

D3.6M:2017
An American National Standard

Underwater Welding Code



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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



International Standard Book Number: 978-0-87171-902-7

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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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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.

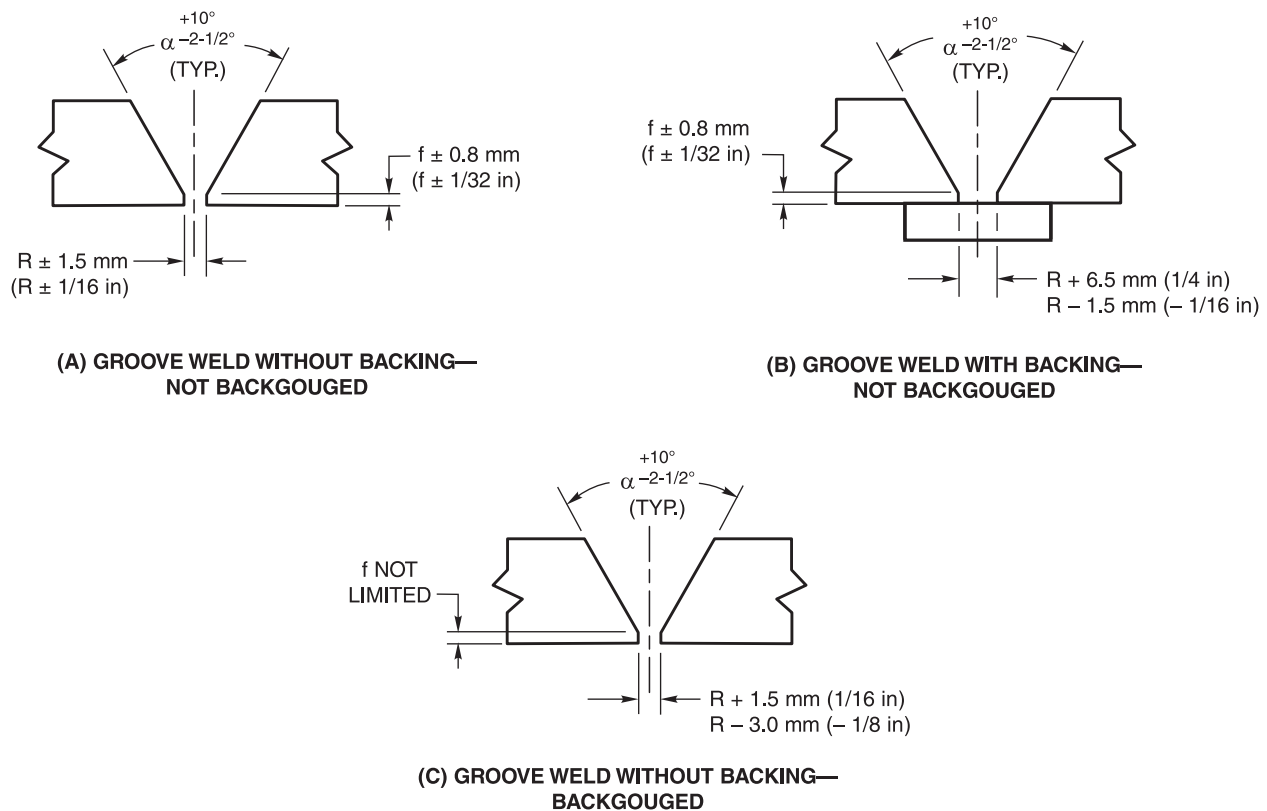
5.9 Peening. The root layer shall not be peened. Peening of subsequent beads shall be permitted only with prior approval of the Customer. The operator shall visually inspect the weld surface for slag, overlap, undercut, and cracks prior to peening. If any of these weld defect conditions are present, 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. f—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:

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

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

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

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) <u>Any change beyond that qualified in Table 7.4</u>	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 <u>uphill to downhill or vice versa</u>	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) <u>Addition or deletion of ultrasonic stress relieving</u>	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 <u>uphill to downhill</u> 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) <u>Addition or deletion of ultrasonic stress relieving</u>	<u>Essential</u>
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 <u>nickel-based</u> 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		All

^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) (6GR)	All	All	All ^d	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.

