

Specification for the Welding of Hydraulic Cylinders



Documents

Document Sharing Hub

**AWS D14.9/D14.9M:2022-AMD1
An American National Standard**

**Approved by the
American National Standards Institute
September 8, 2022
Amendment: September 26, 2023**

Specification for the Welding of Hydraulic Cylinders

2nd Edition

Revises AWS D14.9/D14.9M:2013

Prepared by the
American Welding Society (AWS) D10 Committee on Piping and Tubing

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification provides standards for the design and manufacture of pressure containing welded joints and structural welded joints used in the manufacture of hydraulic cylinders. Manufacturer's responsibilities are presented as they relate to the welding practices that have been proven successful within the industry in the production of hydraulic cylinders. Included are clauses defining procedure qualification, performance qualification, workmanship and quality requirements as well as inspection requirements and repair requirements.



ISBN Print: 978-1-64322-287-5

ISBN PDF: 978-1-64322-288-2

© 2023 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 revised, 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: Managing Director, Standards Development, 8669 NW 36 St, # 130, Miami, FL 33166 (see Annex F). 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 D14 Committee on Machinery and Equipment. 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 D14 Committee on Machinery and Equipment 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 D14 Committee on Machinery and Equipment 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 (Amendment)

AWS D14 Committee on Machinery and Equipment

J. S. Bailey, Chair	<i>Vermeer Corporation</i>
B. K. Banzhaf, 1 st Vice Chair	<i>CNH Industrial America LLC</i>
D. L. Jones, 2 nd Vice Chair	<i>Flowserve</i>
K. R. Bulger, Secretary	<i>American Welding Society</i>
R. L. Arn	<i>Trinity Industries Incorporated</i>
F. D. Borns	<i>Consultant</i>
J. E. Campbell	<i>Machinery & Welder Corp</i>
B. S. Daines	<i>SpaceX</i>
C. L. Decker	<i>The Lincoln Electric Company</i>
W. E. DePorter	<i>Komatsu Mining Corp Group</i>
T. F. Gary	<i>G & W Products Incorporated</i>
R. K. Goyal	<i>John Deere and Co.</i>
S. A. Harris	<i>Altec Industries Incorporated</i>
R. L. Larsen	<i>John Deere Des Moines Works</i>
R. Leemans	<i>Consultant</i>
J. T. McMurtrey	<i>Atlas Materials Testing & Inspection</i>
D. K. Miller	<i>The Lincoln Electric Company</i>
D. W. Moers	<i>CRC-Evans</i>
C. L. Rasmussen	<i>Brigham Young University—Idaho</i>
D. B. Rizor	<i>Werk-Brau Co., Inc.</i>
M. K. Shriver	<i>Crown Equipment Corporation</i>
J. D. Slipke	<i>Rosenboom Machine & Tool Incorporated</i>
P. T. Snyder	<i>Consultant</i>
M. A. Stevenson	<i>Stevenson Fabrication Services Inc</i>
K. M. Wald	<i>Felling Trailers</i>
D. R. Wisner	<i>M and M Engineering</i>
R. R. Wyers	<i>Komatsu Mining Corp Group</i>

Advisors to the AWS D14 Committee on Machinery and Equipment

S. L. Blankman	<i>Matheson Trigas East Region</i>
D. D. Jones	<i>Texas Hydraulics</i>
L. L. Schweinegruber	<i>Consultant</i>

AWS D14I Subcommittee for the Welding of Hydraulic Cylinders

B. K. Banzhaf, Chair	<i>CNH Industrial America LLC</i>
J. D. Slipke, Vice-Chair	<i>Rosenboom Machine & Tool Incorporated</i>
K. R. Bulger, Secretary	<i>American Welding Society</i>
J. S. Bailey	<i>Vermeer Corporation</i>
F. D. Borns	<i>Consultant</i>
J. E. Campbell	<i>Machinery & Welder Corp</i>
W. E. DePorter	<i>Komatsu Mining Corp Group</i>
S. A. Harris	<i>Altec Industries Incorporated</i>
R. L. Larsen	<i>John Deere Des Moines Works</i>

