the base metal being welded.

**C7.10.4 All-Weld-Metal Tension Test.** All-weld-metal tension tests are specified for Class A and Class O welds to evaluate potential hydrogen damage, and to ensure that a particular filler metal meets the ultimate tensile strength, yield strength, and elongation requirements specified at the depths and in the environment applicable to the actual welding.

If the all-weld-metal specimen is machined from a procedure qualification test weld, it may be necessary to prepare a smaller specimen proportional to the specified size. In this case, the diameter, D, should be the largest able to be machined from the test weld, and the L/D ratio must meet that specified.

**C7.10.5 Charpy Impact Tests.** The orientation of the Charpy impact specimen relative to plate rolling direction can have a pronounced effect on the measured impact toughness of the HAZ. Maximum toughness is generally obtained when the fracture plane is perpendicular to the rolling direction. Some material specifications and codes give different minimum toughness requirements for transversely and longitudinally oriented specimens.

**C7.10.6 Hardness Test.** In underwater welding, high hardness is most likely to be found in the HAZ of the base metal; as carbon content and carbon equivalent increase so does HAZ hardness. Developmental work has demonstrated that with special temper bead welding techniques, Class B wet welds made on steels with carbon content up to 0.20% and carbon equivalent up to 0.46% may meet AWS D3.6M specified maximum hardness of 325 HV10 for Class A welds.

**C7.10.7 Fillet Weld Break Test.** The fillet weld break test is a simple method for evaluating the soundness of fillet welds. If it fractures through the weld, visual examination of the fracture surfaces provides information on the amount and size of porosity, slag inclusions, and root penetration.

**C7.10.8 Fillet Weld Shear Strength Test.** Fillet weld shear strength tests are required for fillet weld procedure qualification in order to ensure that the extent of any weld discontinuities and the influence of the underwater environment do not result in a strength level failing to meet the specified requirements. 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.

### C7.12 Supplemental Requirements

Supplemental requirements are sometimes specified in the contract to verify conformance with specific design criteria applicable to unique situations. The most common supplemental testing requirements imposed on procedure qualification are hardness testing (specifically identified as to type, quantity, and location of measurement points), Charpy impact (including specific quantity, and location of specimens and notches), and special fracture toughness tests such as crack tip opening displacement (CTOD).

### C7.15 Limitations of Variables

The mandatory variables identified in the code have been revised to include only those related to skill and ability of the welder/diver and to exclude those which relate more to physical stamina. Variables which have been excluded include working environment (wet, dry chamber, dry habitat), change in diving suit protection, thermal environment and length of exposure time, and reduction support provided to the welder/diver.

Although these conditions can have a significant impact on a person’s ability under certain circumstances, they are not always applicable and are no longer classified as essential. They should, however, be considered as potential supplemental essential variables whenever more severe production conditions exist.

(1) A welder who needs to utilize GTAW welding on a job and is only currently qualified for the SMAW process cannot use the GTAW process until he/she qualifies on that additional process.

(11) Direction of vertical travel applies only to the PF and PG (3G, 3F, 6G, and 5F positions where the vertical weld orientation may be encountered), and H-L045 and J-L045 (6G) positions. A welder who only qualifies welding vertical downhill is not qualified to weld vertical uphill, or vice versa.

# C8. Inspection

## *Part I*
## *General Requirements*

**C8.8 Personnel Qualification**

Underwater ultrasonic examination is often accomplished as a team effort, requiring considerable skill on the part of a topside ultrasonic inspector employing clear, effective communication with a diver. In this case, a qualified, certified ultrasonic inspector performs the testing with a diver serving to position the transducer at the required locations on the tested component. The diver also provides comments and input on conditions such as pitting, biofouling, or coating failures. All data interpretation, equipment adjustment, etc. is performed topside by the inspector whose qualification should include demonstration of ability to effectively communicate with and provide direction to a relatively inexperienced diver manipulating the transducer.

