

AWS D1.1/D1.1M:2025
An American National Standard

Structural Welding Code Steel



AWS D1.1/D1.1M:2025
An American National Standard

Approved by the
American National Standards Institute
March 19, 2025

Structural Welding Code—Steel

5th Edition

Revised AWS D1.1/D1.1M:2020

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. Chapters 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.



ISBN Print: 978-1-64322-372-8
ISBN PDF: 978-1-64322-373-5
© 2025 by American Welding Society
All rights reserved
Printed in the United States of America

Photocopy Rights. No portion of this standard may be reproduced, stored in a retrieval system, or transmitted in any form, including mechanical, photocopying, recording, or otherwise, without the prior written permission of the copyright owner.

Authorization to photocopy items for internal, personal, or educational classroom use only or the internal, personal, or educational classroom use only of specific clients is granted by the American Welding Society provided that the appropriate fee is paid to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, tel: (978) 750-8400; Internet: <www.copyright.com>.

Statement on the Use of American Welding Society Standards

All standards (codes, specifications, recommended practices, methods, classifications, and guides) of the American Welding Society (AWS) are voluntary consensus standards that have been developed in accordance with the rules of the American National Standards Institute (ANSI). When AWS American National Standards are either incorporated in, or made part of, documents that are included in federal or state laws and regulations, or the regulations of other governmental bodies, their provisions carry the full legal authority of the statute. In such cases, any changes in those AWS standards must be approved by the governmental body having statutory jurisdiction before they can become a part of those laws and regulations. In all cases, these standards carry the full legal authority of the contract or other document that invokes the AWS standards. Where this contractual relationship exists, changes in or deviations from requirements of an AWS standard must be by agreement between the contracting parties.

AWS American National Standards are developed through a consensus standards development process that brings together volunteers representing varied viewpoints and interests to achieve consensus. While AWS administers the process and establishes rules to promote fairness in the development of consensus, it does not independently test, evaluate, or verify the accuracy of any information or the soundness of any judgments contained in its standards.

AWS disclaims liability for any injury to persons or to property, or other damages of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, or reliance on this standard. AWS also makes no guarantee or warranty as to the accuracy or completeness of any information published herein.

In issuing and making this standard available, AWS is neither undertaking to render professional or other services for or on behalf of any person or entity, nor is AWS undertaking to perform any duty owed by any person or entity to someone else. Anyone using these documents should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances. It is assumed that the use of this standard and its provisions is entrusted to appropriately qualified and competent personnel.

This standard may be superseded by new editions. This standard may also be corrected through publication of amendments or errata, or supplemented by publication of addenda. Information on the latest editions of AWS standards including amendments, errata, and addenda is posted on the AWS web page (www.aws.org). Users should ensure that they have the latest edition, amendments, errata, and addenda.

Publication of this standard does not authorize infringement of any patent or trade name. Users of this standard accept any and all liabilities for infringement of any patent or trade name items. AWS disclaims liability for the infringement of any patent or product trade name resulting from the use of this standard.

AWS does not monitor, police, or enforce compliance with this standard, nor does it have the power to do so.

Official interpretations of any of the technical requirements of this standard may only be obtained by sending a request, in writing, to the appropriate technical committee. Such requests should be addressed to the American Welding Society, Attention: Director, Standards Development, 8669 NW 36 St, # 130, Miami, FL 33166 (see Annex T). With regard to technical inquiries made concerning AWS standards, oral opinions on AWS standards may be rendered. These opinions are offered solely as a convenience to users of this standard, and they do not constitute professional advice. Such opinions represent only the personal opinions of the particular individuals giving them. These individuals do not speak on behalf of AWS, nor do their oral opinions constitute official or unofficial opinions or interpretations of AWS. In addition, oral opinions are informational and should not be used as a substitute for an official interpretation.

This standard is subject to revision at any time by the AWS D1 Committee on Structural Welding. It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are requested and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the AWS D1 Committee on Structural Welding and the author of the comments will be informed of the Committee's response to the comments. Guests are invited to attend all meetings of the AWS D1 Committee on Structural Welding to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

This page is intentionally blank.

Currently in preview, click buy full version

Personnel

AWS D1 Committee on Structural Welding

T. L. Niemann, Chair	<i>Fickett Structural Solutions</i>
R. D. Medlock, 1st Vice Chair	<i>High Steel Structures, LLC</i>
N. S. Lindell, 2nd Vice Chair	<i>Project & Quality Solutions</i>
J. A. Molin, Secretary	<i>American Welding Society</i>
J. M. Rosario, Secretary	<i>American Welding Society</i>
U. W. Aschemeier	<i>Subsea Global Solutions</i>
E. L. Bickford	<i>Reaves Welding Industries, LLC</i>
L. M. Bower	<i>Cornerstone Building Brands</i>
T. W. Burns	<i>Thom Burns Consulting, LLC</i>
H. H. Campbell	<i>Pazuzu Engineering</i>
R. D. Campbell	<i>Bechtel</i>
N. M. Choy	<i>California Department of Transportation</i>
B. M. Connelly	<i>Eustis Engineering, LLC</i>
R. B. Corbit	<i>Consultant</i>
M. E. Gase	<i>Midwest Steel, Incorporated</i>
H. E. Gilmer	<i>Pennoni Associates, Incorporated</i>
T. P. Green	<i>Wick-Johnson, Elstner Associates, Incorporated</i>
I. W. Houston	<i>Stanley Black & Decker–Nelson Stud Welding</i>
M. G. Iverson	<i>TRC Dathen</i>
M. D. Kerr	<i>Consultant</i>
J. H. Kiefer	<i>JH Kiefer and Associates</i>
P. G. Kinney	<i>Sandia National Laboratories</i>
B. R. Kregger	<i>Los Alamos National Laboratory</i>
V. Kuzmina	<i>Lexicon, Incorporated</i>
J. Lawton	<i>American Engineering and Manufacturing, Incorporated</i>
D. Luciani	<i>CWB Group</i>
D. L. McQuaid	<i>D. L. McQuaid & Associates, Incorporated</i>
J. K. Merrill	<i>TRC Companies</i>
D. K. Miller	<i>The Lincoln Electric Company</i>
D. D. Rager	<i>Rager Consulting, Incorporated</i>
T. J. Schlafly	<i>American Institute of Steel Construction</i>
R. E. Shaw	<i>Steel Structures Technology Center, Incorporated</i>

Advisors to the D1 Committee on Structural Welding

N. J. Altebrando	<i>STV, Incorporated</i>
S. E. Anderson	<i>Anderson Inspections</i>
R. V. Clarke	<i>Consultant</i>
C. L. Decker	<i>The Lincoln Electric Company</i>
G. L. Fox	<i>Consultant</i>
M. A. Grieco	<i>Massachusetts Department of Transportation</i>
W. S. Houston	<i>Houston Labs – Consultant</i>
P. W. Marshall	<i>Moonshine Hill Proprietary Systems Engineering</i>
G. S. Martin	<i>TRC Companies</i>
M. J. Mayes	<i>Terracon Consultants</i>
A. W. Sindel	<i>TRC Companies</i>

R. E. Stachel	<i>HRV Conformance Verification Associates, Incorporated</i>
M. M. Tayarani	<i>Pennoni Associates, Incorporated</i>
B. D. Wright	<i>Advantage Aviation Technologies</i>

