

**AWS D15.1/D15.1M:2025**  
**An American National Standard**



# **Railroad Welding Specification for Cars and Locomotives**



**AWS D15.1/D15.1M:2025**  
**An American National Standard**

**Approved by the**  
**American National Standards Institute**  
**July 12, 2024**

# **Railroad Welding Specification for Cars and Locomotives**

**7th Edition**

**Revises AWS D15.1/D15.1M:2019-AMD1**

Prepared by the  
American Welding Society (AWS) D15 Committee on Railroad Welding

Under the Direction of the  
AWS Technical Activities Committee

Approved by the  
AWS Board of Directors

## **Abstract**

This specification establishes minimum welding standards for the manufacture and maintenance of railcars, locomotives, and their components, intended for North American railroad service. Clauses 4 through 16 cover the general requirements for welding in the railroad industry. Clauses 17 through 22 cover specific requirements for the welding of base metals thinner than 1/8 in [3 mm].



ISBN Print: 978-1-64322-330-8  
ISBN PDF: 978-1-64322-331-5  
© 2024 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](http://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](http://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 G). 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 D15 Committee on Railroad 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 D15 Committee on Railroad 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 D15 Committee on Railroad 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 D15 Committee on Railroad Welding

D. M. Smook, Chair	<i>Midwest Railcar Repair, Incorporated</i>
M. R. Untermeyer, 1st Vice Chair	<i>Alltranstek</i>
M. A. Forsstrom, 2nd Vice Chair	<i>CIT</i>
J. M. Rosario, Secretary	<i>American Welding Society</i>
K. L. Anderson	<i>CSX</i>
T. R. Berg	<i>New York Air Brake</i>
M. A. Bohmont	<i>Kawasaki Motors Manufacturing Corporation</i>
P. A. Burys	<i>Raul V. Bravo &amp; Associates</i>
R. A. Conrad	<i>ITW Welding North America</i>
R. M. Dull	<i>Edison Welding Institute</i>
J. L. Everidge	<i>Union Pacific Railroad</i>
I. T. Fuller	<i>Progress Rail</i>
D. S. Galda	<i>ITW Welding North America</i>
B. K. Gattie	<i>Norfolk Southern Corporation</i>
J. S. Gronberg	<i>WATCO</i>
T. C. Guevin	<i>Alstom</i>
R. M. Haskins	<i>BNSF Railway Company</i>
S. J. Hopper	<i>The Greenbrier Companies</i>
L. W. Inman	<i>CSX</i>
J. M. Killion	<i>Union Tank Car Company</i>
W. W. Krev	<i>Airgas</i>
J. I. Matson-Warner	<i>Wabtec Corporation</i>
S. J. McCullough	<i>Alltranstek</i>
H. F. McMullin	<i>Salco Products</i>
D. L. McVay	<i>Trinity Industries, Incorporated</i>
L. W. Miller	<i>Select Arc, Incorporated</i>
R. M. Miller	<i>Camfil APC</i>
B. S. Morris	<i>CSX</i>
S. A. Muñoz	<i>Alstom</i>
T. M. Nelson	<i>Hatch</i>
M. E. Oddie	<i>Progress Rail</i>
J. L. Pasqua	<i>Salco Products</i>
B. S. Quig	<i>Integral Railroad Services</i>
K. G. Rawlins	<i>TTX Company</i>
T. A. Robertson	<i>Tri-State Industrial Contractors, Incorporated</i>
T. Schmidt	<i>ECE Global</i>
D. E. Seely	<i>Steel Dynamics, Incorporated</i>
B. E. Senior	<i>National Steel Car Limited</i>
J. H. Shomo	<i>CR Quality Services</i>
J. C. Siemer	<i>Wabtec Corporation</i>
L. H. Strouse	<i>Federal Railroad Administration</i>
Z. Tanacs	<i>National Steel Car</i>
A. L. Trevett	<i>Cathcart Rail</i>
J. W. Weaver	<i>The Greenbrier Companies</i>
A. P. Willaredt	<i>Midwest Railcar Corporation</i>

**Advisors to the AWS D15 Committee on Railroad Welding**

J. A. Barrett	<i>Wabtec Corporation</i>
R. C. Bly	<i>Consultant</i>
L. B. Broadway	<i>The Greenbrier Companies</i>
C. J. Gamblin	<i>Marmon Rail Corporation</i>
J. B. Pearson	<i>ALRV Consultant, LLC</i>
J. P. Plummer	<i>Norfolk Southern Corporation</i>
B. W. Siebold	<i>BNSF Railway Company</i>

