AWS D1.1/D1.1M:2020
An American National Standard

Structural Welding Code—Steel



American Welding Society®



AWS D1.1/D1.1M:2020
An American National Standard

Approved by the
American National Standards Institute
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Structural Welding Code—Steel

24th Edition

Supersedes AWS D1.1/D1.1M:2015

Prepared by the
American Welding Society (AWS) D1 Committee on Structural Welding

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This code covers the welding requirements for any type of welded structure made from the commonly used carbon and low-alloy constructional steels. Clauses 1 through 11 constitute a body of rules for the regulation of welding in steel construction. There are eight normative and eleven informative annexes in this code. A Commentary of the code is included with the document.



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Foreword

This foreword is not part of AWS D1.1/D1.1M:2020, *Structural Welding Code—Steel*, but is included for informational purposes only.

The first edition of the *Code for Fusion Welding and Gas Cutting in Building Construction* was published by the American Welding Society in 1928 and called Code 1 Part A. It was revised in 1930 and 1937 under the same title. It was revised again in 1941 and given the designation D1.0. D1.0 was revised again in 1946, 1963, 1966, and 1969. The 1963 edition published an amended version in 1965, and the 1966 edition published an amended version in 1967. The code was combined with D2.0, *Specifications for Welding Highway and Railway Bridges*, in 1972, given the designation D1.1, and retitled AWS *Structural Welding Code*. D1.1 was revised again in 1975, 1979, 1980, 1981, 1982, 1983, 1984, 1985, 1986, 1988, 1990, 1992, 1994, 1996, 1998, 2000, 2002, 2004, 2006, 2008 and 2010. A second printing of D1.1:2010 was published in 2011. From 1972 to 1988, the D1.1 code covered the welding of both buildings and bridges.

In 1988, AWS published its first edition of AASHTO/AWS D1.5, *Bridge Welding Code*; coincident with this, the D1.1 code changed references of buildings and bridges to statically loaded and dynamically loaded structures, respectively, in order to make the document applicable to a broader range of structural applications. After the publishing of the 2010 edition, it was decided that the AWS *Structural Welding Code—Steel* would be published on a five year revision cycle instead of a two year revision cycle. This was done in order to sync the publication cycle of AWS Structural Welding Code-Steel with the publication cycles of the AISC Steel Building Specification and the International Building Code. This 2020 edition is the 24th edition of D1.1.

Changes in Code Requirements, underlined text in the clauses, subclauses, tables, figures, or forms indicates a change from the 2015 edition. A vertical line in the margin of a table or figure also indicates a change from the 2015 edition.

The following is a summary of the most significant technical changes contained in D1.1/D1.1M:2020:

Summary of Changes

Clause/Table/Figure/Annex	Modification
Clause 1	
Clause 2	This is a new clause listing normative references. It replaces subclause 1.9 and Annex S from the previous edition.
Clause 3	This is a new clause that provides terms and definitions specific to this standard. It replaces subclause 1.3 and Annex J from the previous edition.
Clause 4	Clause 4 was presented as Clause 2 in the previous edition. Annex A Figures in the previous edition were incorporated into Clause 4.
Clause 5	Clause 5 was presented as Clause 3 in the previous edition. The Clause has also been restructured to follow the normal progression of writing a prequalified WPS. Table 5.2 has been editorially renamed and reorganized to list WPS essential variables. Additional requirements have been added when using shielding gases and a new Table 5.7 was added on shielding gases. New materials have been added to Tables 5.3 and 5.8.
Clause 6	Clause 6 was presented as Clause 4 in the previous edition. Revisions include the requirements for the qualification of WPSs using waveform technology. All the CVN testing requirements have been added to Table 6.7, so they now are all contained in a single place. The WPS retest requirements have been clarified. The PJP Groove weld clause has been reorganized to clarify the qualification of PJP Groove welds using the Joint Details in Figure 5.2. Part D of the Clause has been reorganized to better align the testing procedures and qualification of CVNs with the order that they would be accomplished.

(Continued)

Summary of Changes (Continued)

Clause/Table/Figure/Annex	Modification
Clause 7	Clause 7 was presented as Clause 5 in the previous edition. Revisions were made to the weld restoration of base metal with mislocated holes.
Clause 8	Clause 8 was presented as Clause 6 in the previous edition. Revisions were made to the qualification requirements for inspection personnel to ensure that all welding inspectors are qualified. The Engineer's responsibilities as it relates to Inspection were also clarified. Digital radiography has been added to Radiographic Testing. The limitations for geometric unsharpness have been added to the Code and the equation has been revised to match the equation in ASME *Boiler and Pressure Vessel Code*, Section V, Article 2. The methodology to determine the attenuation factor has been updated to reflect that UT instruments are now capable of reporting a fractional value for dB.
Clause 9	Clause 9 was presented as Clause 7 in the previous edition. The code was updated to require the manufacturer's permanent identification on headed studs and deformed anchor bars. Revisions were made to provide weld procedure requirements for fillet welding of studs.
Clause 10	Clause 10 was presented as Clause 9 in the previous edition. The calculations for static strength of welded tubular connections were removed in deference to AISC design provisions.
Clause 11	Clause 11 was presented as Clause 8 in the previous edition.
Annex A	Annex A was presented as Annex B in the previous edition.
Annex B	Annex B was presented as Annex H in the previous edition.
Annex D	Annex D was presented as Annex F in the previous edition.
Annex E	Annex E was presented as Annex D in the previous edition.
Annex F	Annex F was presented as Annex E in the previous edition.
Annex H	New Annex that addresses phased array ultrasonic testing (PAUT)
Annex J	Annex J was presented as Annex M in the previous edition.
Annex K	Annex K was presented as Annex P in the previous edition.
Annex L	Annex L was presented as Annex T in the previous edition.
Annex M	Annex M was presented as Annex U in the previous edition.
Annex N	Annex N was presented as Annex K in the previous edition.
Annex O	Annex O was presented as Annex Q in the previous edition.
Annex P	Annex P was presented as Annex L in the previous edition.
Annex Q	Annex Q was presented as Annex O in the previous edition.
Annex R	Annex R has been modified to contain preliminary design of circular tube connections previously contained in the Tubular Structures clause as well as ovalizing parameter alpha.
Annex T	Annex T was presented as Annex N in the previous edition.
C-Annex H	Commentary was added for Annex H