AWS D1Q Subcommittee on Steel

T. P. Green, Chair	<i>Wiss, Janney, Elstner Associates, Incorporated</i>
J. A. Molin, Secretary	<i>American Welding Society</i>
J. M. Rosario, Secretary	<i>American Welding Society</i>
U. W. Aschemeier	<i>Subsea Global Solutions</i>
E. L. Bickford	<i>Reaves Welding Industries, LLC</i>
L. M. Bower	<i>Cornerstone Building Brands</i>
H. H. Campbell	<i>Pazuzu Engineering</i>
R. V. Clarke	<i>Consultant</i>
S. J. Findlan	<i>Westinghouse Electric Company, LLC</i>
M. E. Gase	<i>Midwest Steel, Incorporated</i>
H. E. Gilmer	<i>Pennoni Associates, Incorporated</i>
R. L. Holdren	<i>ARC Specialties, Incorporated</i>
I. W. Houston	<i>Stanley Black & Decker–Nelson, Steel Welding</i>
W. S. Houston	<i>Houston Labs – Consultant</i>
M. D. Kerr	<i>CB&I</i>
J. H. Kiefer	<i>JH Kiefer and Associates</i>
P. G. Kinney	<i>Sandia National Laboratories</i>
V. Kuruvilla	<i>Lexicon, Incorporated</i>
D. R. Luciani	<i>CWB Group</i>
R. P. Marslender	<i>Kierulff & Moore Services, Ltd.</i>
G. S. Martin	<i>TRC Companies</i>
J. K. Merrill	<i>TRC Companies</i>
J. I. Miller	<i>Consultant</i>
S. P. Moran	<i>General Dynamics - Electric Boat</i>
D. D. Rager	<i>Rager Consulting, Incorporated</i>
T. J. Schlafly	<i>American Institute of Steel Construction</i>
R. E. Shaw	<i>Steel Structures Technology Center, Incorporated</i>
J. L. Warren	<i>CB&I</i>
C. Zanfir	<i>CWB Group</i>

Advisors to the AWS D1Q Subcommittee on Steel

W. P. Capers	<i>Walt Disney World Company</i>
N. S. Lindell	<i>Project & Quality Solutions</i>
P. W. Marshall	<i>Moonshine Hill Proprietary Systems Engineering</i>
M. J. Mayes	<i>Terracon Consultants</i>
R. D. Medlock	<i>High Steel Structures, LLC</i>
D. K. Miller	<i>The Lincoln Electric Company</i>
T. L. Niemann	<i>Fickett Structural Solutions</i>
J. A. Packer	<i>University of Toronto</i>
D. A. Wright	<i>Wright Welding Tech.</i>

AWS D1Q Subcommittee Task Group on Design

D. K. Miller, Co-Chair	<i>The Lincoln Electric Company</i>
T. J. Schlafly, Co-Chair	<i>American Institute of Steel Construction</i>
T. P. Green, Vice Chair	<i>Wiss, Janney, Elstner Associates, Incorporated</i>
C. P. Ahlskog	<i>Modjeski and Masters, Incorporated</i>

C. L. Decker	<i>The Lincoln Electric Company</i>
D. Ferrell	<i>Ferrell Engineering, Incorporated (deceased)</i>
J. J. Fonzi	<i>WSP</i>
C. Hanson Carbonneau	<i>Cimolai HY</i>
D. A. Koch	<i>Pacific Northwest National Laboratory</i>
L. A. Malm	<i>Wiss, Janney, Elstner Associates, Incorporated</i>
J. A. Packer	<i>University of Toronto</i>
G. A. Rassati	<i>University of Cincinnati</i>

Advisors to the AWS D1Q Subcommittee Task Group on Design

W. P. Capers	<i>Walt Disney World Company</i>
T. L. Niemann	<i>Fickett Structural Solutions</i>
J. M. Ocel	<i>Federal Highway Administration</i>
J. Ross	<i>U.S. Army Corps of Engineers (retired)</i>

AWS D1Q Subcommittee Task Group on Prequalification

C. Zanfir, Chair	<i>CWB Group</i>
L. M. Bower, Vice Chair	<i>Cornerstone Building Brands</i>
W. J. Bell	<i>Atlantic Testing Laboratories</i>
H. H. Campbell	<i>Pazuzu Engineering</i>
M. R. Cates	<i>Jesse Co.</i>
D. R. Luciani	<i>CWB Group</i>
D. K. Miller	<i>The Lincoln Electric Company</i>
J. I. Miller	<i>Consultant</i>
S. P. Moran	<i>General Dynamics - Electric Boat</i>
D. D. Rager	<i>Rager Consulting, Incorporated</i>

Advisors to the AWS D1Q Subcommittee Task Group on Prequalification

P. W. Marshall	<i>Moonshine Hill Proprietary Systems Engineering</i>
T. L. Niemann	<i>Fickett Structural Solutions</i>

AWS D1Q Subcommittee Task Group on Qualification

S. J. Adlan, Chair	<i>Westinghouse Electric Company, LLC</i>
K. Welch, Vice Chair	<i>Miller Electric Manufacturing Company</i>
E. L. Bickford	<i>Reaves Welding Industries, LLC</i>
T. R. Blissett	<i>Accurate Weldment Testing, LLC</i>
V. Burke	<i>Westinghouse Electric Company, LLC</i>
C. A. Einspahr	<i>Kawasaki Motors Manufacturing Corporation USA</i>
J. F. Hernandez	<i>Kansas Department of Transportation</i>
R. L. Holdren	<i>ARC Specialties, Incorporated</i>
J. H. Kiefer	<i>JH Kiefer and Associates</i>
B. D. Kirby	<i>Fullerton College</i>
R. P. Marslender	<i>Kiewit Offshore Services, Ltd.</i>
J. D. Niemann	<i>Kawasaki Motors Manufacturing Corporation USA</i>
D. D. Rager	<i>Rager Consulting, Incorporated</i>
Z. E. Sanders	<i>Caterpillar, Incorporated</i>
D. A. Stickel	<i>Caterpillar, Incorporated</i>
P. L. Sturgill	<i>Sturgill Welding & Code Consulting</i>
J. Topham	<i>Wood PLC</i>
B. M. Toth	<i>Westinghouse Electric Company, LLC</i>
D. G. Viar	<i>Moraine Valley Community College/Techno-Weld Consultants</i>

Advisors to the AWS D1Q Subcommittee Task Group on Qualification

M. Bernasek	<i>C-Spec</i>
N. S. Lindell	<i>Project & Quality Solutions</i>
G. S. Martin	<i>TRC Companies</i>
T. L. Niemann	<i>Fickett Structural Solutions</i>

AWS D1Q Subcommittee Task Group on Fabrication

M. E. Gase, Chair	<i>Midwest Steel, Incorporated</i>
M. D. Kerr, Vice Chair	<i>CB&I</i>
S. E. Anderson	<i>Anderson Inspections</i>
S. Barrett	<i>Haberle Steel, Incorporated</i>
L. M. Bower	<i>Cornerstone Building Brands</i>
H. H. Campbell	<i>Pazuzu Engineering</i>
N. M. Choy	<i>California Department of Transportation</i>
R. V. Clarke	<i>Consultant</i>
G. W. Ehler	<i>Texas NDT Academy/Exo Group</i>
H. E. Gilmer	<i>Pennoni Associates, Incorporated</i>
J. K. Hilton Jr.	<i>KTA-Tator, Incorporated</i>
P. G. Kinney	<i>Sandia National Laboratories</i>
V. Kuruvilla	<i>Lexicon, Incorporated</i>
A. J. Lye	<i>Schuff Steel Company</i>
G. S. Martin	<i>TRC Companies</i>
E. S. Mattfield	<i>City of New York</i>
R. D. Medlock	<i>High Steel Structures, LLC</i>
J. E. Mellinger	<i>Pennoni Associates, Incorporated</i>
J. I. Miller	<i>Consultant</i>
R. E. Monson	<i>Pennoni Associates, Incorporated</i>
T. E. Rogers Jr	<i>Modjeski & Masters, Incorporated</i>

