



Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles



American Welding Society®



AWS D15.2/D15.2M:2013
An American National Standard

Approved by the
American National Standards Institute
October 30, 2012

Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles

3rd Edition

Supersedes AWS D15.2:2003

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 document recommends the minimum standards for the welding of rails and related rail components used by rail vehicles. Repair procedures for rails and austenitic manganese steel components are covered. Thermite welding and electric flash welding guidelines are discussed. Procedure qualification, welder qualification, and general welding safety procedures are addressed.



American Welding Society®

International Standard Book Number: 978-0-87171-829-7
American Welding Society
8669 Doral Blvd., Suite 130, Doral, FL 33166
© 2013 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: Managing Director, Technical Services Division, 8669 Doral Blvd., Suite 130, Doral, 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 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 required 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 Doral Blvd., Suite 130, Doral, FL 33166.

This page is intentionally blank.

Personnel

AWS D15 Committee on Railroad Welding

M. R. Untermeyer, Chair	<i>Union Tank Car Company</i>
R. A. Wolbert, Vice Chair	<i>Progress Rail Services Corporation</i>
J. B. Pearson, Jr., 2nd Vice Chair	<i>LTK Engineering Services</i>
S. N. Borrero, Secretary	<i>American Welding Society</i>
D. M. Allbritten	<i>GE Equipment Services-Rail</i>
R. C. Bly	<i>TTX Company – Hamburg Division</i>
C. Boulden	<i>TrinityRail Group</i>
L. B. Broadway	<i>American Railcar Industries</i>
N. S. Brown	<i>Canadian Pacific Railway</i>
R. A. Conrad	<i>Hobart Brothers</i>
S. A. Coughlin	<i>Consultant</i>
M. R. Desjardins	<i>National Steel Car Limited</i>
M. A. Forsstrom	<i>Greenbrier Rail Services</i>
C. J. Gamblin	<i>ALLTRANSTEK, LLC</i>
J. Haacke	<i>Motive Power</i>
D. S. Lassen	<i>Greenbrier Rail Services</i>
T. M. Nelson	<i>LTK Engineering Services</i>
B. W. Siebold	<i>BNSF Railway Company</i>
T. D. Spry	<i>Electro Motive Diesel, Incorporated</i>
L. H. Strouse	<i>Federal Railroad Administration</i>
A. Willaredt	<i>American Railcar Industries</i>

Advisors to the AWS D15 Committee on Railroad Welding

B. C. Blackwell	<i>Standard Car Truck Company</i>
W. Blamire	<i>Norfolk Southern Corporation</i>
J. L. Cooley	<i>JC and Associates, Incorporated</i>
W. Jaxa-Rozen	<i>Bombardier Transportation</i>
M. MacGillivray	<i>Hobart Brothers of Canada, LTD</i>
J. R. Murray	<i>TTX Company</i>
R. D. Stiffler	<i>PA</i>
D. A. Wright	<i>Wright Welding Technologies</i>

AWS D15C Subcommittee on Track Welding

R. L. Bell, Chair	<i>BNSF Railway Company</i>
A. Hernandez, Vice Chair	<i>Union Pacific Railroad Company</i>
S. N. Borrero, Secretary	<i>American Welding Society</i>
R. E. Adler	<i>BNSF Railway Company</i>
D. A. Bjork	<i>Canadian National Railway Company</i>
W. M. Blamire	<i>Norfolk Southern Corporation</i>
D. N. Blowatt	<i>Canadian National Railway Company</i>
M. J. Boos	<i>Union Pacific Railroad</i>
W. C. Bragg	<i>Orgo-Thermit, Incorporated</i>
N. S. Brown	<i>Canadian Pacific Railway</i>
C. J. Bunzendahl	<i>J.B. Railroad Services, LLC</i>
G. K. Clem	<i>GKC Consulting Company</i>
T. Y. Gehr, Jr.	<i>Esco Equipment Service Company</i>
D. I. Gregory	<i>Track-Weld</i>

J. R. Hansen	<i>Railworks</i>
F. C. Hefer	<i>Orgo-Thermit, Incorporated</i>
R. Kral	<i>Holland Company</i>
N. A. Kruckenberg	<i>Canadian National Railway Company</i>
P. J. Lawless	<i>BNSF Railway Company</i>
S. E. Markis	<i>Norfolk Southern Corporation</i>
B. A. Meade	<i>The Lincoln Electric Company</i>
T. A. Nelson	<i>LTK Engineering Services</i>
J. B. Pearson, Jr.	<i>LTK Engineering Services</i>
A. Pierson	<i>Norfolk Southern Corporation</i>
R. P. Roper	<i>CSX Transportation</i>
T. L. Swalboski	<i>Railworks</i>
S. W. Tribble	<i>Track-Weld Industries, Incorporated</i>
M. K. Wilson	<i>CSX Transportation</i>
B. E. Wylie	<i>Orgo-Thermit, Incorporated</i>

Advisors to the AWS D15C Subcommittee on Track Welding

T. L. Baxley	<i>Norfolk Southern Corporation</i>
K. K. Hamik	<i>BNSF Railway Company</i>
R. S. Koblinski	<i>METRA</i>
S. O. Scharnweber	<i>Cold Railroad Builders</i>
J. Sun	<i>Association of American Railroads</i>
M. R. Untermeyer	<i>Union Tank Car Company</i>
J. S. Wiederholt	<i>BNSF Railway Company</i>

Foreword

This foreword is not part of AWS D15.2/D15.2M:2013, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*, but is included for informational purposes only.

This recommended practice establishes standards for the joining, repair, maintenance and inspection of rail welds, and the welding of related rail components. It was developed and is maintained by the Subcommittee on Track Welding within the AWS Committee on Railroad Welding.

The welding of rails and related rail components for use by rail vehicles is vital to the safe and economical operation of American railroads. This subcommittee has endeavored to develop these recommended practices to serve as a guideline for the railroad and related industries in the establishment of track welding specifications. The subcommittee is made up of individuals from all segments of the railroad industry, both users and suppliers, and representatives of both the Association of American Railroads and the American Railway Engineering and Maintenance-of-Way Association.

The purpose of this document is to provide a single comprehensive source of information that will be used throughout the railroad industry. It should act as a guideline towards improving welding quality through the economical joining and repair of rail and rail components.

The evolution of AWS D15.2, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*, is shown below:

ANSI/AWS D15.2-94, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*

AWS D15.2:2003, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS D15 Committee on Railroad Welding, American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

This page is intentionally blank.

Table of Contents

	Page No.
<i>Personnel</i>	v
<i>Foreword</i>	vii
<i>List of Tables</i>	xi
<i>List of Figures</i>	xi
<i>List of Forms</i>	xi
1. General Requirements	1
1.1 Scope	1
1.2 Units of Measurement	1
1.3 Safety	1
2. Normative References	2
3. Terms and Definitions	2
4. Rail, Rail Components Manufactured from Rail, and Their Repair	3
4.1 Specific Items	3
4.2 Welding and Joining Processes	3
4.3 Railroad Rail Welding	3
4.4 Repair of Battered Rail Ends and Wheel Burns (Carbon Steel or Premium Carbon Steel Rail)	3
4.5 Repair of Rail-Type Switch Points and Switch Point Protectors	5
4.6 Frogs, Crossings, and Other Components Made From Rail Steel	5
4.7 Miscellaneous Carbon Steel and Premium Carbon Steel Components	5
5. Repair or Fabrication of Components Manufactured from Austenitic Manganese Steel	6
5.1 Metallurgical Background	6
5.2 Components	6
5.3 Welding Processes	6
5.4 Filler Metals	6
5.5 Preparation for Welding	6
5.6 General Welding Recommendations for Austenitic Manganese Steel	7
5.7 Welding Recommendations—Frogs and Crossings in Track	8
6. Recommended Practices for Joining of Rails by Thermite Welding (TW)	8
6.1 General Description	9
6.2 Application	9
6.3 Preparation of Final Gap for Welding	9
6.4 Welding Procedure	9
6.5 Care of Thermite Materials	9
6.6 Procedure Qualification	10
6.7 Welder Qualification	10
6.8 Thermite Welding Safety Precautions	11
7. Recommended Practices for Joining of Rails by Flash Welding (FW)	12
7.1 General Process Description	12
7.2 Rail Preparation	12
7.3 Rail Welding	12
7.4 Finishing Operations	13
7.5 Continuous Welded Rail Storage	13

8. Application of Rail Bonds Using External Heat	13
8.1 General Process Description	13
8.2 Rail Preparation	13
8.3 Rail Preheating	13
8.4 Bond Wire Application	13
8.5 Controlled Cooling	13
9. Track Welder Qualification—Arc Welding Processes	14
9.1 General Information for Austenitic Manganese (Hadfield) Steel	14
9.2 Qualification by Standard Test for Austenitic Manganese Steel	15
9.3 Qualification by Workmanship Test for Austenitic Manganese Steel	15
9.4 Test Weldments for Austenitic Manganese Steel	15
9.5 Examination Procedures and Acceptance Criteria for Austenitic Manganese Steel	16
9.6 Performance Qualification Variables for Austenitic Manganese Steel	20
9.7 General Information for Rail Steel	20
9.8 Qualification by Standard Test for Rail Steel	21
9.9 Qualification by Workmanship Test for Rail Steel	21
9.10 Test Weldments for Rail Steel	23
9.11 Examination Procedures and Acceptance Criteria for Rail Steel	24
9.12 Performance Qualification Variables for Rail Steel	26
10. Testing	26
10.1 Nondestructive Testing	26
10.2 Other Testing	26
Annex A (Informative)—Welding Processes	31
Annex B (Informative)—Welding of Austenitic Manganese Steel	37
Annex C (Informative)—Flash Welding Guidance	41
Annex D (Informative)—AREMA Tests for Continuous Welded Rail	43
Annex E (Informative)—Sample Forms	47
Annex F (Informative)—Guidelines for the Preparation of Technical Inquiries	49
List of AWS Documents on Railroad Welding	51

List of Tables

Table	Page No.
4.1	Welding Processes for Carbon and Premium Carbon Steel Rail Components 3
9.1	Examination Requirements for Performance Qualification 15
9.2	Position Limitations for Performance Tests 17
9.3	Examination Requirements for Performance Qualification 21
9.4	Position Limitations for Performance Tests 25
10.1	Minimum Performance Specifications for New Flash and Thermite Welded Rail 27
D.1	Wheel Loads for Rolling Load Test 44

List of Figures

Figure	Page No.
4.1	Typical Weld Pattern for Rail End Repair 4
5.1	Typical Skip Welding Repair 8
9.1(a)	Typical Test Plates 16
9.1(b)	Typical Weld Bead Sequence for Test Weldments 17
9.1(c)	Typical Weld Bead Sequence for Test Weldments 17
9.2	Typical Test Weldments 18
9.3	Dimensions for Inspection 19
9.4(a)	Typical Weld Bead Sequence for Test Weldments 22
9.4(b)	Typical Weld Bead Sequence for Test Weldments 23
9.4(c)	Typical Weld Bead Sequence for Test Weldments 23
9.5	Typical Test Plates 24
9.6	Dimensions for Inspection 25
10.1	Layout of Hardness Survey on Rail Head 28
10.2	Layout of Transverse Hardness Survey 29
A.1	Shielded Metal Arc Welding (SMAW) 31
A.2	Gas Metal Arc Welding (GMAW) 32
A.3	Flux Cored Arc Welding (FCAW) 33
A.4	Section Through a Thermite Mold and Crucible 34
A.5	Automatic Hydraulically Operated Flash Welding Machine with Horizontal Clamping 34
A.6	Rail Welding Production Line 35
A.7	Oxyfuel Gas Welding (OFW) 35
D.1	Loading Arrangement for the 12 in [305 mm] Stroke Rolling Load Machine 43
D.2	Load Arrangement for the Slow Bend Test and Formula for Deriving the Modulus of Rupture 45

List of Forms

Form	Page No.
E-1	Typical Welding Procedure Qualification Test Record 47
E-2	Typical Welder Performance Qualification Test Record 48

This page is intentionally blank.

Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles

1. General Requirements

1.1 Scope. This document recommends standards for joining, repair, maintenance, inspection of rail welds, and related rail components. For the purposes of this document, rails include railroad rails, crane rails, guard rails, electrical contact rails, girder rails, and retarder rails. Classification of rails is based on the American Railway Engineering and Maintenance-of-Way Association (AREMA) specifications governing the manufacture of rails.

Related rail components include rail crossings and turnouts which further include switch points, stock rails, switch point guards, spacer blocks, connecting rods, switch rods, plates, frogs, and frog components.

The use of track components reconditioned by welding is a decision of the rail owner outside the scope of this document. This document does not include road bed maintenance except where it affects the expected life of the repair.

Welding processes addressed in this document include shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), flash welding (FW), and thermite welding (TW). See Annex A and the *Welding Handbook*, Volumes 2 and 3, Ninth Edition for details on these processes.

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

Applicable Regulatory Agencies

- (1) *Code of Federal Regulations (CFR), Title 49, Part 214, Railroad Workplace Safety*.

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 standards listed below contain provisions that, through reference in this text, constitute mandatory provisions of this AWS standard. 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) documents:¹

AWS A2.4, *Standard Symbols for Welding, Brazing, and Nondestructive Examination* ;
AWS A3.0M/A3.0, *Standard Welding Terms and Definitions* ;
AWS A5.13/A5.13M, *Specification for Surfacing Electrodes for Shielded Metal Arc Welding* ;
AWS A5.21/A5.21M, *Specification for Composite Surfacing Welding Rods and Electrodes* ;
AWS B1.10M/B1.10, *Guide for the Nondestructive Examination of Welds* ;
AWS B2.1/B2.1M, *Specification for Welding Procedure and Performance Qualification* ;
AWS D15.1/D15.1M, *Railroad Welding Specification for Cars and Locomotives* ; and
AWS *Welding Handbook*, Volumes 2 and 3, Ninth Edition.

American National Standards Institute (ANSI) document:²

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

American Railway Engineering and Maintenance-of-Way Association (AREMA) document:³

AREMA Manual for Railway Engineering, Chapter 4, *Rail*.

ASTM International documents:⁴

ASTM A36/A36M, *Standard Specification for Carbon Structural Steel* ;
ASTM E140, *Standard Hardness Conversion for Metals (Relationship Among Brinell Hardness, Vickers Hardness, Rockwell Hardness, Superficial Hardness, Knoop Hardness, and Scleroscope Hardness)* ;
ASTM E164, *Standard Practice for Contact Ultrasonic Testing of Weldments* ;
ASTM E1417, *Standard Practice for Liquid Penetrant Testing* ; and
ASTM E709, *Standard Guide for Magnetic Particle Testing* .

Code of Federal Regulations (CFR) document:⁵

Code of Federal Regulation, Title 49 (Transportation), Volume 4, Chapter 2, Parts 200–299.

3. Terms and Definitions

AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, provides the basis for terminology used herein.

¹ AWS documents are published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

² This ANSI standard is published by the American Welding Society, 8669 Doral Blvd., Suite 130, Doral, FL 33166.

³ AREMA documents are published by the American Railway Engineering and Maintenance-of-Way Association, 10003 Derekwood Lane, Suite 210, Lanham, MD 20706–4875.

⁴ ASTM International standards are published by ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428–2959.

⁵ Federal regulations are published by the U.S. Government Bookstore, Wells Fargo Building, 201 West 8th, Pueblo, CO 81003, or <http://www.gpo.gov/>.

4. Rail, Rail Components Manufactured from Rail, and Their Repair

It is essential to identify the rail or rail base metal material to attain optimal results in selecting the welding procedure.

4.1 Specific Items. These recommendations apply to, but are not limited to, the items listed in the scope of this document.

4.2 Welding and Joining Processes. Processes include shielded metal arc welding (SMAW), gas metal arc welding (GMAW), flux cored arc welding (FCAW), flash welding (FW), and thermite welding (TW).

4.3 Railroad Rail Welding

4.3.1 Railroad Rail Grades

4.3.1.1 Standard Carbon steel rail has a minimum hardness of 248 BHN.

4.3.1.2 Premium carbon steel rail has a nominal hardness exceeding 341 BHN. This hardness may be the result of alloy composition (nonheat treated) or heat treatment process. Heat treated rail and other variations may require special welding procedures as recommended by the rail manufacturer or filler metal producer, or both.

4.3.1.3 Electrical contact rails are low carbon steel rails without hardness requirements.

4.3.2 Procedure Requirements for Arc Welding of Carbon Steel Rail

4.3.2.1 Preheating the weld area to a minimum of 700°F [370°C] not to exceed 1000°F [538°C] as measured immediately before welding is recommended to equalize temperature in the workpiece and to reduce the cooling rate.

4.3.2.2 Interpass temperature shall be within the same range as the preheat temperature to maintain temperature in the workpiece.

4.3.2.3 Weld deposit should have a nominal surface hardness compatible with the existing base metal to eliminate deformation or cracking of the weld.

4.3.2.4 Postweld heat treatment is recommended between 1000°F to 1100°F [538°C to 593°C], but is not required unless dictated by past experience or by approved railroad welding procedures.

4.3.3 Procedure Requirements for Arc Welding of Premium Carbon Steel Rail

4.3.3.1 Remove grease, oil, paint, dirt, and other deleterious matter that will adversely affect weld quality. Inspect the entire area for cracks and other defects. Liquid penetrant testing may be used to locate and define the cracks.