Commentary. The Commentary is nonmandatory and is intended only to provide insightful information into provision rationale.

Normative Annexes. These annexes address specific subjects in the code and their requirements are mandatory requirements that supplement the code provisions.

Informative Annexes. These annexes are not code requirements but are provided to clarify code provisions by showing examples, providing information, or suggesting alternative good practices.

Index. As in previous codes, the entries in the Index are referred to by subclause number rather than by page number. This should enable the user of the Index to locate a particular item of interest in minimum time.

(Continued)

Errata. It is the Structural Welding Committee's Policy that all errata should be made available to users of the code. Therefore, any significant errata will be published in the Society News Section of the *Welding Journal* and posted on the AWS web site at: http://www.aws.org/standards/page/errata.

Suggestions. Your comments for improving AWS D1.1/D1.1M:2015, *Structural Welding Code—Steel* are welcome. Submit comments to the Secretary of the D1Q Subcommittee, American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

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Structural Welding Code—Steel

1. General Requirements

1.1 Scope

This code contains the requirements for fabricating and erecting welded steel structures. When this code is stipulated in contract documents, conformance with all provisions of the code shall be required, except for those provisions that the Engineer (see 1.5.1) or contract documents specifically modifies or exempts.

The following is a summary of the code clauses:

1. General Requirements. This clause contains basic information on the scope and limitations of the code, key definitions, and the major responsibilities of the parties involved with steel fabrication.

2. Normative References. This clause contains a list of reference documents that assist the user in implementation of this code or are required for implementation.

3. Terms and Definitions. This clause contains terms and definitions as they relate to this code.

4. Design of Welded Connections. This clause contains requirements for the design of welded connections composed of tubular, or nontubular, product form members.

5. Prequalification of WPSs. This clause contains the requirements for exempting a Welding Procedure Specification (WPS) from the WPS qualification requirements of this code.

6. Qualification. This clause contains the requirements for WPS qualification and the performance qualification tests required to be passed by all welding personnel (welders, welding operators, and tack welders) to perform welding in accordance with this code.

7. Fabrication. This clause contains general fabrication and erection requirements applicable to welded steel structures governed by this code, including the requirements for base metals, welding consumables, welding technique, welded details, material preparation and assembly, workmanship, weld repair, and other requirements.

8. Inspection. This clause contains criteria for the qualifications and responsibilities of inspectors, acceptance criteria for production welds, and standard procedures for performing visual inspection and nondestructive testing (NDT).

9. Stud Welding. This clause contains the requirements for the welding of studs to structural steel.

10. Tubular Structures. This clause contains exclusive tubular requirements. Additionally, the requirements of all other clauses apply to tubulars, unless specifically noted otherwise.

11. Strengthening and Repair of Existing Structures. This clause contains basic information pertinent to the welded modification or repair of existing steel structures.

1.2 Standard Units of Measurement

This standard makes use of both U.S. Customary Units and the International System of Units (SI). The latter are shown within brackets ([ ]) or in appropriate columns in tables and figures. The measurements may not be exact equivalents; therefore, each system must be used independently.

1.3 Safety Precautions

Safety and health issues and concerns are beyond the scope of this standard and therefore are not fully addressed herein. It is the responsibility of the user to establish appropriate safety and health practices. 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

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 Limitations

The code was specifically developed for welded steel structures that utilize carbon or low alloy steels that are 1/8 in [3 mm] or thicker with a minimum specified yield strength of 100 ksi [690 MPa] or less. The code may be suitable to govern structural fabrications outside the scope of the intended purpose. However, the Engineer should evaluate such suitability, and based upon such evaluations, incorporate into contract documents any necessary changes to code requirements to address the specific requirements of the application that is outside the scope of the code. The Structural Welding Committee encourages the Engineer to consider the applicability of other AWS D1 codes for applications involving aluminum (AWS D1.2), sheet steel equal to or less than 3/16 in [5 mm] thick (AWS D1.3), reinforcing steel (AWS D1.4), stainless steel (AWS D1.6), strengthening and repair of existing structures (AWS D1.7), seismic supplement (AWS D1.8), and titanium (AWS D1.9). The AASHTO/AWS D1.5 *Bridge Welding Code* was specifically developed for welding highway bridge components and is recommended for those applications.