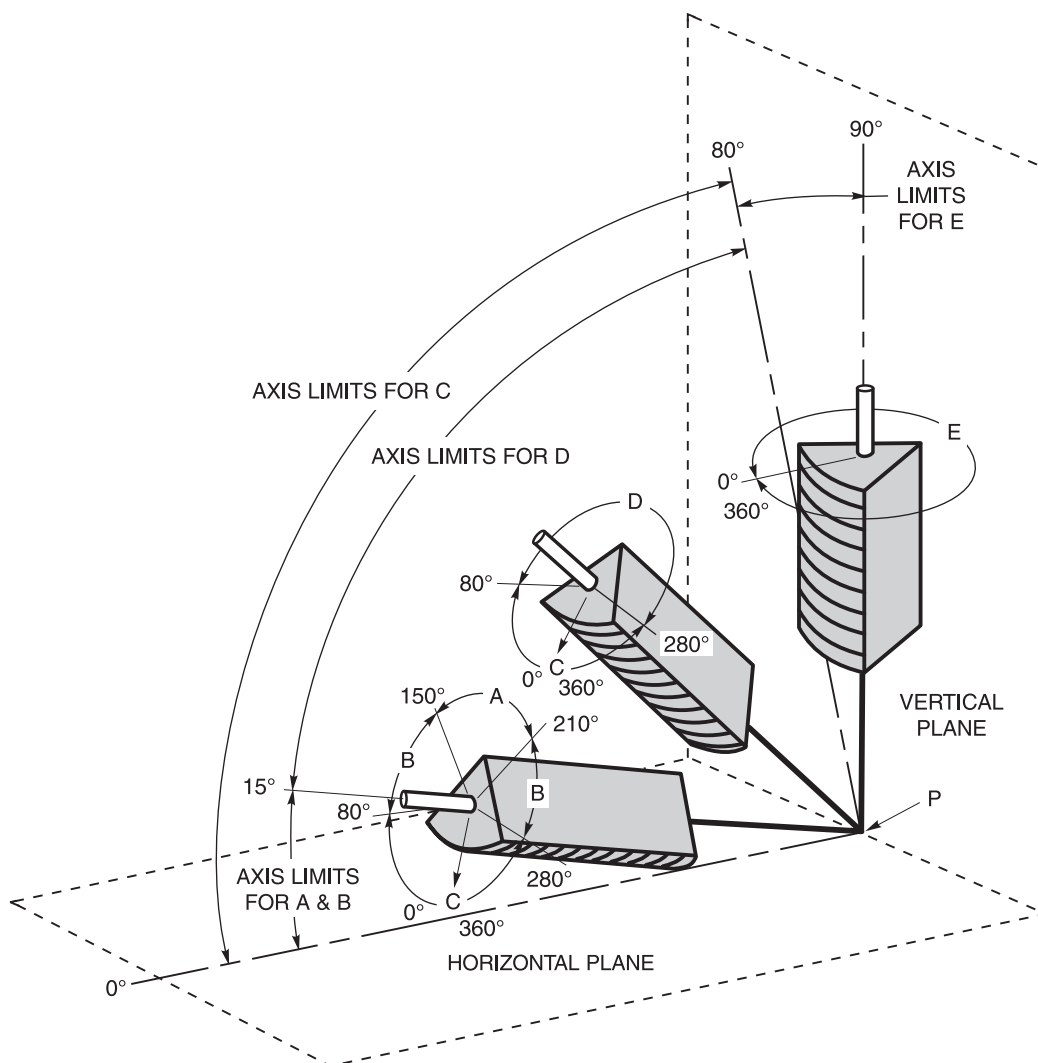
Table 7.6
Pipe Diameter Groups for Welder Performance Qualification