J. Peterson	<i>Doomsday Diesel LLC</i>
C. L. Rasmussen	<i>Brigham Young University—Idaho</i>
J. D. Redding	<i>Vermeer Corporation</i>
B. Rosenboom	<i>Rosenboom Machine & Tool Incorporated</i>
M. K. Shriver	<i>Crown Equipment Corporation</i>
P. T. Snyder	<i>Consultant</i>
M. A. Stevenson	<i>Stevenson Fabrication Services Inc</i>
R. R. Wyers	<i>Komatsu Mining Corp Group</i>

Advisors to the AWS D14I Subcommittee for the Welding of Hydraulic Cylinders

S. L. Blankman	<i>Matheson Trigas East Region</i>
D. D. Jones	<i>Texas Hydraulics</i>
L. L. Schweinegruber	<i>Consultant</i>

Personnel (Original)

AWS D14 Committee on Machinery and Equipment

J. S. Bailey, Chair	<i>Vermeer Corporation</i>
B. K. Banzhaf, 1 st Vice Chair	<i>CNH Industrial America LLC</i>
D. L. Jones, 2 nd Vice Chair	<i>Flowserve</i>
K. R. Bulger, Secretary	<i>American Welding Society</i>
R. L. Arn	<i>Trinity Industries Incorporated</i>
F. D. Borns	<i>Consultant</i>
T. J. Bruno	<i>Link-Belt Construction Equipment Co</i>
J. E. Campbell	<i>Machinery & Welder Corp</i>
B. S. Daines	<i>SpaceX</i>
W. E. DePorter	<i>Komatsu Mining Corp Group</i>
T. F. Gary	<i>G & W Products Incorporated</i>
R. K. Goyal	<i>John Deere and Co.</i>
S. A. Harris	<i>Altec Industries Incorporated</i>
R. L. Larsen	<i>John Deere Des Moines Works</i>
R. Leemans	<i>Consultant</i>
J. T. McMurtrey	<i>Atlas Materials Testing & Inspection</i>
D. K. Miller	<i>The Lincoln Electric Company</i>
D. W. Moers	<i>CRC-Evans</i>
C. L. Rasmussen	<i>Brigham Young University—Idaho</i>
M. K. Shriver	<i>Crown Equipment Corporation</i>
J. D. Slipke	<i>Rosenboom Machine & Tool Incorporated</i>
P. T. Snyder	<i>Consultant</i>
M. A. Stevenson	<i>Stevenson Fabrication Services Inc</i>
D. R. Wisner	<i>M and M Engineering</i>
R. R. Wyers	<i>Komatsu Mining Corp Group</i>

Advisors to the AWS D14 Committee on Machinery and Equipment

S. L. Blankman	<i>Matheson Trigas East Region</i>
D. D. Jones	<i>Texas Hydraulics</i>
L. L. Schweinegruber	<i>Consultant</i>

AWS D14I Subcommittee for the Welding of Hydraulic Cylinders

B. K. Banzhaf, Chair	<i>CNH Industrial America LLC</i>
J. D. Slipke, Vice-Chair	<i>Rosenboom Machine & Tool Incorporated</i>
K. R. Bulger, Secretary	<i>American Welding Society</i>
J. S. Bailey	<i>Vermeer Corporation</i>
F. D. Borns	<i>Consultant</i>
J. E. Campbell	<i>Machinery & Welder Corp</i>
W. E. DePorter	<i>Komatsu Mining Corp Group</i>
S. A. Harris	<i>Altec Industries Incorporated</i>
R. L. Larsen	<i>John Deere Des Moines Works</i>
J. Peterson	<i>Doomsday Diesel LLC</i>
C. L. Rasmussen	<i>Brigham Young University—Idaho</i>

