

Structural Welding Code— Steel

PRELIMINARY



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

Approved by the
American National Standards Institute
Month, Day, Year

Structural Welding Code—Steel

25th Edition

Revises 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. 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.



DRAFT

ISBN Print: XXX

ISBN PDF: XX

© XX 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.

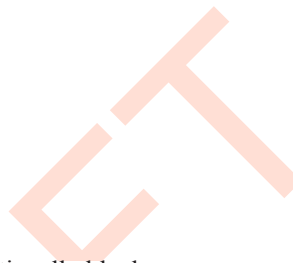
This standard may be superseded by new editions. This standard may also be corrected through publication of amendments or errata, or supplemented by publication of addenda. Information on the latest editions of AWS standards including amendments, errata, and addenda is posted on the AWS web page (www.aws.org). 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 these oral opinions constitute official or unofficial opinions or interpretations of AWS. In addition, oral opinions are informal 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.

Personnel

AWS D1 Committee on Structural Welding

T. L. Niemann, Chair	<i>Fickett Structural Solutions, LLC</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>Wiss, Janney, Elstner Associates</i>
I. W. Houston	<i>Stanley Black & Decker–Nelson Stud Welding</i>
M. G. Iverson	<i>OTC Daihen</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>
B. R. Krueger	<i>Los Alamos National Laboratory</i>
V. Kuruvilla	<i>Lexicon, Incorporated</i>
J. Lawmon	<i>American Engineering and Manufacturing, Incorporated</i>
D. R. Luciani	<i>Canadian Welding Bureau</i>
D. L. McQuaid	<i>D. L. McQuaid & Associates, Incorporated</i>
J. K. Merrill	<i>TRC Solutions</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>Stanley Black & Decker–Nelson Stud Welding</i>
P. W. Marshall	<i>Moonshine Hill Proprietary Systems Engineering</i>
G. S. Martin	<i>TRC Solutions</i>
M. J. Mayes	<i>Terracon Consultants</i>

A. W. Sindel	<i>TRC Solutions</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</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 Stud Welding</i>
W. S. Houston	<i>Stanley Black & Decker–Nelson Stud Welding</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>Canadian Welding Bureau</i>
R. P. Marslender	<i>Kiewit Offshore Services, Ltd.</i>
G. S. Martin	<i>TRC Solutions</i>
J. K. Merrill	<i>TRC Solutions</i>
J. I. Miller	<i>Chevron</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. Zafir	<i>Canadian Welding Bureau</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, LLC</i>
J. A. Packer	<i>University of Toronto</i>
D. A. Wright	<i>Wright Welding Technologies</i>

AWS D1Q Subcommittee Task Group on Design

D. K. Miller, Chair	<i>The Lincoln Electric Company</i>
T. J. Schlafly, Chair	<i>American Institute of Steel Construction</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</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 Assoc, 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, LLC</i>
J. M. Ocel	<i>Federal Highway Administration</i>
J. Ross	<i>U.S. Army Corps of Engineers</i>

AWS D1Q Subcommittee Task Group on Prequalification

C. Zanfir, Chair	<i>Canadian Welding Bureau</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 Company</i>
D. R. Luciani	<i>Canadian Welding Bureau</i>
D. K. Miller	<i>The Lincoln Electric Company</i>
J. I. Miller	<i>Chevron</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, LLC</i>

AWS D1Q Subcommittee Task Group on Qualification

S. J. Findlan, 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 Solutions</i>
T. L. Niemann	<i>Fickett Structural Solutions, LLC</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 / Clover Field Services, LLC</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 Nondestructive Testing Academy</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 Solutions</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>Chevron</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>
G. L. Fox	<i>Consultant</i>
R. L. 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>Haberle Steel, Incorporated / 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 Nondestructive Testing Academy</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>The Lincoln Electric Co</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 Solutions</i>
J. E. Mellinger	<i>Pennoni Associates, Incorporated</i>
J. K. Merrill	<i>TRC Solutions</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–Nelson 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 Industries, Incorporated</i>
W. S. Houston	<i>Stanley Black & Decker–Nelson Stud Welding</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. Workman	<i>Tru-Weld Equipment Company</i>

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

A. D. D'Amico	<i>Montana Precision Products</i>
D. R. Luciani	<i>Canadian Welding Bureau</i>
R. D. Medlock	<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. 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, LLC</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>Consolidated Nuclear Security</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 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 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 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 a new subclause 4.7 on Load and Resistance Factor (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 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 S	New annex that addresses the addition of base materials to D1.1.