4.3.3.2 A preheat temperature of a minimum of 700°F [370°C] not to exceed 1000°F [538°C] is recommended for alloy steel rail.

4.4 Repair of Battered Rail Ends and Wheel Burns (Carbon Steel or Premium Carbon Steel Rail)

4.4.1 Carbon steel or premium carbon steel rail may be repaired using an arc welding process selected from 4.2 and Table 4.1.

Table 4.1
Welding Processes for Carbon and Premium Carbon Steel Rail Components

Component Material	Processes
Carbon Steel	Shielded metal arc welding (SMAW) Gas metal arc welding (GMAW) Flux cored arc welding (FCAW)
Premium Carbon Steel	Flash welding (FW) Thermite welding (TW)

4.4.2 Rail Preparation

4.4.2.1 Visually inspect the rail to determine repairability in accordance with the rail owner's policy.

4.4.2.2 Defective material shall be removed to sound base metal. Soundness may be checked using liquid penetrant or magnetic particle testing (see Clause 10).

4.4.3 Welding Procedure

4.4.3.1 As outlined in 4.3.2 or 4.3.3, preheat the repair area a minimum of 4 in [100 mm] longitudinally beyond the weld area in both directions.

4.4.3.2 Interpass temperature shall be the same as the preheat temperature range outlined in 4.3.2.2.

4.4.3.3 All the above recommended temperatures are dependent on the base metal composition, the filler metal used, ambient temperature, weather conditions, and the manufacturer's recommendations.

4.4.3.4 Welding should progress primarily along the rail length by placing weld metal in a chevron or diagonal pattern across the rail.

4.4.3.5 See Figure 4.1 for a typical chevron pattern.

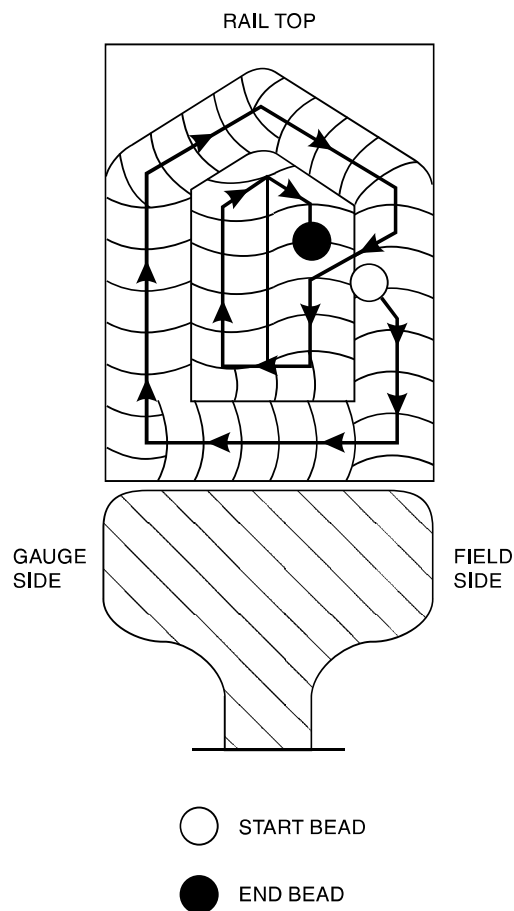


Figure 4.1—Typical Weld Pattern for Rail End Repair

4.4.3.6 Provisions must be made to minimize distortion of the weld area.

4.4.3.7 All weld craters should be filled by reversing direction and welding back into the bead before breaking the arc.

4.4.3.8 Arc strikes shall not be permitted outside the preheated repair area. Accidental arc strikes outside the repair area shall be repaired in accordance with the provisions of 4.4.2.2.

4.4.4 Finish Grinding

4.4.4.1 Welds should be finish ground according to approved procedures on the same work day the rail is welded to minimize impact loading and prevent weld deformation.

4.4.4.2 Finish surface of the weld should be smooth and uniform with the existing rail contour.

4.5 Repair of Rail-Type Switch Points and Switch Point Protectors

4.5.1 Weld repair of austenitic manganese steel switch points is not recommended because the heat input is difficult to control properly to limit distortion.

4.5.2 Carbon steel and premium carbon steel rail components may be welded by the arc welding processes shown in Table 4.1.

4.5.3 Visually inspect the switch point or switch point protector to determine the repairability in accordance with the rail owner's policy.

4.5.4 Defective material shall be removed to sound base metal. Soundness may be determined by liquid penetrant (see Clause 10).

4.5.5 In order to minimize distortion of the switch point and stock rail during cooling, pre- and postheating should be balanced over the base/web intersection and the repair area.

4.5.6 Switch Point Repair Procedure

4.5.6.1 Welding the switch point against a stock rail without the use of a copper backing plate is not recommended because of the possibility of arc strikes on the stock rail.

4.5.6.2 Switch point must be protected from traffic movement during welding, cooling, and finish grinding.

4.5.6.3 When using arc welding processes, hammer shaping of repaired carbon steel or heat treated rail switch points is not recommended as hot tearing at the weld metal grain boundaries may occur.

4.5.7 Preheat Procedure. Preheat the switch point assembly in the weld areas, as measured immediately before welding, to a minimum of 700°F [370°C] not to exceed 1000°F [538°C] unless otherwise recommended by the rail owner. If there are differences between the recommendations of the rail owner and this document, the rail owner's recommendation shall prevail.

4.5.8 Minimum interpass temperature shall be the same as the preheat temperature.

4.5.9 Application of Filler Metal

4.5.9.1 Weld bead pattern shall be in accordance with the welding procedure specification (WPS).

4.5.9.2 All welds shall be finished to the existing rail contour.

4.5.9.3 Arc strikes shall not be permitted outside the preheated weld repair area because they may cause cracks. Arc strikes outside the repair area shall be repaired by grinding defective material to sound metal. Soundness may be determined by liquid penetrant inspection (see Clause 10). If welding repairs are required, see 4.3.3.

4.6 Frogs, Crossings, and Other Components Made from Rail Steel. Practices outlined in 4.4 are applicable.

4.7 Miscellaneous Carbon Steel and Premium Carbon Steel Components. Practices outlined in 4.4 may be applicable.

5. Repair or Fabrication of Components Manufactured from Austenitic Manganese Steel

5.1 Metallurgical Background. For a general discussion of the welding of austenitic manganese steel see Annex B.

5.2 Components. Components that may be made of austenitic manganese steel include, but are not limited to, frogs, crossings, switch point guards, casting inserts, and bridge track components.

If composition of the component is in doubt, use a hand magnet for identification purposes. Austenitic manganese steel components will be nonmagnetic or slightly magnetic. The carbon steel or premium carbon steel component will be strongly magnetic.

5.3 Welding Processes

5.3.1 Manual welding processes are restricted to shielded metal arc welding.

5.3.2 Semiautomatic welding processes are restricted to flux cored arc welding.

5.4 Filler Metals

5.4.1 Austenitic manganese steel shall not be surfaced nor joined using carbon steel or low alloy steel welding electrodes or welding wires.

5.4.2 Austenitic Manganese Steel Welding Electrodes

5.4.2.1 Details for several basic compositions of filler materials are found in AWS A5.13/A5.13M, *Specification for Surfacing Electrodes for Shielded Metal Arc Welding*, and AWS A5.21/A5.21M, *Specification for Composite Surfacing Welding Rods and Electrodes*.

5.4.2.2 AWS A5.13/A5.13M and AWS A5.21/A5.21M reflect the variety of modifications of the basic austenitic manganese steel composition currently available. The electrodes generally deposit undiluted weld metal with manganese content in excess of 14% plus smaller additions, alone or in combination, of nickel, molybdenum, chromium, or vanadium.

5.4.2.3 The range of properties developed by these electrodes enables the user to select the combination best suited for the particular application. For example, an overlay with relatively high yield strength might be used to build up the running surface of frogs whereas an alloy with a yield strength more closely matching that of the base metal might be used to repair a deep crack.

5.4.3 Special chromium-nickel-iron and chromium-manganese-nickel-iron austenitic electrodes are acceptable to weld austenitic manganese steel base metal.

5.5 Preparation for Welding

5.5.1 Austenitic Manganese Steel Castings

5.5.1.1 Grease, rust, and dirt shall be removed from the surfaces by appropriate means and the entire casting inspected for cracks and other defects. Liquid penetrant testing may be used to locate and define the cracks (see Clause 10).

5.5.1.2 Cracks shall be removed as completely as practical by grinding or air arc gouging. The latter is the preferred process. When air arc gouging, follow these procedures:

- (1) Locate the end of the crack using a shallow cut.
- (2) Make a deeper cut moving from the end of the crack towards the edge of the casting.
- (3) If the crack does not extend to the edge, proceed from the ends towards the middle of the crack.
- (4) Utilize straight rapid cuts when gouging.
- (5) Groove should be kept just wide enough to permit electrode manipulation during welding.
- (6) Base metal temperature shall not exceed 500°F [260°C] at a point 1 in [25 mm] from the area being gouged.
- (7) Metal and oxides shall be eliminated from the cut groove by grinding.

5.5.1.3 Worn areas should be located using a straight edge or template and marked.

5.5.1.4 Work hardened (plastically deformed) metal shall be removed (this includes weld deposits impacted by traffic during repair).

5.5.1.5 Sharp edges along flangeway surfaces should be rounded slightly.

5.5.2 For Castings to be Welded in Track. Track conditions that may have contributed to the damaged or worn casting shall be corrected prior to welding.

5.5.3 For Castings to be Shop Repaired

5.5.3.1 Disassemble rail-bound frogs before examination for cracks.

5.5.3.2 Distortion control procedures such as pre- or postweld bending should be considered by the repair shop.

5.6 General Welding Recommendations for Austenitic Manganese Steel

The repair of each worn casting tends to be an individual job not subject to rigid definition. Therefore, the recommendations of this subclause are of a general nature applicable to a wide variety of applications.

5.6.1 When the casting temperature is below 32°F [0°C], it shall be warmed to approximately 70°F [21°C] before any welding or gouging. Interpass temperatures shall not exceed 500°F [260°C] at a point 1 in [25 mm] from the area being welded.

5.6.2 Diameter of covered electrodes for SMAW should not exceed 3/16 in [5 mm].

5.6.3 Diameter of flux cored wire for semiautomatic welding should not exceed 5/64 in [2 mm].

5.6.4 Welding current and travel speed should be appropriate to ensure adequate penetration, bead tie-in, and lowest thermal input. Excessive current should be avoided to prevent heat buildup.

5.6.5 Arc length should be maintained as short as possible while maintaining good arc characteristics.

5.6.6 Weld beads should be slightly crowned and no more than 5/8 in [16 mm] in width.

5.6.7 Length of individual weld bead should not exceed 10 in [250 mm] when welding in track. In the shop where precautions can be taken to minimize distortion and heat buildup, longer welds are permitted.

5.6.8 Casting temperature shall be monitored frequently. Welding shall be discontinued in any area where the interpass temperature exceeds 500°F [260°C] measured 1 in [25 mm] from the weld area.

5.6.8.1 Quenching is recommended to prevent overheating the casting.

5.6.8.2 Skip welding should be used to minimize heat buildup (see Figure 5.1).

5.6.9 Carbon blocks or copper plates may be used in the flangeways to maintain proper contour and minimize finish grinding.

5.6.10 Flangeway beads should be deposited first.

5.6.11 Adjacent beads should have tie-in by 35%–50%.

5.6.12 The direction of travel for the successive beads shall be reversed to minimize stress buildup.

5.6.13 The end of welds should be staggered to further minimize stress buildup.

5.6.14 Weld beads shall not be started or stopped at the edge of the casting to prevent weld undercut.

5.6.15 Weld beads on frog wings or points should be parallel to the flangeways.

5.6.16 The general procedure for welding frog points is as follows:

5.6.16.1 Welding should start at the lowest point of the repair area gradually building up to the full width of the repair to maintain weld integrity.

5.6.16.2 The arc should be struck about 1/2 in [13 mm] ahead of the direction of travel where the beads are to begin.

5.6.16.3 Craters shall be filled by reversing direction and welding back into the bead before breaking the arc.

5.6.17 Successive layers may be applied to achieve the desired thickness of buildup.

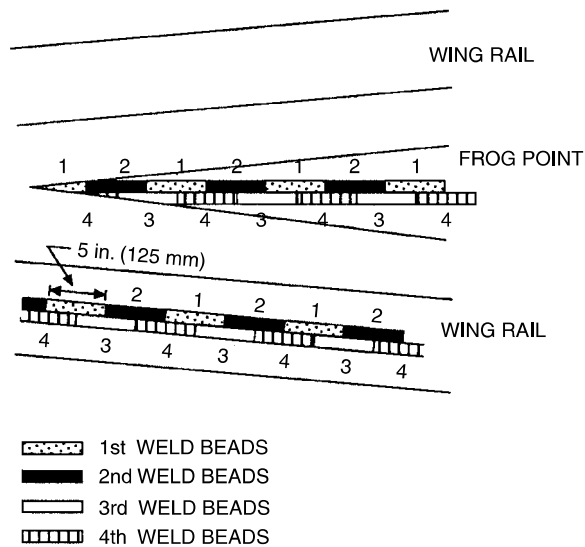


Figure 5.1—Typical Skip Welding Repair

5.6.18 Individual layers of weld metal shall be visually examined prior to proceeding with the next layer. Any unacceptable indications shall be repaired prior to starting the next layer.

5.6.19 If defect removal requires grinding through the thickness of the casting, a back-up bar of austenitic manganese steel should be used to provide a base for welding.

5.6.20 Specifically modified stainless steel filler metal may be used for a root pass or initial pass.

5.7 Welding Recommendations—Frogs and Crossings in Track

5.7.1 The general recommendations of 5.6 shall apply, as applicable.

5.7.2 Safe movement of trains while frogs are being repaired shall be the first priority.

5.7.2.1 Cracks and major break-out areas should be repaired prior to the buildup of worn areas.

5.7.2.2 Large areas to be welded should be subdivided into sections in such a way that train movement will not be disrupted.

5.7.2.3 The guards of self-guarded frogs shall be rebuilt to their original dimension prior to other repairs. Enough time should be allowed between traffic movements to allow complete welding and finish grinding of the raised guard. After the guards have been repaired, the tread portion should be restored.

5.7.2.4 Immediately after completing each bead, stress relieve the bead by peening with the ball end of a two pound ball-peen hammer. The bead should be struck two to four times per inch of weld using moderate blows that produce an indentation of approximately 0.040 in [1.0 mm]. Peening should start at the crater and proceed toward the start of the weld. Do not peen the first bead layer, as this will prevent damage between the bead interface and the parent material. Do not peen the final layer, as this will prevent blemishes in the finished surface.

6. Recommended Practices for Joining of Rails by Thermite Welding (TW)

Thermite is defined as a mixture of finely divided aluminum and iron oxide. When the aluminum and iron oxide react, the reaction is called a *thermite reaction*. Thermite welding is accomplished with the heat produced by the thermite reaction. Filler metal is obtained from the combination of the iron reaction product and pre-alloyed shot in the mixture.

6.1 General Description. Thermite welding is a welding process that joins rail ends by melting them with super-heated liquid metal from a chemical reaction between aluminum and iron oxide. Filler metal is obtained from the liquid metal (see Figure A.4).

6.1.1 For a general discussion of the process, see *Welding Handbook*, Volumes 2 and 3, Ninth Edition.

6.1.2 Thermite welding supplies are sold under a number of commercial trade names.

6.2 Application

6.2.1 Application includes, but is not limited to, those rail grades listed in 4.3.

6.2.2 The thermite welding process may be utilized to weld both carbon steel rail and premium carbon steel rail. Special procedures may be necessary when welding premium carbon steel rail to prevent hardening and cracking when the weld is cooled too rapidly through the transformation range.

6.3 Preparation of the Final Gap for Welding

6.3.1 Rail ends shall be aligned properly, both laterally and vertically. Rail ends shall be secured to prevent movement during the welding process.

6.3.2 The gap between rails may be oxyfuel gas cut, sawed, or cut with an abrasive disc. Of these, oxyfuel gas cutting is the least desirable.

6.3.2.1 If the final gap is to be prepared by OFC, the rail shall be preheated to a minimum of 700°F [370°C] not to exceed 1000°F [538°F] prior to the oxyfuel gas cut to prevent cracking.

6.3.2.2 Care should be exercised to ensure smooth cut surfaces. An end squareness of $\pm 1/16$ in [± 2 mm] both horizontally and vertically is recommended.

6.3.2.3 Remove cutting dross and residual oxide from ends of oxyfuel cut rails by grinding.

6.3.3 The gap between the rail end faces may vary depending on the specific commercial process.

6.3.4 Remove all moisture and foreign substances such as dirt, grease, loose oxide, burns, fins, and metal flow at least 6 in [150 mm] on each side of the gap. In addition, a 6 in [150 mm] hole-free zone in the rail web is recommended.

6.3.5 Copper material from track circuit bonds must be removed for at least 2 in [50 mm] on each side of the weld area.

6.4 Welding Procedure. Limits for welding procedure variables, including preheating techniques, method of ignition, rate of cooling, and mold removal, should be based on the manufacturer's instructions for the specific thermite kit being employed.

6.4.1 Qualification welds made in accordance with 6.4 should be subjected to the following tests and meet the minimum requirements as specified in Table 10.1:

- (1) Slow bend tests to determine load and deflection (see Annex D)
- (2) Hardness tests to evaluate resistance to wear and deformation (see Figure 10.1)
- (3) Rolling load test to determine fatigue life (see Annex D) at the rail owner's option.