J. D. Redding	<i>Vermeer Corporation</i>
B. Rosenboom	<i>Rosenboom Machine & Tool Incorporated</i>
M. K. Shriver	<i>Crown Equipment Corporation</i>
P. T. Snyder	<i>Consultant</i>
M. A. Stevenson	<i>Stevenson Fabrication Services Inc</i>
R. R. Wyers	<i>Komatsu Mining Corp Group</i>

Advisors to the AWS D14I Subcommittee for the Welding of Hydraulic Cylinders

S. L. Blankman	<i>Matheson Trigas East Region</i>
D. D. Jones	<i>Texas Hydraulics</i>
L. L. Schweinegruber	<i>Consultant</i>

Foreword

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

This specification reflects the welding processes and practices employed by manufacturers within the industry and it incorporates various methods which have been proven successful by individual manufacturers. No restrictions are placed on the use of any welding process or procedure, provided the weld produced meets the qualification requirements of this specification. No attempt is made to limit or restrict technological progress in the welding of hydraulic cylinders, nor should any such limitation be inferred.

This is the second edition of AWS D14.9/D14.9M, *Specification for the Welding of Hydraulic Cylinders*. This second edition has added a revision of the scope, procedure qualifications, and stud welding.

All errata to a standard shall be published in the *Welding Journal* and posted on the AWS website.

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

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS D14 Committee on Machinery and Equipment, American Welding Society, 8669 NW 36th St #130, Miami, FL 33166.

This page is intentionally blank.

Amendment

The following amendments have been identified and is incorporated in this reprint.

AWS Standard: D14.9/D14.9M:2022-AMD1

Amendment Number: 1

Subject: Table 8.1 (Fillet Weld Size changed from “ $>3/8$ in [10 mm]” to “ $\geq 3/8$ in [10 mm]”)

Table 8.1
Arc Weld Acceptance Criteria (Not Including Arc Stud Welding)

Surface Discontinuity		High Cycle Cylinder Pressure and Non-Pressure Containing Welds	Low Cycle Cylinder Pressure Containing Welds	Low Cycle Cylinder Non-Pressure Containing Welds
Undercut		Not Permitted	Maximum of 10% of base metal thickness up to 1/32 in [0.75 mm] for maximum of 10% Weld Length	Maximum of 10% of base metal thickness up to 1/32 in [0.75 mm] for maximum of 10% Weld Length
ix.	Porosity	Not Permitted	Not Permitted	Maximum diameter 3/64 in [1.2 mm] Sum of diameters $\leq 1/8$ in [3 mm] in any 4 in [100 mm] length of weld
	Cracks	Not Permitted	Not Permitted	Not Permitted
	Incomplete Fusion	Not Permitted	Not Permitted	Not Permitted
	Incomplete Fusion (Fillet)	To or beyond root of the joint	To or beyond root of the joint	To or beyond root of the joint
	Profile	See Figure 8.4	See Figure 8.4	See Figure 8.4
	Toe Reentrant Fillet	$\geq 110^\circ$	$\geq 90^\circ$	$\geq 90^\circ$
	Angle Groove	$\geq 110^\circ$	$\geq 110^\circ$	$\geq 110^\circ$
	Reinforcement of Grooves	1/8 in [3 mm] Maximum	1/8 in [3 mm] Maximum	1/8 in [3 mm] Maximum
Underfill of Grooves		None	Maximum of 5% of Thickness up to 10% Length	Maximum of 5% of Thickness up to 10% Length

Table 8.1
Arc Weld Acceptance Criteria (Not Including Arc Stud Welding)