## *Part II*
## *Visual Examination*

**C8.9 General** The logistics and expense associated with diving support for third-party inspection personnel often necessitate that remote video examination methods be employed for inspection of underwater welding. Recent technological improvements, such as solid-state video pickups and enhanced white light sources, permit continuous viewing of the welding operation, which can be advantageous to the experienced inspector in confirming the overall acceptability of an underwater weldment. Such video methods, combined with audio communication with the welder/diver, may also be employed by a topside inspector to verify dimensions, weld sizes, and weld locations.

**C8.10 Procedure** Remote video inspection procedures for critical applications often require in situ calibration by demonstrating ability to detect a fine object, such as a 0.025 mm (0.001 in) wire positioned on the surface of the weld to be examined. When magnified video is used in cases where surface examination techniques would normally be used (such as for wet underwater stainless steel weldments) the inspection procedure and visual inspectors should be qualified by demonstrating ability to detect sample discontinuities rejectable by the surface examination acceptance criteria.

## *Part III*
## *Radiographic Examination*

**C8.12 Procedure** It is important that radiographic equipment identified in the procedure be designed and constructed for underwater (wet or hyperbarically pressurized) environments. Improperly contained radiation sources can become flooded, resulting in contaminated spill hazards. Cathode ray tubes, on the other hand, usually necessitate very stable mounting. Lengthy exposure time and even thin films of water can adversely affect the results. In all cases, there is a potential for film anomalies caused by static-electric charging of film during transport between the surface and the underwater work site.

## *Part IV*
## *Ultrasonic Examination*

**C8.13 General** Other ultrasonic methods which may be approved by the Customer can be found in AWS D1.1/D1.1M, *Structural Welding Code—Steel*.

**C8.15 Procedure** Ultrasonic examination procedures should consider routine maintenance necessitated by use in the underwater environment. In particular, attention should be paid to the fact that coax cables will deteriorate after several weeks exposure to salt water, and may require frequent testing to establish need for replacement.

**C8.15.2 Minimum Requirements.** The type of weld joint design is required to be documented on the procedure because certain geometries utilized for underwater wet welds may not be conducive to ultrasonic examination techniques. Surface preparation, is addressed because it can be dependent upon the type of examination used. For example, use of shear wave for flaw detection could require more extensive surface cleaning.

The following should be considered in the selection of equipment for use in the underwater environment: Suitability for use with long cable lengths, watertightness of transducer bodies, waterproof sealing of transducer connections (e.g., use of self-vulcanizing rubber tape) and use of a local ultrasonic CRT screen to help the transducer direction. In some cases, it may be beneficial to utilize a superimposed video image of transducer manipulation with the ultrasonic CRT screen.

## *Part V*
## *Magnetic Particle Examination*

### C8.17 Procedure

Since the apparent weight of magnetic particles is less in water than in air, the particles are more mobile in the water and "find" cracks or other unacceptable indications more readily. Additionally, since magnetic forces are unaffected by water and gravitational forces are reduced, leakage fields are more effective in holding particles at the site of a discontinuity. Underwater magnetic particle equipment typically consists of permanent magnet or waterproofed alternating current (ac) yokes with articulating legs, utilized with a slurry of magnetic particles and water. A white or ultraviolet light source is normally required to provide adequate lighting of the inspected areas. Magnetic particle examination procedures used in underwater applications require prior verification testing of field strengths using metallic field strength indicators. Refer to B8 Inspections and Examination in Annex B for information regarding safety precautions when using alternating current (ac).

## *Part VI*
## *Electromagnetic Technique Examination*

### C8.18 General

Electromagnetic technique testing can be effective in detecting the presence of cracks open to the surface, but may require supplemental magnetic particle examination, where feasible, to provide visual indication of the discontinuity for removal purposes. Electromagnetic technique examination can be particularly advantageous for inspecting through coatings, in poor visibility conditions, and at locations affected by wave action or sea currents.

Geometric shape and surface finish of the weldment should be considered in selection of equipment for performance of electromagnetic technique examination in the underwater environment. In addition, the following should be considered.