Advisors to the AWS D1Q Subcommittee Task Group on Fabrication

B. R. Anderson	<i>Molex, Incorporated</i>
L. Fox	<i>Consultant</i>
R. J. Holdren	<i>ARC Specialties, Incorporated</i>
C. W. Holmes	<i>Modjeski & Masters, Incorporated (retired)</i>
D. L. McQuaid	<i>D. L. McQuaid & Associates, Incorporated</i>
T. J. Schlafly	<i>American Institute of Steel Construction</i>

AWS D1 Committee Standing Task Group on Inspection

M. E. Gase, Chair	<i>Midwest Steel, Incorporated</i>
S. E. Anderson	<i>Anderson Inspections</i>
U. W. Aschemeier	<i>Subsea Global Solutions</i>
S. Barrett	<i>Clover Field Services, LLC</i>
R. V. Clarke	<i>Consultant</i>
J. A. Cochran	<i>Kiewit Offshore Services, Ltd.</i>
G. W. Ehler	<i>Texas NDT Academy/Exo Group</i>
P. A. Furr	<i>Loenbro Inspection</i>
H. E. Gilmer	<i>Pennoni Associates, Incorporated</i>
J. H. Gravley Jr	<i>KTA-Tator, Incorporated</i>
C. W. Hayes	<i>Consultant</i>
J. K. Hilton Jr.	<i>KTA-Tator, Incorporated</i>
P. G. Kinney	<i>Sandia National Laboratories</i>
N. S. Lindell	<i>Project & Quality Solutions</i>

A. J. Lye	<i>Schuff Steel Company</i>
G. S. Martin	<i>TRC Companies</i>
J. E. Mellinger	<i>Pennoni Associates, Incorporated</i>
J. K. Merrill	<i>TRC Companies</i>
C. E. Pennington	<i>NOVA Engineering & Environmental LLC</i>
G. K. Sowa	<i>Skanska USA Civil</i>
R. E. Stachel	<i>HRV Conformance Verification Associates, Incorporated</i>

Advisors to the AWS D1 Committee Standing Task Group on Inspection

J. J. Edwards	<i>DOT Quality Services</i>
R. K. Holbert	<i>Alstom Power</i>
E. S. Mattfield	<i>City of New York</i>
D. L. McQuaid	<i>D. L. McQuaid & Associates, Incorporated</i>
R. E. Monson	<i>Pennoni Associates, Incorporated</i>
K. J. Steinhagen	<i>Examiner NDT Services, LLC</i>

AWS D1 Committee Standing Task Group on Stud Welding

I. W. Houston, Chair	<i>Stanley Black & Decker–Inisor Stud Welding</i>
S. P. Moran, Vice Chair	<i>General Dynamics – Electric Boat</i>
U. W. Aschemeier	<i>Subsea Global Solutions</i>
R. D. Campbell	<i>Bechtel</i>
B. C. Hobson	<i>Image Industrial, Incorporated</i>
W. S. Houston	<i>Houston Inisor – Consultant</i>
J. E. Koski	<i>Stud Welding Products, Incorporated</i>
C. W. Makar	<i>Cox Stud Welding</i>
S. J. Wirtz	<i>Savannah River Nuclear Solutions</i>
P. A. Workman	<i>Stud Weld Stud Welding</i>

Advisors to the AWS D1 Committee Standing Task Group on Stud Welding

A. D. D'Amico	<i>Montana Precision Products</i>
D. P. Eschian	<i>CWB Group</i>
K. D. Hedcock	<i>High Steel Structures, LLC</i>
M. M. Tayarani	<i>Pennoni Associates, Incorporated</i>

AWS D1 Committee Standing Task Group on Tubulars

N. S. Lindell, Chair	<i>Project & Quality Solutions</i>
S. J. Bajcer, Vice Chair	<i>The Lincoln Electric Company</i>
E. L. Bickford	<i>Reaves Welding Industries, LLC</i>
N. M. Choy	<i>California Department of Transportation</i>
R. V. Clarke	<i>Consultant</i>
P. A. Huckabee	<i>Gill Engineering Associates, Incorporated</i>
C. L. Long	<i>Southwest Research Institute</i>
R. P. Marslender	<i>Kiewit Offshore Services, Ltd.</i>
J. P. McCormick	<i>University of Michigan</i>
R. E. Monson	<i>Pennoni Associates, Incorporated</i>
K. T. Olson	<i>Nucor</i>
J. A. Packer	<i>University of Toronto</i>
S. Roy	<i>Federal Highway Administration</i>
R. Sause	<i>ATLSS Center Lehigh University</i>

Advisors to the AWS D1 Committee Standing Task Group on Tubulars

J. J. Edwards	<i>DOT Quality Services</i>
V. Kuruvilla	<i>Lexicon, Incorporated</i>
P. W. Marshall	<i>Moonshine Hill Proprietary Systems Engineering</i>
M. J. Mayes	<i>Terracon Consultants</i>
R. D. Medlock	<i>High Steel Structures, LLC</i>
T. L. Niemann	<i>Fickett Structural Solutions</i>
D. D. Rager	<i>Rager Consulting, Incorporated</i>
T. J. Schlafly	<i>American Institute of Steel Construction</i>

AWS D1 Committee Standing Task Group on New Materials

M. S. Vernon, Chair	<i>Nucor—Yamato Steel</i>
J. K. Trosen, Vice Chair	<i>Pantex Plant</i>
M. D. Kerr	<i>CB&I</i>
D. A. Koch	<i>Pacific Northwest National Laboratory</i>
V. Kuruvilla	<i>Lexicon, Incorporated</i>
R. D. Medlock	<i>High Steel Structures, LLC</i>
T. M. Nelson	<i>Hatch</i>
P. R. Niewiarowski	<i>Sargent & Lundy</i>
D. D. Rager	<i>Rager Consulting, Incorporated</i>
T. J. Schlafly	<i>American Institute of Steel Construction</i>
C. Urtz	<i>ArcelorMittal</i>
J. L. Warren	<i>CB&I</i>

Advisors to the AWS D1 Committee Standing Task Group on New Materials

W. P. Capers	<i>Walt Disney World Company</i>
M. L. Hoitomt	<i>Consultant</i>
D. Rees-Evans	<i>New Millennium</i>

Foreword

This foreword is not part of AWS D1.1/D1.1M:2025, *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, 2010, 2015, and 2020. A second printing of *AWS D1.1/D1.1M:2010, 2015, and 2020* were published in 2011, 2016, and 2022, respectively. 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 D1.5M/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 *ANSI/AISC 360, Specification for Structural Steel Buildings* and the *International Building Code*. This 2025 edition is the 25th edition of D1.1.