6.5 Care of Thermite Materials

6.5.1 DANGER: INTRODUCTION OF MOISTURE TO THE THERMITE WELDING PROCESS MAY CAUSE SERIOUS OR FATAL INJURY. Molten steel and hot slag can cause serious explosion upon coming into contact with snow, ice, standing water, frozen ballast, or soil.

6.5.2 Molds shall be protected from moisture contamination and freezing during storage. Charges shall be protected from moisture contamination during storage.

6.5.3 Charges and molds shall be protected from moisture contamination during transportation from storage to work site.

6.5.4 Molds and charges shall be used within the shelf-life period recommended by the manufacturer.

6.5.5 Crucibles (reaction chambers) shall be clean and dry at all times.

6.5.6 Crucible, mold, charge, and adjacent rail area shall be protected from moisture.

6.5.7 Rail weld geometry shall be checked with a straight edge and taper gauge in accordance with the requirements of *AREMA Manual for Railway Engineering*, Chapter 4, Part 3.14, *Specification for Quality Assurance of Thermite Welding of Rail*, or those selected by the operating authority.

6.5.8 Alignment and Finish Requirements

6.5.8.1 Alignment tolerance of running surfaces shall be within the requirements of the rail owner.

6.5.8.2 Additional grinding to remove surface defects should be kept to a minimum.

6.5.8.3 If required, a light grinding of the weld collar area to remove sharp corners or surface blemishes is permissible. Exercise care to prevent aggressive grinding. All grinding of the weld collar should be symmetrical; the as-cast geometry shall be left intact.

6.5.8.4 Radiography is not recommended for inspection of thermite welds as defects are very difficult to detect and interpret.

6.5.8.5 Visual and ultrasonic examinations of finished welds are recommended.

6.6 Procedure Qualification. Procedure tests performed by the thermite manufacturer may be accepted by the user if individual testing is not feasible.

6.7 Welder Qualification

6.7.1 Prior to qualification, welders should receive training from qualified instructors.

6.7.2 Welding Operator Qualification

The qualification test described in 6.7.2 is a specifically devised test to determine a welding operator's ability to produce sound thermite welds. The welding operator shall properly demonstrate the following:

6.7.2.1 Knowledge of product being used

- Weld Kit Manufacturer
- Rail Section and Type
- Weld Kit Size and Type

6.7.2.2 Performance of basic trackwork

- Remove and apply track fasteners
- Remove and apply joint bars and bolts
- Level and hand tamp track
- Remove and apply tie plates
- Dig ballast for cribbing joints

6.7.2.3 Safe operation of oxyfuel gas equipment for heating and torch cutting

- Torch cut track bolts and rail ends
- Preheating rail ends in preparation for welding

6.7.2.4 Establishment of correct rail gap for the type of weld being made

- Use of oxyfuel gas cutting equipment
- Use of abrasive rail saw

6.7.2.5 Cleaning of rail ends

- Flame clean rail ends
- Remove any slag or residue from the cutting process
- Remove any oil or grease

6.7.2.6 Alignment and crowning of rail ends for welding

- Use of rail alignment tools
- Proper use of straight edge
- Alignment of straight and compromise welds

6.7.2.7 Ability to fit, install, and lute (seal) molds

- Fit-up of straight molds
- Fit-up of compromise molds
- Leak-free luting (sealing) of molds

6.7.2.8 Crucible preparation and placement

- Cleaning and loading
- Height
- Alignment

6.7.2.9 Operation of preheating equipment

- Mechanical preheating apparatus set-up
- Torch height
- Torch alignment
- Gas pressure settings
- Torch flame adjustment
- Monitor preheat time

6.7.2.10 Ignition of thermite material

- Igniter placement
- Ignition
- Monitor tap time

6.7.2.11 Disassembly procedures

- Remove crucible and slag basin(s)
- Remove weld hardware
- De-mold at correct time
- Safe disposal of hot material
- Shear weld

6.7.2.12 Weld finishing

- Grind rail head to original contour
- Remove sharp corners and surface blemishes

6.7.2.13 Restoration of track for safe operations

- Remove alignment tools
- Re-apply rail fasteners
- Dress track at weld area
- Place weld identification if required

6.7.2.14 Inspection of thermite weld

- Visual inspection

6.7.3 Results of the evaluation of the welder should be made a part of the welder's permanent record.

6.8 Thermite Welding Safety Precautions

6.8.1 Over tightening of the base plate or mold clamp screws may cause cracking of the mold and subsequent leaking of molten metal.

6.8.2 Improper or careless luting (sealing) of the mold may cause leakage of the molten metal.

6.8.3 Molten steel and slag can cause serious explosions when contacted by any form of moisture.

6.8.4 Slag basin shall be emptied only after the slag has completely solidified. Solid slag shall be disposed of in such a manner as not to pose any hazard to operating personnel.

7. Recommended Practices for Joining of Rails by Flash Welding (FW)

7.1 General Process Description

7.1.1 The automated resistance welding process (see Figures A.5 and A.6) preheats the rail ends, provides a nonoxidizing environment, and forges the rail ends into a welded joint. Critical flash welding parameters are shown in Annex C.

7.1.2 The process and related equipment may contain the following operations: preparation, preheating, flashing, forging, shearing, postweld heat treatment, and finishing.

7.1.3 The *AREMA Manual for Railway Engineering*, Chapter 4, Part 2, [Chapter 4, Part 3.12, *Specification for Fabrication of Continuous Welded Rail*] provides minimum specifications for rail welding.

7.2 Rail Preparation

7.2.1 Remove rust, dirt, grease, or other foreign material from rail ends that would impede the start of a low-voltage electric arc.

7.2.2 Remove rust, slag, and raised lettering from the locations on the rail where electrical contact will be made, as these might provide added electrical resistance. Poor electrical contact may cause electrode burns on the rail.

7.2.3 An electrode burn on welded rails is defined as one of the following:

- (1) Any electrode contact areas that have transformed to martensite.
- (2) Any electrode contact areas that have been displaced during welding.
- (3) Any electrode contact areas that contain transferred electrode copper.

7.2.4 Rails should be presented to the stations of the welding plant in a consistent manner to enhance production and performance. Rails should be grouped by length, composition, type, and wear to minimize adjustments required by operating personnel.

7.3 Rail Welding

7.3.1 Railroad rails shall be flash welded using the following:

- (1) A qualified welding procedure.
- (2) Welding equipment able to consistently reproduce the required welding program.
- (3) A qualified operator with the ability to set up the welding program, and monitor and maintain the equipment.

7.3.1.1 Acceptable welds shall qualify the welding procedure, the welding equipment, or the welding operator.

7.3.2 Welds made in accordance with 7.3.1 should be subjected to the following tests and meet the minimum requirements as specified in Table 10.1:

7.3.2.1 Slow bend tests to determine load and deflection (see Annex D).

7.3.2.2 Hardness tests to evaluate resistance to wear and deformation (see Figure 10.1).

7.3.2.3 Macroetch tests to determine metallurgical soundness, forging patterns, and heat-affected zone (HAZ) (see Figure 10.2).

7.3.2.4 Rolling load test to determine fatigue life (see Annex D) at the customer's option.

7.3.2.5 Microscopic examination to evaluate metallurgical quality at the customer's option.

7.3.3 Test welds should be evaluated by qualified personnel designated by the engineer in charge and experienced in the flash welding of rail before production welds are made.

7.3.4 Production operations should be monitored by an inspector to ensure compliance with specifications.

7.3.5 Weld parameters for each weld shall be recorded.

7.3.5.1 Recorders should be calibrated daily before use.

7.3.5.2 Records of weld parameters should be retained by the verification inspector, operating authority, or manufacturer.

7.3.5.3 Records should be compared with those certified by qualified personnel during qualification testing.

7.3.6 Table 10.1 lists a number of tests that may be used to evaluate the quality of maintenance welds.

7.4 Finishing Operations

7.4.1 Grind welds to existing contour.

7.4.2 Finished contour should meet the operating authority's requirements. In the absence of specific instructions, the requirements of the *AREMA Manual for Rail Engineering*, 2009, Chapter 4, Part 3.11, *Specification for Fabrication of Continuous Welded Rail* apply.

7.4.3 Final inspection of the welded rail (see Clause 10) shall be done at the last station of the welding plant prior to acceptance for transportation and installation (see Figure A.6).

7.5 Continuous Welded Rail Storage

7.5.1 A point person should safely guide and monitor transfer of the welded rail string from the production line into, or onto, the storage rack, ground storage, or continuous welded rail (CWR) train.

7.5.2 Care should be exercised to prevent kinking the rail string.

7.5.3 Rail strings should be supported at 25 ft–35 ft [8 m–11 m] intervals to prevent bending during handling and storage.

8. Application of Rail Bonds Using External Heat

8.1 General Process Description

8.1.1 Manual or automatic external heat processes may be used to apply signal bonds to rail.

8.1.2 The process and related equipment may contain the following operations: rail preparation and preheating, the use of external heat to apply signal bond to the rail, and postheating the rail.

8.2 Rail Preparation

8.2.1 Remove rust, dirt, grease, or other foreign material from the bond application area, as these may affect the integrity of the bond application.

8.2.2 Clean rail with a non-resin abrasive wheel or de-burring tool.

8.3 Rail Preheating

8.3.1 Bond applications that induce heat into the rail should have the application area preheated to a minimum of 700°F [371°C] not to exceed 1000°F [538°C].

8.3.2 Preheating may be accomplished using an oxyfuel flame, thermal heating block, or induction heater.

8.4 Bond Wire Application

8.4.1 Apply bond according to manufacturer's recommendations.

8.4.2 Bond wire application location:

- Do not apply to the base of any rail.
- If web application is required, apply at the neutral axis.
- If applying on the field side of rail head, apply within the limits of joint bars.
- Do not apply over previous bond application locations.

8.5 Controlled Cooling

8.5.1 Bond application area of the rail may require controlled cooling due to wind, moisture, or temperature conditions.

NOTE: It is noted that there are several types of bond wire systems available, and that all wire applications involve either the removal of material via drilling and grinding or an elevated temperature application such as welding, brazing, or soldering. Some methods may impact the structure of the rail requiring that the rail's structural requirement be taken into account when choosing a methodology.

9. Track Welder Qualification—Arc Welding Processes

Qualification of welders joining steel components other than austenitic manganese and rail steel are not covered in this document. For other railroad related welding, refer to D15.1/D15.1M, *Railroad Welding Specification for Cars and Locomotives*.

9.1 General Information for Austenitic Manganese (Hadfield) Steel

9.1.1 Welders and welding operators qualified to earlier editions of this standard are also qualified to the current edition.

9.1.2 Personnel currently qualified by the employer to meet the requirements of other codes or specifications are considered qualified under this standard provided the basis for their qualification meets all requirements of this specification. However, the limits of qualification shall be in accordance with 9.6. In such cases, a certification form shall be initiated and signed by the employer attesting to compliance with this specification. If an existing form is used, the certifying statement shall be added or appended. If a new form is issued, it shall reference any prior certification form which shall be attached to or traceable from the new form.

9.1.3 Qualification testing using one of two methods is permitted:

- (1) Qualification by Standard Test (see 9.2)
- (2) Qualification by Workmanship Test (see 9.3)

9.1.4 A Standard Test shall qualify the individual to perform production welding where either a Standard Test or a Workmanship Test is specified. Where AWS B2.1/B2.1M, *Specification for Welding Procedure and Performance Qualification*, permits qualification by visual examination, a Workmanship Test may qualify a welder or welding operator for production welding.

9.1.5 If AWS B2.1/B2.1M allows performance qualification by Workmanship Test, a production weldment may be used for performance qualification provided the production weld is visually inspected and meets the requirements of 9.5.2.

9.1.6 The qualification test for each welder or welding operator shall be documented by the qualifier for both acceptable and unacceptable tests. (See example in Annex F.) There is no required format for Welder Qualification Record (WQR). Any WQR form may be used. Documentation shall:

- (1) Identify the Welding Procedure Specification (WPS) used,
- (2) Address each of the qualification variables in 9.6,
- (3) Identify test and examination methods used and results, and
- (4) Identify the limits of qualification for the welder or welding operator.

9.1.7 Acceptance of test results is the responsibility of the qualifier. Qualification records shall be signed and dated by the qualifier. Qualification records shall reference and may include mechanical test and nondestructive examination test reports that are signed by others. Retention of mechanical test and nondestructive examination test reports is not required after acceptance by the qualifier.

9.1.8 A welder or welding operator who fails the performance test may be retested at the option of the test supervisor, using (1) or (2) below:

- (1) If a retest is permitted by the qualifier without further training or practice, it shall consist of two test weldments for each position failed. Both test weldments shall be acceptable for the welder or welding operator to qualify.
- (2) Provided there is evidence satisfactory to the qualifier that the welder or welding operator has had further training or practice, one test weld for each position failed is permitted.

9.1.9 The performance qualification of a welder or welding operator shall be affected when one of the following conditions occurs:

(1) When he or she has not welded with a process during a period of six months or more, his or her qualifications for that process shall expire.

(2) Re-qualification as a result of (1) is permitted by having the welder or welding operator make one test weldment using the same process. If the test weldment meets the requirements of this specification, then all of the welder's or welding operator's previous qualifications for that process, for materials, thicknesses, product forms, and other variables are reinstated.

(3) When there is a specific reason to question his or her ability to make welds that meet the specification, the qualifications which support the welding he or she is doing shall be revoked. All other qualifications not questioned remain in effect.

(4) Requalification as a result of (3) is permitted by having the welder or welding operator successfully complete performance qualification test(s) that support the qualification(s) questioned.

9.1.10 Completion of an acceptable procedure or performance qualification test shall qualify the welder or welding operator who welded the test weldment within the limits of performance qualification variables specified in 9.6.

9.1.11 Successful qualification using the test WPS shall also qualify an individual to weld with any other WPS using the same process and within the limits of performance variables in 9.6. Qualification as a welder does not qualify the individual as a welding operator or vice versa.

9.1.12 Welders qualified on a groove weld are also qualified to perform weld buildup of surfaces to replace or repair base material with similar composition weld metal.

9.2 Qualification by Standard Test for Austenitic Manganese Steel

9.2.1 Qualification requires completion of a standard test weldment in accordance with a qualified WPS, evaluation of the test weldment by the methods listed in Table 9.1, and acceptance of the weldment in accordance with the criteria of 9.5.

9.3 Qualification by Workmanship Test for Austenitic Manganese Steel

9.3.1 Qualification by Workmanship Test is permitted only when allowed by AWS B2.1/B2.1M.

9.3.2 Qualification requires completion of a Workmanship Test welded in accordance with a qualified WPS that addresses typical production joints and conditions. Workmanship weldments are accepted or rejected primarily on the basis of the visual examination criteria of 9.5. Other tests or examinations (macro examination, etc.) may be specified by AWS B2.1/B2.1M. Some typical Workmanship Test weldments are shown in Figures 9.1(a), 9.1(b), and 9.1(c).

9.4 Test Weldments for Austenitic Manganese Steel

9.4.1 Allowable test materials are ASTM A36 steel plate or austenitic Hadfield manganese steel plate.

9.4.2 Tests shall be performed using a qualified austenitic manganese steel filler metal.

9.4.3 Test coupons welded in the specific test position described in Table 9.2 qualify the welder to weld austenitic manganese steel track components in the flat position. Weldment orientations other than the specific test position shown in Table 9.2 are permitted, but such tests qualify only for the orientation tested.