**AWS D15A Subcommittee on Cars and Locomotives**

M. R. Untermeyer, Chair	<i>Alltranstek</i>
S. J. Hopper, 1st Vice Chair	<i>The Greenbrier Companies</i>
R. A. Conrad, 2nd Vice Chair	<i>ITW Welding North America</i>
J. M. Rosario, Secretary	<i>American Welding Society</i>
K. L. Anderson	<i>CSX</i>
T. R. Berg	<i>New York Air Brake</i>
M. A. Bohmont	<i>Kawasaki Motors Manufacturing Corporation</i>
P. A. Bury	<i>Raul V. Bravo &amp; Associates</i>
P. Dostie	<i>CMP Advanced Mechanical Solutions LTD</i>
R. M. Dull	<i>Edison Welding Institute</i>
J. L. Everidge	<i>Union Pacific Railroad</i>
M. A. Forsstrom	<i>CIT</i>
I. T. Fuller	<i>Progress Rail</i>
D. S. Galda	<i>ITW Welding North America</i>
B. K. Gattie	<i>Norfolk Southern Corporation</i>
J. S. Gronberg	<i>WATCO</i>
T. C. Guevin	<i>Alstom</i>
R. M. Haskins	<i>BNSF Railway Company</i>
L. W. Inman	<i>CSX</i>
J. M. Killion	<i>Union Tank Car Company</i>
K. D. Knife	<i>Select Arc, Incorporated</i>
W. W. Krev	<i>Airgas</i>
J. I. Matson-Warner	<i>Wabtec Corporation</i>
S. J. McCullough	<i>Alltranstek</i>
P. McCunney	<i>AtkinsRéalis</i>
H. F. McMullin	<i>Salco Products</i>
D. L. McVay	<i>Trinity Industries, Incorporated</i>
L. W. Miller	<i>Select Arc, Incorporated</i>
R. M. Miller	<i>Camfil APC</i>
B. S. Morris	<i>CSX</i>
T. M. Nelson	<i>Hatch</i>
M. E. Oddie	<i>Progress Rail</i>
J. L. Pasqua	<i>Salco Products</i>
J. P. Plummer	<i>Norfolk Southern Corporation</i>
B. S. Quig	<i>Integral Railroad Services</i>
K. G. Rawlins	<i>TTX Company</i>
T. A. Robertson	<i>Tri-State Industrial Contractors, Incorporated</i>
T. Schmidt	<i>ECE Global</i>
B. E. Senior	<i>National Steel Car Limited</i>
J. H. Shomo	<i>CR Quality Services</i>
J. C. Siemer	<i>Wabtec Corporation</i>
D. M. Smook	<i>Midwest Railcar Repair, Incorporated</i>
B. Stempka	<i>Advanced Welding Technologies Inc.</i>
L. H. Strouse	<i>Federal Railroad Administration</i>

Z. Tanacs	<i>National Steel Car</i>
A. L. Trevett	<i>Cathcart Rail</i>
M. Triplett	<i>Union Tank Car Company</i>
J. W. Weaver	<i>The Greenbrier Companies</i>
A. P. Willaredt	<i>Midwest Railcar Corporation</i>

**Advisors to the AWS D15A Subcommittee on Cars and Locomotives**

J. A. Barrett	<i>Wabtec Corporation</i>
R. C. Bly	<i>Consultant</i>
L. B. Broadway	<i>The Greenbrier Companies</i>
C. J. Gamblin	<i>Marmon Rail Corporation</i>
J. B. Pearson	<i>ALRV Consultant, LLC</i>
B. W. Siebold	<i>BNSF Railway Company</i>
J. Sokolewicz	<i>Trinity Industries, Incorporated (Retired)</i>



This page is intentionally blank.

## Foreword

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

This specification establishes minimum welding standards for the manufacture and maintenance of railcars, locomotives, and their components, intended for North American railroad service. It was developed and is maintained by the D15 Committee on Railroad Welding of the American Welding Society.

Welding of railroad components is vital to the industry. An investigating committee was formed in 1982 which recommended a Railroad Welding Committee be formed to establish minimum welding standards for the industry. This recommendation was made because of confusion and incompleteness of the existing welding specifications and guides as applied to the railroad industry needs. The committee is made up of individuals from all segments of the railroad industry: both users and suppliers, the general public, and representatives of the Association of American Railroads.

