

**AWS G2.3M/G2.3:2009**  
**An American National Standard**



# **Guide for the Joining of Wrought Solid Solution Austenitic Stainless Steels**



**American Welding Society**

---



**AWS G2.3M/G2.3:2009**  
**An American National Standard**

**Approved by the**  
**American National Standards Institute**  
**February 2, 2009**

# **Guide for the Joining of Wrought Solid Solution Austenitic Stainless Steels**

**1st Edition**

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 wrought 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**

550 N.W. LeJeune Road, Miami, FL 33126

## Foreword

This foreword is not part of AWS G2.3M/G2.3:2009, *Guide for the Joining of Wrought Solid Solution Austenitic Stainless Steels*, but is included for informational purposes only.

The American Welding Society formed the G2 Committee on Joining 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 Joining Metals and Alloys.

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS G2 Committee on Joining Metals and Alloys, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

# Table of Contents

|   | <b>Page No.</b> |
|---|-----------------|
| <i>Personnel</i> .....                                      | v               |
| <i>Foreword</i> .....                                       | vii             |
| <i>List of Tables</i> .....                                 | xi              |
| <i>List of Figures</i> .....                                | xi              |
| <b>1. Scope</b> .....                                       | <b>1</b>        |
| <b>2. Normative References</b> .....                        | <b>1</b>        |
| <b>3. Terms and Definitions</b> .....                       | <b>2</b>        |
| <b>4. General Information</b> .....                         | <b>3</b>        |
| 4.1 Alloy Description .....                                 | 3               |
| 4.2 Properties .....  | 5               |
| 4.3 Product Forms .....                                     | 5               |
| 4.4 Specifications .....                                    | 5               |
| <b>5. Metallurgy</b> .....                                  | <b>5</b>        |
| 5.1 Ferrite Discussion .....                                | 5               |
| 5.2 Sigma Phase .....                                       | 14              |
| 5.3 Corrosion Resistance Related to Welding .....           | 14              |
| 5.4 Heat Tint .....   | 16              |
| 5.5 Elevated Temperature Performance .....                  | 17              |
| <b>6. Welding and Fabrication Considerations</b> .....      | <b>19</b>       |
| 6.1 Weld Joint Design .....                                 | 19              |
| 6.2 Cleaning Prior to Welding .....                         | 20              |
| 6.3 Thermal Arc Gouging and/or Grinding .....               | 21              |
| 6.4 Distortion Control .....                                | 22              |
| 6.5 Welding Preheat and Maximum Interpass Temperature ..... | 22              |
| 6.6 Welding Position .....                                  | 22              |
| 6.7 Root Pass Welding .....                                 | 22              |
| 6.8 Shielding Gas and Cleanliness .....                     | 23              |
| 6.9 Copper Contamination .....                              | 23              |
| 6.10 Fixtures and Fitting Devices .....                     | 23              |
| <b>7. Weldability Considerations</b> .....                  | <b>23</b>       |
| 7.1 Solidification Cracking and Prevention .....            | 23              |
| 7.2 Ferrite in Consumables .....                            | 23              |
| 7.3 Various Effects of Sulfur .....                         | 24              |
| 7.4 Reheat Cracking in Type 347-SS .....                    | 24              |
| 7.5 Welding Techniques to Minimize Weld Cracking .....      | 24              |
| <b>8. Welding Processes</b> .....                           | <b>24</b>       |
| 8.1 Shielded Metal Arc Welding (SMAW) .....                 | 24              |
| 8.2 Gas Tungsten Arc Welding (GTAW) .....                   | 28              |
| 8.3 Gas Metal Arc Welding (GMAW) .....                      | 34              |
| 8.4 Flux Core Arc Welding (FCAW) .....                      | 42              |
| 8.5 Submerged Arc Welding (SAW) .....                       | 46              |

|   |           |
|---|-----------|
| 8.6 Plasma Arc Welding (PAW).....   | 49        |
| 8.7 Laser Beam Welding (LBW) and Electron Beam Welding (EBW).....   | 49        |
| 8.8 Resistance Welding .....  | 49        |
| 8.9 Brazing .....   | 49        |
| <b>9. Postweld Operations.....</b>  | <b>50</b> |
| 9.1 Visual Inspection.....  | 50        |
| 9.2 Weld Size .....   | 50        |
| 9.3 Final Visual Inspection .....   | 50        |
| 9.4 Weld Discontinuities.....   | 50        |
| 9.5 Slag Removal .....  | 51        |
| 9.6 Grinding and Finishing .....  | 51        |
| 9.7 Media Blasting .....  | 51        |
| 9.8 Cleaning, Pickling, and Passivation .....   | 52        |
| 9.9 Electropolishing .....  | 54        |
| <b>10. Heat Treatment.....</b>  | <b>54</b> |
| 10.1 Solution Annealing .....   | 54        |
| 10.2 Stress Relief .....  | 55        |
| 10.3 Stabilization Anneal.....  | 55        |
| <b>11. Storage and Shipping Recommendations .....</b>   | <b>55</b> |
| <b>12. Maintenance and Repair .....</b>   | <b>55</b> |
| 12.1 Maintenance.....   | 55        |
| 12.2 Repair.....  | 56        |
| Annex A (Informative)—Suggested Filler Metal Selection Chart .....  | 59        |
| Annex B (Informative)—Informative References .....  | 65        |
| Annex C (Informative)—ASTM International Material Standards for Wrought Austenitic Stainless Steels ..... | 67        |
| Annex D (Informative)—Engineering Terms, Common Conversions, and SMAW Electrode Diameters .....           | 69        |
| Annex E (Informative)—Guidelines for the Preparation of Technical Inquiries .....                         | 74        |
| List of AWS Documents on Joining Metals and Alloys.....   | 75        |