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 Welding Processes Requiring Qualification	136
6.16 General	137
<i>Part C—Performance Qualification</i>	137
6.17 Type of Qualification Tests Required	137
6.18 Weld Types for Welder and Welding Operator Performance Qualification	138
6.19 Preparation of Performance Qualification Forms	139
6.20 Essential Variables	139
6.21 CJP Groove Welds for Nontubular Connections	139
6.22 Extent of Qualification	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	192
7.1 Scope	192
7.2 Base Metal	192
7.3 Welding Consumables and Electrode Requirements	192
7.4 ESW and EGW Processes	195
7.5 WPS Variables	195
7.6 Preheat and Interpass Temperatures	195
7.7 Heat Input Control for Quenched and Tempered Steels	196
7.8 Stress-Relief Heat Treatment	196
7.9 Backing	197
7.10 Welding and Cutting Equipment	198
7.11 Welding Environment	198
7.12 Conformance with Design	198
7.13 Minimum Fillet Weld Sizes	198
7.14 Preparation of Base Metal	198
7.15 Reentrant Corners	201
7.16 Weld Access Holes, Beam Copes, and Connection Material	201
7.17 Tack Welds and Construction Aid Welds	201
7.18 Camber in Built-Up Members	202
7.19 Splices	202
7.20 Control of Distortion and Shrinkage	202
7.21 Tolerance of Joint Dimensions	203
7.22 Dimensional Tolerance of Welded Structural Members	204
7.23 Weld Profiles	207
7.24 Technique for Plug and Slot Welds	207
7.25 Repairs	207
7.26 Peening	209
7.27 Caulking	209
7.28 Arc Strikes	209
7.29 Weld Cleaning	209
7.30 Weld Tabs	209
8. Inspection	222
<i>Part A—General Requirements</i>	222
8.1 Scope	222
8.2 Inspection of Materials and Equipment	224
8.3 Inspection of WPSs	224
8.4 Inspection of Welder, Welding Operator, and Tack Welder Qualifications	224
8.5 Inspection of Work and Records	224
<i>Part B—Contractor Responsibilities</i>	225
8.6 Obligations of the Contractor	225
<i>Part C—Acceptance Criteria</i>	225
8.7 Scope	225
8.8 Engineer's Approval for Alternate Acceptance Criteria	225
8.9 Visual Inspection	225
8.10 Magnetic Particle Testing (MT) and Penetrant Testing (PT)	226
8.11 Nondestructive Testing (NDT)	226
8.12 Radiographic Testing (RT)	226
8.13 Ultrasonic Testing (UT)	228
<i>Part D—NDT Procedures</i>	228
8.14 Procedures	228
8.15 Extent of Testing	229
<i>Part E—Radiographic Testing (RT)</i>	230
8.16 RT of Groove Welds in Butt Joints	230

8.17	RT Procedures	230
8.18	Examination, Report, and Disposition of Radiographs	233
	<i>Part F—Ultrasonic Testing (UT) of Groove Welds</i>	234
8.19	General	234
8.20	Qualification Requirements	234
8.21	UT Equipment	234
8.22	Reference Standards	235
8.23	Equipment Qualification	236
8.24	Calibration for Testing	236
8.25	Testing Procedures	237
8.26	Preparation and Disposition of Reports	238
8.27	Calibration of the UT Unit with IIW Type or Other Approved Reference Blocks (Annex G)	239
8.28	Equipment Qualification Procedures	240
8.29	Discontinuity Size Evaluation Procedures	242
8.30	Scanning Patterns	242
8.31	Examples of dB Accuracy Certification	243
	<i>Part G—Other Examination Methods</i>	243
8.32	General Requirements	243
8.33	Radiation Imaging Systems	243
8.34	Advanced Ultrasonic Systems	243
8.35	Additional Requirements	244
9.	Stud Welding	277
9.1	Scope	277
9.2	General Requirements	277
9.3	Mechanical Requirements	278
9.4	Workmanship/Fabrication	278
9.5	Technique	279
9.6	Stud Application Qualification Requirements	280
9.7	Production Control	281
9.8	Fabrication and Verification Inspection Requirements	282
9.9	Manufacturers' Stud Base Qualification Requirements	282
10.	Tubular Structures	290
10.1	Scope	290
	<i>Part A—Design of Tubular Connections</i>	290
10.2	Design Criteria	290
10.3	Identification and Parts of Tubular Connections	292
10.4	Symbols	292
10.5	Weld Design	292
10.6	Thickness Transition	293
10.7	Material Limitations	293
	<i>Part B—Prequalification of Welding Procedure Specifications (WPSs)</i>	294
10.8	Fillet Weld Requirements	294
10.9	PJP Requirements	294
10.10	CJP Groove Weld Requirements	294
	<i>Part C—Welding Procedure Specification (WPS) Qualification</i>	295
10.11	Common Requirements for WPS and Welding Personnel Performance Qualification	295
10.12	Production Welding Positions Qualified	295
10.13	Type of Qualification Tests, Methods of Testing, and Acceptance Criteria for WPS Qualification	295
10.14	CJP Groove Welds for Tubular Connections	296
10.15	PJP and Fillet Welds Tubular T-, Y-, or K-Connections and Butt Joints	297

