AWS G2.3M/G2.3:2019
An American National Standard

Guide for the Joining of Solid Solution Austenitic Stainless Steels

American Welding Society®

AWS G2.3M/G2.3:2019
An American National Standard

Approved by the
American National Standards Institute
August 16, 2018

Guide for the Joining of Solid Solution Austenitic Stainless Steels

3rd Edition

Supersedes AWS G2.3M/G2.3:2012

Prepared by the
American Welding Society (AWS) G2 Committee on Joining of Metals and Alloys

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This guide presents a description of solid solution austenitic stainless steels and the processes and procedures that can be used for the joining of these materials. This standard discusses the welding processes and welding parameters, qualifications, inspection and repair methods, cleaning, and safety considerations. Practical information has been included in the form of figures, tables, and graphs that should prove useful in determining capabilities and limitations in the joining of austenitic stainless steels.

American Welding Society®

ISBN Print: 978-1-64322-016-1
ISBN PDF: 978-1-64300-017-8
© 2018 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, Standards Development, 8669 NW 36 St, # 130, Miami, FL 33166 (see Annex G). With regard to technical inquiries made concerning AWS standards, oral opinions on AWS standards may be rendered. These opinions are offered solely as a convenience to users of this standard, and they do not constitute professional advice. Such opinions represent only the personal opinions of the particular individuals giving them. These individuals do not speak on behalf of AWS, nor do these oral opinions constitute official or unofficial opinions or interpretations of AWS. In addition, oral opinions are informal and should not be used as a substitute for an official interpretation.

This standard is subject to revision at any time by the AWS G2 Committee on Joining of Metals and Alloys. 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 G2 Committee on Joining of Metals and Alloys 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 G2 Committee on Joining of Metals and Alloys to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

This page is intentionally blank.

Foreword

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

The American Welding Society formed the G2 Committee on the Joining of Metals and Alloys in 1992 in response to an industry demand for information on welding the metals and alloys that have not been covered by other documents and committees. This document is written by the G2 Committee on the Joining of Metals and Alloys.

NOTE: The user's attention is called to the possibility that compliance with this standard may require use of an invention covered by patent rights.

By publication of this standard, no position is taken with respect to the validity of any such claim(s) or of any patent rights in connection therewith. If a patent holder has filed a statement of willingness to grant a license under these rights on reasonable and nondiscriminatory terms and conditions to applicants desiring to obtain such a license, then details may be obtained from the standards developer.

A vertical line in the margin or underlined text in clauses, tables, or figures indicates an editorial or technical change from the 2012 edition.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS G2 Committee on Joining of Metals and Alloys, American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

This page is intentionally blank.

Table of Contents

Page No.

Personnel v
Foreword vii
List of Tables xi
List of Figures xii

1. General Requirements 1
1.1 Scope 1
1.2 Units of Measure 1
1.3 Safety 1

2. Normative References 2

3. Terms and Definitions 2

4. General Information 4
4.1 History 4
4.2 Properties 8
4.3 Product Forms 8
4.4 Specifications 8

5. Metallurgy 15
5.1 Ferrite Discussion 15
5.2 The Ferrite-Sigma Phase Relationship 21
5.3 Corrosion Resistance Related to Welding 22
5.4 Heat Tint 23

6. Welding and Fabrication Considerations 24
6.1 Weld Joint Design 24
6.2 Cleaning Prior to Welding 25
6.3 Thermal Arc Gouging and Grinding 26
6.4 Distortion Control 27
6.5 Welding Preheat and Maximum Interpass Temperature 28
6.6 Welding Position 28
6.7 Root Pass Welding 28
6.8 Shielding Gas and Cleanliness 32

7. Weldability Considerations 32
7.1 Solidification Cracking 32
7.2 Reheat Cracking in Type 347-SS 33
7.3 Other Forms of Weld Cracking and Prevention Strategies 33
7.4 Reheat Cracking in FCAW Deposits 34

8. Welding Processes 34
8.1 Shielded Metal Arc Welding (SMAW) 34
8.2 Gas Tungsten Arc Welding (GTAW) 40
8.3 Gas Metal Arc Welding (GMAW) 44
8.4 Flux Cored Arc Welding (GCAW) 52
8.5 Submerged Arc Welding (SAW) 56
8.6 Plasma Arc Welding (PAW) 58

Page No.

8.7 Laser Beam Welding (LBW) and Electron Beam Welding (EBW) 59
8.8 Resistance Welding 59
8.9 Brazing 59

9. Postweld Operations 60
9.1 Visual Examination 60
9.2 Weld Size 60
9.3 Final Visual Examination 60
9.4 Weld Discontinuities 60
9.5 Slag Removal 61
9.6 Grinding and Finishing Techniques 61
9.7 Media Blasting 61
9.8 Cleaning, Pickling, and Passivation 62
9.9 Electropolishing 64

10. Heat Treatment 65
10.1 Solution Annealing 65
10.2 Stress Relief 65
10.3 Stabilization Anneal 66

11. Storage and Shipping Recommendations 67

12. Maintenance and Repair 67
12.1 Maintenance 67
12.2 Repair 68

Annex A (Informative)—Suggested Filler Metal Selection Chart 71
Annex B (Informative)—Informative References 79
Annex C (Informative)—ASTM Base Metal Specifications for Austenitic Stainless Steels 83
Annex D (Informative)—Estimating the Ferrite Content of Cast Base Materials 87
Annex E (Informative)—Engineering Terms, Common Conversions, and SMAW Electrode Diameters 89
Annex F (Informative)—Example Purchase Specification Topics 93
Annex G (Informative)—Requesting an Official Interpretation on an AWS Standard 95