The purpose of this specification is to provide a single comprehensive document of welding data that will be used throughout the railroad industry. Also, it should contribute to improvements in welding quality and performance.

AWS D15.1-86 was titled simply *Railroad Welding Specification*. For the 1993 revision, the suffix *Cars and Locomotives* was added because the locomotive section had been introduced. A later revision was published in 2001, AWS D15.1:2001. The welding of rail is addressed in AWS D15.2/D15.2M, *Recommended Practice for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*.

Several significant modifications have been made in AWS D15.1/D15.1M:2025. A vertical line in the margin or underlined text in clauses, tables, or figures indicates an editorial or technical change from the 2019 edition.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary of the AWS D15 Committee on Railroad Welding, American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

This page is intentionally blank.

# Table of Contents

	<b>Page No.</b>
<i>Personnel</i> .....	v
<i>Foreword</i> .....	ix
<i>List of Tables</i> .....	xv
<i>List of Figures</i> .....	xvi
<b>1. General Requirements</b> .....	<b>1</b>
1.1 Scope .....	1
1.2 Units of Measurement .....	1
1.3 Safety .....	1
<b>2. Normative References</b> .....	<b>1</b>
<b>3. Terms and Definitions</b> .....	<b>3</b>
<b>4. General Information</b> .....	<b>4</b>
4.1 Base Metals .....	4
4.2 <u>Material Coatings</u> .....	4
4.3 <u>Material Thickness</u> .....	4
4.4 <u>Weld Quality Responsibility</u> .....	4
4.5 <u>Engineering Judgement</u> .....	4
4.6 <u>Requirements Hierarchy</u> .....	5
4.7 <u>Approvals</u> .....	5
4.8 <u>Applications</u> .....	5
4.9 <u>Engines</u> .....	5
4.10 <u>AAR Requirements</u> .....	5
4.11 <u>Fatigue Design</u> .....	5
<b>5. Requirements for All Welding</b> .....	<b>5</b>
5.1 General—Welding Procedure Specification Data .....	5
5.2 Processes .....	5
5.3 Welding Procedure Qualification .....	8
5.4 Qualification of Welders and Welding Operators .....	9
5.5 Design of Welded Joints .....	9
5.6 Consumables .....	12
5.7 Preparation for Welding .....	14
<b>6. Technique and Workmanship</b> .....	<b>23</b>
6.1 General .....	23
6.2 Preparation of Base Metal .....	23
6.3 Steel and Aluminum Assembly Criteria .....	25
6.4 Weld Profiles .....	26
6.5 Repairs—After Welding .....	27
6.6 Arc Strikes .....	28
6.7 Cleaning and Protective Coatings .....	28
6.8 Weld Termination .....	28
6.9 Groove Weld Backing .....	29
6.10 Heat Input Control for Quenched and Tempered Steel .....	29
6.11 Stress-Relief/Postweld Heat Treatment (PWHT) .....	29

6.12	Peening	29
6.13	Workmanship for Stud Arc Welding (SW)	29
6.14	Welding Air Brake Pipe	30
<b>7.</b>	<b>Prequalified Welding Procedure Specifications—Joint Design Details</b>	<b>33</b>
7.1	Groove Weld Size (Effective Weld Size)	33
7.2	Joint Designs	34
7.3	Fillet Welds	34
7.4	Details of Plug and Slot Welds	34
7.5	Complete Joint Penetration Groove Welds	34
7.6	Partial Joint Penetration Groove Welds	34
<b>8.</b>	<b>Technique for Prequalified Welding Procedure Specifications</b>	<b>66</b>
8.1	Base Metal, Filler Metal, and other Material Requirements	66
8.2	Preheat, Interpass, and Postweld Heat Treatment (PWHT) Requirements	66
8.3	Shielded Metal Arc Welding (SMAW)	66
8.4	Submerged Arc Welding (SAW)	67
8.5	Gas Metal Arc and Flux Cored Arc Welding (GMAW and FCAW)	70
8.6	Plug and Slot Welds	70
8.7	Welding Wear Plates and Wear Liners	71
<b>9.</b>	<b>General Requirements for Qualification</b>	<b>81</b>
9.1	Prequalified Procedures	81
9.2	Qualified Procedures	81
9.3	Welders, Welding Operators, and Tack Welders	82
9.4	Qualification Responsibility	82
<b>10.</b>	<b>Procedure Qualification</b>	<b>82</b>
10.1	Limitation of Essential Variables	82
10.2	Types of Tests and Purposes	82
10.3	Base Metal and Its Preparation	83
10.4	Position of Test Welds	83
10.5	Joint Welding Procedure Specification	84
10.6	Test Specimens: Number, Type, and Preparation	84
10.7	Special Test Conditions	86
10.8	Method of Testing Specimens	86
10.9	Test Results Required	87
10.10	Records	88
10.11	Retests	88
10.12	Flash Welding	88
<b>11.</b>	<b>Welder Qualification</b>	<b>114</b>
11.1	General	114
11.2	Limitation of Variables	114
11.3	Qualification Tests Required	114
11.4	Groove Weld Plate Qualification Test for Plate	115
11.5	Groove Weld Qualification Test for Pipe or Square or Rectangular Tubing	115
11.6	Fillet Weld Qualification Test for Fillet Welds Only	115
11.7	Position of Test Welds	115
11.8	Base Metal	115
11.9	Joint Welding Procedure Specification	115
11.10	Test Specimens	116
11.11	Method of Testing Specimens	116
11.12	Test Results Required	116
11.13	Retests	117
11.14	Period of Effectiveness	117
11.15	Records	118