		High Cycle Cylinder Pressure and Non-Pressure Containing Welds	Low Cycle Cylinder Pressure Containing Welds	Low Cycle Cylinder Non-Pressure Containing Welds
Surface Discontinuity	<3/8 in [10 mm]	+1/8 [3 mm], -1/32 [1 mm]	+1/8 [3 mm], -1/32 [1 mm]	+1/8 [3 mm], -1/32 [1 mm]
	≥3/8 in [10 mm]	+1/8 [3 mm], -1/16 [1.6 mm]	+1/8 [3 mm], -1/16 [1.6 mm]	+1/8 [3 mm], -1/16 [1.6 mm]
Subsurface Discontinuity				
Cracks		None	None	None
Incomplete	PJP	Shall achieve specified weld size	Shall achieve specified weld size	Shall achieve specified weld size
Penetration	CJP	None	None	None
Planar		None	None	Up to 10% weld size and 10% of length. Maximum 1/8 in [3 mm] in 1 in [25 mm] length
Three Dimensional		None	None	Up to 10% weld size and 10% of length. Maximum 1/8 in [3 mm] in 1 in [25 mm] length

¹ The average weld size of a given length of weld shall not be less than the weld size specified on the engineering drawing. The average weld size is determined by the average of leg length measurements obtained at 3 in [75 mm] intervals along the weld length. For welds under 3 in [75 mm] in length, the above tolerances are applied directly. For welds exceeding these tolerances, see 8.12.6 and 8.12.7.

Table of Contents

	Page No.
<i>Personnel (Amendment)</i>	v
<i>Personnel (Original)</i>	vii
<i>Foreword</i>	ix
<i>Amendment</i>	xi
<i>List of Tables</i>	xv
<i>List of Figures</i>	xv
1. General Requirements	1
1.1 Scope	1
1.2 Units of Measure	2
1.3 Safety	2
1.4 Symbols	2
2. Normative References	2
3. Terms and Definitions	3
4. Base Materials	4
4.1 Ferrous and Nonferrous Metals	4
4.2 Properties	4
5. Welding Consumables	4
5.1 Shielding Gases	4
5.2 Filler Metals, Consumable Inserts and Fluxes	4
6. Weld Joint Design	4
6.1 <u>Weld Joint Design Responsibility</u>	4
6.2 <u>Fillet Weld Determination</u>	4
6.3 <u>Combination Fillet and Groove Weld Determination</u>	4
6.4 Combination J and Single Bevel <u>Groove Welds</u>	5
6.5 Effective <u>Groove Weld</u> Size for Flare-Groove Welds	5
7. Welding Process Controls	7
7.1 Procedure Qualification	7
7.2 Performance Qualification	11
7.3 Welding Equipment Qualification	14
7.4 Welding Process Audits	15
8. Workmanship and Quality Requirements	25
8.1 Scope	25
8.2 General Requirements	25
8.3 Equipment	25
8.4 Preparation of Materials	25
8.5 Assembly	25
8.6 Preheat	26
8.7 Arc Strikes	26
8.8 Cleaning of Welds	26
8.9 Peening	26
8.10 Stress Relief	26

8.11	Quality of Welds	27
8.12	Repair of Weld Defects	27
9.	Quality Assurance	34
9.1	<u>Quality Personnel</u>	34
9.2	<u>Welding Procedures</u>	34
9.3	<u>Welding Personnel Qualification</u>	34
9.4	<u>Inspection Personnel Qualification</u>	34
9.5	<u>Weld Quality Acceptance Criteria</u>	34
9.6	<u>Welder Requalification</u>	34
10.	Repair and Modification	34
10.1	<u>Weld Repair</u>	34
10.2	<u>Repair Instruction</u>	34
10.3	<u>Welding Personnel Qualification</u>	34
10.4	<u>Repair Welding Procedures</u>	34
10.5	<u>Weld Quality</u>	34
10.6	<u>Resource</u>	34
	Annex A (Informative)—Commonly Used Welding Processes and Hydraulic Cylinder Component Nomenclature	35
	Annex B (Informative)—Preheat and Postweld Heat Treatment Recommendations	39
	Annex C (Informative)—Recommended Practices for Storage and Treatment of Electrodes and Fluxes	43
	Annex D (Informative)—Magnetism, a Cause of Arc Blow	47
	Annex E (Informative)—Informative References	49
	Annex F (Informative)—Requesting an Official Interpretation on an AWS Standard	51
	List of AWS Documents on Machinery and Equipment	53