Use of a phase display for differentiation of surface conditions, durability and compatibility of the probe, waterproofing of the probe, suitability of equipment for driving the signals over long cable lengths. The probe should be capable of examining the toes of welds, and the probe-coil arrangement should be of a proven design (e.g., reflection coil). In some cases, it may be worthwhile to superimpose a video image of the probe manipulation with the electromagnetic technique CRT phase display.

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# Annex D (Informative)
# References

This annex is not part of this standard but is included for informational purposes only.

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

## A. Construction Standards

(1) *ANSI/ASME Boiler and Pressure Vessel Code*, American Society of Mechanical Engineers.

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

(3) *Guide for Building and Classing Facilities on Offshore Installations*, American Bureau of Shipping.

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

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

## B. Diving

(1) 29 CFR 1910, *Occupational Safety and Health Standards*, Subpart T, Commercial Diving Operations.

(2) 46 CFR 197.200, *U.S. Coast Guard Commercial Diving Regulations*.

(3) *International Consensus Standards for Commercial Diving and Underwater Operations*, Association of Diving Contractors International.

(4) IMCA D014, *IMCA International Code of Practice for Offshore Diving*.

(5) NAVSEA SS521-AG-PRO–010, *U.S. Navy Diving Manual*.

(6) *NOAA Diving Manual: Diving for Science and Technology*, U.S. Department of Commerce.

## C. Destructive Testing

(1) AWS B4.0, *Standard Methods for Mechanical Testing of Welds*, American Welding Society.

(2) AWS B4.0M, *Standard Methods for Mechanical Testing of Welds*, American Welding Society.

(3) ASTM E8/E8M, *Standard Test Methods for Tension Testing of Metallic Materials*, American Society for Testing and Materials.

(4) ASTM E18, *Standard Test Methods for Rockwell Hardness of Metallic Materials*, American Society for Testing and Materials.

(5) ASTM E23, *Standard Methods for Notched Bar Impact Testing of Metallic Materials*, American Society for Testing and Materials.

(6) ASTM E190, *Standard Method for Guided Bend Test for Ductility of Welds*, American Society for Testing and Materials.

(7) ISO 148, *Metallic Materials—Charpy pendulum impact test—Part 1: Test Method*.

(8) ISO/R 442, *Verification of pendulum impact machines for testing steels.*

(9) ISO/R 615, *Methods for determining the mechanical properties of the weld metal deposited by electrodes 3.15 mm or more in diameter*.

(10) ISO 716, *Metallic materials—Hardness test—Verification of Rockwell hardness testing machines* (scales A-B-C-D-E-F-G-H-K).

(11) ISO 4964, *Steel—Hardness conversions*.

(12) ISO 5173, *Destructive tests on welds in metallic materials — Bend tests*.

(13) ISO 6507–1, *Metallic materials—Vickers hardness Test—Part 1: Test method.*

(14) ISO 6507–2, *Metallic materials—Vickers hardness test—Part 2: Verification of testing machines.*

(14) ISO 6508, *Metallic materials—Hardness test—Rockwell test* (scales A-B-C-D-E-F-G-H-K).

(15) ISO 7500–1, *Metallic materials—Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*.

(16) ISO/TR 10108, *Steel—Conversion of hardness values to tensile strength values*.

(17) ISO/TR 12735–1, *Mechanical testing of metals—Symbols used with their definitions—Part 1: Symbols and definitions in published standards*.

(18) *Welding Handbook*, 9th ed., Vol. 1, Welding Technology, Chapter 6, Test Methods for Evaluating Welded Joints, American Welding Society.

## D. Nondestructive Examination

(1) AWS B1.10M/B1.10, *Guide for the Nondestructive Examination of Welds*, American Welding Society.

(2) AWS B1.11M/B1.11, *Guide for the Visual Examination of Welds*, American Welding Society.

(3) AWS B5.1, *Specification for the Qualification of Welding Inspectors.*

(4) ASNT, Recommended Practice No. SNT-TC–1A, American Society for Nondestructive Testing, Inc.