<i>Part D—Performance Qualification</i>	297
10.16 Production Welding Positions, Thicknesses, and Diameters Qualified	297
10.17 Weld Types for Welder and Welding Operator Performance Qualification	297
10.18 CJP Groove Welds for Tubular Connections	298
10.19 PJP Groove Welds for Tubular Connections	298
10.20 Fillet Welds for Tubular Connections	298
10.21 Methods of Testing and Acceptance Criteria for Welder and Welding Operator Qualification	298
<i>Part E—Fabrication</i>	299
10.22 Backing	299
10.23 Tolerance of Joint Dimensions	299
<i>Part F—Inspection</i>	300
10.24 Visual Inspection	300
10.25 NDT	300
10.26 UT	300
10.27 RT Procedures	300
10.28 Supplementary RT Requirements for Tubular Connections	301
10.29 UT of Tubular T-, Y-, and K-Connections	301
11. Strengthening and Repair of Existing Structures	354
11.1 Scope	354
11.2 General	354
11.3 Base Metal	354
11.4 Design for Strengthening and Repair	354
11.5 Fatigue Life Enhancement	355
11.6 Workmanship and Technique	355
11.7 Quality	355
Annexes	
Annex A (Normative)—Effective Throats of Fillet Welds in Skewed T-Joints	357
Annex B (Normative)—Guideline on Alternative Methods for Determining Preheat	359
Annex D (Normative)—Temperature-Moisture Content Charts	371
Annex E (Normative)—Flatness of Girder Webs—Statically Loaded Structures	375
Annex F (Normative)—Flatness of Girder Webs—Cyclically Loaded Structures	379
Annex G (Normative)—Qualification and Calibration of UT Units with Other Approved Reference Blocks	385
Annex H (Normative)—Phased Array Ultrasonic Testing (PAUT)	389
Annex I (Normative)—Symbols for Tubular Connection Weld Design	405
Annex J (Informative)—Sample Welding Forms	409
Annex K (Informative)—Contents of Prequalified WPS	431
Annex L (Informative)—Filler Metal Strength Properties	433
Annex M (Informative)—Guide for Specification Writers	445
Annex N (Informative)—UT Examination of Welds by Alternative Techniques	447
Annex O (Informative)—UT Equipment Qualification and Inspection Forms	463
Annex P (Informative)—Local Dihedral Angle	473
Annex Q (Informative)—Preliminary Design Circular Tube Connections	479
Annex R (Informative)—List of Reference Documents	485
Annex S (Informative)—Guidelines for the Preparation of Proposals for Additions of Base Materials not Listed in D1.1	487
Annex T (Informative)—Guidelines for the Preparation of Technical Inquiries for the Structural Welding Committee	489
Commentary	491
List of AWS Documents on Structural Welding	.000
Index	.000

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 WPS Requirements 68
5.2	Essential Variables for Prequalified WPSs. 69
5.3	Approved Base Metals for Prequalified WPSs 70
5.4	Filler Metals for Matching Strength for Table 5.6, Groups I, II, III, and IV Materials 71
5.5	Minimum Prequalified PJP Weld Size (S) 72
5.6	Filler Metal Requirements for Exposed Bare Applications of Weathering Steels. 73
5.7	Prequalified WPS Shielding Gas Options for GMAW electrodes conforming to AWS A5.18/A5.18M. . . 76
5.8	Prequalified Minimum Preheat and Interpass Temperature. 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	WPS Qualification—Plug and Slot Welds: Number and Type of Test Specimens and Range of Thickness. 148
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—Tests on Plate – Number and Type of Specimens and Range of Thickness and Diameter 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 211
7.2	Minimum Holding Time 211
7.3	Alternate Stress-Relief Heat Treatment 211
7.4	Limits on Acceptability and Repair of Mill Induced Laminar Discontinuities in Cut Surfaces 212
7.5	Camber Tolerance for Typical Girder 212