List of Tables

Table		Page No.
6.1	Effective Weld Sizes of Flare Groove Welds <u>Filled Flush</u>	5
7.1	Minimum Fillet Weld Size for Small Diameter Studs	16
8.1	<u>Arc Weld Acceptance Criteria (Not Including Arc Stud Welding)</u>	29
8.2	<u>Friction Weld Acceptance Criteria</u>	30
8.3	<u>Arc Stud Weld Acceptance Criteria</u>	30
C.1	Electrodes Covered by AWS A5.1/A5.1M, <i>Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding</i>	44
C.2	Electrodes Covered by AWS A5.5/A5.5M, <i>Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding</i>	44

List of Figures

Figure		Page No.
6.1	Fillet Weld Symbol for Groove Width Less Than 3/32 in [2.5 mm].	5
6.2	Welding Symbol for Combination Weld Types.	6
6.3	Welding Symbol for <u>Weld Groove with J- and Single-Bevel Edge Shapes</u>	7
7.1	Typical Location for Cross-Sections in an End Cap Weld	17
7.2	Typical Location of Cross-Sections for Rod Welds with Groove Width Less than 3/32 in [2.5 mm]	18
7.3	Typical Location of Cross-Sections for Rod Welds with Groove Width 3/32 in [2.5 mm] and Greater	18
7.4	Typical Location for Cross-Sections in a Port Weld	19
7.5	<u>Fillet and Groove Weld Cross-Sections and Microhardness Locations</u>	20
7.6	<u>Port Stud Weld Cross-Section and Microhardness Locations</u>	21
7.7	<u>Friction Welded Rod End Cross-Section and Microhardness Locations</u>	22
7.8	Fillet Weld Break Specimen—Tack Welder Qualification	23
7.9	Method for Rupturing Specimen—Tack Welder Qualification.	23
7.10	Groove Weld Break Specimen—Tack Welder	24
7.11	Method of Evaluating Tack Welder Qualification for Grooves	24
8.1	Flat Based Port Design on Round Tube	31
8.2	Coped Port Design	31
8.3	Spot Faced Port Design.	32
8.4	Acceptable and Unacceptable Weld Profiles.	33
A.1	Hydraulic Cylinder Component Nomenclature.	38

This page is intentionally blank.

Specification for the Welding of Hydraulic Cylinders

1. General Requirements

1.1 Scope. This specification provides requirements for the design and manufacture of welded joints of hydraulic cylinders. When specified in the contract documents, compliance with all the requirements shall be required. This specification does not apply to the manufacture of welded tubing used for hydraulic cylinders which is covered under ASTM and other recognized specifications. This specification does not specify load determination, design assumptions, safety factors, or calculation methods for non-weld related areas of the hydraulic cylinder.

1.1.1 Responsibilities

1.1.1.1 The Manufacturer's adherence to this specification shall include responsibility for the following:

- (1) welding, as defined in 1.1, in accordance with this specification;
- (2) producing welds as designated on drawings by appropriate symbols and notes, with sufficient detail to show joint preparation compatible with applied processes;
- (3) providing written welding procedure specifications (WPSs);
- (4) recording and maintaining results of all welding procedure and welder performance qualification tests;
- (5) controlling use of designated base metals and welding consumables;
- (6) inspecting the welds to the requirements of this specification;
- (7) having a welding quality program in place. The requirements of AWS B5.17, *Specification for the Qualification of Welding Fabricators* may be used as a guide in establishing this welding quality program. Accreditation of quality systems of welding fabricators may be obtained through the AWS Certified Welding Fabricator (CWF) or equivalent programs.
- (8) determining the responsible technical authority when the term "Engineer" is used. If the Owner wants to assume engineering responsibility, it shall be specified in the contract documents.

1.1.1.2 The 'Engineer' in this document shall have specific technical expertise, such as, but not limited to, welding engineering or design engineering.