(5) ASTM A577/A577M, *Standard Specification for Ultrasonic Angle-Beam Examination of Steel Plates*, American Society for Testing and Materials.

(6) ASTM A578/A578M, *Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications*, American Society for Testing and Materials.

(7) ASTM E94, *Standard Guide for Radiographic Testing*, American Society for Testing and Materials.

(8) ASTM E142, *Controlling Quality of Radiographic Testing*, American Society for Testing Materials.

(9) Document No. CSWIP-DIV–7–95-Part 1, Requirements for the Certification of Underwater (Diver) Inspectors.

(10) ISO 1027, *Radiographic image quality indicators for non-destructive testing—Principles and identification.*

(11) ISO 3058, *Non-destructive testing—Aids to visual inspection—Selection of low-power magnifiers.*

(12) ISO 3059, *Non-Destructive Testing—Penetrant testing and magnetic particle testing — Viewing conditions*.

(13) ISO 3452, *Non-Destructive Testing—Penetrant testing—Part 1: General principles*.

(14) ISO 3999, *Apparatus for industrial gamma radiography — Specifications for performance, design and tests*.

(15) ISO 5576, *Non-destructive testing—Industrial x-ray and gamma-ray radiology—Vocabulary*.

(16) ISO 5580, *Non-destructive testing—Industrial radiographic illuminators—Minimum requirements*.

(17) ISO 5655, *Industrial radiographic films (roll and sheet) and metal intensifying screens—Dimensions*.

(18) ISO 6520–1, *Welding and allied processes—Classification of geometric imperfections in metallic materials—Part 1: Fusion welding*.

(19) ISO 8249, *Welding—Determination of Ferrite Number (FN) in austenitic and duplex ferritic-austenitic Cr-Ni stainless steel weld metals*.

(20) ISO 9712, *Non-destructive testing—Qualification and certification of personnel*.

(21) ISO 9935, *Non-destructive testing—Penetrant flaw detectors—General technical requirements*.

(22) ISO 10375, *Non-destructive testing—Ultrasonic inspection—Characterization of search unit and sound field*.

(23) *ASM Handbook*, Vol. 17, 1989, Nondestructive Evaluation and Quality Control, ASM International.

(24) *Guide for Nondestructive Inspection of Hull Welds*, American Bureau of Shipping.

(25) *Welding Inspection Handbook*, American Welding Society.

## E. Safety

(1) 29 CFR 1915, Subpart D, Welding, Cutting and Heating, *Occupational Safety and Health Standards for Shipyard Employment*.

(2) 46 CFR Chapter 1, Subchapter V, *Marine Occupational Safety and Health Standards*, Part 197, Code of Federal Regulations.

(3) *International Consensus Standards for Commercial Diving and Underwater Operations*, Association of Diving Contractors International.

(4) AWS F4.1, *Safe Practices for the Preparation of Containers and Piping for Welding and Cutting*, American Welding Society.

(5) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, American Welding Society.

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

(7) IMCA D045/IMCA R015, *Code of Practice for the Safe Use of Electricity Underwater*.

(8) *National Electrical Code*, National Fire Protection Association.

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

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

(11) OSHA 1910 (Subpart T), *Occupational Safety and Health Act*.

(12) *Welding Handbook*, 8th ed., Vol. 3, Materials and Applications—Part 1, Chapter 10, Underwater Welding and Cutting, American Welding Society.

## F. Welding

(1) AWS A5.1/A5.1M, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*, American Welding Society.

(2) AWS A5.4/5.4M, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*, American Welding Society.

(3) AWS A5.5/A5.5M, *Specification for Low Alloy Steel Covered Arc Welding Electrodes*, American Welding Society.

(4) TWI Certification Ltd., Granta Park, Great Abington, Cambridge CD21 6AL, UK.

(5) AWS A5.18/A5.18M, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*, American Welding Society.

(6) AWS A5.20/A5.20M, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*, American Welding Society.