1.5 Responsibilities

1.5.1 Engineer's Responsibilities. The Engineer shall be responsible for the development of the contract documents that govern products or structural assemblies produced under this code. The Engineer may add to, delete from, or otherwise modify, the requirements of this code to meet the particular requirements of a specific structure. All requirements that modify this code shall be incorporated into contract documents. The Engineer shall determine the suitability of all joint details to be used in a welded assembly.

The Engineer shall specify in contract documents, as necessary, and as applicable, the following:

(1) Code requirements that are applicable only when specified by the Engineer.

(2) All additional NDT that is not specifically addressed in the code.

(3) Extent of verification inspection, when required.

(4) Weld acceptance criteria other than that specified in Clause 8.

(5) CVN toughness criteria for weld metal, base metal, and/or HAZ when required.

(6) For nontubular applications, whether the structure is statically or cyclically loaded.

(7) Which welded joints are loaded in tension.

(8) All additional requirements that are not specifically addressed in the code.

(9) For OEM applications, the responsibilities of the parties involved.

1.5.2 Contractor's Responsibilities. The Contractor shall be responsible for WPSs, qualification of welding personnel, the Contractor's inspection, and performing work in conformance with the requirements of this code and contract documents.

1.5.3 Inspector's Responsibilities

1.5.3.1 Contractor Inspection. Contractor inspection shall be supplied by the Contractor and shall be performed as necessary to ensure that materials and workmanship meet the requirements of the contract documents.

1.5.3.2 Verification Inspection. The Engineer shall determine if Verification Inspection shall be performed. Responsibilities for Verification Inspection shall be established between the Engineer and the Verification Inspector.

1.6 Approval

All references to the need for approval shall be interpreted to mean approval by the Authority Having Jurisdiction or the Engineer.

1.7 Mandatory and Nonmandatory Provisions

1.7.1 Code Terms "Shall," "Should," and "May." "Shall," "should," and "may" have the following significance:

1.7.1.1 Shall. Code provisions that use "shall" are mandatory unless specifically modified in contract documents by the Engineer.

1.7.1.2 Should. The word "should" is used to recommend practices that are considered beneficial, but are not requirements.

1.7.1.3 May. The word "may" in a provision allows the use of optional procedures or practices that can be used as an alternative or supplement to code requirements. Those optional procedures that require the Engineer's approval shall either be specified in the contract documents, or require the Engineer's approval. The Contractor may use any option without the Engineer's approval when the code does not specify that the Engineer's approval shall be required.

1.8 Welding Symbols

Welding 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 Examination*

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

AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

AWS A5.01M/A5.01:2013 (ISO 14344:2010 MOD), *Procurement Guidelines for Consumables—Welding and Allied Processes—Flux and Gas Shielded Electrical Welding Processes*

AWS A5.1/A5.1M:2012, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*

AWS A5.5/A5.5M:2014, *Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*

AWS A5.12M/A5.12:2009 (ISO 6848:2004 MOD), *Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting*

AWS A5.17/A5.17M-97 (R2007), *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*

AWS A5.18/A5.18M:2005, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*

AWS A5.20/A5.20M:2005, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*

AWS A5.23/A5.23M:2011, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*

AWS A5.25/A5.25M-97 (R2009), *Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding*

AWS A5.26/A5.26M-97 (R2009), *Specification for Carbon and Low-Alloy Steel Electrodes for Electrogas Welding*

AWS A5.28/A5.28M:2005, *Specification for Low-Alloy Steel Filler Metals for Gas Shielded Arc Welding*

AWS A5.29/A5.29M:2010, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*

AWS A5.30/A5.30M:2007, *Specification for Consumable Inserts*

AWS A5.32M/A5.32:2011 (ISO 14175:2008 MOD), *Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*

AWS A5.36/A5.36M:2012, *Specification for Carbon and Low-Alloy Steel Flux Cored Electrodes for Flux Cored Arc Welding and Metal Cored Electrodes for Gas Metal Arc Welding*

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

AWS B4.0, *Standard Methods for Mechanical Testing of Welds*

AWS C4.1-77 (R2010), *Criteria for Describing Oxygen-Cut Surfaces and Oxygen Cutting Surface Roughness Gauge*

AWS D1.0, *Code for Welding in Building Construction*

AWS D1.8/D1.8M, *Structural Welding Code—Seismic Supplement*

AWS D2.0, *Specification for Welded Highway and Railway Bridges*

AWS QC1, *Standard for AWS Certification of Welding Inspectors*

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

American Institute of Steel Construction (AISC) Standards:

ANSI/AISC 360, *Specification for Structural Buildings*

American Petroleum Institute (API) Standards:

API 2W, *Specification for Steel Plates for Offshore Structures, Produced by Thermo-Mechanical Control Processing*

API 2Y, *Specification for Steel Plates, Quenched and- Tempered, for Offshore Structures*

American Society of Mechanical Engineers (ASME) Standards:

ASME *Boiler and Pressure Vessel Code*, Section V, Article 2

ASME B46.1, *Surface Texture (Surface Roughness, Waviness, and Lay)*

American Society for Nondestructive Testing (ASNT) Standards:

ASNT CP–189, *ASNT Standard for Qualification and Certification of Nondestructive Personnel*

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

American Society for Testing and Materials (ASTM) Standards:

All ASTM base metals listed in Table 5.3 and Table 6.9 are found in ASTM 01.04, *Steel—Structural, Reinforcing, Pressure Vessel Railway*, ASTM 01.03, *Steel-Plate, Sheet, Strip, Wire; Stainless Steel Bar*, or ASTM 01.01, *Steel-Piping, Tubing, Fittings*

ASTM A6, *Standard Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling*

ASTM A109, *Standard Specification for Steel, Strip, Carbon, (0.25 Maximum Percent), Cold–Rolled*

ASTM A370, *Mechanical Testing of Steel Products*

ASTM A435, *Specification for Straight Beam Ultrasonic Examination of Steel Plates*

ASTM A673, *Specification for Sampling Procedure for Impact Testing of Structural Steel*

ASTM E23, *Standard Methods for Notched Bar Impact Testing of Metallic Materials, for Type A Charpy (Simple Beam) Impact Specimen*

ASTM E92, *Test Method for Vickers Hardness of Metallic Materials*

ASTM E94, *Standard Guide for Radiographic Examination Using Industrial Radiographic Film*

ASTM E140, *Hardness Conversion Tables for Metals*

ASTM E165, *Test Method for Liquid Penetrant Examination*

ASTM E709, *Guide for Magnetic Particle Inspection*

ASTM E747, *Controlling Quality of Radiographic Testing Using Wire Parameters*

ASTM E1032, *Radiographic Examination of Weldments Using Industrial X-Ray Film*

ASTM E1254, *Standard Guide for Storage of Radiographs and Unexposed Industrial Radiographic Films*

ASTM E2033, *Standard Practice for Radiographic Examination using Computed Radiology (Photostimulable Luminescence Method)*

ASTM E2445, *Standard Practice for Performance Evaluation and Long-Term Stability of Computed Radiology Systems*

ASTM E2698, *Standard Practice for Radiological Examination Using Digital Detector Arrays*

ASTM E2699, *Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for Digital Radiographic (DR) Test Methods*.

ASTM E2737, *Standard Practice for Digital Detector Array Performance Evaluation and Long-Term Stability*

Canadian Standards Association (CSA) Standards:

CSA W178.2, *Certification of Welding Inspectors*

International Institute of Welding (IIW) Ultrasonic Reference Block

The Society for Protective Coatings (SSPC) Standards:

SSPC-SP2, *Hand Tool Cleaning*

3. Terms and Definitions

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, provides the basis for terms and definitions used herein. However, the following terms and definitions are included below to accomodate usage specific to this document.

The terms and definitions in this glossary are divided into three categories: (1) general welding terms compiled by the AWS Committee on Definitions and Symbols; (2) terms, defined by the AWS Structural Welding Committee, which apply only to UT, designated by (UT) following the term; and (3) other terms, preceded by asterisks, which are defined as they relate to this code.

For the purposes of this document, the following terms and definitions apply:

A

***alloy flux.** A flux upon which the alloy content of the weld metal is largely dependent.

***all-weld-metal test specimen.** A test specimen with the reduced section composed wholly of weld metal.

***amplitude length rejection level (UT).** The maximum length of discontinuity allowed by various indication ratings associated with weld size, as indicated in Tables 8.2 and 8.3.

***angle of bevel.** See **bevel angle**.

arc gouging. Thermal gouging that uses an arc cutting process variation to form a bevel or groove.

as-welded. The condition of weld metal, welded joints, and weldments after welding, but prior to any subsequent thermal, mechanical, or chemical treatments.

***attenuation (UT).** The loss in acoustic energy which occurs between any two points of travel. This loss may be due to absorption, reflection, etc. (In this code, using the shear wave pulse-echo method of testing, the attenuation factor is 2 dB per inch of sound path distance after the first inch.)

automatic welding. Welding with equipment that requires only occasional or no observation of the welding, and no manual adjustment of the equipment controls. Variations of this term are **automatic brazing, automatic soldering, automatic thermal cutting**, and **automatic thermal spraying**.

***auxiliary attachments.** Members or appurtenances attached to main stress-carrying members by welding. Such members may or may not carry loads.

average instantaneous power (AIP), *waveform-controlled welding*. The average of products of amperages and voltages determined at sampling frequencies sufficient to quantify waveform changes during a welding interval.

axis of a weld. See **weld axis.**

B

backgouging. The removal of weld metal and base metal from the weld root side of a welded joint to facilitate complete fusion and CJP upon subsequent welding from that side.

backing. A material or device placed against the back side of the joint, or at both sides of a weld in ESW and EGW, to support and retain molten weld metal. The material may be partially fused or remain unfused during welding and may be either metal or nonmetal.

backing pass. A weld pass made for a backing weld.

backing ring. Backing in the form of a ring, generally used in the welding of pipe.

backing weld. Backing in the form of a weld.

***backup weld (tubular structures).** The initial closing pass in a CJP groove weld, made from one side only, which serves as a backing for subsequent welding, but is not considered as a part of the theoretical weld (Figures 10.9 through 10.11, Details C and D).

back weld. A weld made at the back of a single groove weld.

base metal. The metal or alloy that is welded, brazed, soldered, or cut.

bevel angle. The angle between the bevel of a joint member and a plane perpendicular to the surface of the member.

box tubing. Tubular product of square or rectangular cross section. See **tubular**.

***brace intersection angle, θ (tubular structures).** The acute angle formed between brace centerlines.

***Building Code.** The building law or specification or other construction regulations in conjunction with which this code is applied.