1.1.1.3 Welding Engineer. The Manufacturer's technical authority typically responsible for developing welding procedure specifications (WPS), procedure qualification records (PQR) and performance qualification test record (PQTR). The Welding Engineer may also have expertise in welding process selection; weld metallurgy and weld filler metal selection; weld joint design and weld sizing; weld fixture design and weld robot programming; weld inspection and weld defect/failure root cause analysis. Qualifications for a welding engineer shall meet one of the following criteria:

- (1) An AWS Certified Welding Engineer in conformance with the provisions of AWS B5.16, *Specification for the Qualification of Welding Engineers*,
- (2) IIW International Welding Engineer (IWE),
- (3) Professional Engineer – Welding, or
- (4) An individual who by degree, training, or experience is qualified in welding engineering disciplines.

1.1.1.4 Design Engineer. The technical authority typically responsible for developing equipment configuration; analyzing stress levels (such as but not limited to finite element analysis (FEA) and strain gage data); choosing material

type and thickness; determining weld joint type and weld size; and evaluating cyclic loading and fatigue life. The Design Engineer may also provide judgments on weld defect criticality and weld inspection requirements. See AWS D14.4/D14.4M, *Specification for the Design of Welded Joints in Machinery and Equipment* for design criteria for allowable stresses for the base and weld metal and the fatigue analysis for welded joints. Qualification for a Design Engineer shall meet one of the following criteria:

- (1) Professional or Chartered Engineer—Mechanical, Civil, Structural, Agricultural, or
- (2) An individual who by degree, training, or experience is qualified in design of structures.

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

1.3 Safety. Safety and health issues and concerns are beyond the scope of this standard, and therefore are not addressed herein. Safety and health information is available from the following sources:

American Welding Society:

- (1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*
- (2) AWS Safety and Health Fact Sheets
- (3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

- (1) Safety Data Sheets (SDSs) supplied by materials manufacturers
- (2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies:

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

1.4 Symbols. Welding symbols shown on drawings shall be compatible with those shown in AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination*. In addition, welding symbols not conforming to the requirements of AWS A2.4, but conforming to the requirements of this specification, may be allowed on drawings. Special conditions or deviations shall be fully explained by added notes, details, or definitions on the drawings. Combination groove weld symbols may not match those in AWS A2.4; the perpendicular leg of the groove weld symbol may or may not be included.

2. Normative References

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

American Welding Society (AWS) standards:

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

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

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

AWS A5.01M/A5.01 (ISO 14344 MOD), *Welding and Brazing Consumables—Procurement of Filler Metals and Fluxes*

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

AWS B2.1/B2.1M, *Specification for Welding Procedure and Performance Qualification*

AWS B4.0, *Standard Methods for Mechanical Testing of Welds (US Customary Units)*

AWS B4.0M, *Standard Methods for Mechanical Testing of Welds (Metric Customary Units)*

AWS B5.16, *Specification for the Qualification of Welding Engineers*

AWS B5.17, *Specification for the Qualification of Welding Fabricators*

AWS C4.1-77, *Criteria for Describing Oxygen-Cut Surfaces*

AWS C6.2/C6.2M, *Specification for Friction Welding of Metals*

AWS D14.4/D14.4M, *Specification for the Design of Welded Joints in Machinery and Equipment*

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

CSA standards:

CSA W178.2, *Certification of Welding Inspectors*

3. Terms and Definitions

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

Engineer. Responsible technical authority. See 1.1.1 for additional information on Engineer responsibilities and qualifications.

fracture toughness variable (T). A qualification variable required when fracture toughness is specified by the Engineer.

groove width. The opening between groove faces in a groove joint. See Figure 6.2 (the z dimension) for combination joints.

high cycle cylinder. A cylinder designed for an expected life equal to or greater than one million cycles.

low cycle cylinder. A cylinder designed for an expected life of less than one million cycles.

Manufacturer. The organization responsible for the fabrication of the end product created using this specification.

Operator of Automatic Welding Equipment. A person who operates equipment requiring only occasional or no observation and no manual adjustment of the controls.