Table 9.1
Examination Requirements for Performance Qualification

	Plate	Surfacing
Type Of Test	Groove	Clad and Hardfacing (Buildup)
Visual Examination	Yes	Yes
Macro Examination	Yes	Yes

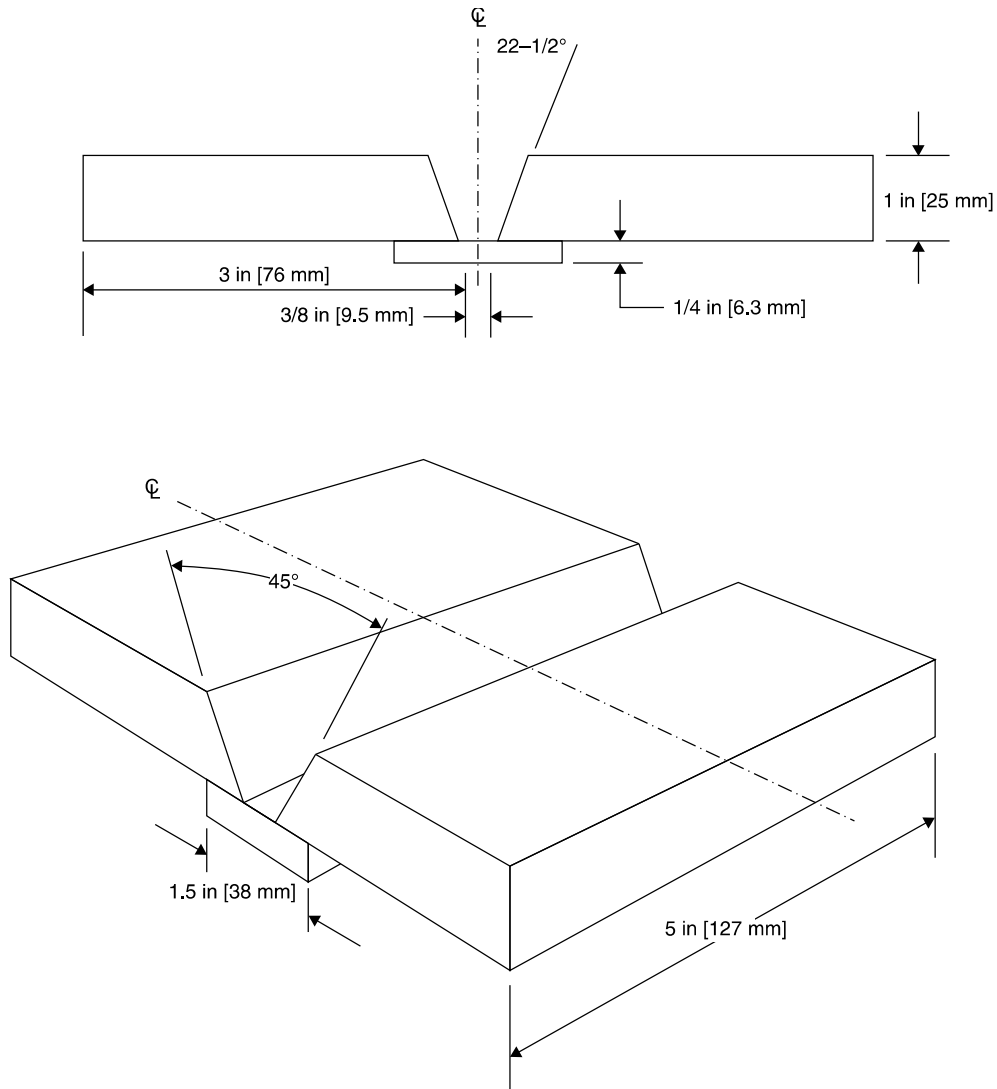


Figure 9.1(a)—Typical Test Plates

9.4.4 Figure 9.1 shows typical test plate setup. Figure 9.2 illustrates typical test weldments. Figure 9.3 illustrates the locations for the removal of required specimen blanks.

9.4.5 Buildup. Prior to removing test specimen blanks identified in Figure 9.3, the built up surface shall be visually examined in accordance with AWS B2.1/B2.1M. Unless otherwise specified in AWS B2.1/B2.1M, three transverse macros shall be removed as shown in Figure 9.3, and the weld shall show complete fusion.

9.5 Examination Procedures and Acceptance Criteria for Austenitic Manganese Steel Unless otherwise specified in AWS B2.1/B2.1M, examination procedures and acceptance criteria shall be as specified in the following paragraphs.

9.5.1 Standard Test Weldments. The test weld may be examined visually by the test supervisor at any time, and the test terminated at any stage if the necessary skills are not exhibited. Procedure and acceptance criteria for standard test weldments shall be as follows:

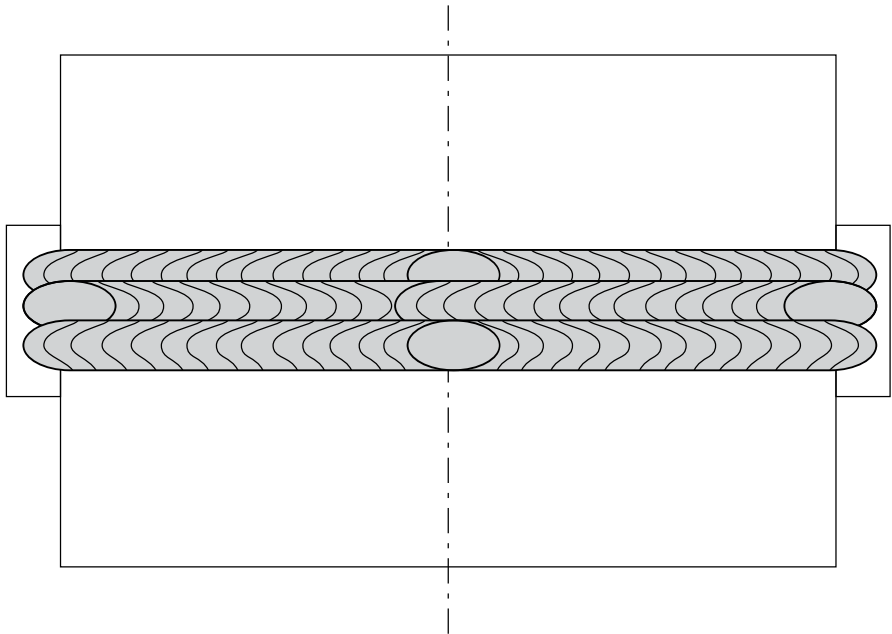


Figure 9.1(b)—Typical Weld Bead Sequence for Test Weldments

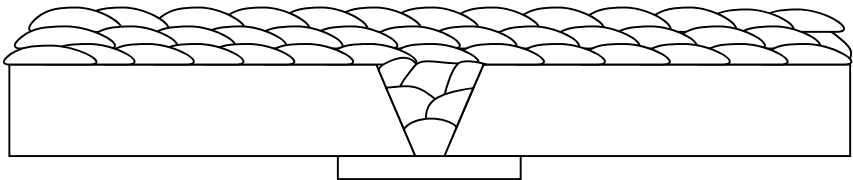


Figure 9.1(c)—Typical Weld Bead Sequence for Test Weldments

Table 9.2 Position Limitations for Performance Tests			
Test Positions		Qualified Positions ^a	
Weld	Positions	Groove	Clad and Hardfacing (Buildup)
Plate Groove	1G	F	
Clad or Hardfacing ^b (Buildup)	1C		F

^a F = Flat.
^b Positions for surfacing applications are defined as 1C = Flat.

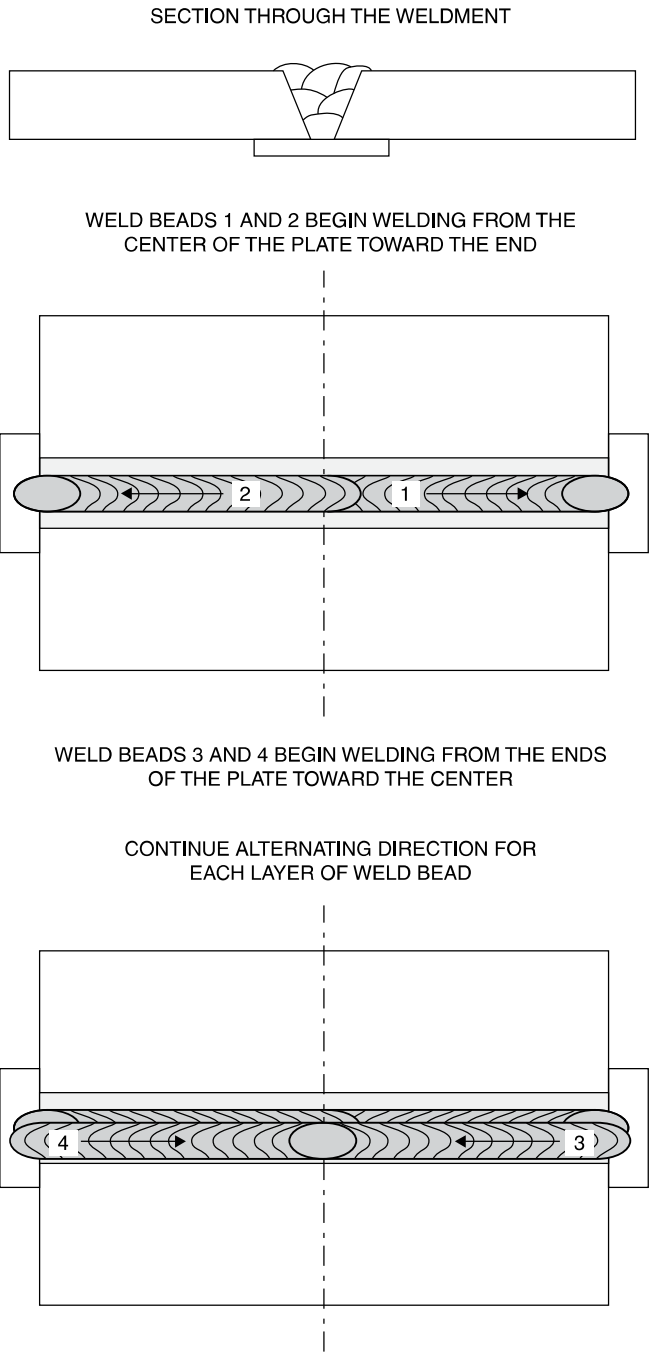


Figure 9.2—Typical Test Weldments

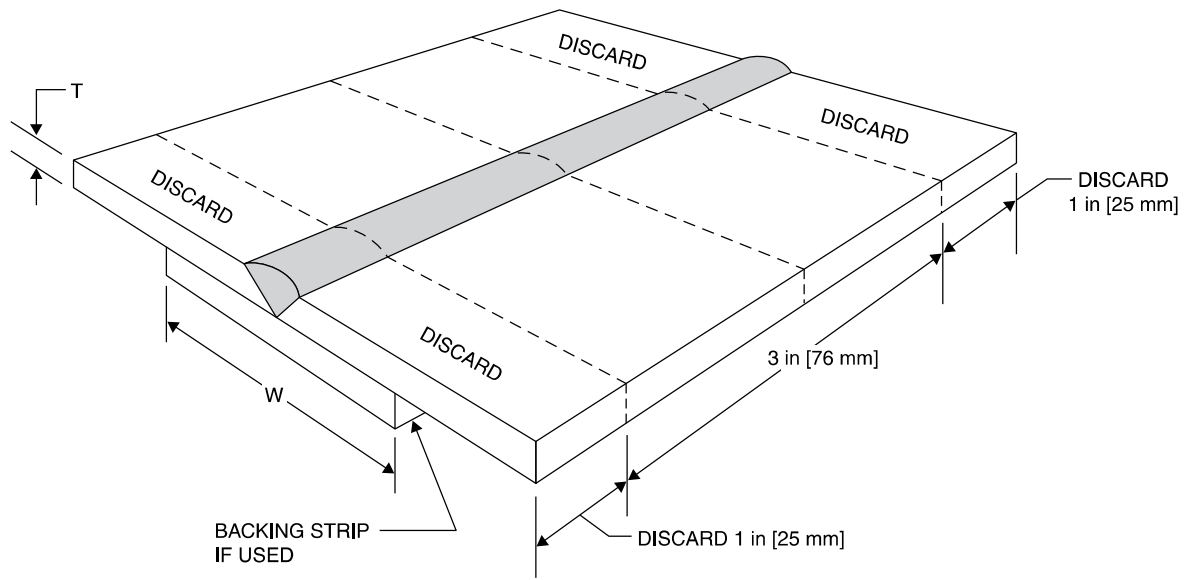


Figure 9.3—Dimensions for Inspection

- (a) Amperage range of 250 amps to 300 amps for 5/64 in [2 mm] diameter wire.
- (b) Voltage range of 26 volts to 30 volts (as per manufacturer's specifications)
- (c) Arc length should be maintained as short as possible while maintaining good arc characteristics. Recommended welding wire stick-out is between 1 and 1-1/4 in [25 mm and 32 mm].
- (d) Maintain a drag angle of 15° to 30°.
- (e) Apply weld beads in alternating directions, starting and ending in the center of the plate as per Figure 9.2 to Workmanship Test Weldments.
- (f) Clean each weld bead by manual or mechanical means.
- (g) Immediately after completing each pass, peen the bead with the ball end of a two pound ball-peen hammer to stress relieve the weld bead. The bead should be struck two to four times per inch of weld using moderate blows that produce an indentation of approximately 0.040 in [1 mm].
- (h) Base metal shall not exceed 500°F [260°C] at a point 1 in [25 mm] from the area being gouged or welded.
- (i) Air cooling is permitted to maintain base metal temperature.
- (j) Cover layer shall consist of three passes.

9.5.2 Visual Examination. The completed test weld shall be visually examined without magnification:

- (a) No cracks or incomplete fusion are permitted.
- (b) No incomplete joint penetration in groove welds is allowed.
- (c) Undercut depth shall not exceed the lesser of 10% of the base metal thickness or 1/16 in [1.6 mm].
- (d) No single pore shall exceed 1/16 in [1.6 mm] diameter.

9.5.3 Macroetch Test. The weld test specimens shall be prepared with a finish suitable for macroetch examination. A suitable solution shall be used for etching to give a clear definition of the weld.

9.5.3.1 Groove Weldments. Both weld cross sections of the macroetch specimen from the groove weld shall be examined.

- (a) The weld cross section shall show no incomplete fusion and no cracks.
- (b) Discontinuities of the weld, not exceeding 1/16 in [1.58 mm], shall be acceptable.
- (c) Accumulation of defects shall not exceed 3/16 in [4.63 mm] per face.

9.5.3.2 Plate Buildup Weldment.

- (a) The specimen shall show complete fusion.
- (b) Discontinuities of the weld, not exceeding 1/16 in [1.6 mm], shall be acceptable.
- (c) Accumulation of defects shall not exceed 3/16 in [4.8 mm].

9.6 Performance Qualification Variables for Austenitic Manganese Steel

9.6.1 Qualification on one WPS will also qualify for welding with any other WPS within the limits given in 9.4.

9.7 General Information for Rail Steel

9.7.1 Qualification of welders and welding operators requires that a weldment be made according to a Standard Welding Procedure Specification (SWPS) or a qualified Welding Procedure Specification (WPS). The weldment shall be prepared and tested in accordance with the requirements of this specification.

9.7.2 Welders and welding operators qualified to earlier editions of this standard are also qualified to the current edition.

9.7.3 Personnel currently qualified by the employer to meet the requirements of other codes or specifications are considered qualified under this standard provided the basis for their qualification meets all requirements of this specification. However, the limits of qualification shall be in accordance with 9.12. In such cases, a certification form shall be initiated and signed by the employer attesting to compliance with this document. If an existing form is used, the certifying statement shall be added or appended. If a new form is issued, it shall reference any prior certification form which shall be attached to or traceable from the new form.

9.7.4 Qualification testing using one of two methods is permitted:

- (1) Qualification by Standard Test (see 9.8)
- (2) Qualification by Workmanship Test (see 9.9)

9.7.5 A Standard Test shall qualify the individual to perform production welding where either a Standard Test or a Workmanship Test is specified. Where AWS B2.1/B2.1M permits qualification by visual examination, a Workmanship Test may qualify a welder or welding operator for production welding.

9.7.6 If AWS B2.1/B2.1M allows performance qualification by Workmanship Test, a production weldment may be used for performance qualification provided the production weld is visually inspected and meets the requirements of 9.11.2.

9.7.7 The welder or welding operator undertaking performance qualification tests shall be under the full supervision and control of the qualifier during the welding of test weldments.

9.7.8 The qualification test for each welder or welding operator shall be documented by the qualifier for both acceptable and unacceptable tests. There is no required format for Performance Qualification Test Records (PQTR). Any PQTR form may be used. Documentation shall:

- (1) Identify the WPS used;
- (2) Address each of the qualification variables in 9.12;
- (3) Identify test and examination methods used and results; and
- (4) Identify the limits of qualification for the welder or welding operator.

9.7.9 Acceptance of test results is the responsibility of the qualifier. Qualification records shall be signed and dated by the qualifier. Qualification records shall reference and may include mechanical test and nondestructive examination test reports that are signed by others. Retention of mechanical test and nondestructive examination test reports is not required after acceptance by the qualifier.

Table 9.3
Examination Requirements for Performance Qualification

	Plate	Surfacing
Type of Test	Groove	Clad or Hardfacing (Buildup)
Visual Examination	Yes	Yes
Macro-Examination	Yes	Yes

9.7.10 A welder or welding operator who fails the performance test may be retested at the option of the qualifier, using (1) or (2) below:

(1) If a retest is permitted by the qualifier without further training or practice, it shall consist of two test weldments for each position failed. Both test weldments shall be acceptable for the welder or welding operator to qualify.

(2) Provided there is evidence satisfactory to the qualifier that the welder or welding operator has had further training or practice, one test weld for each position failed is permitted.

9.7.11 The performance qualification of a welder or welding operator shall be affected when one of the following conditions occurs:

(1) When he or she has not welded with a process during a period of six months or more, his or her qualifications for that process shall expire.

(2) Requalification as a result of (1) is permitted by having the welder or welding operator make one test weldment using the same process. If the test weldment meets the requirements of this specification, then all of the welder's or welding operator's previous qualifications for that process, materials, thicknesses, product forms, and other variables are reinstated.

(3) When there is a specific reason to question his or her ability to make welds that meet the specification, the qualifications that support the welding he or she is doing shall be revoked. All other qualifications not questioned remain in effect.

(4) Requalification as a result of (3) is permitted by having the welder or welding operator successfully complete performance qualification test(s) that support the qualification(s) questioned.

9.7.12 Completion of an acceptable procedure or performance qualification test shall qualify the welder or welding operator who welded the test weldment within the limits of performance qualification variables specified in 9.12.

9.7.13 Successful qualification using the test WPS shall also qualify an individual to weld with any other WPS using the same process and within the limits of performance variables in 9.12. Qualification as a welder does not qualify the individual as a welding operator or vice versa.

9.7.14 Welders qualified on a groove weld are also qualified to perform weld buildup of surfaces to replace or repair base material with similar composition weld metal.