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°
Horizontal	B	0° to 15°	80° to 150°
Overhead	C	0° to 80°	210° to 280°
Vertical	D	15° to 80°	0° to 80°
	E	80° to 90°	280° to 360°

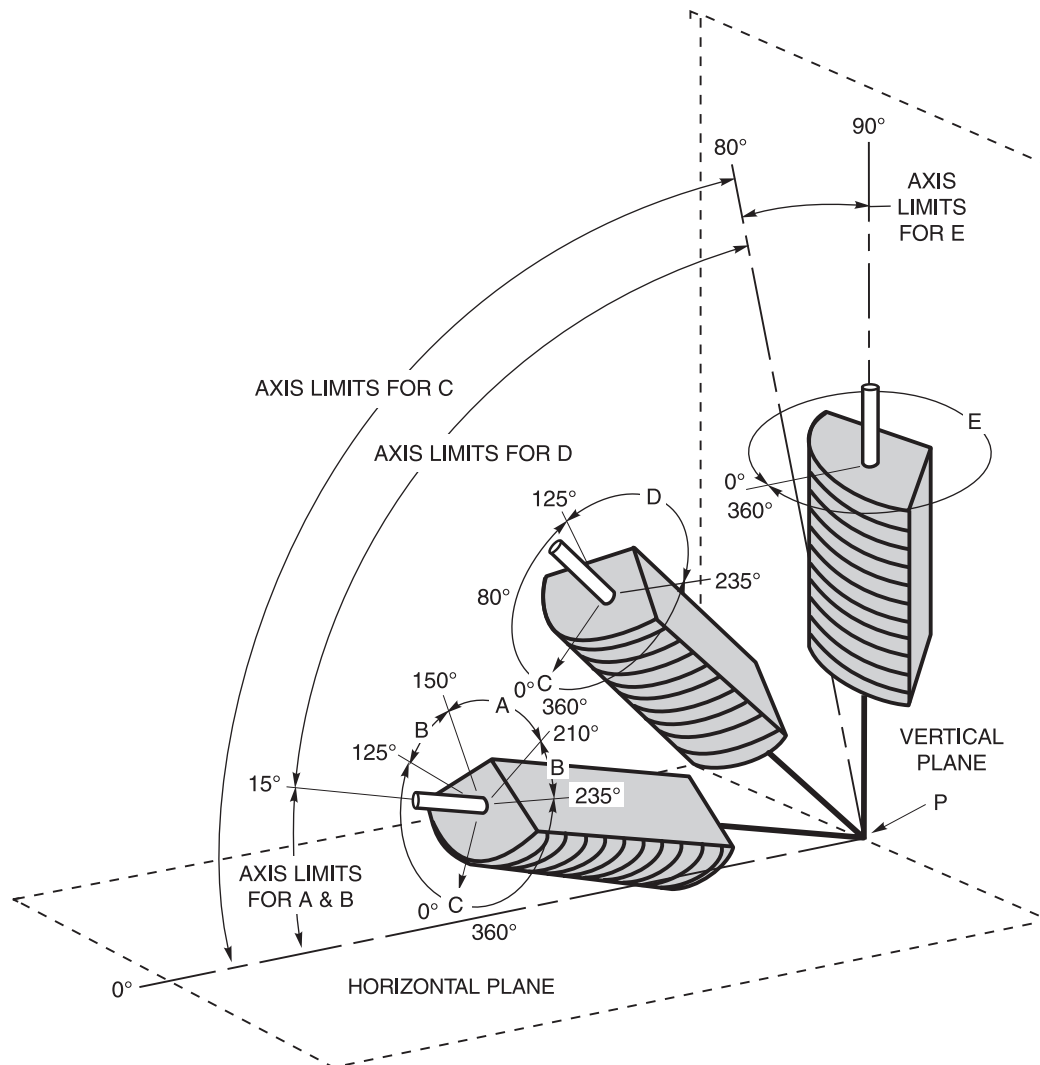


Notes:

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 Horizontal	A	0° to 15°	150° to 210°
	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