List of AWS Documents on the Joining of Metals and Alloys 97

List of Tables

Table		Page No.
4.1	The Chemical Composition Limits of Common Wrought Austenitic Stainless Steel Base Materials	5
4.2	The Chemical Composition Limits of Common Cast Austenitic Stainless Steel Base Materials	9
4.3	Mechanical Properties of Wrought Annealed Stainless Steel Alloys	12
4.4	Minimum Mechanical Properties of Common Cast Austenitic Stainless Steel Base Materials	14
5.1	Ferrite Diagram Comparisons of Chrome and Nickel Equivalencies	19
6.1	Typical Physical Property Comparisons of Austenitic Stainless Steels versus Carbon Steels	27
6.2	Purging Guidelines for Piping	31
8.1	Chemical Composition of Undiluted SMAW Weld Deposits	35
8.2	All-Weld-Metal Mechanical Property Requirements Undiluted SMAW Weld Deposits (AWS A5.4/A5.4M)	37
8.3	SMAW Electrodes: Welding Current, Position of Welding, and Operating Characteristics	38
8.4	SMAW Electrodes: Suggested Current Ranges for E3xx-15, -16, and -17 Type Electrodes	39
8.5	Tungsten Amperage Limits, GTAW	41
8.6	Suggested Argon Torch Flow Rates, Manual GTAW	42
8.7	Suggested Gas Cup Size versus Maximum Welding Current, Manual GTAW	42
8.8	GTAW (TIG) Shielding Gas Selection	43
8.9	Chemical Compositions of Bare Stainless Steel Filler Metals (AWS A5.9/A5.9M) and of Metal Cored Filler Metal Deposits (AWS A5.22/A5.22M)	45
8.10	Nickel-Based Consumables, Chemical Composition Ranges	47
8.11	Nickel-Based SMAW Electrodes, Specified Tensile Properties	48
8.12	GMAW (MIG) Shielding Gas Selection	49
8.13	GMAW Parameters (Short Circuit, DCEP, He + 7.5%Ar + 2.5%CO_2 Shielding Gas)	50
8.14	GMAW Parameters (Spray Transfer, DCEP, 98%Ar + 2%O_2 Shielding Gas)	50
8.15	FCAW Electrodes Classification Scheme (AWS A5.22/A5.22M:2012)	52
8.16	Stainless Steel Weld Deposit Composition Requirements for FCAW Electrodes and Rods (AWS A5.22/A5.22M)	53
8.17	Stainless Steel Weld Deposit Tensile Requirements for Flux Cored Electrodes and Rods (AWS A5.22/A5.22M)	55
8.18	Shielding Gas Selection for Flux Cored Arc Welding	55
8.19	Typical Submerged Arc Welding Parameters, DCEP	58
A.1	Suggested Filler Metal Selection Chart—Wrought Standard Grades	73
A.2	Suggested Filler Metal Selection Chart—Wrought Proprietary Grades	76
A.3	Filler Selection for Stainless Steel Castings	77
E.1	Common Engineering Terms	89
E.2	Data	89
E.3	Common Welding-Related Conversion Factors	90

List of Figures

Figure **Page No.**

4.1 Alloying Variations of Common Austenitic Stainless Steels 7
5.1 The Schaeffler Diagram 16
5.2 The DeLong Diagram 17
5.3 WRC-1992 Diagram for Stainless Steel Weld Metal 18
5.4a Carbide Precipitation in Type 304 Austenitic Stainless Steel 23
5.4b Carbide Reaction Temperature Ranges 24
D.1 The Schoefer Diagram 87

Guide for the Joining of Solid Solution Austenitic Stainless Steels

1. General Requirements

1.1 Scope. This guide presents a description of solid solution austenitic stainless steels and the most commonly used welding processes and procedures for joining these materials. The most commonly used welding processes, including shielded metal arc welding (SMAW), gas tungsten arc welding (GTAW), gas metal arc welding (GMAW), submerged arc welding (SAW), and flux cored arc welding (FCAW), are discussed in detail; laser beam, electron beam, plasma arc, resistance, and braze welding are not covered in great detail.

The welding processes discussed in this guide include recommended welding parameters, filler metals, shielding gases, and fluxes. Procedure qualifications, inspection and repair considerations and methods, and cleaning and safety considerations are also discussed. Practical information has been included as figures, tables, and graphs that should prove useful for determining the capabilities and limitations in the joining of austenitic stainless steels. This guide does not address martensitic, ferritic, or duplex stainless steels.

Although this guide is not written with mandatory requirements, mandatory language, such as the use of "shall," will be found in those portions of the document where failure to follow the instructions or procedures could produce inferior, misleading, or unsafe results.

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

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

Safety and health information is available from the following sources:

American Welding Society:

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

(2) AWS Safety and Health Fact Sheets

(3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

(1) Safety Data Sheets supplied by materials manufacturers

(2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

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