Owner. The person, company or agency purchasing the product created utilizing this specification.

performance qualification variable. One of a set of requirements defining the limits of qualification of welders and welding operators. A change beyond the limits used in qualification requires requalification.

procedure qualification variable. One of a set of requirements defining the limits of use of a welding procedure specification. A change beyond the limits used in qualification requires requalification.

qualification variable (Q). See performance qualification variable and procedure qualification variable.

welding consumables. Filler metals, consumable inserts, fluxes, and shielding gases used in the welding process.

welding variable. Any controllable detail of a welding procedure which is required to be addressed on the WPS.

WPS data variable (D). A welding variable that if changed, does not require requalification. However, a revised WPS or new WPS shall be prepared.

4. Base Materials

4.1 Ferrous and Nonferrous Metals. Rolled steels, steel castings and forgings, and nonferrous metals used in the weldments for hydraulic cylinder applications shall be identified by a specification. Specifications developed by the Manufacturer or commonly used industry-wide specifications developed by organizations such as the American Society for Testing and Materials (ASTM), American Iron and Steel Institute (AISI), Society of Automotive Engineers (SAE), and American Foundrymen's Society (AFS) may be used.

4.2 Properties. Base metal specifications shall designate the chemical composition of the material to be used and shall include the mechanical properties, heat treatment of the material, or both when required for proper identification. Base metals are expected to be compatible with the welding process and consumables recommended in this specification. This standard does not impose restrictions on the selection of base materials; however, weldability factors must be considered when selecting base materials.

5. Welding Consumables

5.1 Shielding Gases

5.1.1 When a gas or gas mixture is used for shielding in any gas shielded welding process, it shall conform to the requirements of AWS A5.32M/A5.32 (ISO 14175 MOD), *Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*.

5.1.2 When mixed at the Manufacturer's plant, suitable meters shall be used for proportioning the gases. The percentage of constituent gases shall conform to the requirements of the WPS.

5.1.3 A calibrated monitoring gas analyzer with suitable limit range settings shall be used to verify gas mixtures where shielding gases are mixed at the Manufacturer's plant for welding applications.

5.2 Filler Metals, Consumable Inserts and Fluxes

5.2.1 Procurement of welding filler metals for hydraulic cylinder welding shall follow the method set forth in AWS A5.01M/A5.01 (ISO 14344 MOD), *Welding and Brazing Consumables—Procurement of Filler Metals and Fluxes*.

5.2.2 When requested by the Owner, the Manufacturer shall furnish certification that the welding filler metals used for welding hydraulic cylinders conform to the requirements of the specification and classification in accordance with AWS A5.01M/A5.01 (ISO 14344 MOD), *Welding and Brazing Consumables—Procurement of Filler Metals and Fluxes* for heat, lot, testing, and certification requirements.

5.2.3 Welding consumables which are not procured following the methods set forth in AWS A5.01M/A5.01 (ISO 14344 MOD), *Welding and Brazing Consumables—Procurement of Filler Metals and Fluxes* shall be tested by the user to meet the requirements of the applicable AWS filler metal specification.

5.2.4 Welding filler metals shall be protected and stored so that their characteristics or welding properties are not adversely affected. The welding filler metal manufacturer's specific recommendations shall be applied. Annex C contains general practices for storage and the use of filler metals employed for application within the scope of this specification.

6. Weld Joint Design

6.1 Weld Joint Design Responsibility. The Engineer shall be responsible for the weld joint design. AWS D14.4/D14.4M, *Specification for the Design of Welded Joints in Machinery and Equipment* may be used to determine fatigue life. The Engineer shall ensure that the joint design will meet the requirements of this specification and the contract documents. When the Owner requests design validation, the need shall be specified in the contract documents.

6.2 Fillet Weld Determination. For combination of weld types that progressively transition between fillet and groove welds such as port to tube welds or rod to cross tube, if the maximum groove width (as designed) is less than 3/32 in [2.5 mm], the weld shall be considered a fillet and shall be depicted using a fillet weld symbol. Refer to Figure 6.1.