9.8 Qualification by Standard Test for Rail Steel

9.8.1 Qualification requires completion of a standard test weldment in accordance with a qualified WPS, evaluation of the test weldment by the methods listed in Table 9.3, and acceptance of the weldment in accordance with the criteria of 9.11.

9.9 Qualification by Workmanship Test for Rail Steel

9.9.1 Qualification by Workmanship Test is permitted only when allowed by AWS B2.1/B2.1M.

9.9.2 Qualification requires completion of a Workmanship Test welded in accordance with a qualified WPS that addresses typical production joints and conditions. Workmanship weldments are accepted or rejected primarily on the basis of the visual examination criteria of 9.11. Other tests or examinations (macro-examination, etc.) may be specified by AWS B2.1/B2.1M. Some typical Workmanship Test weldments are shown in Figures 9.4(a) through 9.4(c).

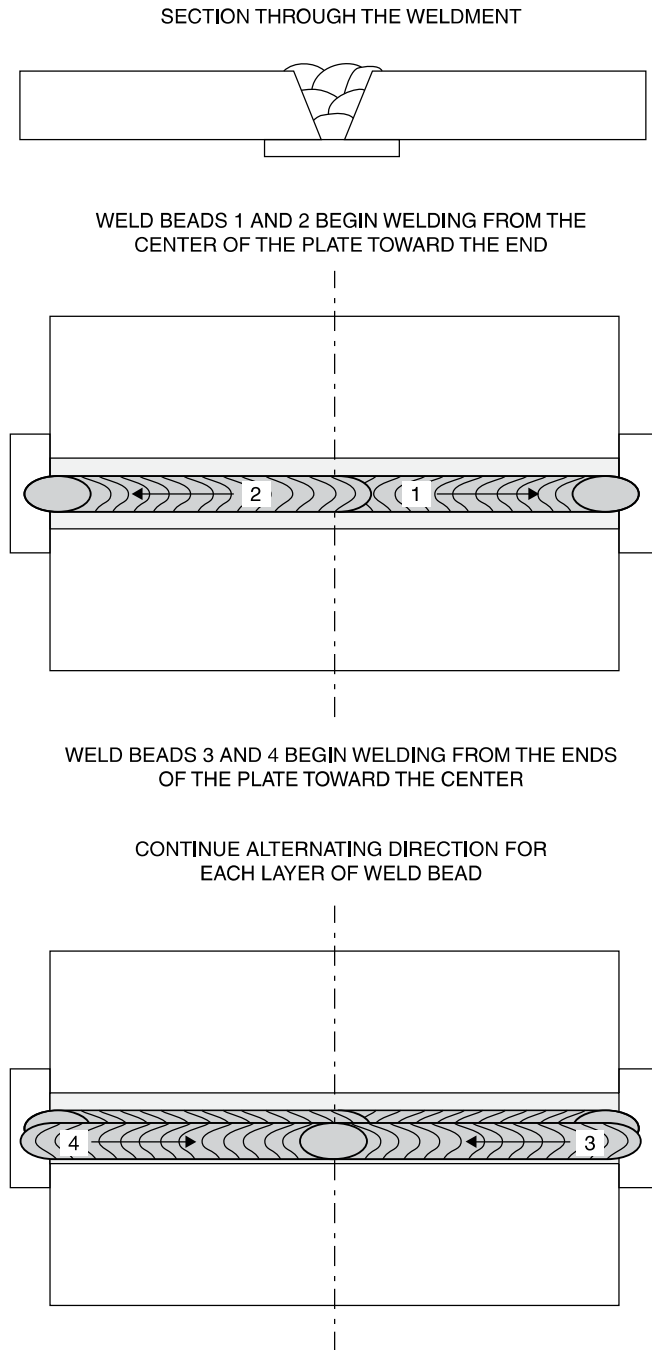


Figure 9.4(a)—Typical Weld Bead Sequence for Test Weldments

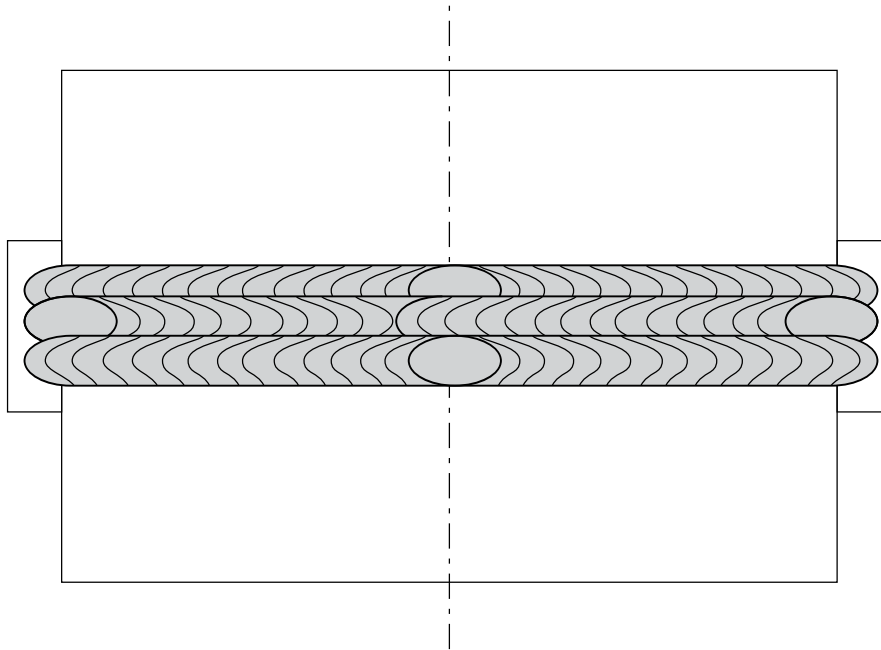


Figure 9.4(b)—Typical Weld Bead Sequence for Test Weldments

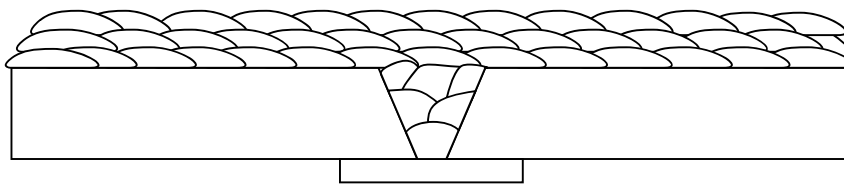


Figure 9.4(c)—Typical Weld Bead Sequence for Test Weldments

9.10 Test Weldments for Rail Steel

9.10.1 The test material shall be ASTM A36 steel plate.

9.10.2 Tests shall be performed using rail owner specified rail steel filler metals.

9.10.3 Test coupons welded in the specific test positions described in Table 9.4 qualify the welder to weld rail steel track components in the flat position. Weldment orientations other than the specific test position shown in Table 9.4 are permitted, but such tests qualify only for the orientation tested.

9.10.4 One or more welding process may be qualified on a single test weldment. Multiple welders and welding operators may be qualified for specific portions of one test. Failure of any portion of such test weldments constitutes failure for all processes, welders, and welding operators used in that test weldment.

9.10.5 Figure 9.4 shows typical weld bead progression. Figure 9.5 illustrates typical test plate setup. Figure 9.6 illustrates the locations for the removal of required specimen blanks.

9.10.6 Buildup. Prior to removing test specimen blanks identified in Figure 9.6, the built up surface shall be visually examined in accordance with AWS B2.1/B2.1M. Unless otherwise specified in AWS B2.1/B2.1M, three transverse macros shall be removed as shown in Figure 9.6, and the weld shall show complete fusion.

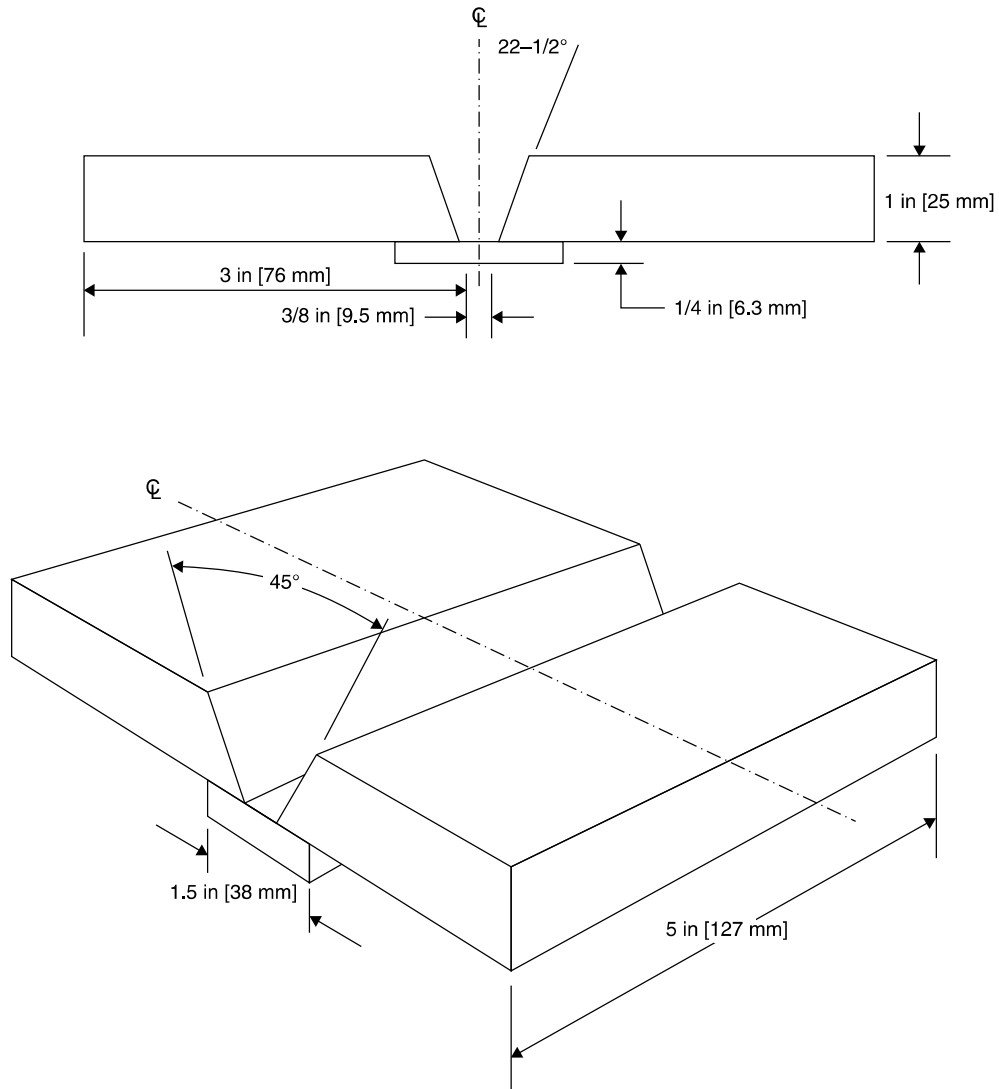


Figure 9.5—Typical Test Plates

9.11 Examination Procedures and Acceptance Criteria for Rail Steel

Unless otherwise specified in AWS B2.1/B2.1M, examination procedures and acceptance criteria shall be specified as follows:

9.11.1 Standard Test Weldments. The test weld may be examined visually by the qualifier at any time, and the test terminated at any stage if the necessary skills are not exhibited. Procedure and acceptance criteria for standard test weldments shall be as follows:

- (a) Preheat base metal to a minimum temperature of 700°F [370°C] not to exceed 1000°F [538°C].
- (b) Arc length should be maintained as short as possible while maintaining good arc characteristics. Recommend welding wire stick-out between 1 in and 1-1/4 in [25 mm and 32 mm].
- (c) Maintain a drag angle of 15° to 30°.
- (d) Clean weld beads by manual or mechanical means after each pass.

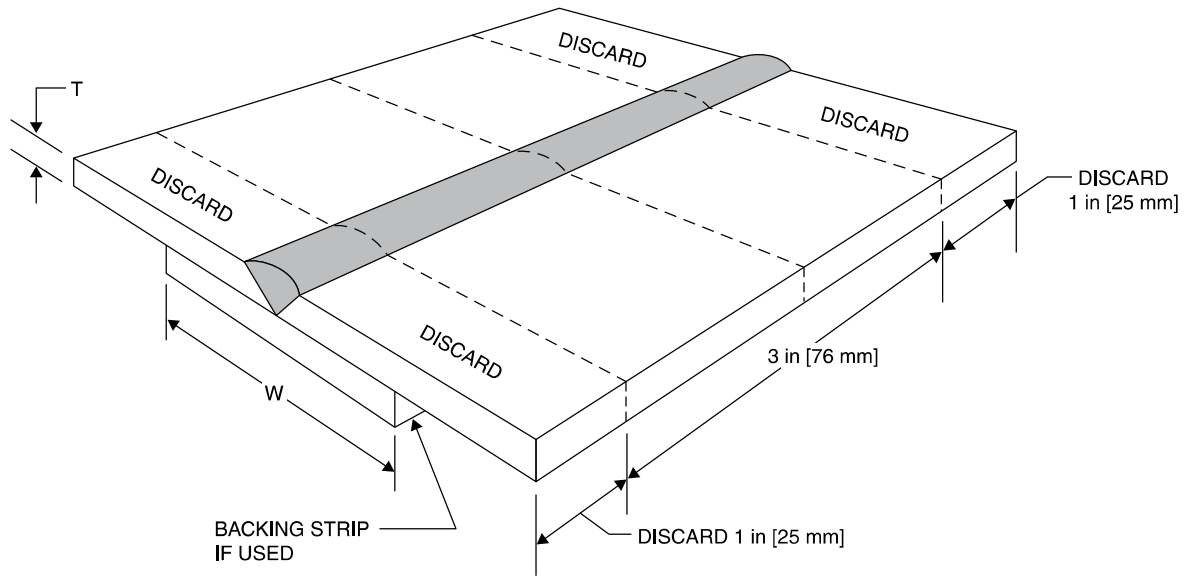


Figure 9.6—Dimensions for Inspection

**Table 9.4
Position Limitations for Performance Tests**

Test Positions		Qualified Positions ^a	
Weld	Positions	Groove	Clad and Hardfacing (Buildup)
Plate Groove	1G	F	
Clad or Hardfacing ^b (Buildup)	1C		F

^a F = Flat.

^b Positions for surfacing applications are defined as 1C = Flat.

- (e) Maintain interpass temperature between 700°F [371 °C] and 1000°F [538 °C].
- (f) Apply weld beads in alternating directions, starting and ending in center of plate as per Figure 9.4.
- (g) A minimum of three cover passes shall be visible on the groove weld face. See Figure 9.4(b).
- (h) Weld buildup shall consist of three layers applied across the entire test plate. See Figure 9.4(c).
- (i) Postheat the test plate to a temperature of 1000°F [538 °C] to 1250°F [677 °C].
- (j) Controlled cooling shall be maintained.

9.11.2 Visual Examination. Visually inspect the completed test weld without magnification.

- (a) No cracks or incomplete fusion are permitted.
- (b) No incomplete joint penetration in groove welds is allowed.
- (c) Undercut depth shall not exceed the lesser of 10% of the base metal thickness or 1/16 in [1.6 mm].
- (d) No single pore shall exceed 1/16 in [1.6 mm] diameter.

9.11.3 Macroexamination. Specimens shall be etched to provide a clear definition of the weld metal and heat-affected zone (HAZ) (see Annex B). Visually examine etched surfaces.

9.11.3.1 Groove Weldment. Both weld cross sections of the macroetch specimen from the groove weld shall be examined.

- (a) The weld cross section shall show no incomplete fusion and no cracks.
- (b) Discontinuities of the weld, not exceeding 1/16 in [1.6 mm], shall be acceptable.
- (c) Accumulation of defects shall not exceed 3/16 in [5 mm].

9.11.3.2 Plate Buildup Weldment

- (a) The specimen shall show complete fusion.
- (b) Discontinuities of the weld, not exceeding 1/16 in [1.6 mm], shall be acceptable.
- (c) Accumulation of defects shall not exceed 3/16 in [5 mm].

9.12 Performance Qualification Variables for Rail Steel

9.12.1 Qualification on one WPS will also qualify for welding with any other WPS within the limits given in 9.10.

10. Testing

10.1 Nondestructive Testing

10.1.1 Geometry Inspection (Rail Weld Alignment). Rail weld geometry shall be checked with a straight edge and taper gauge in accordance with the requirements of the *AREMA Manual for Railway Engineering*, Chapter 4, Part 3.12, *Specification for Fabrication of Continuous Welded Rail*, or those selected by the operating authority. If alignment adjustments are required they shall be performed at a temperature below 900°F [482°C].

10.1.2 Magnetic Particle Inspection. Magnetic particle inspection shall be used to inspect for surface defects such as piped rail, shear tears, or craters pushed to the surface. Testing shall be in accordance with ASTM E709, *Standard Guide for Magnetic Particle Testing*, and performed below 800°F [427°C]. Results of the inspection shall meet or exceed the requirements of the operating railroad.

10.1.3 Ultrasonic Inspection. Ultrasonic inspection is best suited for inspection of welds installed in the field. It may be used, with reservations, in the production line. Results of the inspection shall meet or exceed the requirements of the operating railroad. Examination should follow established guidelines of ASTM E164, *Standard Practice for Contact Ultrasonic Testing of Weldments*.

10.1.4 Radiography. Radiography is not recommended for the inspection of rail welds. Defects are very difficult to detect and interpret.