(7) AWS A5.28/5.28M, *Specification for Low Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*, American Welding Society.

(8) AWS A5.29/A5.29M, *Specification for Low Alloy Steel Electrodes for Flux Cored Arc Welding*, American Welding Society.

(9) AWS A5.32/A5.32M, *Specification for Welding Shielding Gases*, American Welding Society.

(10) A5.35/A5.35M:2015, *Specification for Covered Electrodes for Underwater Wet Shielded Metal Arc Welding*.

(11) AWS B2.1/B2.1M, *Specification for Welding Procedure and Performance Qualification*, American Welding Society.

(12) API RP 1107, *Recommended Pipelines Maintenance Welding Practices*, American Petroleum Institute.

(13) API Std. 1104, *Standard for Welding Pipelines and Related Facilities*, American Petroleum Institute.

(14) ASME Boiler and Pressure Vessel Code, Section IX, *Welding and Brazing Qualifications*, American Society of Mechanical Engineers.

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

(16)Det Norske Veritas, Recommended Practice RP B604, January 1987.

(17) IIW DOC SCUW 124–90, *Standard Guidelines for Specification of Underwater Fusion Welding*.

(18) ISO 3088, *Welding Requirements—Factors to be Considered in Specifying Requirements for Fusion Welded Joints in Steel (Technical Influencing Factors)*.

(19) ISO 3834–1, *Quality Requirements for Welding—Fusion Welding of Metallic Materials—Part 1: Guidelines for Selection and Use*.

(20) ISO 9606, *Approval Testing of Welders—Fusion Welding*.

(21) ISO 9956, *Specification and Approval of Welding Procedures for Metallic Materials*.

(22) ISO 15618–1, *Qualification Testing of Welders for Underwater Welding—Part 1: Diver-Welders for Hyperbaric Wet Welding*.

(23) ISO 15618–2, *Qualification Testing of Welders for Underwater Welding—Part 2: Diver-Welders and Welding Operators for Hyperbaric Dry Welding*.

(24) MIL-STD–22, *Welded Joint Design*.

(25) MIL-STD–248, *Welding and Brazing Procedure and Performance Qualification*.

(26) MIL-STD–271, *Requirements for Nondestructive Testing Methods*.

(27) MIL-STD–1628, *Fillet Weld Size, Strength, and Efficiency Determination*.

(28) NAVSEA S0300-BB-MAN–010, *U.S. Navy Underwater Cutting and Welding Manual*.

(29) *Welding Handbook*, 8th ed., Vol. 3, Materials and Applications—Part 1, Chapter 10, Underwater Welding and Cutting, Miami, FL: American Welding Society.

**Addresses of Publishers of Documents**
**Listed in Annex D**

American Bureau of Shipping (ABS)
16855 Northchase Drive
Houston, TX 77060
United States

American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036
United States

American Petroleum Institute (API)
1220 L Street,
N.W. Washington,
DC 20005
United States

The American Society for Nondestructive Testing, Inc. (ASNT)
1711 Arlingate Lane
P.O. Box 28518
Columbus, OH 43228–0518
United States

American Society for Testing and Materials (ASTM)
100 Barr Harbor Drive
West Conshohocken, Pennsylvania 19428
United States

American Welding Society (AWS)
8669 NW 36 St #130
Miami, FL 33166
United States

ASM International (formerly: American Society for Metals)
9639 Kinsman Road
Materials Park, OH 44073–0002
United States

Association of Diving Contractors International (ADCI)
5206 FM 1960 Rd W # 202
Houston, TX 77069
United States

Government Printing Office (GPO)
Superintendent of Documents
710 North Capitol Street,
N.W. Washington, DC 20401
United States

International Marine Contractors Association (IMCA)
52 Grosvenor Gardens
London SW1W OAU
United Kingdom

International Organization for Standardization (ISO)
Case Postale 56
CH–1211, Geneva 20
Switzerland
(Note: ISO standards are available from ANSI)

National Fire Protection Association (NFPA)
1 Batterymarch Park
P.O. Box 9101
Quincy, MA 02269–9904
United States