Changes in Code Requirements, underlined text in the clauses, subclauses, tables, figures, or forms indicates a change from the 2020 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 *AWS D1.1/D1.1M:2025*:

Summary of Changes

Clause/Table/Figure/Annex	Modification
General	AWS A5.36 filler metal classifications and properties have been removed throughout the standard.
Clause 2—Normative References	The normative references were amended.
Clause 3—Terms and Definitions	New terms and definitions were added.
Clause 4—Design of Welded Connections	Clarified base metal and filler metal strength requirements, added provisions for matching filler metals, added provisions for toughness, added a new subclause 4.7 on Load and Resistance Factor Design (LRFD), added a new Table 4.3 for available strength of welded joints, and added a new Figure 4.7, clarifying the maximum specified fillet weld size along edges.
Clause 5—Prequalification of WPSs	Revised subclause 5.6.1 on matching and undermatching filler metal strength, converted Table 5.1 on prequalified WPS requirements from the previous edition into 4 separate tables, added Group V metals to Table 5.7 on filler metals for matching strengths, and replaced the joint details in Figures 5.1 and 5.2 with new drawings.
Clause 6—Qualification	Qualification for preheat and interpass temperatures were revised, acceptance criteria for macroetch testing was updated, and the WPS qualification tables were changed.
Clause 7—Fabrication	Text was introduced, clarifying production welding requirements and preheat and interpass temperatures, and new weld tab exemptions were listed.

(Continued)

Summary of Changes (Continued)

Clause/Table/Figure/Annex	Modification
Clause 8—Inspection	Additional provisions for Magnetic Particle Testing (MT) and Penetrant Testing (PT) were added, language was included to clarify the certification of personnel performing nondestructive testing (NDT), and the acceptance criteria for visual inspection was updated.
Clause 9—Stud Welding	New provisions for type D studs were added.
Clause 10—Tubular Structures	Revised the requirements for tubular connections and clarified the requirements for T-, Y-, and K- connection procedures.
Annex M	It was presented as Annex N in the previous edition.
Annex N	It was presented as Annex O in the previous edition.
Annex O	It was presented as Annex P in the previous edition.
Annex P	It was presented as Annex Q in the previous edition.
Annex R	It was presented as Annex S in the previous edition and new reference documents were listed.
Annex Q	It was presented as Annex R in the previous edition.
Annex S	New annex that addresses the addition of base materials to AWS D1.1/D1.1M.

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.

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:2025, *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.

Table of Contents

	Page No.
<i>Personnel</i>	v
<i>Foreword</i>	xi
<i>List of Tables</i>	xviii
<i>List of Figures</i>	xx
1. General Requirements	1
1.1 Scope	1
1.2 Standard Units of Measurement	1
1.3 Safety Precautions	2
1.4 Limitations	2
1.5 Responsibilities	2
1.6 Approval	3
1.7 Mandatory and Nonmandatory Provisions	3
1.8 Welding Symbols	3
2. Normative References	4
3. Terms and Definitions	6
4. Design of Welded Connections	17
4.1 Scope	17
<i>Part A—Common Requirements for Design of Welded Connections (Nontubular and Tubular Members)</i>	17
4.2 General	17
4.3 Contract Plans and Specifications	17
4.4 Base Metal/Filler Metal Strength Requirements	19
4.5 Effective Areas	19
<i>Part B—Specific Requirements for Design of Nontubular Connections (Statically or Cyclically Loaded)</i>	22
4.6 General	22
4.7 Strength	22
4.8 Joint Configuration and Details	24
4.9 Joint Configuration and Details—Groove Welds	25
4.10 Joint Configuration and Details—Fillet Welded Joints	25
4.11 Joint Configuration and Details—Plug and Slot Welds	26
4.12 Filler Plates	26
4.13 Built-Up Members	26
<i>Part C—Specific Requirements for Design of Nontubular Connections (Cyclically Loaded)</i>	27
4.14 General	27
4.15 Limitations	27
4.16 Calculation of Stresses	27
4.17 Available Strength and Allowable Stress Ranges	28
4.18 Detailing, Fabrication, and Erection	29
4.19 Prohibited Joints and Welds	30
4.20 Inspection	30
5. Prequalification of WPSs	62
5.1 Scope	62

<i>Part A—WPS Development</i>	62
5.2 General WPS Requirements	62
<i>Part B—Base Metal</i>	63
5.3 Base Metal	63
<i>Part C—Weld Joints</i>	63
5.4 Weld Joints	63
<i>Part D—Welding Processes</i>	65
5.5 Welding Processes	65
<i>Part E—Filler Metals and Shielding Gases</i>	65
5.6 Filler Metal and Shielding Gas	65
<i>Part F—Preheat and Interpass Temperature Requirements</i>	66
5.7 Preheat and Interpass Temperature Requirements	66
<i>Part G—WPS Requirements</i>	67
5.8 WPS requirements	67
<i>Part H—Postweld Heat Treatment</i>	67
5.9 Postweld Heat Treatment	67
6. Qualification	128
6.1 Scope	128
<i>Part A—General Requirements</i>	128
6.2 General	128
6.3 Common Requirements for WPS and Welding Personnel Performance Qualification	129
<i>Part B—Welding Procedure Specification (WPS) Qualification</i>	129
6.4 Production Welding Positions Qualified	129
6.5 Type of Qualification Tests	129
6.6 Weld Types for WPS Qualification	130
6.7 Preparation of WPS	130
6.8 Essential Variables	130
6.9 WPS Requirements for Production Welding Using Existing Non-Waveform or Waveform WPSs	132
6.10 Methods of Testing and Acceptance Criteria for WPS Qualification	132
6.11 CJP Groove Welds	134
6.12 PJP Groove Welds	134
6.13 Fillet Welds	135
6.14 Plug and Slot Welds	136
6.15 Consumable Verification Test	136
6.16 Welding Processes Requiring Qualification	137
<i>Part C—Performance Qualification</i>	137
6.17 General	137
6.18 Type of Qualification Tests Required	138
6.19 Weld Types for Welder and Welding Operator Performance Qualification	139
6.20 Preparation of Performance Qualification Forms	139
6.21 Essential Variables	139
6.22 CJP Groove Welds for Nontubular Connections	139
6.23 Methods of Testing and Acceptance Criteria for Welder and Welding Operator Qualification	140
6.24 Method of Testing and Acceptance Criteria for Tack Welder Qualification	141
6.25 Retest	141
<i>Part D—Requirements for CVN Toughness Testing</i>	141
6.26 General: CVN Testing	141
6.27 CVN Tests	142
6.28 Combining FCAW-S with Other Welding Processes in a Single Joint	143
6.29 Reporting	144