6.3 Combination Fillet and Groove Weld Determination. For a combination of weld types that progressively transition between fillet and groove welds such as port to tube or rod to cross tube, if the maximum groove width (as designed) is

3/32 in [2.5 mm] or greater, the weld shall be considered a combination fillet and groove weld. The symbol may be shown using multiple sub-reference lines. Individual weld symbols or combination weld symbols shall be placed on their own sub-reference lines connected to a single reference line. For examples of combination groove and fillet welds and their weld symbols see Figure 6.2.

6.4 Combination J and Single Bevel Groove Welds. End cap welds may be made with various groove joint types including a combination of two different edge shapes in a single joint as shown in Figure 6.3. The welding symbol can include a combination J- or bevel-groove weld symbol to represent two different edge preparations.

6.5 Effective Groove Weld Size for Flare-Groove Welds. Flare-groove welds are a special case that do not conform to all the accepted conventions associated with other types of groove welds. The effective groove weld size for flare groove welds, when filled to the surface of a bar, 90° bend in a formed section, or a rectangular tube shall be as follows:

- (1) For GMAW (except GMAW-S), FCAW and SAW the effective groove weld size shall be as shown in Table 6.1.
- (2) For the use of GMAW-S and other processes not mentioned in 6.5(1) the Manufacturer shall establish the effective groove weld size by validation in accordance with 6.5(4).
- (3) For a given set of procedural conditions, groove weld sizes larger than those shown in Table 6.1 may be used, provided that the effective groove weld size is validated by the Manufacturer in accordance with 6.5(4) and approved by the Engineer.
- (4) Validation required by 6.5(2) or (3) shall consist of sectioning the radiused member, normal to its axis, at mid length and at the ends of the weld. Such sectioning shall be made on a number of combinations of material sizes representative of the range used by the Manufacturer or as required by the Engineer. A macro etch and visual inspection shall be performed, verifying that complete fusion through the desired groove weld size has been achieved.

Table 6.1
Effective Weld Sizes of Flare Groove Welds Filled Flush^a

Flare-Bevel-Groove Welds	Flare-V-Groove Welds
(5/16) R	(1/2) R

^a R = Radius of outside surface.

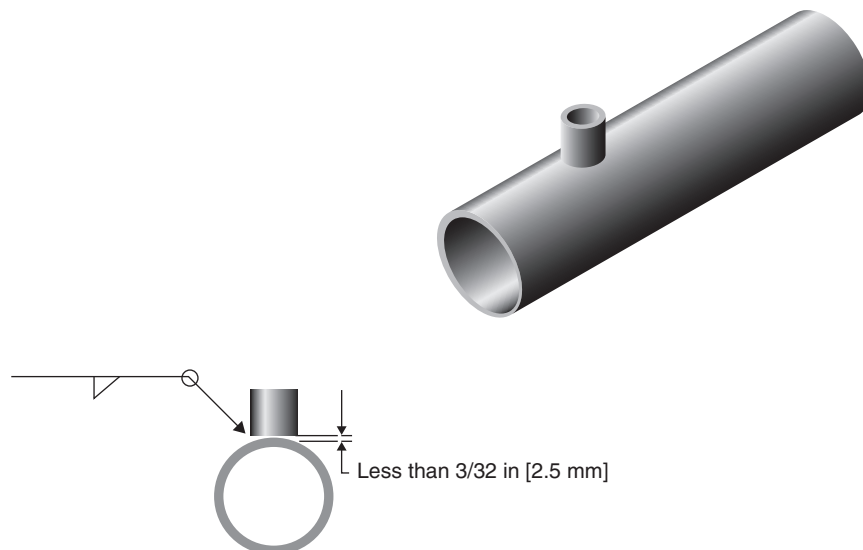


Figure 6.1—Fillet Weld Symbol for Groove Width Less Than 3/32 in [2.5 mm]