<b>12. Welding Operator Qualification</b>	130
12.1 General	130
12.2 Limitation of Variables	130
12.3 Qualification Tests Required for Welding Operators	130
12.4 Base Metal	130
12.5 Joint Welding Procedure Specification	130
12.6 Test Specimens: Number, Type, and Preparation	130
12.7 Method of Testing Specimens	130
12.8 Test Results Required	130
12.9 Retests	131
12.10 Period of Effectiveness	131
12.11 Records	131
12.12 Flash Welding Operator Qualification	131
<b>13. Tack Welder Qualification</b>	132
13.1 General	132
13.2 Limitation of Variables	132
13.3 Qualification Tests Required	132
13.4 Base Metal	132
13.5 Test Specimens: Number, Type, and Preparation	132
13.6 Method of Testing Specimens	132
13.7 Test Results Required	132
13.8 Retests	132
13.9 Period of Effectiveness	132
13.10 Records	132
<b>14. Inspection—General Requirements</b>	133
14.1 Manufacturer’s Responsibility	133
14.2 Designated Inspector	133
14.3 Fabrication Inspection	133
14.4 Verification Inspection	134
<b>15. Nondestructive Examination</b>	135
15.1 Nondestructive Examination	135
15.2 Personnel Qualifications	135
15.3 Radiographic Testing of Groove Welds	135
15.4 Ultrasonic Testing of Groove Welds	136
15.5 Liquid Penetrant Testing of Welds	137
15.6 Magnetic Particle Testing of Welds	137
<b>16. Acceptance Criteria</b>	147
16.1 Temporary Welds	147
16.2 Visual Inspection Acceptance Criteria	147
16.3 Radiographic Inspection Acceptance Criteria	147
16.4 Ultrasonic Inspection Acceptance Criteria	148
16.5 Liquid Penetrant Inspection Acceptance Criteria	148
16.6 Magnetic Particle Inspection Acceptance Criteria	148
<b>17. Requirements for Welding Sheet Metal</b>	150
17.1 Design of Welded Joints	150
17.2 Joint and Procedure Qualification for Welding Sheet Metal	150
17.3 Records	151
<b>18. Welder, Welding Operator, and Tack Welder Qualification—Sheet Metals</b>	160
18.1 General	160
18.2 Limitation of Variables	160
18.3 Retests	160

18.4 Period of Effectiveness. . . . . 160

18.5 Records. . . . . 161

**19. Technique and Workmanship for Welding Sheet Metal . . . . . 163**

**20. Inspection of Welding Procedure Qualification and Equipment for Welding Sheet Metal . . . . . 163**

**21. Weld Details—Sheet Metal . . . . . 163**

21.1 Groove Welds (Butt Joints) . . . . . 163

21.2 Fillet Welds. . . . . 163

**22. Sheet Metal Weld Quality—Visual Inspection Acceptance Criteria . . . . . 163**

Annex A (Normative)—Alternate Base Material Specifications (Steel) . . . . . 165

Annex B (Informative)—Filler Metal Classifications . . . . . 167

Annex C (Informative)—Effective Weld Size—Special Cases . . . . . 171

Annex D (Informative)—Sample Report Forms . . . . . 173

Annex E (Informative)—Gage Thickness of Sheet Metal and Aluminum Filler Alloy Selection Guide. . . . . 197