7. Fabrication	193
7.1 Scope	193
7.2 Base Metal	193
7.3 Welding Consumables and Electrode Requirements	193
7.4 ESW and EGW Processes	196
7.5 Production Welding	196
7.6 Preheat and Interpass Temperatures	196
7.7 Heat Input Control for Quenched and Tempered Steels	197
7.8 Postweld Heat Treatment (PWHT) for Stress Relief	197
7.9 Backing	198
7.10 Welding and Cutting Equipment	199
7.11 Welding Environment	199
7.12 Conformance with Design	199
7.13 Minimum Fillet Weld Sizes	199
7.14 Preparation of Base Metal	199
7.15 Reentrant Corners	202
7.16 Weld Access Holes, Beam Copes, and Connection Material	202
7.17 Tack Welds and Construction Aid Welds	202
7.18 Camber in Built-Up Members	203
7.19 Subassembly Sequence	203
7.20 Control of Distortion and Shrinkage	203
7.21 Tolerance of Joint Dimensions	204
7.22 Dimensional Tolerance of Welded Structural Members	205
7.23 Weld Profiles	208
7.24 Technique for Plug and Slot Welds	208
7.25 Repairs	208
7.26 Peening	210
7.27 Caulking	210
7.28 Arc Strikes	210
7.29 Weld Cleaning	210
7.30 Weld Tabs	210
8. Inspection	223
<i>Part A—General Requirements</i>	223
8.1 Scope	223
8.2 Inspection of Materials and Equipment	225
8.3 Inspection of WPSs	225
8.4 Inspection of Welder, Welding Operator, and Tack Welder Qualifications	225
8.5 Inspection of Work and Records	225
<i>Part B—Contractor Responsibilities</i>	226
8.6 Obligations of the Contractor	226
<i>Part C—Acceptance Criteria</i>	226
8.7 Scope	226
8.8 Engineer’s Approval for Alternate Acceptance Criteria	226
8.9 Visual Inspection	226
8.10 Magnetic Particle Testing (MT) and Penetrant Testing (PT)	227
8.11 Nondestructive Testing (NDT)	227
8.12 Radiographic Testing (RT)	227
8.13 Ultrasonic Testing (UT)	229
<i>Part D—NDT Procedures</i>	229
8.14 Procedures	229
8.15 Extent of Testing	230
<i>Part E—Radiographic Testing (RT)</i>	231
8.16 RT of Groove Welds in Butt Joints	231

8.17	RT Procedures	231
8.18	Examination, Report, and Disposition of Radiographs	234
	<i>Part F—Ultrasonic Testing (UT) of Groove Welds</i>	235
8.19	General	235
8.20	Qualification Requirements	235
8.21	UT Equipment	235
8.22	Reference Standards	236
8.23	Equipment Qualification	237
8.24	Calibration for Testing	237
8.25	Testing Procedures	238
8.26	Preparation and Disposition of Reports	239
8.27	Calibration of the UT Unit with IIW Type or Other Approved Reference Blocks (Annex G)	240
8.28	Equipment Qualification Procedures	241
8.29	Discontinuity Size Evaluation Procedures	243
8.30	Scanning Patterns	243
8.31	Examples of dB Accuracy Certification	244
	<i>Part G—Other Examination Methods</i>	244
8.32	General Requirements	244
8.33	Radiation Imaging Systems	244
8.34	Advanced Ultrasonic Systems	244
8.35	Additional Requirements	245
9.	Stud Welding	278
9.1	Scope	278
9.2	General Requirements	278
9.3	Mechanical Requirements	279
9.4	Workmanship/Fabrication	279
9.5	Technique	280
9.6	Stud Application Qualification Requirements	281
9.7	Production Control	282
9.8	Fabrication and Verification Inspection Requirements	283
9.9	Manufacturers' Stud Base Qualification Requirements	283
10.	Tubular Structures	291
10.1	Scope	291
	<i>Part A—Design of Tubular Connections</i>	291
10.2	Design Criteria	291
10.3	Identification and Parts of Tubular Connections	293
10.4	Symbols	293
10.5	Weld Design	293
10.6	Thickness Transition	294
10.7	Material Limitations	294
	<i>Part B—Prequalification of Welding Procedure Specifications (WPSs)</i>	295
10.8	Fillet Weld Requirements	295
10.9	PJP Requirements	295
10.10	CJP Groove Weld Requirements	295
	<i>Part C—Welding Procedure Specification (WPS) Qualification</i>	296
10.11	Common Requirements for WPS and Welding Personnel Performance Qualification	296
10.12	Production Welding Positions Qualified	296
10.13	Type of Qualification Tests, Methods of Testing, and Acceptance Criteria for WPS Qualification	296
10.14	CJP Groove Welds for Tubular Connections	297
10.15	PJP and Fillet Welds Tubular T-, Y-, or K-Connections and Butt Joints	298

<i>Part D—Performance Qualification</i>	298
10.16 Production Welding Positions, Thicknesses, and Diameters Qualified	298
10.17 Weld Types for Welder and Welding Operator Performance Qualification	298
10.18 CJP Groove Welds for Tubular Connections	299
10.19 PJP Groove Welds for Tubular Connections	299
10.20 Fillet Welds for Tubular Connections	299
10.21 Methods of Testing and Acceptance Criteria for Welder and Welding Operator Qualification	299
<i>Part E—Fabrication</i>	300
10.22 Backing	300
10.23 Tolerance of Joint Dimensions	300
<i>Part F—Inspection</i>	301
10.24 Visual Inspection	301
10.25 NDT	301
10.26 UT	301
10.27 RT Procedures	301
10.28 Supplementary RT Requirements for Tubular Connections	302
10.29 UT of Tubular T-, Y-, and K-Connections	302
11. Strengthening and Repair of Existing Structures	353
11.1 Scope	353
11.2 General	353
11.3 Base Metal	353
11.4 Design for Strengthening and Repair	353
11.5 Fatigue Life Enhancement	354
11.6 Workmanship and Technique	354
11.7 Quality	354
Annexes	
Annex A (Normative)—Effective Throats of Fillet Welds in Skewed T-Joints	355
Annex B (Normative)—Guideline on Alternative Methods for Determining Preheat	357
Annex D (Normative)—Temperature-Moisture Content Charts	369
Annex E (Normative)—Flatness of Girder Webs—Statically Loaded Structures	373
Annex F (Normative)—Flatness of Girder Webs—Cyclically Loaded Structures	377
Annex G (Normative)—Qualification and Calibration of UT Units with Other Approved Reference Blocks	383
Annex H (Normative)—Phased Array Ultrasonic Testing (PAUT)	387
Annex I (Normative)—Symbols for Tubular Connection Weld Design	403
Annex J (Informative)—Sample Welding Forms	407
Annex K (Informative)—Contents of Prequalified WPS	429
Annex L (Informative)—Filler Metal Strength Properties	431
Annex M (Informative)—Guide for Specification Writers	443
Annex N (Informative)—UT Examination of Welds by Alternative Techniques	445
Annex O (Informative)—UT Equipment Qualification and Inspection Forms	461
Annex P (Informative)—Local Dihedral Angle	471
Annex Q (Informative)—Preliminary Design Circular Tube Connections	477
Annex R (Informative)—List of Reference Documents	483
Annex S (Informative)—Guidelines for the Preparation of Proposals for Additions of Base Materials not Listed in D1.1	485
Annex T (Informative)—Guidelines for the Preparation of Technical Inquiries for the Structural Welding Committee	487
Commentary	489
List of AWS Documents on Structural Welding	607
Index	609