10.1.5 Liquid Penetrant Inspection. Liquid penetrant inspection may be used for detection of discontinuities, such as lack of fusion, corrosion, cracks, laps, cold shuts, and porosity that are open or connected to the surface. Testing shall be in accordance with ASTM E1417, *Standard Practice for Liquid Penetrant Testing*.

10.2 Other Testing

See other testing methods in the figures below.

Table 10.1
Minimum Performance Specifications for New Flash and Thermite Welded Rail

Slow Bend Testing				
Material	Flash Welding		Thermite Welding	
	Modulus of Rupture ^a	Deflection Min.	Modulus of Rupture ^a	Deflection Min.
Soft Carbon Steel Rail (248 HB Min.)	100 000 psi [689 MPa]	1.5 in [38 mm]	100 000 psi [689 mm]	1.0 in [25 mm]
Standard Carbon Steel Rail (300 HB Min.)	120 000 psi [827 MPa]	1.0 in [25 mm]	110 000 psi [758 MPa]	0.9 in [23 mm]
Premium Carbon Steel Rail (341 HB Min.)	125 000 psi [862 MPa]	0.7 in [19 mm]	120 000 psi [827 MPa]	0.6 in [15 mm]
Optional Rolling Load Test				
Material	Loads		Cycles	
All rails	See Table D.1		2 000 000	
Hardness Survey ^b				
Flash Welding				
Material	Deviation from Parent Material, through HAZ Area			
Standard Carbon Rail	+40 HB/–60 HB to maximum 410 HB			
Premium Steel Rail	+60 HB/–80 HB to maximum 415 HB			
Thermite Welding				
The hardness of the weld metal shall be within +30 HB points of the manufacturer’s specified hardness for the specific welding kit being used.				
Macroetch (Flash Welded Rail Only)				
Structure	Specification			
Flow Line Grain turn-out angle	35°–75°			
Parallel Heat-affected zone	0.25 in [6.350 mm] maximum deviation			

^a Modulus of Rupture = $\frac{(9 \times \text{Load psi})}{\text{Section Modulus}}$

^b Measurements may be taken in Rockwell Hardness Numbers and converted to Brinell Hardness. These conversions may be done according to Table 1 in ASTM E140. Numbers providing a minimum of five Rockwell Hardness readings are obtained, discarding the highest and lowest reading and averaging the remaining readings.

PROPOSED MODE OF CONDUCTING A HARDNESS SURVEY ON THE HEAD
OF A WELDED RAIL SAMPLE, AND MODE OF INTERPRETATION
OF THE DATA DERIVED FROM THAT HARDNESS TRAVERSE

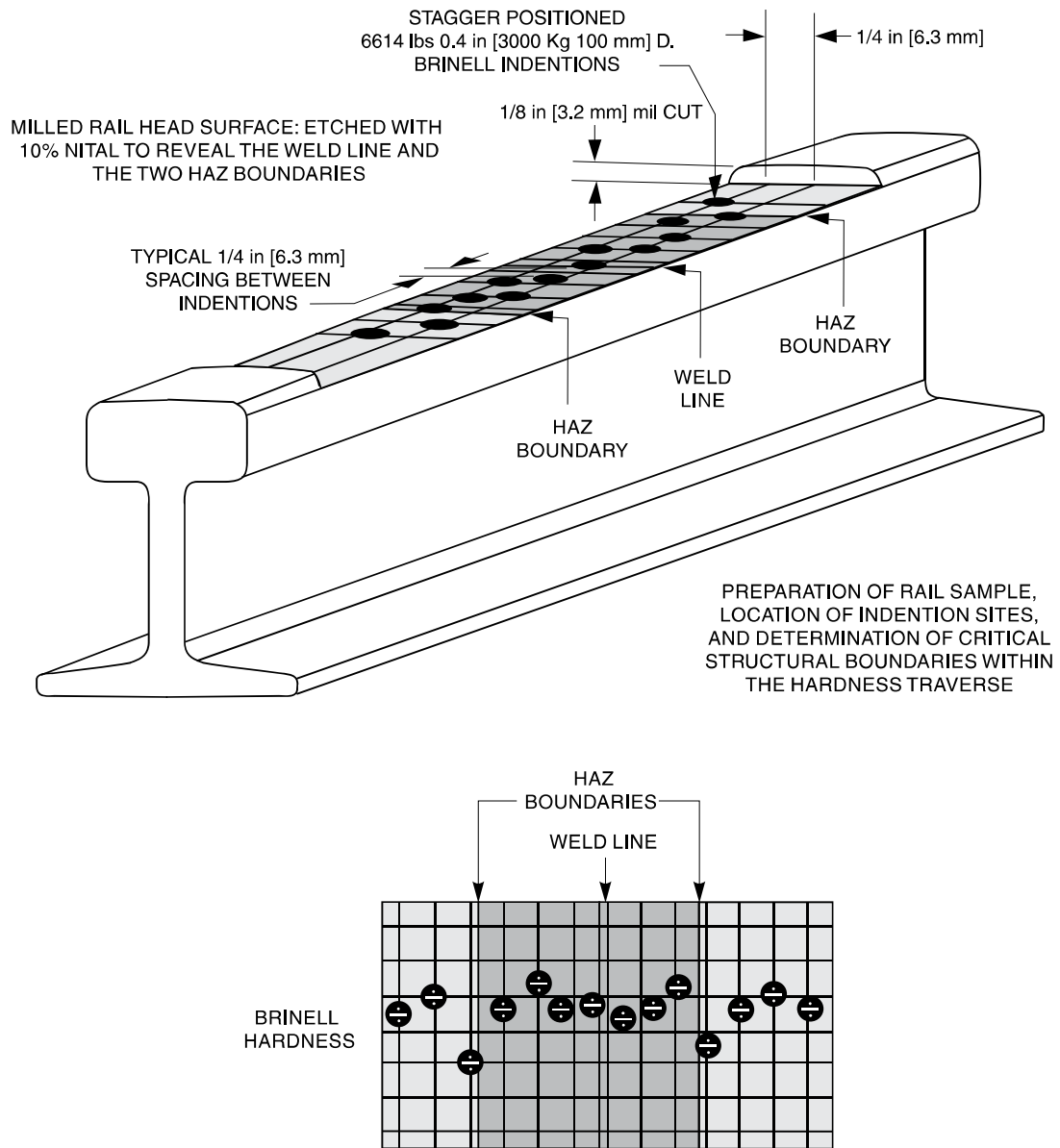


Figure 10.1—Layout of Hardness Survey on Rail Head

LOCATION OF 331LBS [150 Kg] – BRALE ROCKWELL C INDENTATION TESTS
ON A VERTICAL CENTRAL LONGITUDINAL SECTION PLANE
SURFACE OF A WELDED RAIL AND THE MODES OF
INTERPRETATION OF EACH TRAVERSE'S DATA

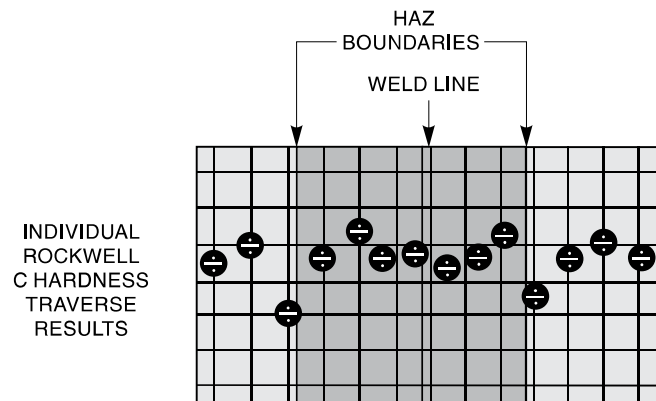
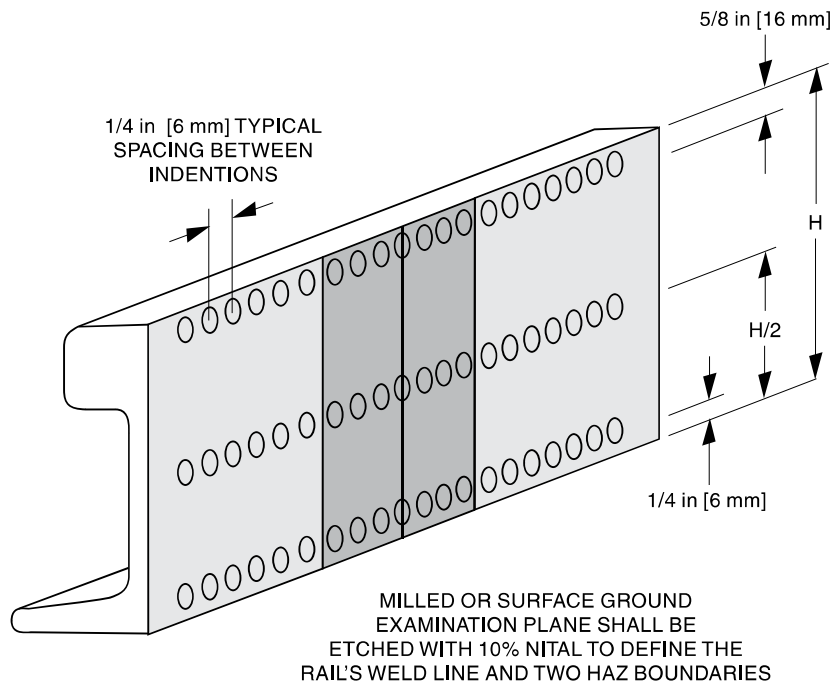


Figure 10.2—Layout of Transverse Hardness Survey

This page is intentionally blank.

Annex A (Informative) Welding Processes

This annex is not part of AWS D15.2/D15.2M:2013, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*, but is included for informational purposes only.

A1. Arc Welding

A1.1 Shielded Metal Arc Welding (SMAW) (Stick Welding)

A1.1.1 An arc welding process with an arc between a covered electrode and the weld pool. The process is used with shielding from the decomposition of the electrode covering, without the application of pressure, and with filler metal from the electrode.

A1.1.2 See Figure A.1 for a schematic of the process.

A1.2 Gas Metal Arc Welding (GMAW)

A1.2.1 An arc welding process that uses an arc between a continuous filler metal electrode and the weld pool. The process is used with shielding from an externally supplied gas and without the application of pressure.

A1.2.2 See Figure A.2 for a schematic of the process.

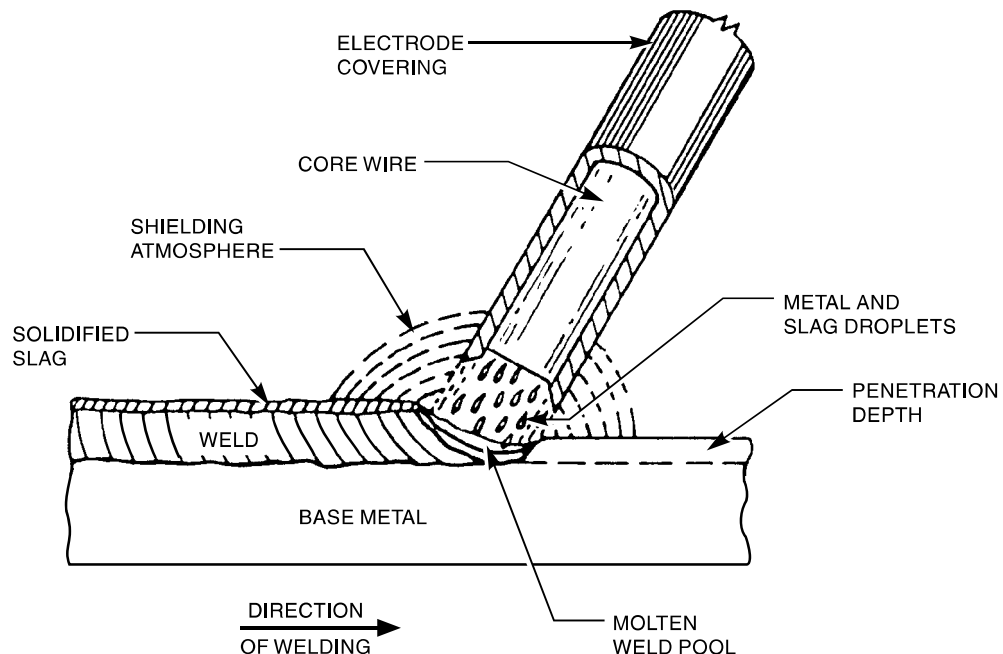


Figure A.1—Shielded Metal Arc Welding (SMAW)

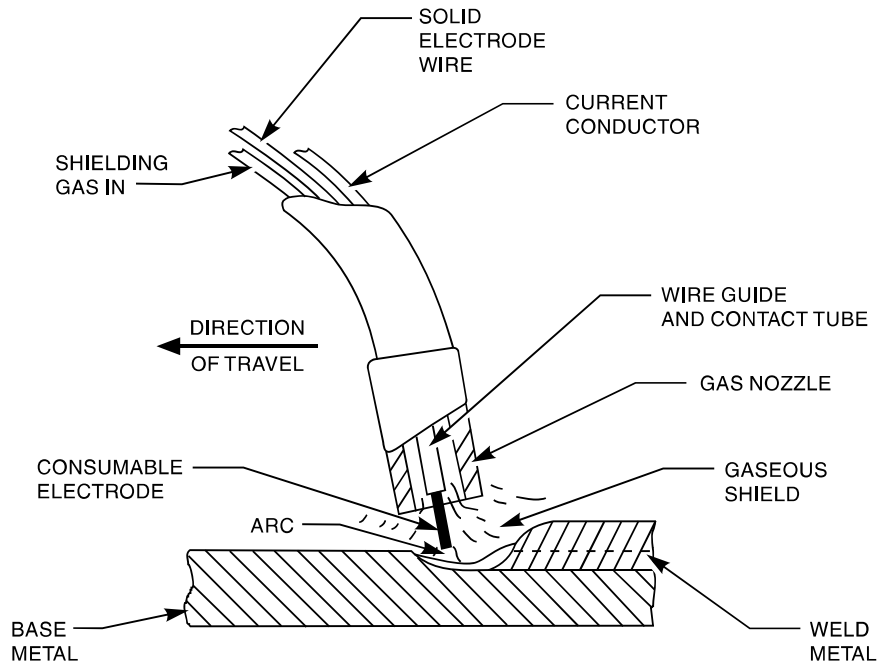


Figure A.2—Gas Metal Arc Welding (GMAW)

A1.3 Flux Cored Arc Welding (FCAW)

A1.3.1 An arc welding process that uses an arc between a continuous filler metal and the weld pool. The process is used with a shielding gas from a flux contained within the tubular electrode, with or without additional shielding from an externally supplied gas, and without the application of pressure.

A1.3.2 See Figure A.3 for a schematic of the process.

A2. Thermite Welding (TW)

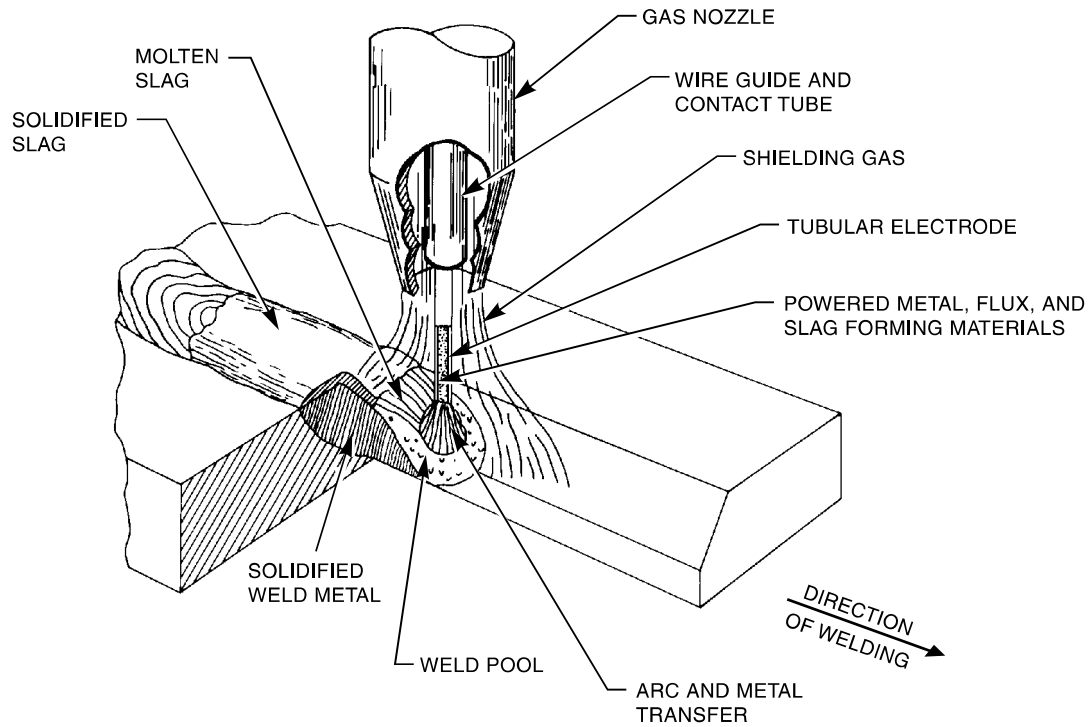
A2.1 A welding process that produces coalescence of metals by heating them with superheated liquid metal from a chemical reaction between a metal oxide and aluminum, with or without the application of pressure. Filler metal is obtained from the liquid metal.