## List of Tables

| Table | Page No.   |
|-------|--|
| 1     | The Chemical Composition Limits of Most Common Austenitic Stainless Steel Base Materials.....6 |
| 2     | Mechanical Properties of Annealed Stainless Steel Alloys .....8                                |
| 3     | Ferrite Diagram Comparisons of Chrome and Nickel Equivalence..... 12                           |
| 4     | Typical Physical Properties ..... 19   |
| 5     | Chemical Analysis of Stainless Steel SMAW Electrodes.....26                                    |
| 6     | AWS A5.4/A5.4M SMAW Electrodes.....28  |
| 7     | SMAW Welding Current, Position of Welding, and Characteristics .....28                         |
| 8     | SMAW, Suggested Amperage Ranges for E3xx-15, -16, and -17 Type Electrodes .....29              |
| 9     | Suggested Welding Parameters, Manual GTAW .....30  |
| 10    | Suggested Argon Flow Rates, Manual GTAW .....30  |
| 11    | Suggested Gas Cup Size versus Maximum Welding Amperage Manual GTAW .....30                     |
| 12    | GTAW (TIG) Shielding Gas Selection, Austenitic Stainless Steels ..... 31                       |
| 13    | Purging Piping ..... 33  |
| 14    | Chemical Compositions of Filler Metals .....36   |
| 15    | GMAW (MIG) Shielding Gas Selection, Austenitic Stainless Steels.....38                         |
| 16    | GMAW Parameters (Short Circuit, DCEP, He + 7.5%Ar + 2.5%CO <sub>2</sub> Shielding Gas) .....39 |
| 17    | GMAW Parameters (Spray Transfer, DCEP, 98%Ar + 2%O <sub>2</sub> Shielding Gas) .....39         |
| 18    | AWS A5.22-95 (R2005) Classification Scheme for FCAW Electrodes .....42                         |
| 19    | Chemical Composition Requirements for Undiluted FCAW Weld Metal.....43                         |
| 20    | AWS A5.22 FCAW Electrodes and Rods .....45   |
| 21    | Shielding Gas Selection for Flux Core Arc Welding Austenitic Stainless Steels.....45           |
| 22    | Typical Submerged Arc Welding Parameters, DCEP .....48   |
| A.1   | Suggested Filler Metal Selection Chart—Standard Grades..... 61                                 |
| A.2   | Suggested Filler Metal Selection Chart—Proprietary Grades .....64                              |
| D.1   | Common Engineering Terms .....69   |
| D.2   | Data .....69   |
| D.3   | Common Welding-Related Conversion Factors.....70   |

## List of Figures

| Figure | Page No.  |
|--------|---|
| 1      | Alloying Variations of Common Austenitic Stainless Steels.....4                                       |
| 2      | The Schaeffler Diagram .....9   |
| 3      | The DeLong Diagram ..... 11   |
| 4      | WRC-1992 Diagram for Stainless Steel Weld Metal ..... 12  |
| 5A     | Carbide Precipitation in Type 304 Austenitic Stainless Steel..... 15                                  |
| 5B     | Carbide Reaction Temperature Ranges..... 16   |
| 6      | The Effects of Chromium and Nickel on the Oxidation Resistance of Steels and Stainless Steels..... 18 |
| 7      | Waveform Components and Arc and Burn-Off Rate .....41   |

# Guide for the Joining of Wrought Solid Solution Austenitic Stainless Steels

## 1. Scope

This guide presents a description of wrought 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 core 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, duplex stainless steels, or cast stainless steels.

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.

Safety and health issues may not be fully addressed by this standard. Users of this standard should consult ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, applicable federal, state, and local regulations, and other relevant documents concerning safety and health issues not addressed herein. Additional information is available via the AWS Safety and Health Fact Sheets—available for free at [www.aws.org](http://www.aws.org). Material Safety Data Sheets (MSDSs) are available through the material suppliers; they provide information on the health and safety precautions associated with the materials and processes discussed within this document.

## 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) standards:<sup>1</sup>

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

AWS A4.2M:2006 (ISO 8249:2000 MOD), *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*;

AWS A5.4/A5.4M, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*;

AWS A5.8/A5.8M, *Specification for Filler Metals for Brazing and Braze Welding*;

AWS A5.9/A5.9M, *Specification for Bare Stainless Steel Welding Electrodes and Rods*;

AWS A5.12/A5.12M, *Specification for Tungsten and Tungsten Alloy Electrodes for Arc Welding*;

AWS A5.22, *Specification for Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding*;

AWS A5.32/A5.32M, *Specification for Welding Shielding Gas*; and

AWS A5.34/A5.34M:2007, *Specification for Nickel-Alloy Electrodes for Flux Cored Arc Welding*.

<sup>1</sup> AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.