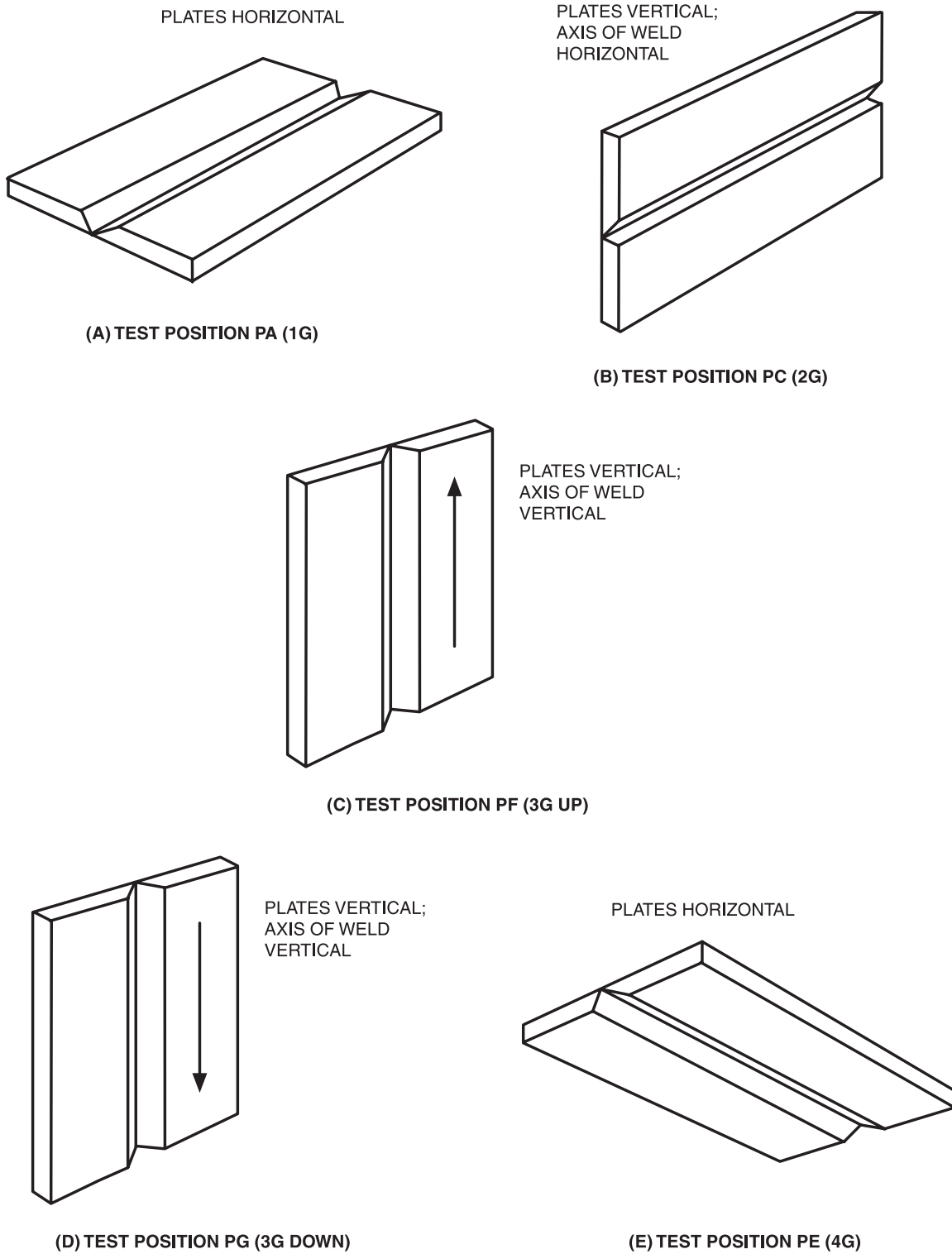


Figure 7.3—Welding Test Positions for Groove Welds in Plate