Annex F (Informative)—Macroetch Procedures . . . . . 203

Annex G (Informative)—Requesting an Official Interpretation on an AWS Standard . . . . . 207

Annex H (Informative)—Informative References . . . . . 209

List of AWS Documents on Railroad Welding . . . . . 211

Index . . . . . 213

## List of Tables

Table	Page No.	
5.1	Minimum Weld Size for Partial Joint Penetration Groove Welds. . . . .	14
5.2	Allowable Weld Stresses (Steel) . . . . .	15
5.3	Allowable Weld Stresses (Aluminum) . . . . .	15
5.4	Minimum Mechanical Properties for Welded Aluminum Alloys (Gas Tungsten Arc or Gas Metal Arc Welding with No Postweld Heat Treatment) . . . . .	16
5.5	Minimum Mechanical Properties for Before Welding . . . . .	17
5.6	Allowable Atmospheric Exposure of Low Hydrogen Electrodes . . . . .	19
6.1	Limits on Acceptability and Repair of Cut Edge Discontinuities . . . . .	30
6.2	Joint Dimension Tolerances . . . . .	30
6.3	Maximum Exposure Time at Temperature Preparatory to Forming or Welding of Aluminum Alloys. . . . .	31
7.1	Minimum and Maximum Plug Diameter and Slot Width . . . . .	35
7.2	Effective Size of Flare-Groove Welds Filled Flush. . . . .	36
7.3	Minimum Fillet Weld Size . . . . .	36
7.4	Legend for Figures 7.1A–7.1L and 7.2A–7.2J . . . . .	37
8.1	Prequalified Base Metal—Filler Metal Combinations for Matching Strength . . . . .	72
8.2	Prequalified Minimum Preheat and Interpass Temperature (Steel) . . . . .	78
10.1	PQR Essential Variable Changes Requiring WPS Requalification for SMAW, SAW, GMAW, FCAW, GTAW, and FW . . . . .	90
10.2	Procedure Qualification—Number and Type of Specimens and Range of Thickness Qualified—Complete Joint Penetration Groove Weld . . . . .	95
10.3	Procedure Qualification—Number and Type of Specimens and Range of Thickness Qualified—Partial Joint Penetration Groove Weld . . . . .	95
10.4	Procedure Qualification—Number and Type of Specimens and Range of Thickness Qualified—Fillet Weld . . . . .	96
10.5	Supplemental Essential Variables—Position Limitations (When Notch Toughness is a Requirement). . . . .	96
10.6	As-Welded Strength of Aluminum Alloys (GTAW or GMAW) . . . . .	97
11.1	Performance Qualification—Limitation of Essential Variables . . . . .	118
11.2	Electrode Classification Groups for Welder and Tack Welder Qualification . . . . .	118
11.3	Number and Type of Specimens and Range of Thickness Qualified—Welder and Welding Operator Qualification. . . . .	119
11.4	Welder and Welding Operator Qualification—Type and Position Limitation. . . . .	120
11.5	Maximum Reinforcement—Pipe Welds . . . . .	120
16.1	Weld Crater Limitations . . . . .	148
16.2	Undercut and Porosity Limitations . . . . .	148
16.3	Ultrasonic Testing Acceptance—Rejection Criteria . . . . .	149
17.1	Essential and Non-Essential Variables for Inclusion in WPS—FCAW, GMAW, GTAW, and SMAW. . . . .	152
17.2	Procedure Qualification Tests . . . . .	154
18.1	Limitation of Variables for Welder Qualification—FCAW, GMAW, GTAW, and SMAW. . . . .	161
18.2	Welder Qualification Tests . . . . .	162
A.1	Numerical Indexing of Base Material Specifications (Steel) . . . . .	165
B.1	Grouping of Welding Electrodes and Rods for Qualification . . . . .	167
C.1	Equivalent Fillet Weld Leg Size Factors for Skewed T-Joints . . . . .	172
E.1	Hot-Rolled and Cold-Rolled Sheet Metal . . . . .	198
E.2	Galvanized Sheet Metal . . . . .	199
E.3	Guide to the Choice of Filler Metal for General Purpose Welding of Aluminum . . . . .	200