Naval Sea Systems Command (NAVSEA)
Naval Publication & Forms Center
5801 Tabor Avenue
Philadelphia, PA 19120
United States

Military Standards (MIL-STD)
Naval Publication and Forms Center
5801 Taber Avenue
Philadelphia, PA 19120
United States

DNV GL
Veritasveien 1
1363 Høvik
Norway

International Institute of Welding
(IIW) ZI Paris Nord II
BP 50362
F–95942 Roissy CDG Cedex
France

# Annex E (Informative)
# Marine Welding Inspectors

This annex is not part of this standard but is included for informational purposes only.

## E1. Scope

**E1.1** This annex establishes the recommended requirements for qualification of marine welding inspection personnel providing third-party surveillance. It describes how personnel are qualified, and the principles of conduct and practice by which qualification may be maintained.

Although this annex is not written with mandatory requirements, mandatory language, such as the use of "shall," will be found in those portions of the annex where failure to follow the instructions or procedures could produce inferior, misleading or unsafe results.

**E1.2** This annex is to be used in conjunction with the requirements from the latest edition of the AWS B5.1, *Specification for the Qualification of Welding Inspectors*.

**E1.3** In the qualification process, the employer conducts an examination to determine a person's general knowledge of underwater welding inspection and related technical areas.

**E1.4** The employer is responsible for determining that a person has all qualifications as stated herein.

**E1.5** It shall be the responsibility of the employer to determine that the Marine Welding Inspectors are capable of performing the duties involved in the particular underwater welding inspection assignments.

**E1.6** This annex is intended to supplement the requirements of an employer, code, or other documents and shall not be construed as a preemption of the employer's responsibility for the work or for the performance of the work.

**E1.7** This annex is not intended to address safety and health matters regarding Marine Welding Inspectors. Safety and health requirements are provided in ANSI Z49.1, *Safety in Welding and Cutting*, ADCI consensus standards, other applicable safety and health standards, and federal, state, and local government regulations. This annex only covers the requirements of qualification.

## E2. Functions

### E2.1 Capability

**E2.1.1** The Marine Welding Inspector shall be able to perform independent third-party quality assurance inspections to verify that the work performed and the records maintained conform to the requirements of the applicable standards and contract documents.

### E2.2 Duties

**E2.2.1** The Marine Welding Inspector's specific duties are defined by the employer; however, inspectors shall be able to demonstrate their abilities to perform the following duties for both underwater and surface welding operations including.

**E2.2.1.1** Surveillance of procedure and performance qualification work to include welding and visual inspection of test plates and review of the destructive and nondestructive test reports.

**E2.2.1.2** Surveillance of production work to encompass, but not be limited to, the following:

1. Verification that welding and NDE procedures are currently qualified for actual welding and NDE performed.
2. Verification that welding and NDE personnel are currently qualified for actual welding and NDE performed.
3. Verification of the requirements AWS D3.6M, with specific emphasis on fit-up and intermediate and final weld inspections.
4. Verification of confirmation welding.
5. Verification of base metals and filler metals, performing activity certification, quality assurance plan application, adequacy of underwater video coverage, equipment adequacy for the intended application, conformance to the workmanship and welding requirements of AWS D3.6M.

## E3. Education and Experience

**E3.1** Each Marine Welding Inspector shall satisfy the following criteria.

**E3.1.1** Hold a valid CWI or SCWI certificate issued by AWS in accordance with ANSI/AWS QC1 or equivalent as approved by the Customer.

**E3.1.2** Shall have no fewer than five years experience directing or supervising underwater welding projects, or performing underwater welding. This shall include demonstrated experience in applying AWS D3.6M requirements and be directly involved in one of the following:

1. Design
2. Production
3. Construction
4. Examination
5. Repair
6. Quality assurance.

**E3.1.3** Shall have no fewer than five years experience in quality assurance related work associated with welding and NDE requirements.