NOTE: In the absence of any locally applicable building law or specifications or other construction regulations, it is recommended that the construction be required to comply with the Specification for Structural Steel Buildings (AISC).

butt joint. A joint between two members aligned approximately in the same plane.

butt weld. A nonstandard term for a weld in a butt joint. See **butt joint**.

C

***cap pass.** One or more weld passes that form the weld face (exposed surface of completed weld). Adjacent cap passes may partially cover, but not completely cover, a cap pass.

***caulking.** Plastic deformation of weld and base metal surfaces by mechanical means to seal or obscure discontinuities.

complete fusion. Fusion over the entire fusion faces and between all adjoining weld beads.

complete joint penetration (CJP). A joint root condition in a groove weld in which weld metal extends through the joint thickness.

***Computed radiography (CR).**

***CJP groove weld (statically and cyclically loaded structures).** A groove weld which has been made from both sides or from one side on a backing having CJP and fusion of weld and base metal throughout the depth of the joint.

***CJP groove weld (tubular structures).** A groove weld having CJP and fusion of weld and base metal throughout the depth of the joint or as detailed in Figures 10.4 10.7 through 10.11, and 10.19. A CJP tubular groove weld made from one side only, without backing, is allowed where the size or configuration, or both, prevent access to the root side of the weld.

complete penetration. A nonstandard term for **CJP**. See **complete joint penetration**.

construction aid weld. A weld made to attach a piece or pieces to a weldment for temporary use in handling, shipping, or working on the structure.

consumable guide ESW. See **ESW, consumable guide**.

continuous weld. A weld that extends continuously from one end of a joint to the other. Where the joint is essentially circular, it extends completely around the joint.

***contract documents.** Any codes, specifications, drawings, or additional requirements that are contractually specified by the Owner.

***Contractor.** Any company, or that individual representing a company, responsible for the fabrication, erection manufacturing or welding, in conformance with the provisions of this code.

***Contractor's Inspector.** The duly designated person who acts for, and in behalf of, the Contractor on all inspection and quality matters within the scope of the code and of the contract documents.

corner joint. A joint between two members located approximately at right angles to each other in the form of an L.

***cover pass.** See **cap pass**.

CO_2 welding. A nonstandard term for **GMAW** with carbon dioxide shielding gas.

crater. A depression in the weld face at the termination of a weld bead.

*** Charpy V-notch (CVN).**

D

*** digital detector array (DDA).**

***decibel (dB) (UT).** The logarithmic expression of a ratio of two amplitudes or intensities of acoustic energy.

***decibel rating (UT).** See preferred term **indication rating**.

defect. A discontinuity or discontinuities that by nature or accumulated effect (for example total crack length) render a part or product unable to meet minimum applicable acceptance standards or specifications. This term designates rejectability.

defective weld. A weld containing one or more defects.

***defect level (UT**). See **indication level**.

***defect rating (UT).** See **indication rating**.

depth of fusion. The distance that fusion extends into the base metal or previous bead from the surface melted during welding.

***dihedral angle.** See **local dihedral angle. discontinuity.** An interruption of the typical structure of a material, such as a lack of homogeneity in its mechanical or metallurgical, or physical characteristics. A discontinuity is not necessarily a defect.

downhand. A nonstandard term for **flat welding position**.

***direct radiography (DR).**

***drawings.** Refers to plans design and detail drawings, and erection plans.

E

***edge angle (tubular structures).** The acute angle between a bevel edge made in preparation for welding and a tangent to the member surface, measured locally in a plane perpendicular to the intersection line. All bevels open to outside of brace.

***effective length of weld.** The length throughout which the correctly proportioned cross section of the weld exists. In a curved weld, it shall be measured along the weld axis.

electrogas welding (EGW). An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool, employing approximately vertical welding progression with backing to confine the molten weld metal. The process is used with or without an externally supplied shielding gas and without the application of pressure.

electroslag welding (ESW). A welding process that produces coalescence of metals with molten slag that melts the filler metal and the surfaces of the workpieces. The weld pool is shielded by this slag, which moves along the full cross section of the joint as welding progresses. The process is initiated by an arc that heats the slag. The arc is then extinguished by the conductive slag, which is kept molten by its resistance to electric current passing between the electrode and the workpieces.

ESW, consumable guide. An electroslag welding process variation in which filler metal is supplied by an electrode and its guiding member.

***end return.** The continuation of a fillet weld around a corner of a member as an extension of the principal weld.

***Engineer.** A duly designated individual who acts for and in behalf of the Owner on all matters within the scope of the code.

F

***fatigue.** Fatigue, as used herein, is defined as the damage that may result in fracture after a sufficient number of stress fluctuations. Stress range is defined as the peak-to-trough magnitude of these fluctuations. In the case of stress reversal, stress range shall be computed as the numerical sum (algebraic difference) of maximum repeated tensile and compressive stresses, or the sum of shearing stresses of opposite direction at a given point, resulting from changing conditions of load.

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

filler metal. The metal or alloy to be added in making a welded, brazed, or soldered joint.

fillet weld leg. The distance from the joint root to the toe of the fillet weld.

fin. A defect in a bar or other rolled section caused by the steel spreading into the clearance between the rolls. This produces a thick overfill which, if rolled again, usually becomes a lap.

flare-bevel-groove weld. A weld in the groove formed between a joint member with a curved surface and another with a planar surface.