List of Tables

Table	Page No.
4.1	Effective Size of Flare-Groove Welds Filled Flush. 31
4.2	Z Loss Dimension (Nontubular) 31
4.3	Available Strength of Welded Joints 32
4.4	Equivalent Strength Coefficients for Obliquely Loaded Fillet Welds 33
4.5	Fatigue Stress Design Parameters 34
5.1	Prequalified SMAW WPS Requirements. 68
5.2	Prequalified SAW WPS Requirements 69
5.3	Prequalified GMAW (solid wire) WPS Requirements 70
5.4	Prequalified FCAW and GMAW Metal Cored WPS Requirements 71
5.5	Essential Variables for Prequalified WPSs. 72
5.6	Approved Base Metals for Prequalified WPSs 73
5.7	Filler Metals for Matching Strength for Table 5.6, Groups I, II, III, IV , and IV Metals—SMAW and SAW 76
5.8	Minimum Prequalified PJP Groove Weld Size (S) 80
5.9	Filler Metal Requirements for Exposed Bare Applications of Weathering Steels. 80
5.10	Prequalified WPS Shielding Gas Options for GMAW Electrodes Conforming to AWS A5.18/A5.18M 80
5.11	Prequalified Minimum Preheat and Interpass Temperature. 81
6.1	WPS Qualification—Production Welding Positions Qualified by Plate Tests. 145
6.2	WPS Qualification—CJP Groove Welds: Number and Type of Test Specimens and Range of Thickness Qualified. 146
6.3	WPS Qualification—PJP Groove Welds: Number and Type of Test Specimens and Range of Thickness Qualified. 146
6.4	WPS Qualification—Fillet Welds: Number and Type of Test Specimens and Range of Thickness Qualified. 147
6.5	<u>WPS Qualification—Plug and Slot Welds: Number and Type of Test Specimens and Range of Thickness Qualified. 148</u>
6.6	PQR Essential Variable Changes Requiring WPS Requalification for SMAW, SAW, GMAW, FCAW, and GTAW. 149
6.7	PQR Essential Variable Changes Requiring WPS Requalification for ESW or EGW 152
6.8	PQR Supplementary Essential Variable Changes for CVN Testing Applications Requiring WPS Requalification for SMAW, SAW, GMAW, FCAW, GTAW, and ESW/ EGW 154
6.9	Table 5.6, Table 6.10, and Unlisted Steels Qualified by PQR 155
6.10	Code-Approved Base Metals and Filler Metals Requiring Qualification per Clause 6. 156
6.11	Welding Personnel Qualification—Production Welding Positions Qualified by Plate Tests. 160
6.12	Welder and Welding Operator Qualification— <u>Tests on Plate</u> – Number and Type of Specimens and Range of Thickness Qualified. 161
6.13	Welding Personnel Performance Essential Variable Changes Requiring Requalification. 162
6.14	Electrode Classification Groups. 162
6.15	CVN Test Temperature Reduction. 163
6.16	Charpy V-Notch Test Acceptance Criteria for Various Sub-Size Specimens. 163
6.17	Filler Metal Essential Variables—FCAW-S Substrate/Root 164
7.1	Allowable Atmospheric Exposure of Low-Hydrogen Electrodes 212
7.2	Minimum Holding Time 212
7.3	Alternate Stress-Relief Heat Treatment 212
7.4	Limits on Acceptability and Repair of Mill Induced Laminar Discontinuities in Cut Surfaces 213

7.5	Camber Tolerance for Typical Girder	213
7.6	Camber Tolerance for Girders without a Designed Concrete Haunch	214
7.7	Minimum Fillet Weld Sizes	214
7.8	Weld Profiles	215
7.9	Weld Profile Schedules	215
8.1	Visual Inspection Acceptance Criteria	246
8.2	UT Acceptance-Rejection Criteria (Statically Loaded Nontubular Connections and Cyclically Loaded Nontubular Connections in Compression)	248
8.3	UT Acceptance-Rejection Criteria (Cyclically Loaded Nontubular Connections in Tension)	249
8.4	Hole-Type IQI Requirements	250
8.5	Wire IQI Requirements	250
8.6	IQI Selection and Placement	250
8.7	Testing Angle	251
8.8	UT Equipment Qualification and Calibration Requirements	253
9.1	Mechanical Property Requirements for Studs	285
9.2	Minimum Fillet Weld Size for Studs	285
10.1	Fatigue Stress Design Parameters	305
10.2	Available Stresses in Tubular Connection Welds	306
10.3	Stress Categories for Type and Location of Material for Circular Sections	308
10.4	Fatigue Category Limitations on Weld Size or Thickness and Weld Profile (Tubular Connections)	310
10.5	Z Loss Dimensions for Calculating Prequalified PJP T-, Y-, and K-Tubular Connection Minimum Weld Sizes	310
10.6	Joint Detail Applications for Prequalified CJP T-, Y-, and K-Tubular Connections	311
10.7	Prequalified Joint Dimensions and Groove Angles for CJP Groove Welds in Tubular T-, Y, and K-Connections Made by SMAW, GMAW-S, and FCAW	312
10.8	WPS, <u>Welder and Welding Operator</u> Qualification—Production Welding Positions Qualified by Pipe and Box Tube Tests	313
10.9	WPS Qualification—CJP Groove Welds: Number and Type of Test Specimens and Range of Thickness and Diameter Qualified	314
10.10	WPS Qualification—PJP Groove Welds: Number and Type of Test Specimens and Range of Thickness Qualified	316
10.11	WPS Qualification—Fillet Welds: Number and Type of Test Specimens and Range of Thickness Qualified	316
10.12	Welder and Welding Operator Qualification— <u>Number and Type of Specimens and Range of Thickness and Diameter Qualified</u>	317
10.13	Tubular Root Opening Tolerances, Butt Joints Welded Without Backing	319
10.14	Visual Inspection Acceptance Criteria	320
10.15	Hole-Type IQI Requirements	321
10.16	Wire IQI Requirements	321
10.17	IQI Selection and Placement	321
A.1	Equivalent Fillet Weld Leg Size Factors for Skewed T-Joints	356
B.1	Susceptibility Index Grouping as Function of Hydrogen Level “H” and Composition Parameter P_{cm}	361
B.2	Minimum Preheat and Interpass Temperatures for Three Levels of Restraint	361
E.1	Intermediate Stiffeners on Both Sides of Web	374
E.2	No Intermediate Stiffeners	374
E.3	Intermediate Stiffeners on One Side Only of Web	375
F.1	Intermediate Stiffeners on Both Sides of Web, Interior Girders	378
F.2	Intermediate Stiffeners on One Side Only of Web, Fascia Girders	379
F.3	Intermediate Stiffeners on One Side Only of Web, Interior Girders	380
F.4	Intermediate Stiffeners on Both Sides of Web, Fascia Girders	381
F.5	No Intermediate Stiffeners, Interior or Fascia Girders	382
H.1	Essential Variables for PAUT	397
H.2	PAUT Acceptance Criteria	397
H.3	Discontinuity Classification	397

N.1	Acceptance-Rejection Criteria	451
Q.1	Terms for Strength of Connections (Circular Sections).	480
	<i>Commentary</i>	
C-5.1	Typical Current Ranges for GMAW-S on Steel.	520
C-10.1	Structural Steel Plates	585
C-10.2	Structural Steel Pipe and Tubular Shapes	586
C-10.3	Structural Steel Shapes.	586
C-10.4	Classification Matrix for Applications.	587
C-10.5	CVN Testing Conditions	587
C-10.6	CVN Test Values	588
C-10.7	HAZ CVN Test Values.	588
C-11.1	Guide to Welding Suitability	597
C-11.2	Relationship Between Plate Thickness and Burr Radius.	597