# List of Figures

<b>Figure</b>	<b>Page No.</b>
5.1	Fillers Less than 1/4 in [6 mm] Thick . . . . . 20
5.2	Lap Width and Axial Load . . . . . 20
5.3	Fillers 1/4 in [6 mm] or Thicker . . . . . 21
5.4	Details for Fillet Welds . . . . . 22
5.5	Distribution of Mechanical Properties in the Vicinity of an Aluminum Weld . . . . . 23
6.1	Cut Edge Discontinuity . . . . . 31
6.2	Acceptable and Unacceptable Weld Profiles. . . . . 32
7.1A	Prequalified Complete Joint Penetration (CJP) Groove Welded Joint Details . . . . . 38
7.1B	Prequalified Complete Joint Penetration (CJP) Groove Welded Joint Details . . . . . 39
7.1C	Prequalified Complete Joint Penetration (CJP) Groove Welded Joint Details . . . . . 40
7.1D	Prequalified Complete Joint Penetration (CJP) Groove Welded Joint Details . . . . . 42
7.1E	Prequalified Complete Joint Penetration (CJP) Groove Welded Joint Details . . . . . 45
7.1F	Prequalified Complete Joint Penetration (CJP) Groove Welded Joint Details . . . . . 46
7.1G	Prequalified Complete Joint Penetration (CJP) Groove Welded Joint Details . . . . . 48
7.1H	Prequalified Complete Joint Penetration (CJP) Groove Welded Joint Details . . . . . 49
7.1I	Prequalified Complete Joint Penetration (CJP) Groove Welded Joint Details . . . . . 51
7.1J	Prequalified Complete Joint Penetration (CJP) Groove Welded Joint Details . . . . . 52
7.1K	Prequalified Complete Joint Penetration (CJP) Groove Welded Joint Details . . . . . 53
7.1L	Prequalified Complete Joint Penetration (CJP) Groove Welded Joint Details . . . . . 53
7.2A	Prequalified Partial Joint Penetration (PJP) Groove Welded Joint Details . . . . . 55
7.2B	Prequalified Partial Joint Penetration (PJP) Groove Welded Joint Details . . . . . 56
7.2C	Prequalified Partial Joint Penetration (PJP) Groove Welded Joint Details . . . . . 57
7.2D	Prequalified Partial Joint Penetration (PJP) Groove Welded Joint Details . . . . . 58
7.2E	Prequalified Partial Joint Penetration (PJP) Groove Welded Joint Details . . . . . 59
7.2F	Prequalified Partial Joint Penetration (PJP) Groove Welded Joint Details . . . . . 60
7.2G	Prequalified Partial Joint Penetration (PJP) Groove Welded Joint Details . . . . . 61
7.2H	Prequalified Partial Joint Penetration (PJP) Groove Welded Joint Details . . . . . 62
7.2I	Prequalified Partial Joint Penetration (PJP) Groove Welded Joint Details . . . . . 63
7.2J	Prequalified Partial Joint Penetration (PJP) Groove Welded Joint Details . . . . . 64
8.1	SAW Weld Bead Depth and Width . . . . . 81
10.1	Positions of Groove Welds . . . . . 99
10.2	Positions of Fillet Welds . . . . . 100
10.3	Positions of Test Plates for Groove Welds . . . . . 101
10.4	Positions of Test Pipe or Tubing for Groove Welds . . . . . 102
10.5	Test Positions for Fillet Welds (for Plate) . . . . . 103
10.6	Test Positions for Fillet Welds (for Pipe and Tubing) . . . . . 104
10.7	Location of Test Specimens on Welded Test Pipe. . . . . 105
10.8	Location of Test Specimens for Welded Square and Rectangular Tubing . . . . . 105
10.9	Location of Test Specimens on Welded Test Plate for 1/8 in to 3/8 in [3 mm to 10 mm] (inclusive) Thick Procedure Qualification . . . . . 106
10.10	Location of Test Specimens on Welded Test Plate 3/8 in [10 mm] Thick and Over Procedure Qualification. . . . . 107
10.11	Reduced-Section Tension Specimen . . . . . 108
10.12	All-Weld-Metal Tension Specimen . . . . . 109
10.13	Side-Bend Specimens . . . . . 109
10.14	Face- and Root-Bend Specimens . . . . . 110
10.15	Fillet Weld Soundness Test for Procedure Qualification. . . . . 111
10.16	Location of Test Specimens on Welded Test Plate 1 in [25 mm] Thick—Consumables Verification for Fillet Weld Procedure Qualification . . . . . 112
10.17	Pipe Fillet Weld Soundness Test Procedure Qualification . . . . . 113