***flash.** The material which is expelled or squeezed out of a weld joint and which forms around the weld.

flat welding position. The welding position used to weld from the upper side of the joint at a point where the weld axis is approximately horizontal, and the weld face lies in an approximately horizontal plane.

flux cored arc welding (FCAW). An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding gas from a flux contained within the tubular electrode, with or without additional shielding from an externally supplied gas, and without the application of pressure.

***flux cored are welding—gas shielded (FCAW-G).** A flux cored arc welding process variation in which additional shielding is obtained from an externally supplied gas or gas mixture.

***flux cored arc welding—self shielded (FCAW-S).** A flux cored arc welding process where shielding is exclusively provided by a flux contained within the tubular electrode.

fusion. The melting together of filler metal and base metal (substrate), or of base metal only, to produce a weld.

fusion line. The boundary between weld metal and base metal in a fusion weld.

***fusion-type discontinuity.** Signifies slag inclusion, incomplete fusion, incomplete joint penetration, and similar discontinuities associated with fusion.

fusion zone. The area of base metal melted as determined on the cross section of a weld.

G

gas metal arc welding (GMAW). An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding from an externally supplied gas and without the application of pressure.

gas metal arc welding-short circuit arc (GMAW-S). A gas metal arc welding process variation in which the consumable electrode is deposited during repeated short circuits.

gas pocket. A nonstandard term for **porosity**.

Geometric unsharpness U_g). The fuzziness or lack of definition in a radiographic image resulting from the combination of source size, object-to-film distance, and source-to-object distance.

gouging. See **thermal gouging**.

groove angle. The total included angle of the groove between workpieces.

***groove angle, θ (tubular structures).** The angle between opposing faces of the groove to be filled with weld metals, determined after the joint is fit-up.

groove face. The surface of a joint member included in the groove.

groove weld. A weld made in the groove between the workpieces.

H

heat-affected zone (HAZ). The portion of the base metal whose mechanical properties or microstructure have been altered by the heat of welding, brazing, soldering, or thermal cutting.

horizontal fixed position (pipe welding). The position of a pipe joint in which the axis of the pipe is approximately horizontal, and the pipe is not rotated during welding (see Figures 6.1, 6.2, and 10.12).

horizontal welding position, *fillet weld*. The welding position in which the weld is on the upper side of an approximately horizontal surface and against an approximately vertical surface (see Figures 6.1, 6.2, 6.3, and 6.4).

***horizontal reference line (UT).** A horizontal line near the center of the UT instrument scope to which all echoes are adjusted for dB reading.

horizontal rotated position (pipe welding). The position of a pipe joint in which the axis of the pipe is approximately horizontal, and welding is performed in the flat position by rotating the pipe (see Figures 6.1, 6.2, and 10.12).

***hot-spot strain (tubular structures).** The cyclic total range of strain which would be measured at the point of highest stress concentration in a welded connection.

NOTE: When measuring hot-spot strain, the strain gage should be sufficiently small to avoid averaging high and low strains in the regions of steep gradients.

I

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

***indication (UT).** The signal displayed on the oscilloscope signifying the presence of a sound wave reflector in the part being tested.

***indication level (UT).** The calibrated gain or attenuation control reading obtained for a reference line height indication from a discontinuity.

***indication rating (UT).** The decibel reading in relation to the zero reference level after having been corrected for sound attenuation.

intermittent weld. A weld in which the continuity is broken by recurring unwelded spaces.

interpass temperature. In a multipass weld, the temperature of the weld area between weld passes.

J

joint. The junction of members or the edges of members that are to be joined or have been joined.

joint penetration. The distance the weld metal extends from the weld face into a joint, exclusive of weld reinforcement.

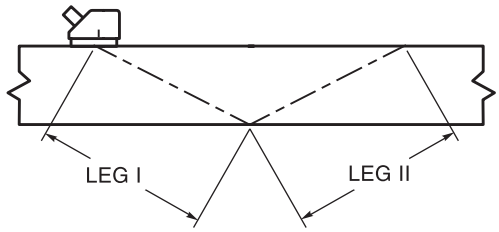
joint root. That portion of a joint to be welded where the members approach closest to each other. In cross section, the joint root may be either a point, a line, or an area.

L

lap joint. A joint between two overlapping members in parallel planes.

***layer.** A stratum of weld metal or surfacing material. The layer may consist of one or more weld beads laid side by side.

***leg (UT).** The path the shear wave travels in a straight line before being reflected by the surface of material being tested. See sketch for leg identification. Note: Leg I plus leg II equals one V-path.



leg of a fillet weld. See **fillet weld leg.**

***local dihedral angle, θ (tubular structures).** The angle, measured in a plane perpendicular to the line of the weld, between tangents to the outside surfaces of the tubes being joined at the weld. The exterior dihedral angle, where one looks at a localized section of the connection, such that the intersecting surfaces may be treated as planes.

M

manual welding. Welding with the torch, gun or electrode holder held and manipulated by hand. Accessory equipment, such as part motion devices and manually controlled filler material feeders may be used. See **automatic welding, mechanized welding**, and **semiautomatic welding**.

mechanized process (XXXX-ME). An operation with equipment requiring manual adjustment by an operator in response to visual observation, with the torch, gun, wire guide assembly, or electrode holder held by a mechanical device. See **mechanized welding**.

mechanized welding (W-ME). See **mechanized process.**

***Magnetic particle testing (MT).**

N

***nondestructive testing (NDT).** The process of determining acceptability of a material or a component in accordance with established criteria without impairing its future usefulness.