List of Figures

Figure		Page No.
4.1	Fillet Weld	51
4.2	Unreinforced Bevel Groove Weld	52
4.3	Bevel Groove Weld with Reinforcing Fillet Weld	52
4.4	Bevel Groove Weld with Reinforcing Fillet Weld	53
4.5	Unreinforced Flare Bevel Groove Weld.	53
4.6	Flare Bevel Groove Weld with Reinforcing Fillet Weld	54
4.7	Maximum Specified Fillet Weld Size Along Edges.	54
4.8	Transition of Thickness (Statically Loaded Nontubular).	55
4.9	Transversely Loaded Fillet Welds	55
4.10	Minimum Length of Longitudinal Fillet Welds at End of Plate or Flat Bar Members	56
4.11	Termination of Welds Near Edges Subject to Tension.	56
4.12	End Return at Flexible Connections	57
4.13	Fillet Welds on Opposite Sides of a Common Plane	57
4.14	Thin Filler Plates in Splice Joint	58
4.15	Thick Filler Plates in Splice Joint	58
4.16	Allowable Stress Range for Cyclically Applied Load (Fatigue) in Nontubular Connections (Graphical Plot of Table 4.5)	59
4.17	Transition of Butt Joints in Parts of Unequal Thickness (Cyclically Loaded Nontubular)	60
4.18	Transition of Width (Cyclically Loaded Nontubular)	61
5.1	Prequalified CJP Groove Welded Joint Details (Dimensions in Inches)	86
5.1	Prequalified CJP Groove Welded Joint Details (Dimensions in Millimeters)	97
5.2	Prequalified PJP Groove Welded Joint Details (Dimensions in Inches)	108
5.2	Prequalified PJP Groove Welded Joint Details (Dimensions in Millimeters)	116
5.3	Prequalified Fillet Weld Joint Details (Dimensions in Inches)	124
5.3	Prequalified Fillet Weld Joint Details (Dimensions in Millimeters)	125
5.4	Prequalified Skewed T-Joint Details (Nontubular)	126
5.5	Prequalified CJP Groove, T-, and Corner Joint	127
5.6	Weld Bead in which Depth and Width Exceed the Width of the Weld Face	127
6.1	Positions of Groove Welds.	165
6.2	Positions of Fillet Welds	166
6.3	Positions of Test Plates for Groove Welds.	167
6.4	Positions of Test Plate for Fillet Welds	168
6.5	Location of Test Specimens on Welded Test Plates—ESW and EGW—WPS Qualification	169

6.6	Location of Test Specimens on Welded Test Plate Over 3/8 in [10 mm] Thick—WPS Qualification.	170
6.7	Location of Test Specimens on Welded Test Plate 3/8 in [10 mm] Thick and Under—WPS Qualification	171
6.8	Face and Root Bend Specimens.	172
6.9	Side Bend Specimens.	173
6.10	Reduced-Section Tension Specimens.	174
6.11	Guided Bend Test Jig	175
6.12	Alternative Wraparound Guided Bend Test Jig	176
6.13	Alternative Roller-Equipped Guided Bend Test Jig for Bottom Ejection of Test Specimen.	176
6.14	All-Weld-Metal Tension Specimen	177
6.15	<u>Macroetch Test Assemblies for Determination of PJP Weld Size</u>	178
6.16	Fillet Weld Soundness Tests for WPS Qualification	179
6.17	<u>Plug and Slot Weld WPS Qualification Test Coupon</u>	180
6.18	<u>Location of Test Specimen on Welded Test Plate 1 in [25 mm] Thick—Consumables Verification for Fillet Weld WPS Qualification</u>	181
6.19	<u>Plug and Slot Weld Test Coupon—WPS Qualification or Welder or Welding Operator Qualification</u> . . .	182
6.20	<u>Method of Rupturing Specimen—Tack Welder Qualification</u>	183
6.21	<u>Test Coupon – Performance Qualification Welder and Welding Operator for SMAW, SAW, GMAW, FCAW, and GTAW</u>	184
6.22	<u>Butt Joint for Welding Operator Qualification—ESW and EGW</u>	185
6.23	<u>Fillet Weld Break and Macroetch Test Plate—Welder or Welding Operator Qualification—Option 1</u> . .	186
6.24	<u>Fillet Weld Root Bend Test Coupon—Welder or Welding Operator Qualification—Option 2</u>	187
6.25	<u>Fillet Weld Test Coupon—Welder or Welding Operator Qualification—Option 3</u>	188
6.26	<u>Fillet Acute Angle Heel Test for Welder or Welding Operator Qualification</u>	188
6.27	<u>Fillet Weld Break Specimen—Tack Welder Qualification</u>	189
6.28	<u>CVN Test Specimen Locations</u>	190
6.29	<u>Intermix Test Plate</u>	191
6.30	<u>Interface Scribe Line Location</u>	192
6.31	<u>Intermix CVN Test Specimen Location</u>	192
7.1	Edge Discontinuities in Cut Material.	216
7.2	Weld Access Hole Geometry	217
7.3	Workmanship Tolerances in Assembly of Groove Welded Joints	218
7.4	Requirements for Weld Profiles	219
8.1	Discontinuity Acceptance Criteria for Statically Loaded Nontubular and Statically or Cyclically Loaded Tubular Connections	255
8.2	Discontinuity Acceptance Criteria for Cyclically Loaded Nontubular Connections in Tension (Limitations of Porosity and Fusion Discontinuities)	259
8.3	Discontinuity Acceptance Criteria for Cyclically Loaded Nontubular Connections in Compression (Limitations of Porosity or Fusion-Type Discontinuities)	263
8.4	Hole-Type IQI	267
8.5	Wire IQI	268
8.6	RT Identification and Hole-Type or Wire IQI Locations on Approximately Equal Thickness Joints 10 in [250 mm] and Greater in Length	269
8.7	RT Identification and Hole-Type or Wire IQI Locations on Approximately Equal Thickness Joints Less than 10 in [250 mm] in Length	269
8.8	RT Identification and Hole-Type or Wire IQI Locations on Transition Joints 10 in [250 mm] and Greater in Length	270
8.9	RT Identification and Hole-Type or Wire IQI Locations on Transition Joints Less than 10 in [250 mm] in Length	271
8.10	RT Edge Blocks	271
8.11	Transducer Crystal	272
8.12	Qualification Procedure of Search Unit Using IIW Reference Block	272
8.13	Typical IIW Type Block	273
8.14	Qualification Blocks	274
8.15	Plan View of UT Scanning Patterns	276