7.6	Camber Tolerance for Girders without a Designed Concrete Haunch	213
7.7	Minimum Fillet Weld Sizes	213
7.8	Weld Profiles	214
7.9	Weld Profile Schedules	214
8.1	Visual Inspection Acceptance Criteria	245
8.2	UT Acceptance-Rejection Criteria (Statically Loaded Nontubular Connections and Cyclically Loaded Nontubular Connections in Compression)	247
8.3	UT Acceptance-Rejection Criteria (Cyclically Loaded Nontubular Connections in Tension)	248
8.4	Hole-Type IQI Requirements	249
8.5	Wire IQI Requirements	249
8.6	IQI Selection and Placement	249
8.7	Testing Angle	250
8.8	UT Equipment Qualification and Calibration Requirements	252
9.1	Mechanical Property Requirements for Studs	284
9.2	Minimum Fillet Weld Size for Studs	284
10.1	Fatigue Stress Design Parameters	304
10.2	Available Stresses in Tubular Connection Welds	305
10.3	Stress Categories for Type and Location of Material for Circular Sections	307
10.4	Fatigue Category Limitations on Weld Size or Thickness and Weld Profile (Tubular Connections)	309
10.5	Z Loss Dimensions for Calculating Prequalified PJP T-, Y-, and K-Tubular Connection Minimum Weld Sizes	309
10.6	Joint Detail Applications for Prequalified CJP T-, Y-, and K-Tubular Connections	310
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	311
10.8	WPS Qualification—Production Welding Positions Qualified by Plate, Pipe, and Box Tube Tests	312
10.9	WPS Qualification—CJP Groove Welds: Number and Type of Test Specimens and Range of Thickness and Diameter Qualified	313
10.10	WPS Qualification—PJP Groove Welds: Number and Type of Test Specimens and Range of Thickness Qualified	315
10.11	WPS Qualification—Fillet Welds: Number and Type of Test Specimens and Range of Thickness Qualified	315
10.12	Welder and Welding Operator Qualification—Production Welding Positions Qualified by Pipe and Box Tube Tests	316
10.13	Welder and Welding Operator Qualification—Number and Type of Specimens and Range of Thickness and Diameter Qualified	317
10.14	Tubular Root Opening Tolerances, Butt Joints Welded Without Backing	319
10.15	Visual Inspection Acceptance Criteria	320
10.16	Hole-Type IQI Requirements	321
10.17	Wire IQI Requirements	321
10.18	IQI Selection and Placement	321
A.1	Equivalent Fillet Weld Leg Size Factors for Skewed T-Joints	358
B.1	Susceptibility Index Grouping as Function of Hydrogen Level “H” and Composition Parameter P_{cm}	363
B.2	Minimum Preheat and Interpass Temperatures for Three Levels of Restraint	363
E.1	Intermediate Stiffeners on Both Sides of Web	376
E.2	No Intermediate Stiffeners	376
E.3	Intermediate Stiffeners on One Side Only of Web	377
F.1	Intermediate Stiffness on Both Sides of Web, Interior Girders	380
F.2	Intermediate Stiffness on One Side Only of Web, Fascia Girders	381
F.3	Intermediate Stiffness on One Side Only of Web, Interior Girders	382
F.4	Intermediate Stiffness on Both Sides of Web, Fascia Girders	383
F.5	No Intermediate Stiffeners, Interior or Fascia Girders	384
H.1	Essential Variables for PAUT	399
H.2	PAUT Acceptance Criteria	399
H.3	Discontinuity Classification	399

N.1	Acceptance-Rejection Criteria	453
Q.1	Terms for Strength of Connections (Circular Sections).	485
	<i>Commentary</i>	
C-5.1	Typical Current Ranges for GMAW-S on Steel	522
C-10.1	Structural Steel Plates	587
C-10.2	Structural Steel Pipe and Tubular Shapes	588
C-10.3	Structural Steel Shapes.	588
C-10.4	Classification Matrix for Applications.	589
C-10.5	CVN Testing Conditions	589
C-10.6	CVN Test Values	590
C-10.7	HAZ CVN Test Values.	590
C-11.1	Guide to Welding Suitability	599
C-11.2	Relationship Between Plate Thickness and Burr Radius	599