***node (UT).** See **leg**.

***nominal tensile strength of the weld metal.** The tensile strength of the weld metal indicated by the classification number of the filler metal (e.g., nominal tensile strength of E60XX is 60 ksi [420 MPa]).

O

***Original Equipment Manufacturer (OEM).** A single Contractor that assumes some or all of the responsibilities assigned by this code to the Engineer.

overhead welding position. The welding position in which welding is performed from the underside of the joint (see Figures 6.1, 6.2, 6.3, and 6.4).

overlap, ***fusion welding.*** The protrusion of weld metal beyond the weld toe or weld root.

***Owner.** The individual or company that exercises legal ownership of the product or structural assembly produced to this code.

oxygen cutting (OC). A group of thermal cutting processes that severs or removes metal by means of the chemical reaction between oxygen and the base metal at elevated temperature. The necessary temperature is maintained by the heat from an arc, an oxyfuel gas flame, or other source.

oxygen gouging. Thermal gouging that uses an oxygen cutting process variation to form a bevel or groove.

P

***parallel electrode. See SAW.**

partial joint penetration (PJP). Joint penetration that is intentionally less than complete**.**

pass. See **weld pass**.

peening. The mechanical working of metals using impact blows.

***pipe.** Hollow circular cross section produced or manufactured in accordance with a pipe product specification. See **tubular**.

***piping porosity (ESW and EGW).** Elongated porosity whose major dimension lies in a direction approximately parallel to the weld axis.

***piping porosity (general).** Elongated porosity whose major dimension lies in a direction approximately normal to the weld surface. Frequently referred to as *pin holes* when the porosity extends to the weld surface.

plug weld. A weld made in a circular hole in one member of a joint fusing that member to another member. A fillet-welded hole shall not be construed as conforming to this definition.

porosity. Cavity-type discontinuities formed by gas entrapment during solidification or in a thermal spray deposit.

positioned weld. A weld made in a joint that has been placed to facilitate making the weld.

***postweld heat treatment.** Any heat treatment after welding.

preheating. The application of heat to the base metal immediately before welding, brazing, soldering, thermal spraying, or cutting.

preheat temperature, ***welding*****.** The temperature of the base metal in the volume surrounding the point of welding immediately before welding is started. In a multiple-pass weld, it is also the temperature immediately before the second and subsequent passes are started.

***Liquid penetrant testing (PT).**

***Postweld heat treatment (PWHT).**

Q

qualification. See welder performance qualification and **WPS qualification.**

R

random sequence. A longitudinal sequence in which the weld bead increments are made at random.

***reference level (UT).** The decibel reading obtained for a horizontal reference-line height indication from a reference reflector.

***reference reflector (UT).** The reflector of known geometry contained in the IIW reference block or other approved blocks.

reinforcement of weld. See **weld reinforcement.**

***resolution (UT).** The ability of UT equipment to give separate indications from closely spaced reflectors.

root face. That portion of the groove face within the joint root.

root gap. A nonstandard term for **root opening. root of joint.** See **joint root**.

root of weld. See **weld root.**

root opening. A separation at the joint root between the workpieces.

***Radiographic testing (RT).**

S

***single electrode.** One electrode connected exclusively to one power source which may consist of one or more power units.

***parallel electrode.** Two electrodes connected electrically in parallel and exclusively to the same power source. Both electrodes are usually fed by means of a single electrode feeder. Welding current, when specified, is the total for the two.

***multiple electrodes.** The combination of two or more single or parallel electrode systems. Each of the component systems has its own independent power source and its own electrode feeder.

***scanning level (UT).** The dB setting used during scanning, as described in Tables 8.2 and 8.3.

semiautomatic welding. Manual welding with equipment that automatically controls one or more of the welding conditions.

***shelf bar.** Steel plates, bars, or similar elements used to support the overflow of excess weld metal deposited in a horizontal groove weld joint.

Shielded metal arc welding (SMAW). An arc welding process with an arc between a covered electrode and the weld pool. The process is used with shielding from the decomposition of the electrode covering, without the application of pressure, and with filler metal from the electrode.

shielding gas. Protective gas used to prevent or reduce atmospheric contamination.

single-welded joint. A joint that is welded from one side only.

size of weld. See **weld size**.

slot weld. A weld made in an elongated hole in one member of a joint fusing that member to another member. The hole may be open at one end. A fillet welded slot shall not be construed as conforming to this definition.

***sound beam distance (UT).** See **sound path distance.**

***sound path distance (UT).** The distance between the search unit test material interface and the reflector as measured along the centerline of the sound beam.

***storage phosphor imaging plate (SPIP).**

spatter. The metal particles expelled during fusion welding that do not form a part of the weld.

stringer bead. A type of weld bead made without appreciable weaving motion.

***stud base.** The stud tip at the welding end, including flux and container, and 1/8 in [3 mm] of the body of the stud adjacent to the tip.

***stud welding (SW).** An arc welding process that produces coalescence of metals by heating them with an arc between a metal stud, or similar part, and the other workpiece. When the surfaces to be joined are properly heated, they are brought together under pressure. Partial shielding may be obtained by the use of a ceramic ferrule surrounding the stud. Shielding gas or flux may or may not be used.