A2.2 See Figure A.4 for a typical thermite installation.

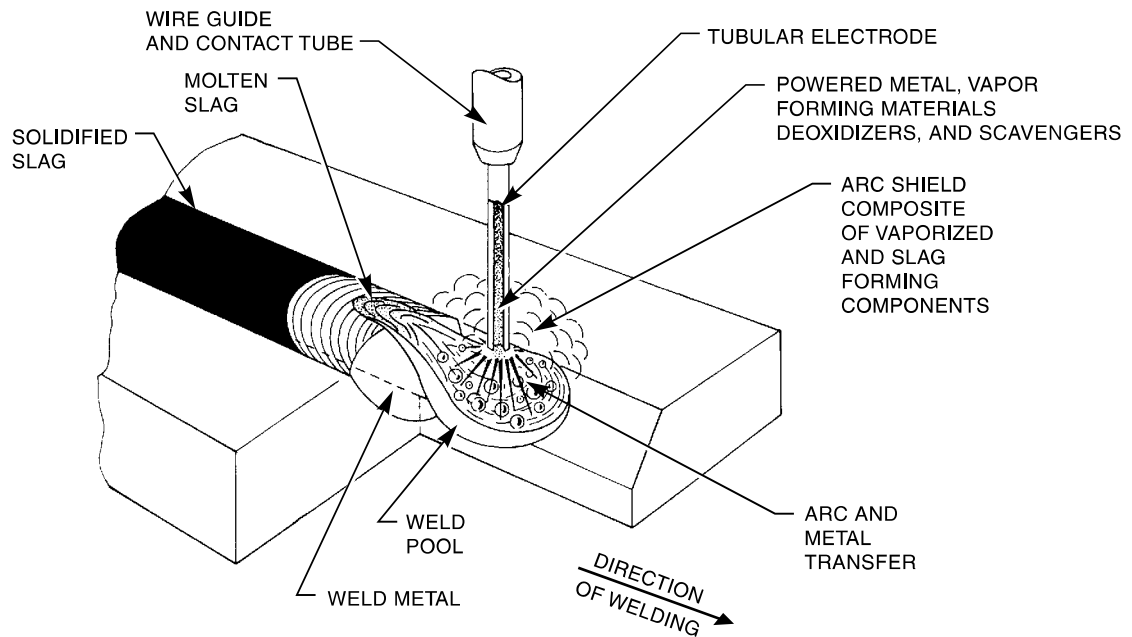
A3. Flash Welding (FW)

A3.1 A resistance welding process that produces a weld at the faying surfaces of a butt joint by a flashing action and by the application of pressure after heating is substantially completed. The flashing action, caused by very high current densities at small contact points between the workpieces, forcibly expels the material from the joint as the workpieces are slowly moved together. The weld is completed by a rapid upsetting of the workpieces.

A3.2 In the welding of continuous rail, the flash welding machine (Figure A.5) is only one station in the production cycle (Figure A.6).



(A) GAS SHIELDED



(B) SELF SHIELDED

Figure A.3 – Flux Cored Arc Welding (FCAW)

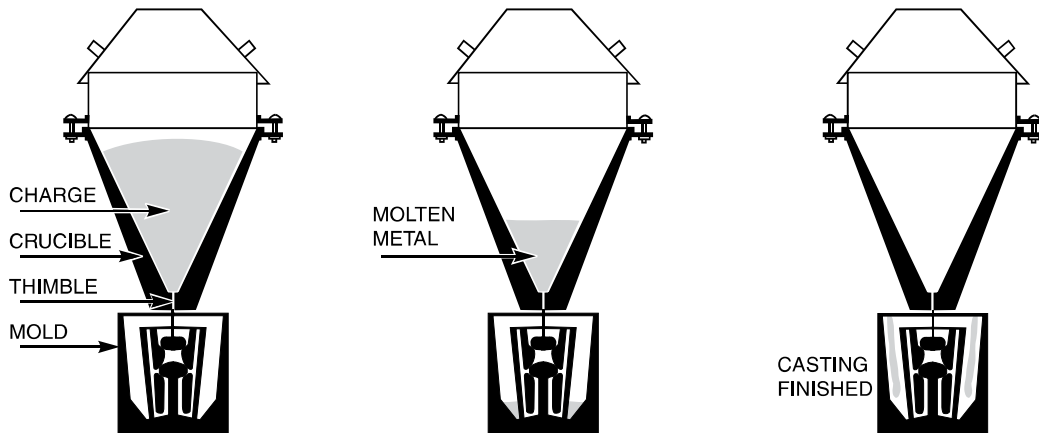


Figure A.4—Section Through a Thermite Mold and Crucible

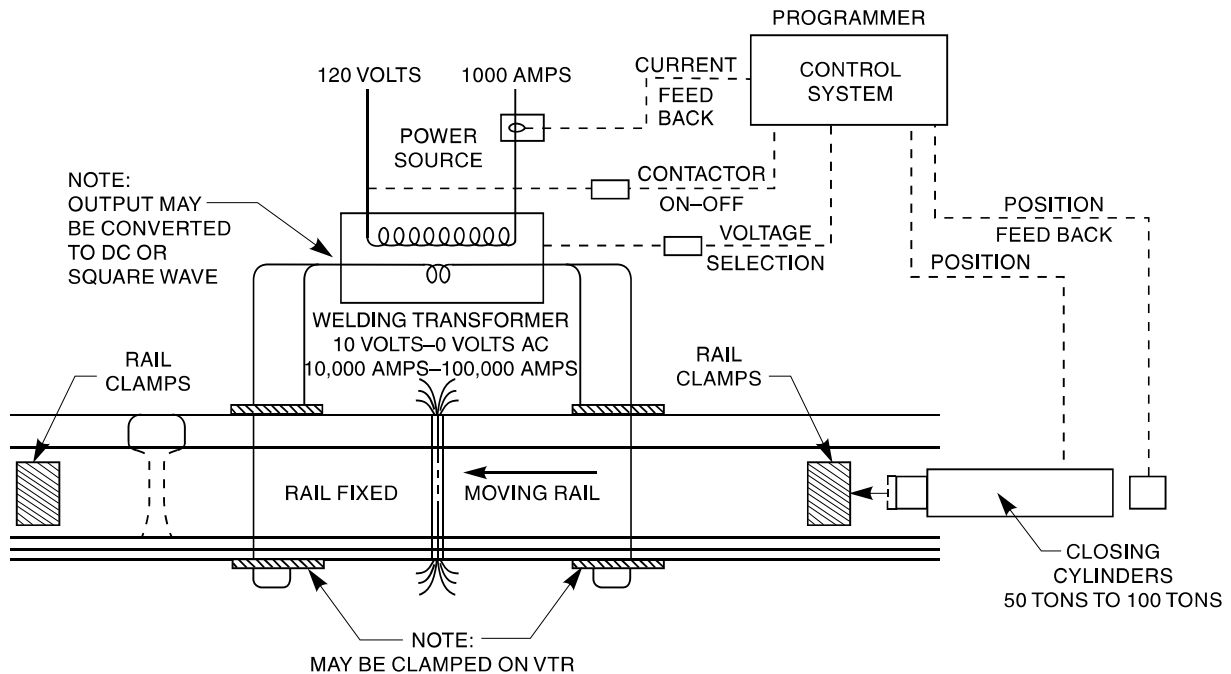


Figure A.5—Automatic Hydraulically Operated Flash Welding Machine with Horizontal Clamping

A4. Oxyfuel Gas Welding (OFW)

A4.1 A group of welding processes that produces coalescence of workpieces by heating them with an oxyfuel gas flame. The processes are used with or without the application of pressure and with or without the addition of filler metal.

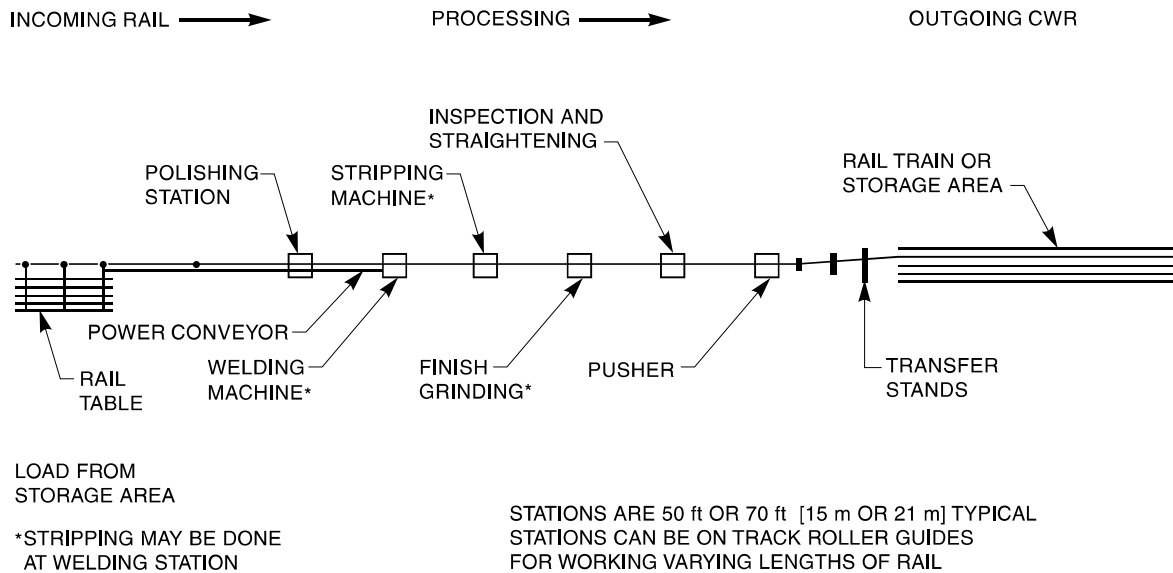


Figure A.6—Rail Welding Production Line

A4.2 See Figure A.7 for a schematic of the process.

A5. For further discussions of the arc welding processes refer to the *Welding Handbook*, Volumes 2 and 3, Ninth Edition.

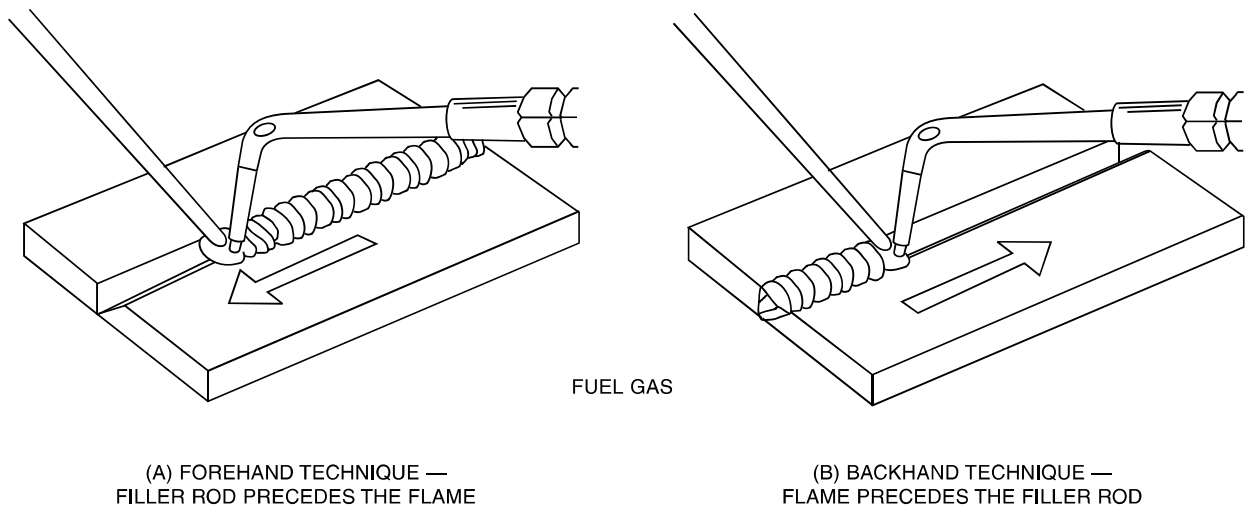


Figure A.7—Oxyfuel Gas Welding (OFW)

This page is intentionally blank.

Annex B (Informative)

Welding of Austenitic Manganese Steel

This annex is not part of AWS D15.2/D15.2M:2013, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*, but is included for informational purposes only.

B1. Introduction

B1.1 Austenitic manganese steel is an extremely tough, nonmagnetic alloy with properties uniquely different from those of most commonly used structural and wear resistant steels. It is the preferred material for a number of trackwork components, with frogs and crossings the most important. It has high strength and durability and resists failure under impact and heavy loading. Its capacity for work hardening is a major asset; the surface of the part hardens under impact, undergoing some deformation, while the underlying body retains its original toughness. The propagation rate of any cracks that may be initiated is extremely slow. Metal-to-metal wear resistance is excellent. Resistance to abrasive wear is good, compared to that of carbon steel and low alloy steels.

B1.2 Austenitic manganese steel is available as castings, which comprise the most tonnage. Rolled plate, bars and wire, as well as electrodes for welding in various forms are also available.

B2. Composition

A number of modifications of the original austenitic (Hadfield) manganese steel composition are produced commercially as castings; ASTM A128, *Standard Specification for Steel Castings, Austenitic Manganese*, lists ten grades. For trackwork castings, the American Railway Engineering and Maintenance of Way Association (AREMA) requires production in conformance with ASTM A128, except that the chemical requirements are modified slightly as follows:

Carbon:	1.00/1.30%
Manganese:	12.00% Min
Silicon:	1.00% Max
Phosphorus:	0.07% Max

Some lower carbon steel castings alloyed with molybdenum are used in special applications.

For many purposes, the optimum carbon content is about 1.15%, considering foundry and heat treating problems, casting properties, and economy. The high austenitic manganese steel content plays a vital role in stabilizing the austenite by retarding its transformation to other structures. Silicon is present mainly for deoxidization purposes. Phosphorus is restricted because of its tendency to promote hot cracking, both in the foundry and in subsequent welding operations.

The composition of filler metals deposited by austenitic manganese steel electrodes differs from casting analyses to provide the desired austenitic structure with weld cooling rates. Carbon commonly is somewhat reduced and additional alloying elements are added to maintain acceptable mechanical properties. Nickel, molybdenum, chromium, and vanadium, alone or in combinations, are used as added alloying elements in austenitic manganese steel welding electrodes.

B3. Basic Metallurgy

B3.1 At high temperatures, the structure of steel is essentially austenitic; most carbon steels and alloy steels transform from the austenitic structure to other structures as the metal cools. Large austenitic manganese steel additions effectively suppress the transformation of austenite; sufficiently fast cooling an austenitic structure will retain it at room temperature.

B3.2 Before heat treatment, austenitic manganese steel castings are relatively brittle, as slow cooling in the molds does not provide a fully austenitic structure. Heat treatment involves heating to the appropriate austenitizing temperature, usually in the 1850°F–1950°F [1010°C–1065°C] range, holding until the sections are fully austenitic and all carbides dissolved, and quenching in cold, agitated water.

B3.3 The microstructure of properly quenched austenitic manganese steel consists of distinct grains of austenite. Excessive carbides in the grain boundaries or in other manifestations are undesirable, as the mechanical properties of the steel will be lower than normal. Either inadequate austenitizing or too slow cooling from the austenitizing temperature can result in excessive carbides.

B3.4 The reheating of austenitic manganese steels can also cause carbide precipitation and impaired properties, with the degree of embrittlement dependent upon both the exposure time and temperature. For this reason, welding procedures avoid prolonged overheating of weldments.

B4. Physical Properties

B4.1 Magnetic Characteristics. The untransformed austenite of austenitic manganese steels is virtually nonmagnetic. The surface skin of castings may be somewhat magnetic; this is not detrimental in castings for wear-resistant service.

B4.2 Thermal Conductivity. The thermal conductivity of austenitic manganese steels is about 25% of mild steel at room temperature, and continues to be substantially less at higher temperatures. This contributes to localized heat buildup during welding.

B4.3 Thermal Expansion. The thermal expansion of austenitic manganese steels is similar to that of most other austenitic materials and greater than that of ferritic steels. The change in length on heating is about 1.5 times that of carbon steel.

B5. Mechanical Properties

B5.1 Tensile and Yield Strengths. The properties of cast austenitic manganese steels vary considerably with composition, section thickness, and grain size. For the grade used for trackwork, typical properties are as follows:

Tensile strength:	100 000 psi–145 000 psi [690 MPa–1000 MPa]
Yield strength:	50 000 psi–57 000 psi [345 MPa–393 MPa]
Elongation, %:	30%–65%
Hardness:	185 Brinell–210 Brinell

B5.2 Impact Characteristics. Austenitic manganese steels have excellent impact properties, as measured by Charpy V-notch impact tests. For unalloyed austenitic manganese steels of the type used for trackwork, the impact strength is about 90 ft-lb–100 ft-lb [122 J–136 J] at 75°F [24°C] and about 45 ft-lb–65 ft-lb [61 J–88 J] at –100°F [–73°C]. These values confirm the outstanding toughness austenitic manganese steels provide in service under extremely cold conditions.