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 Fillet Weld Size Along Edges.	54
4.8	Transition of Thicknesses (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>Fillet Weld Root Bend Test Coupon—Welder or Welding Operator Qualification—Option 2</u>	185
6.23	<u>Butt Joint for Welding Operator Qualification—ESW and EGW</u>	186
6.24	<u>Fillet Weld Break Specimen—Tack Welder Qualification</u>	187
6.25	<u>Fillet Weld Break and Macroetch Test Plate—Welder or Welding Operator Qualification—Option 1</u> . .	187
6.26	<u>CVN Test Specimen Locations</u>	188
6.27	<u>Intermix Test Plate</u>	189
6.28	<u>Interface Scribe Line Location</u>	190
6.29	<u>Intermix CVN Test Specimen Location</u>	190
6.30	<u>Fillet Weld Test Coupon—Welder or Welding Operator Qualification—Option 3</u>	191
6.31	<u>Fillet Acute Angle Heel Test for Welder or Welding Operator Qualification</u>	191
7.1	Edge Discontinuities in Cut Material.	215
7.2	Weld Access Hole Geometry	216
7.3	Workmanship Tolerances in Assembly of Groove Welded Joints	217
7.4	Requirements for Weld Profiles	218
8.1	Discontinuity Acceptance Criteria for Statically Loaded Nontubular and Statically or Cyclically Loaded Tubular Connections	254
8.2	Discontinuity Acceptance Criteria for Cyclically Loaded Nontubular Connections in Tension (Limitations of Porosity and Fusion Discontinuities)	258
8.3	Discontinuity Acceptance Criteria for Cyclically Loaded Nontubular Connections in Compression (Limitations of Porosity or Fusion-Type Discontinuities)	262
8.4	Hole-Type IQI	266
8.5	Wire IQI	267
8.6	RT Identification and Hole-Type or Wire IQI Locations on Approximately Equal Thickness Joints 10 in [250 mm] and Greater in Length	268
8.7	RT Identification and Hole-Type or Wire IQI Locations on Approximately Equal Thickness Joints Less than 10 in [250 mm] in Length	268
8.8	RT Identification and Hole-Type or Wire IQI Locations on Transition Joints 10 in [250 mm] and Greater in Length	269
8.9	RT Identification and Hole-Type or Wire IQI Locations on Transition Joints Less than 10 in [250 mm] in Length	270
8.10	RT Edge Blocks	270
8.11	Transducer Crystal	271
8.12	Qualification Procedure of Search Unit Using IIW Reference Block	271
8.13	Typical IIW Type Block	272
8.14	Qualification Blocks	273
8.15	Plan View of UT Scanning Patterns	275

8.16	Transducer Positions (Typical)	276
9.1	Dimension and Tolerances of Standard-Type Headed Studs	285
9.2	Typical Tension Test Fixture	286
9.3	Torque Testing Arrangement and Table of Testing Torques	287
9.4	Bend Testing Device	288
9.5	Suggested Type of Device for Qualification Testing of Small Studs	289
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 Qualification with and without Backing	342
10.18	Tubular Butt Joint—WPS Qualification with and without Backing	342
10.19	Acute Angle Heel Test (Restraints not Shown)	343
10.20	Test Joint for T-, Y-, and K-Connections without Backing on Pipe or Box Tubing (≥ 6 in [150 mm] O.D.)—Welder and WPS Qualification	344
10.21	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	345
10.22	Corner Macroetch Test Joint for T-, Y-, and K-Connections without Backing on Box Tubing for CJP Groove Welds—Welder and WPS Qualification	346
10.23	Location of Test Specimens on Welded Test Pipe and Box Tubing—Welder Qualification	347
10.24	Class R Indications	348
10.25	Class X Indications	350
10.26	Single-Wall Exposure—Single-Wall View	351
10.27	Double-Wall Exposure—Single-Wall View	351
10.28	Double-Wall Exposure—Double-Wall (Elliptical) View, Minimum Two Exposures	352
10.29	Double-Wall Exposure—Double-Wall View, Minimum Three Exposures	352
10.30	Scanning Techniques	353
B.1	Zone Classification of Steels	365
B.2	Critical Cooling Rate for 350 HV and 400 HV	365
B.3	Graphs to Determine Cooling Rates for Single-Pass SAW Fillet Welds	366
B.4	Relation Between Fillet Weld Size and Energy Input	369
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	372
D.2	Application of Temperature-Moisture Content Chart in Determining Atmospheric Exposure Time of Low-Hydrogen SMAW Electrodes	373
G.1	Other Approved Blocks and Typical Transducer Position	387
H.1	Phased Array Imaging Views	400
H.2	Example of a Supplemental Reference Block	400