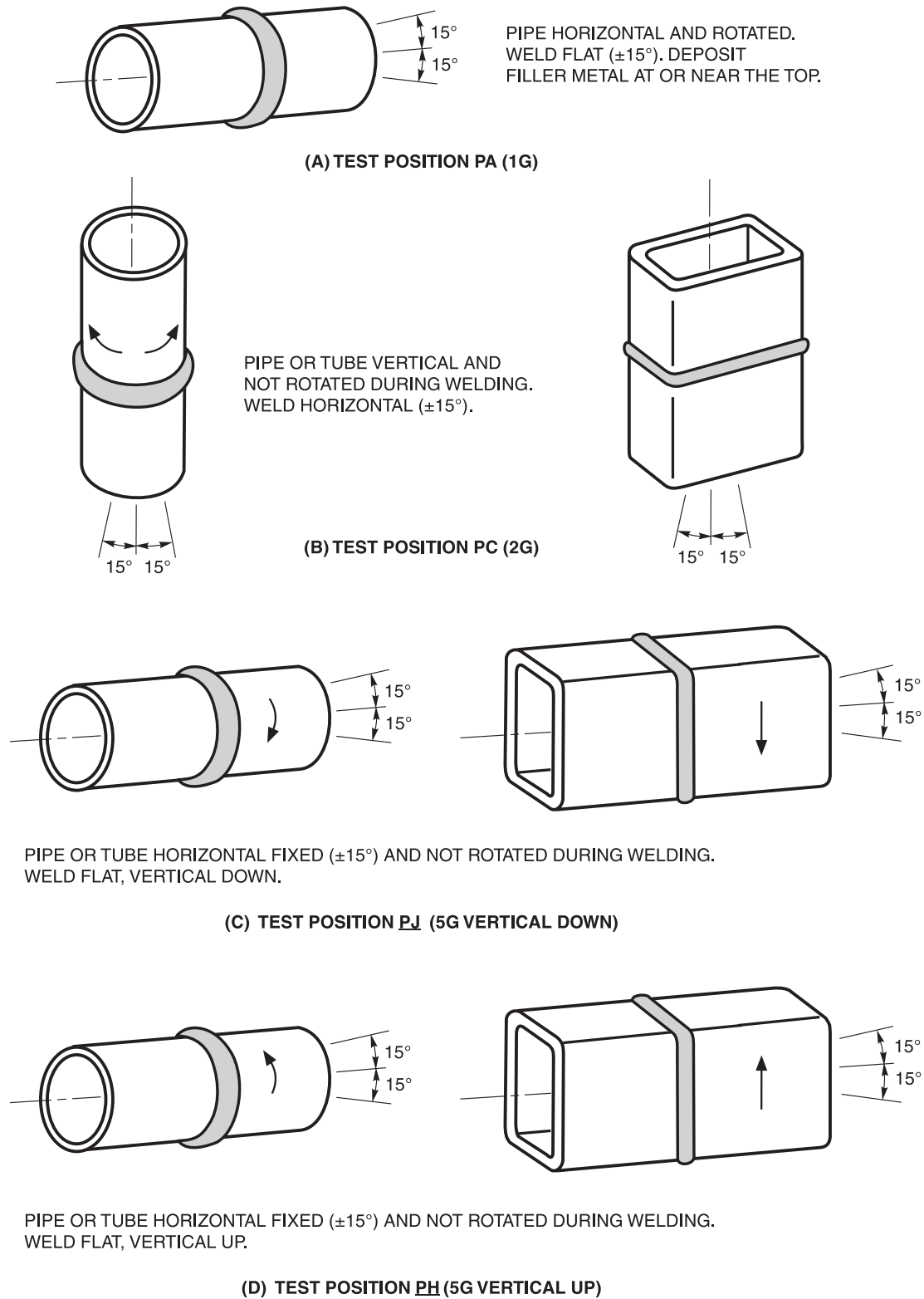


Figure 7.4—Welding Test Positions for Groove Welds in Pipe or Tubing