8.16	Transducer Positions (Typical)	277
9.1	Dimension and Tolerances of Standard-Type Headed Studs	286
9.2	Typical Tension Test Fixture	287
9.3	Torque Testing Arrangement and Table of Testing Torques	288
9.4	Bend Testing Device	289
9.5	Suggested Type of Device for Qualification Testing of Small Studs	290
10.1	Allowable Fatigue Stress and Strain Ranges for Stress Categories, Tubular Structures for Atmospheric Service	322
10.2	Parts of a Tubular Connection	323
10.3	Fillet Welded Lap Joint (Tubular)	326
10.4	Transition of Thickness of Butt Joints in Parts of Unequal Thickness (Tubular)	327
10.5	Fillet Welded Prequalified Tubular Joints Made by SMAW, GMAW, and FCAW	328
10.6	Prequalified Joint Details for PJP T-, Y-, and K-Tubular Connections	329
10.7	Prequalified Joint Details for CJP T-, Y-, and K-Tubular Connections	332
10.8	Definitions and Detailed Selections for Prequalified CJP T-, Y-, and K-Tubular Connections	333
10.9	Prequalified Joint Details for CJP Groove Welds in Tubular T-, Y-, and K-Connections—Standard Flat Profiles for Limited Thickness	334
10.10	Prequalified Joint Details for CJP Groove Welds in Tubular T-, Y-, and K-Connections—Profile with Toe Fillet for Intermediate Thickness	335
10.11	Prequalified Joint Details for CJP Groove Welds in Tubular T-, Y-, and K-Connections—Concave Improved Profile for Heavy Sections or Fatigue	336
10.12	Positions of Test Pipe or Tubing for Groove Welds	337
10.13	Positions of Test Pipes or Tubing for Fillet Welds	338
10.14	Location of Test Specimens on Welded Test Pipe—WPS Qualification	339
10.15	Location of Test Specimens for Welded Box Tubing—WPS Qualification	340
10.16	Pipe Fillet Weld Soundness Test—WPS Qualification	341
10.17	Tubular Butt Joint—Welder and WPS Qualification without and with Backing	342
10.18	Acute Angle Heel Test (Restraints not Shown)	342
10.19	Test Joint for T-, Y-, and K-Connections without Backing on Pipe or Box Tubing (> 4 in [100 mm] O.D.)—Welder and WPS Qualification	343
10.20	Test Joint for T-, Y-, and K-Connections without Backing on Pipe or Box Tubing (\leq 4 in [100 mm] O.D.)—Welder and WPS Qualification	344
10.21	Corner Macroetch Test Joint for T-, Y-, and K-Connections without Backing on Box Tubing for CJP Groove Welds—Welder and WPS Qualification	345
10.22	Location of Test Specimens on Welded Test Pipe and Box Tubing—Welder Qualification	346
10.23	Class R Indications	347
10.24	Class X Indications	349
10.25	Single-Wall Exposure—Single-Wall View	350
10.26	Double-Wall Exposure—Single-Wall View	350
10.27	Double-Wall Exposure—Double-Wall (Elliptical) View, Minimum Two Exposures	351
10.28	Double-Wall Exposure—Double-Wall View, Minimum Three Exposures	351
10.29	Scanning Techniques	352
B.1	Zone Classification of Steels	363
B.2	Critical Cooling Rate for 350 HV and 400 HV	363
B.3	Graphs to Determine Cooling Rates for Single-Pass SAW Fillet Welds	364
B.4	Relation Between Fillet Weld Size and Energy Input	367
D.1	Temperature-Moisture Content Chart to be Used in Conjunction with Testing Program to Determine Extended Atmospheric Exposure Time of Low-Hydrogen SMAW Electrodes	370
D.2	Application of Temperature-Moisture Content Chart in Determining Atmospheric Exposure Time of Low-Hydrogen SMAW Electrodes	371
G.1	Other Approved Blocks and Typical Transducer Position	385
H.1	Phased Array Imaging Views	398
H.2	Example of a Supplemental Reference Block	398
H.3	Example Standard Reflector Locations in Weld Mockup	399

H.4	Sensitivity Levels	399
H.5	Example of Time Based Linearity Verification	400
H.6	Linearity Verification Report Form	401
N.1	Standard Reference Reflector	452
N.2	Recommended Calibration Block	452
N.3	Typical Standard Reflector (Located in Weld Mock-Ups and Production Welds).	453
N.4	Transfer Correction	454
N.5	Compression Wave Depth (Horizontal Sweep Calibration)	454
N.6	Compression Wave Sensitivity Calibration	455
N.7	Shear Wave Distance and Sensitivity Calibration	455
N.8	Scanning Methods	456
N.9	Spherical Discontinuity Characteristics	457
N.10	Cylindrical Discontinuity Characteristics	457
N.11	Planar Discontinuity Characteristics	458
N.12	Discontinuity Height Dimension	458
N.13	Discontinuity Length Dimension	459
N.14	Display Screen Marking	459
N.15	Report of UT (Alternative Procedure)	460
Q.1	Simplified Concept of Punching Shear	481
Q.2	Reliability of Punching Shear Criteria Using Computed Alpha	481
Q.3	Definition of Terms for Computed Alpha	482
	<i>Commentary</i>	
C-4.1	Balancing of Fillet Welds About a Neutral Axis	508
C-4.2	Shear Planes for Fillet and Groove Welds	508
C-4.3	Eccentric Loading	509
C-4.4	Load Deformation Relationship for Welds	509
C-4.5	Example of an Obliquely Loaded Weld Group	510
C-4.6	Graphical Solution of the Capacity of an Obliquely Loaded Weld Group	511
C-4.7	Single Fillet Welded Lap Joints	512
C-5.1	Examples of Centerline Cracking	520
C-5.2	Details of Alternative Groove Preparations for Prequalified Corner Joints	521
C-5.3	Oscillograms and Sketches of GMAW-S Metal Transfer	521
C-6.1	Type of Welding on Pipe That Does Not Require Pipe Qualification.	527
C-7.1	Examples of Unacceptable Reentrant Corners	542
C-7.2	Examples of Good Practice for Cutting Copcs	542
C-7.3	Permissible Offset in Abutting Members	542
C-7.4	Correction of Misaligned Members	543
C-7.5	Typical Method to Determine Variations in Girder Web Flatness	543
C-7.6	Illustration Showing Camber Measurement Methods	544
C-7.7	Measurement of Flange Warpage and Tilt	545
C-7.8	Tolerances at Bearing Points	546
C-8.1	90° T- or Corner Joints with Steel Backing	561
C-8.2	Skewed T- or Corner Joints	561
C-8.3	Butt Joints with Separation Between Backing and Joint	562
C-8.4	Effect of Root Opening on Butt Joints with Steel Backing	562
C-8.5	Resolutions for Scanning with Seal Welded Steel Backing	563
C-8.6	Scanning with Seal Welded Steel Backing	563
C-8.7	Illustration of Discontinuity Acceptance Criteria for Statically Loaded Nontubular and Statically or Cyclically Loaded Tubular Connections	564
C-8.8	Illustration of Discontinuity Acceptance Criteria for Statically Loaded Nontubular and Statically or Cyclically Loaded Tubular Connections 1-1/8 in [30 mm] and Greater, Typical of Random Acceptable Discontinuities	565
C-8.9	Illustration of Discontinuity Acceptance Criteria for Cyclically Loaded Nontubular Connections in Tension	566
C-9.1	Allowable Defects in the Heads of Headed Studs	570

C-10.1	Illustrations of Branch Member Stresses Corresponding to Mode of Loading	588
C-10.2	Improved Weld Profile Requirements	589
C-10.3	Upper Bound Theorem.	589
C-10.4	Yield Line Patterns.	590
C-11.1	Microscopic Intrusions.	598
C-11.2	Fatigue Life	598
C-11.3	Toe Dressing with Burr Grinder.	599
C-11.4	Toe Dressing Normal to Stress.	599
C-11.5	Effective Toe Grinding.	600
C-11.6	End Grinding	600
C-11.7	Hammer Peening	601
C-11.8	Toe Remelting	601

Dedication

The D1 Committee on Structural Welding dedicates this 25th edition of AWS D1.1/D1.1M, Structural Welding Code—Steel, in honor of Philip “Phil” Torchio, III. The D1Q Subcommittee is eternally grateful for Phil’s leadership, mentorship, and more importantly his friendship as a member and Chairman of the D1Q Subcommittee. The members of D1 and D1Q are forever thankful for his devotion to improving the AWS D1 Codes.

This page is intentionally blank.

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).
- 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.