Submerged arc welding (SAW). An arc welding process that uses an arc or arcs between a bare metal electrode or electrodes and the weld pool. The arc and molten metal are shielded by a blanket of granular flux on the workpieces. The process is used without pressure and with filler metal from the electrode and sometimes from a supplemental source (welding rod, flux, or metal granules).

T

tack weld. A weld made to hold parts of a weldment in proper alignment until the final welds are made.

***tack welder.** A fitter, or someone under the direction of a fitter, who tack welds parts of a weldment to hold them in proper alignment until the final welds are made.

***tandem.** Refers to a geometrical arrangement of electrodes in which a line through the arcs is parallel to the direction of welding.

thermal gouging. A thermal cutting process variation that removes metal by melting or burning the entire removed portion, to form a bevel or groove.

throat of a fillet weld.

actual throat. The shortest distance between the weld root and the face of a fillet weld.

theoretical throat. The distance from the beginning of the joint root perpendicular to the hypotenuse of the largest right triangle that can be inscribed within the cross section of a fillet weld. This dimension is based on the assumption that the root opening is equal to zero.

throat of a groove weld. A nonstandard term for **groove weld size**.

T-joint. A joint between two members located approximately at right angles to each other in the form of a T.

toe of weld. See **weld toe.**

***transverse discontinuity.** A weld discontinuity whose major dimension is in a direction perpendicular to the weld axis "X," see Annex P, Form P-11.

total instantaneous energy (TIE), *waveform-controlled welding*. The sum of products of amperages, voltages and time intervals determined at sampling frequencies sufficient to quantify waveform changes during a welding interval.

***tubular.** A generic term that refers to sections including pipe products (see **pipe**) and the family of square, rectangular, and round hollow-section products produced or manufactured in accordance with a tubular product specification. Also referred to as hollow structural section (HSS).

***tubular connection.** A connection in the portion of a structure that contains two or more intersecting members, at least one of which is a tubular member.

***tubular joint.** A joint in the interface created by a tubular member intersecting another member (which may or may not be tubular).

U

***unacceptable discontinuity**. See **defect.**

undercut. A groove melted into the base metal adjacent to the weld toe or weld root and left unfilled by weld metal.

***Ultrasonic testing (UT).**

V

***Verification Inspector.** The duly designated person who acts for, and in behalf of, the Owner on all inspection and quality matters designated by the Engineer.

vertical welding position. The welding position in which the weld axis, at the point of welding, is approximately vertical, and the weld face lies in an approximately vertical plane (see Figures 6.1, 6.2, 6.3, and 6.4).

***vertical position (pipe welding).** The position of a pipe joint in which welding is performed in the horizontal position and the pipe is not rotated during welding (see Figures 6.1, 6.2, and 10.12).

***V-path (UT).** The distance a shear wave sound beam travels from the search unit test material interface to the other face of the test material and back to the original surface.

W

weave bead. A type of weld bead made with transverse oscillation.

weld. A localized coalescence of metals or nonmetals produced by heating the materials to the welding temperature, with or without the application of pressure or by the applications of pressure alone and with or without the use of filler material.

weldability. The capacity of a material to be welded under the imposed fabrication conditions into a specific, suitably designed structure and to perform satisfactorily in the intended service.

weld axis. A line through the length of a weld, perpendicular to and at the geometric center of its cross section.

weld bead. A weld resulting from a pass. See **stringer bead** and **weave bead**.

welder. One who performs a manual or semiautomatic welding operation.

welder certification. Written certification that a welder has produced welds meeting a prescribed standard of welder performance.

welder performance qualification. The demonstration of a welder's ability to produce welds meeting prescribed standards.

weld face. The exposed surface of a weld on the side from which welding was done.

welding. A joining process that produces coalescence of materials by heating them to the welding temperature, with or without the application of pressure or by the application of pressure alone, and with or without the use of filler metal. See also the Master Chart of Welding and Allied Processes in the latest edition of AWS A3.0.

welding machine. Equipment used to perform the welding operation. For example, spot welding machine, arc welding machine, and seam welding machine.

welding operator. One who operates adaptive control, automatic, mechanized, or robotic welding equipment.

welding sequence. The order of making the welds in a weldment.

weld pass. A single progression of welding along a joint. The result of a pass is a weld bead or layer.

weld reinforcement. Weld metal in excess of the quantity required to fill a joint.

weld root. The points, as shown in cross section, at which the root surface intersects the base metal surfaces.

weld size.

fillet weld size. For equal leg fillet welds, the leg lengths of the largest isosceles right triangle that can be inscribed within the fillet weld cross section. For unequal leg fillet welds, the leg lengths of the largest right triangle that can be inscribed within the fillet weld cross section.

NOTE: When one member makes an angle with the other member greater than 105°, the leg length (size) is of less significance than the effective throat, which is the controlling factor for the strength of the weld.

groove weld size. The joint penetration of a groove weld.

weld tab. Additional material that extends beyond either end of the joint, on which the weld is started or terminated.

weld toe. The junction of the weld face and the base metal.

weldment. An assembly whose component parts are joined by welding.

WPS qualification. The demonstration that welds made by a specific procedure can meet prescribed standards.

***welding procedure specification (WPS).** A document providing the detailed methods and practices involved in the production of a weldment.