10.18	Section Tension Specimen for Pipe . . . . .	114
11.1	Test Plate for Unlimited Thickness Welder Qualification . . . . .	121
11.2	Test Plate for Unlimited Thickness Horizontal Position—Welder Qualification . . . . .	121
11.3	Test Plate for Limited Thickness—Welder Qualification . . . . .	122
11.4	Test Plate for Limited Thickness Horizontal Position—Welder Qualification . . . . .	122
11.5	Tubular Butt Joint—Welder Qualification without Backing . . . . .	123
11.6	Tubular Butt Joint—Welder Qualification with Backing . . . . .	123
11.7	Fillet-Weld-Break and Macroetch Test Plate Welder and Welding Operator Qualification—Option 1 . . . . .	123
11.8	Fillet Weld Root-Bend Test Plate Welder and Welding Operator Qualification—Option 2 . . . . .	124
11.9	Fillet Weld on Pipe—Welder and Welding Operator Qualification—Option 3 . . . . .	125
11.10	Location of Test Specimens on Welded Test Pipe and Square or Rectangular Tubing—Welder Qualification . . . . .	126
11.11	Guided-Bend Jig . . . . .	127
11.12	Guided-Bend Wraparound Jig . . . . .	128
11.13	Guided-Bend Roller Jig . . . . .	129
12.1	Test Plate for Unlimited Thickness—Welding Operator Qualification . . . . .	131
13.1	Fillet-Weld-Break Specimen—Tack Welder Qualification . . . . .	133
13.2	Method of Rupturing Specimen—Tack Welder Qualification . . . . .	133
15.1	Weld Quality Requirements for Discontinuities Occurring in Cyclically Loaded Nontubular Tension Welds (Limitations of Porosity and Fusion Discontinuities) . . . . .	139
15.2	Weld Quality Requirements for Discontinuities Occurring in Cyclically Loaded Nontubular Compression Welds (Limitations of Porosity or Fusion-Type Discontinuities) . . . . .	140
15.3	Weld Quality Requirements for Elongated Discontinuities as Determined by RT of Tubular Joints . . . . .	141
15.4	Maximum Acceptable RT Images . . . . .	146
15.5	For RT of Tubular Joints 1-1/8 in [29 mm] and Greater, Typical of Random Acceptable Discontinuities . . . . .	147
17.1	Square-Groove Weld in Butt Joint . . . . .	155
17.2	Arc Spot Welds . . . . .	155
17.3	Arc Spot Weld Using Washer . . . . .	155
17.4	Edge Distances for Arc Spot Welds . . . . .	156
17.5	Lap-Fillet Welds . . . . .	156
17.6	Fillet Welds in T-Joints . . . . .	156
17.7	Single-Flare-Bevel-Groove Weld—Horizontal . . . . .	157
17.8	Single-Flare-V-Groove Weld—Flat . . . . .	157
17.9	Square-Groove Butt Joints . . . . .	157
17.10	Test for Arc Spot Weld . . . . .	158
17.11	Fillet Weld Test Assembly . . . . .	158
17.12	Standard Test Assembly for Flare-Bevel-Groove Welds; Test C—Sheet-to-Sheet . . . . .	159
17.13	Standard Test Assembly for Flare-Bevel-Groove Weld; Test D—Sheet-to-Supporting Plate . . . . .	159
17.14	Standard Test Assembly for Flare-V-Groove Welds . . . . .	160

This page is intentionally blank.

# Railroad Welding Specification for Cars and Locomotives

## 1. General Requirements

**1.1 Scope.** This specification covers the minimum welding requirements applicable to railcars, locomotives, and their components, intended for North American railroad service. For welding tank car tanks, refer to Association of American Railroads (AAR) *Manual of Standards and Recommended Practices, Section C-III, Specifications for Tank Cars, Specification M-1002*.

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

**1.3 Safety.** Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein.

Safety and health information is available from the following sources:

American Welding Society:

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

Material or Equipment Manufacturers:

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

Applicable Regulatory Agencies:

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

## 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 or revisions of the publications may not apply since the relevant requirements may have changed.

American Welding Society (AWS) standards:<sup>1</sup>

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*;

<sup>1</sup> AWS standards are published by the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.