H.3	Example Standard Reflector Locations in Weld Mockup	401
H.4	Sensitivity Levels	401
H.5	Example of Time Based Linearity Verification	402
H.6	Linearity Verification Report Form	403
N.1	Standard Reference Reflector	454
N.2	Recommended Calibration Block	454
N.3	Typical Standard Reflector (Located in Weld Mock-Ups and Production Welds)	455
N.4	Transfer Correction	456
N.5	Compression Wave Depth (Horizontal Sweep Calibration)	456
N.6	Compression Wave Sensitivity Calibration	457
N.7	Shear Wave Distance and Sensitivity Calibration	457
N.8	Scanning Methods	458
N.9	Spherical Discontinuity Characteristics	459
N.10	Cylindrical Discontinuity Characteristics	459
N.11	Planar Discontinuity Characteristics	460
N.12	Discontinuity Height Dimension	460
N.13	Discontinuity Length Dimension	461
N.14	Display Screen Marking	461
N.15	Report of UT (Alternative Procedure)	462
Q.1	Simplified Concept of Punching Shear	483
Q.2	Reliability of Punching Shear Criteria Using Computed Alpha	483
Q.3	Definition of Terms for Computed Alpha	484
	<i>Commentary</i>	
C-4.1	Balancing of Fillet Welds About a Neutral Axis	510
C-4.2	Shear Planes for Fillet and Groove Welds	510
C-4.3	Eccentric Loading	511
C-4.4	Load Deformation Relationship for Welds	511
C-4.5	Example of an Obliquely Loaded Weld Group	512
C-4.6	Graphical Solution of the Capacity of an Obliquely Loaded Weld Group	513
C-4.7	Single Fillet Welded Lap Joints	514
C-5.1	Examples of Centerline Cracking	522
C-5.2	Details of Alternative Groove Preparations for Prequalified Corner Joints	523
C-5.3	Oscillograms and Sketches of GMAW-S Metal Transfer	523
C-6.1	Type of Welding on Pipe That Does Not Require Pipe Qualification	529
C-7.1	Examples of Unacceptable Reentrant Corners	544
C-7.2	Examples of Good Practice for Cutting Copers	544
C-7.3	Permissible Offset in Abutting Members	544
C-7.4	Correction of Misaligned Members	545
C-7.5	Typical Method to Determine Variations in Girder Web Flatness	545
C-7.6	Illustration Showing Camber Measurement Methods	546
C-7.7	Measurement of Flange Warpage and Tilt	547
C-7.8	Tolerances at Bearing Points	548
C-8.1	90° T- or Corner Joints with Steel Backing	563
C-8.2	Skewed T- or Corner Joints	563
C-8.3	Butt Joints with Separation Between Backing and Joint	564
C-8.4	Effect of Root Opening on Butt Joints with Steel Backing	564
C-8.5	Resolutions for Scanning with Seal Welded Steel Backing	565
C-8.6	Scanning with Seal Welded Steel Backing	565
C-8.7	Illustration of Discontinuity Acceptance Criteria for Statically Loaded Nontubular and Statically or Cyclically Loaded Tubular Connections	566
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	567
C-8.9	Illustration of Discontinuity Acceptance Criteria for Cyclically Loaded Nontubular Connections in Tension	568

C-9.1	Allowable Defects in the Heads of Headed Studs	572
C-10.1	Illustrations of Branch Member Stresses Corresponding to Mode of Loading	590
C-10.2	Improved Weld Profile Requirements	591
C-10.3	Upper Bound Theorem.	591
C-10.4	Yield Line Patterns.	592
C-11.1	Microscopic Intrusions.	600
C-11.2	Fatigue Life	600
C-11.3	Toe Dressing with Burr Grinder.	601
C-11.4	Toe Dressing Normal to Stress.	601
C-11.5	Effective Toe Grinding.	602
C-11.6	End Grinding	602
C-11.7	Hammer Peening	603
C-11.8	Toe Remelting	603

DRAFT

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.