B5.3 Work Hardening Characteristics. In comparing austenitic manganese steels to other steels, their very high capacity for work hardening must be considered. The hardness can increase from about 200 Brinell to a maximum of about 550 Brinell, with an accompanying increase in yield strength. Work hardening is produced by deformation and allowance must be made for the metal flow that occurs, either in design or by maintenance practices. For trackwork

buildup, electrodes that provide deposits considerably higher in yield strength than cast austenitic manganese steels can be used to minimize but not eliminate deformation in service.

B6. Welding Electrodes

B6.1 Austenitic Manganese Steel Electrodes. Electrodes may be in the form of solid wire, tubular wire with internal alloying and fluxing ingredients, cut-to-length tubular electrodes with or without external covering, and covered electrodes with part or all of the alloys in the covering.

Austenitic manganese steel electrodes are available as continuous wire and as bare or covered electrodes for manual welding.

In the past, drawn, solid austenitic manganese steel electrodes, bare or with a light coating, were used extensively for the buildup of worn castings. They had the advantage of fast burnoff, high efficiency, and high bead buildup. On the adverse side, usability was relatively poor, requiring highly skilled welders to produce deposits free from porosity, inclusions, and cracking. As the electrodes were produced from large heats of steel, the number of compositions available was very limited and phosphorus levels depended upon the capability of the producing mill.

B6.2 Composite Electrodes. Bare austenitic manganese steel electrodes largely have been replaced by composite electrodes with alloys in the covering. Performance is good and sound welds are obtained readily with normal procedures. Phosphorus content can be held consistently below 0.030%, greatly lessening the likelihood of weld cracking. Several compositions are available, alloyed with additions of nickel, molybdenum, chromium, and vanadium, alone or in combinations. A range of deposit properties is available, providing choices for different application requirements. For example, yield strength matching that of the base metal might be specified for fabrication or crack repair. Higher yield strength with better resistance to deformation might be specified for buildup of a worn railway crossing.

B6.3 Tubular Electrodes. Bare tubular wire electrodes, used for track maintenance, are designed to weld without external shielding gas. As for composite electrodes, the phosphorus content is kept low. The resultant welds have excellent mechanical properties and resistance to cracking. A number of variations in composition are available.

B6.4 Other Austenitic Electrodes. In addition to austenitic manganese steel electrodes, other austenitic compositions can be used for welding austenitic manganese steel. For wear applications, the most commonly used are relatively high-carbon chromium-nickel-manganese and chromium-manganese alloys. These alloys often are more costly than austenitic manganese steel electrodes. Performance advantages in certain applications may more than offset differences in initial cost.

B7. Welding Procedures

Work hardened austenitic manganese steels are more susceptible to cracking when welded than unhardened metal. For that reason, work hardened metal, cracks, and other defects should be removed prior to the start of welding. Grinding, air-carbon-arc gouging, or exothermic metal removal processes should be used. Care should be taken not to overheat the base metal during gouging; therefore, oxyfuel gas cutting is not recommended due to excessive heat input.

Under normal conditions, preheat is not used. In extremely cold weather, the parts may be warmed to approximately 70°F [20°C]. Welding procedures are intended to prevent the buildup of excessive heat in localized areas, and the consequent embrittlement of the base metal under the weld. Current, voltage, and travel speed should be such as to deposit relatively narrow rounded beads; large or very wide beads should be avoided. Skip welding should be used to minimize heat buildup, and can be effectively utilized on most worn castings. The temperature approximately 1 in [25 mm] from the weld should be maintained below 500°F [260°C]. As a rule of thumb, it should be possible to touch the base metal 6 in [150 mm] from the weld without discomfort.

This page is intentionally blank.

Annex C (Informative) Flash Welding Guidance

This annex is not part of AWS D15.2/D15.2M:2013, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*, but is included for informational purposes only.

C1. Primary Welding Current

The primary welding current furnished to welding transformer shall be recorded. The following must be observed:

C1.1 Total electrical energy (heat input) should match the standard certified record.

C1.2 Loss of current flow for more than 3 cycles [50 ms] during the last half inch of burnoff flashing before upset stroke shall be cause for weld rejection and cut out.

C1.3 Current flow must continue at least one half second after upset stroke starts or weld shall be rejected.

C2. Platen Position

The platen position (relationship of fixed and moving rail) shall be recorded. The following must be observed:

C2.1 Total rail consumed to make weld should match standard certified record with tolerances of +1/2 in [+13 mm] and -1/8 in [3 mm].

C2.2 Upset stroke should consume (Forge) the same, or greater, amount of rail as consumed in the standard. Velocity, or upstroke, should be consistent with the standard certified record.

C2.3 The hold time should be consistent with the standard to prevent hot tears and hold alignment.

C3. Force Between Rail Ends

The force between rail ends, as measured through welding cylinders, is an optional recording. The following can be determined:

C3.1 The total force to make the weld should approximately match the standard.

C3.2 A minimum force, as determined by qualified personnel, should be executed between rail ends during the upset stroke.

C4. Recordings

Recordings should be reported on the chart, beginning and end of each shift, and the heat numbers of all rails noted. Also, environmental factors such as temperature, wind, weather, etc., should be recorded on beginning of each chart. Operator should sign chart at end of day or chart shift.

This page is intentionally blank.

Annex D (Informative)

AREMA Tests for Continuous Welded Rail

This annex is not part of AWS D15.2/D15.2M:2013, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles* , but is included for informational purposes only.

D1. Rolling Load Test

D1.1 The rolling load test is a full-scale fatigue test that produces measurable stress; welded specimens can be evaluated on a comparative basis.

D1.2 Test Equipment. Figure D.1 shows the typical load arrangement used for a 12 in [300 mm] stroke test machine.

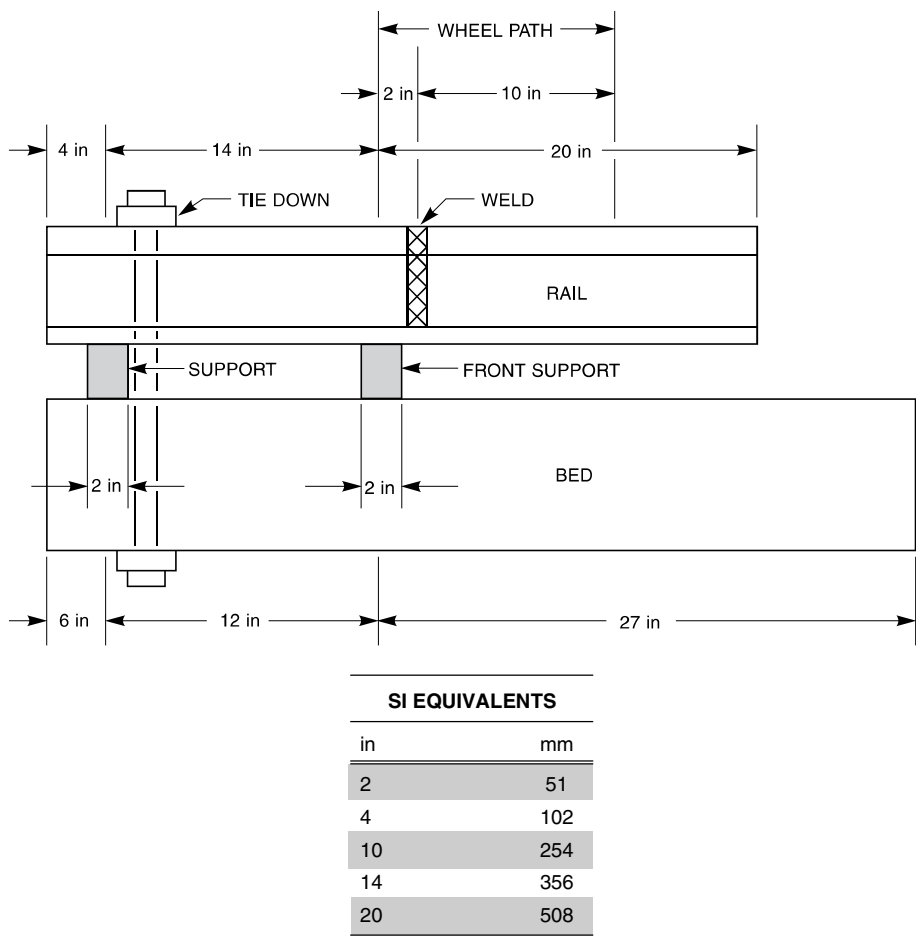


Figure D.1—Loading Arrangement for the 12 in [305 mm] Stroke Rolling Load Machine

D1.2.1 The weld, Figure D.1, is located 2 in [50 mm] in front of the front support providing a 10 in [250 mm] moment arm. The wheel travels over the front support to 10 in [250 mm] past the weld, stressing the longitudinal fibers of welded rail from 0 to maximum stress.

D1.2.2 Wheel load may be varied by adjusting the load spring in accordance with Table D.1.

D1.2.3 Normal test is 60 cycles per minute for a total two million cycles or to failure, whichever occurs first.

D2. Slow Bend Test

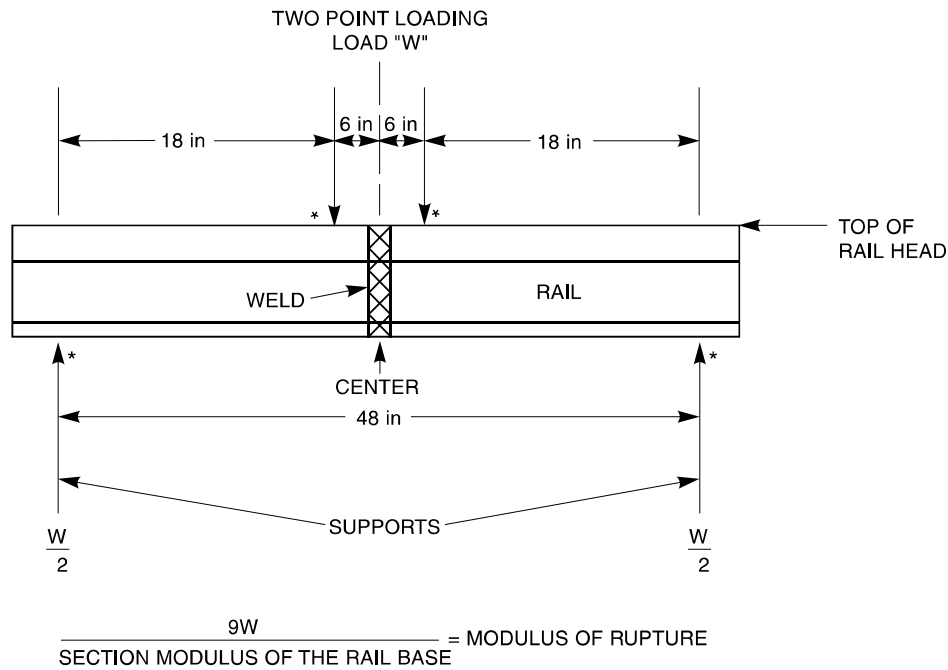
D2.1 Welded assembly is placed head up on a four point loading fixture, Figure D.2, with the base supports 48 in [1200 mm] apart. The fixture is designed so that the one support is stationary and the other support swivels to eliminate torsional loading that might result in uneven bearing between the rail base and the support.

D2.2 Load is applied to the rail head at two loading points spaced 12 in [300 mm] apart.

D2.3 Load is applied to the welded assembly in the center of the fixture until the assembly fractures or deflects 4 in [100 mm], whichever comes first.

Table D.1
Wheel Loads for Rolling Load Test

Weight of Rail Section		Wheel Loads	
Pounds / Yard	Kilograms / Meter	Pounds	Kilograms
80	39.7	29 500	13 380
85	42.2	32 300	14 650
90	44.6	35 000	15 880
100	49.6	40 200	18 230
112	55.6	46 600	21 140
115	57.0	48 200	21 860
119	59.0	50 300	22 820
122	60.5	52 000	22 590
130	64.5	56 200	25 490
131	65.0	56 700	25 720
132	65.5	57 300	25 990
133	66.0	58 700	26 630
136	67.5	59 400	26 940
140	69.4	61 300	27 810



* RECOMMENDED PIN DIAMETER SHALL BE 2 in TO 3 in

SI EQUIVALENTS	
in	mm
2	51
3	76
6	152
18	457
48	1219

Figure D.2—Load Arrangement for the Slow Bend Test and Formula for Deriving the Modulus of Rupture

This page is intentionally blank.

Annex E (Informative)

Sample Forms

This annex is not part of AWS D15.2/D15.2M:2013, *Recommended Practices for the Welding of Rails and Related Rail Components for Use by Rail Vehicles*, but is included for informational purposes only.

Form E-1

Typical Welding Procedure Qualification Test Record

PROCEDURE SPECIFICATION

Base Material Description _____
 Welding Process _____
 Manual / Semiautomatic _____
 Position of Welding _____
 Filler Metal Description _____
 Filler Metal Chemical Composition _____
 Filler Metal AWS Classification _____
 Single or Multiple Pass _____
 Max/Min Base Metal Temperature _____
 Preheat Temperature _____
 Interpass Temperature _____
 Shielding Gas _____

EXAMINATION

Postheat Temperature _____
 Welding Current _____
 Welding Voltage _____
 Welder's Name _____

VISUAL INSPECTION OF WELD

Appearance _____
 Undercut _____
 Porosity _____
 Foreign Material Inclusion _____

ULTRASONIC EXAMINATION

UT Report No. _____

METALLOGRAPHY

Macroetch Size 1. _____ 2. _____
 Microetch detail _____

All Weld Metal Strength Details

Tensile Strength (psi) _____
 Yield Point Strength (psi) _____
 Elongation in 2 in, % _____
 Reduction in Area, % _____

WELDING PROCEDURE							
Pass No.	Electrode Size	Electrical Characteristics		Bead Size	Max Bead Length	Travel Speed	Weld Detail
		Amperes	Volts				

We the undersigned certify that the statements in this record are correct and that the test welds were prepared, welded, and tested in accordance with the requirements of AWS D15.2: (_____) year.

Procedure No. _____

Railroad or Contractor _____

Revision No. _____

Authorized by _____

Date _____

Form E-2**Typical Welder Performance Qualification Test Record**

Welder's Name _____ Welder's ID No. _____
 Welding Process _____ Manual _____ Semiautomatic _____ Machine _____
 Position _____
 In Accordance With Procedure Specification No. _____
 Material Specification _____
 Rail Size _____ Switch Point Size _____ Frog Size _____
 Description and Size of Other Material _____

FILLER METAL

Specification No. _____ Classification _____ F No. _____
 Describe Filler Metal (if not covered by AWS Specification) _____
 Filler Metal Chemical Composition _____
 Filler Metal Diameter _____ Is Backing Plate Used? _____

VISUAL INSPECTION

Appearance _____ Undercut _____ Porosity _____

ULTRASONIC INSPECTION

UT Method	Transducer Type	Result	Remarks

HARDNESS GRADIENT

Base Metal Hardness _____
 Filler Metal Hardness _____
 HAZ Hardness _____

METALLOGRAPHY EXAMINATION

Macroetch Size 1. _____ 2. _____ 3. _____ 4. _____
 Macroetch Detail _____
 Microetch Detail _____
 Test Authorized by _____ Test Witnessed by _____
 Test No. _____

We the undersigned certify that the statements in this record are correct and that the welds were prepared and tested in accordance with the requirements of AWS D15.2: (_____) year.

Railroad or Contractor _____
 Date _____

Annex F (Informative)

Guidelines for the Preparation of Technical Inquiries

This annex is not part of AWS D15.2/D15.2M: 2013. *Recommended Practices for the Welding of Rails and Related Rail components for Use by Rail Vehicles*, but is included for informational purposes only.

F1. Introduction

The American Welding Society (AWS) Board of Directors has adopted a policy whereby all official interpretations of AWS standards are handled in a formal manner. Under this policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is directed through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible, but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

F2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
8669 Doral Blvd., Suite 130
Doral, FL 33166

All inquiries shall contain the name, address, and affiliation of the inquirer, and they shall provide enough information for the committee to understand the point of concern in the inquiry. When the point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and in the format specified below.

F2.1 Scope. Each inquiry shall address one single provision of the standard unless the point of the inquiry involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the inquiry along with the edition of the standard that contains the provision(s) the inquirer is addressing.

F2.2 Purpose of the Inquiry. The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be to obtain an interpretation of a standard's requirement or to request the revision of a particular provision in the standard.

F2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to understand the point of the inquiry. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annex) that bear on the inquiry shall be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry shall provide technical justification for that revision.

F2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry or provide the wording for a proposed revision, if this is what the inquirer seeks.

F3. Interpretation of Provisions of the Standard

Interpretations of provisions of the standard are made by the relevant AWS technical committee. The secretary of the committee refers all inquiries to the chair of the particular subcommittee that has jurisdiction over the portion of the standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire committee for review and approval. Upon approval by the committee, the interpretation is an official interpretation of the Society, and the secretary transmits the response to the inquirer and to the *Welding Journal* for publication.

F4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal* and will be posted on the AWS web site.

F5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The AWS *Board Policy Manual* requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can be obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

F6. AWS Technical Committees

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees or to consideration of revisions to existing provisions on the basis of new data or technology. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on (1) specific engineering problems, (2) requirements of standards applied to fabrications outside the scope of the document, or (3) points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

List of AWS Documents on Railroad Welding

Designation	Title
D15.1/D15.1M	<i>Railroad Welding Specification for Cars and Locomotives</i>
D15.2/D15.2M	<i>Recommended Practices for the Welding of Rails and Related Components for Use by Rail Vehicles</i>

This page is intentionally blank.