**E3.1.4** Shall submit written verification of the documented employment.

## E4. Examination Requirements

**E4.1** Employers shall give potential Marine Welding Inspector's examinations to meet the following.

**E4.1.1** Pass a written examination of no fewer than 25 questions in an open book test on the requirements of AWS D3.6M.

**E4.1.2** Pass a written examination of no fewer than 25 questions in a closed book test on underwater welding, underwater cutting, and underwater nondestructive examination processes.

**E4.2 Examination Resources**

**E4.2.1** Employers may request sample exam questions which can be obtained from the AWS D3B Subcommittee on Underwater Welding and Cutting.

# Annex F (Informative)
# Requesting an Official Interpretation on an AWS Standard

This annex is not part of this standard but is included for informational purposes only.

## F1. Introduction

The following procedures are here to assist standard users in submitting successful requests for official interpretations to AWS standards. Requests from the general public submitted to AWS staff or committee members that do not follow these rules may be returned to the sender unanswered. AWS reserves the right to decline answering specific requests; if AWS declines a request, AWS will provide the reason to the individual why the request was declined.

## F2. Limitations

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on (1) specific engineering problems, (2) requirements of standards applied to fabrications outside the scope of the document, or (3) points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

## F3. General Procedure for all Requests

**F3.1 Submission.** All requests shall be sent to the Managing Director of AWS Standards Development. For efficient handling, it is preferred that all requests should be submitted electronically through technical@aws.org. Alternatively, requests may be mailed to:

Managing Director
Standards Development
American Welding Society
8669 NW 36 St, # 130
Miami, FL 33166

**F3.2 Contact Information.** All inquiries shall contain the name, address, email, phone number, and employer of the inquirer.

**F3.3 Scope.** Each inquiry shall address one single provision of the standard unless the issue in question involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the request along with the edition of the standard (e.g., D1.1:2006) that contains the provision(s) the inquirer is addressing.

**F3.4 Question(s).** All requests shall be stated in the form of a question that can be answered 'yes' or 'no'. The request shall be concise, yet complete enough to enable the committee to understand the point of the issue in question. When the point is not clearly defined, the request will be returned for clarification. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annexes) that bear on the issue in question shall be cited.

**F3.5 Proposed Answer(s).** The inquirer shall provide proposed answer(s) to their own question(s).

**F3.6 Background.** Additional information on the topic may be provided but is not necessary. The question(s) and proposed answer(s) above shall stand on their own without the need for additional background information.

## F4. AWS Policy on Interpretations

The American Welding Society (AWS) Board of Directors has adopted a policy whereby all official interpretations of AWS standards are handled in a formal manner. Under this policy, all official interpretations are approved by the technical committee that is responsible for the standard. Communication concerning an official interpretation is directed through the AWS staff member who works with that technical committee. The policy requires that all requests for an official interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the procedures that must be followed, some requests for an official interpretation may take considerable time to complete.

## F5. AWS Response to Requests

Upon approval by the committee, the interpretation is an official interpretation of the Society, and AWS shall transmit the response to the inquirer, publish it in the Welding Journal, and post it on the AWS website.

## F6. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The AWS Board Policy Manual requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can be obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

# Index

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## V



## W



## Y

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## List of AWS Documents on Marine Welding

| Designation | Title |
|---|---|
| D3.5/D3.5M | *Guide for Steel Hull Welding* |
| D3.6M | *Underwater Welding Code* |
| D3.7/D3.7M | *Guide for Aluminum Hull Welding* |
| D3.9/D3.9M | *Specification for Classification of Weld-Through Paint Primers* |
| **Additional Documents of Fundamental Subject Matter** | |
| A1.1 | *Metric Practice Guide for the Welding Industry* |
| A2.4 | *Standard Symbols for Welding, Brazing, and Nondestructive Examination* |
| A3.0 | *Standard Welding Terms and Definitions* |
| B4.0 | *Standard Methods for Mechanical Testing of Welds* |
| B4.0M | *Standard Methods for Mechanical Testing of Welds* |

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