

ANSI/AWS A5.9-93
An American National Standard

Specification for Bare Stainless Steel Welding Electrodes and Rods



American Welding Society

Keywords — composite electrodes, metal cored electrodes, stainless steel strips, bare stainless steel electrodes, bare stainless steel rods, duplex stainless steel electrodes

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Specification for Bare Stainless Steel Welding Electrodes and Rods

Superseding ANSI/AWS A5.9-81

Prepared by
AWS Committee on Filler Metal

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

The classification and other requirements for more than forty-five bare stainless steel electrodes (solid and composite), rods, and strips are specified, including a number of duplex alloys previously unclassified.



American Welding Society

550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135

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* Advisor

**Deceased

Foreword

(This Foreword is not a part of ANSI/AWS A5.9-93, *Specification for Bare Stainless Steel Electrodes and Rods*, but is included for information purposes only.)

The first specification for bare stainless steel electrodes and rods was prepared in 1953 by a joint committee of the American Society for Testing and Materials and the American Welding Society. The joint committee also prepared the 1962 revision. The first revision prepared exclusively by the AWS Filler Metal Committee was published in 1969. The current revision is the sixth revision and expansion as shown below:

ASTM A371-53T AWS A5.9-53T	<i>Tentative Specifications for Corrosion-Resisting Chromium and Chromium-Nickel Steel Rods and Bare Electrodes</i>
AWS A5.9-62T ASTM A371-62T	<i>Tentative Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes</i>
AWS A5.9-69 ANSI W3.9-1973	<i>Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Rods and Bare Electrodes</i>
AWS A5.9—Add 1-75	<i>1975 Addenda to Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes</i>
AWS A5.9-77	<i>Specification for Corrosion Resisting Chromium and Chromium-Nickel Steel Bare and Composite Metal Cored and Stranded Arc Welding Electrodes and Welding Rods</i>
AWS A5.9-81	<i>Specification for Corrosion Resisting Chromium and Chromium-Nickel Steel Bare and Composite Metal Cored and Stranded Welding Electrodes and Welding Rods</i>

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Managing Director, Technical Services Division, American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.

Official interpretations of any of the technical requirements of this standard may be obtained by sending a request, in writing, to the Managing Director, Technical Services Division, American Welding Society. A formal reply will be issued after it has been reviewed by the appropriate personnel following established procedures.

Table of Contents

	Page No.
<i>Personnel</i>	iii
<i>Foreword</i>	v
<i>List of Tables</i>	vii
<i>List of Figures</i>	vii
1. Scope	1
<i>Part A — General Requirements</i>	
2. Classification	1
3. Acceptance	1
4. Certification	1
5. Units of Measure and Rounding-Off Procedure	1
<i>Part B — Tests, Procedures, and Requirements</i>	
6. Summary of Tests	4
7. Retest	4
8. Chemical Analysis	4
<i>Part C — Manufacture, Identification, and Packaging</i>	
9. Method of Manufacture	4
10. Standard Sizes and Shapes	4
11. Finish and Uniformity	4
12. Standard Package Forms	6
13. Winding Requirements	6
14. Filler Metal Identification	8
15. Packaging	8
16. Marking of Packages	8
<i>Appendix — Guide to Specification for Bare Stainless Steel Welding Electrodes and Rods</i>	
A1. Introduction	9
A2. Classification System	9
A3. Acceptance	10
A4. Certification	10
A5. Preparation of Samples for Chemical Analysis	10
A6. Ventilation During Welding	11
A7. Ferrite in Weld Deposits	11
A8. Description and Intended Use of Filler Metals	13
A9. Usability	20
A10. Special Tests	21
A11. Safety Considerations	21
<i>AWS Filler Metal Specifications and Related Documents</i>	(Inside Back Cover)

List of Tables

Table	Page No.
1 Chemical Composition Requirements	2
2 Standard Wire Sizes of Electrodes and Rods	5
3 Standard Sizes of Strip Electrodes	6
4 Standard Package Dimensions and Weights	6
A1 Variations of Alloying Elements for Submerged Arc Welding	12
A2 Tensile Requirements for All-Weld-Metal from ANSI/AWS A5.4-92	22

List of Figures

Figure	Page No.
1 Standard 4 in. (100 mm) Diameter Spool Dimensions	7
2 Standard 8 and 12 in. (200 and 300 mm) Diameter Spool Dimensions	7
A1 WRC-1988 Diagram for Stainless Steel Weld Metal	14
A2 Espy Percent Ferrite Diagram for Stainless Steel Weld Metal	14
A3 DeLong (FN) Diagram for Stainless Steel Weld Metal	15

Specification for Bare Stainless Steel Welding Electrodes and Rods

1. Scope

This specification prescribes requirements for the classification of bare stainless steel wire, strip, composite metal cored, and stranded welding electrodes and rods. The chromium content of these filler metals is not less than 10.5 percent and the iron content exceeds that of any other element.¹ For purposes of classification, the iron content shall be derived as the balance element when all other elements are considered to be at their minimum specified values.

Part A General Requirements

2. Classification

2.1 The welding materials covered by this specification are classified according to chemical composition (see Table 1).

2.2 Materials may be classified under more than one classification provided they meet all the requirements of those classifications as specified in Table 1.

1. This revision still contains information on ER502, ER505, EC502, and EC505 classifications. These classifications also will be included in the next revision of ANSI/AWS A5.28, *Specification for Low Alloy Steel Electrodes for Gas Metal Arc Welding*. These four classifications will be deleted from the first revision of ANSI/AWS A5.9 following the publication of the revised ANSI/AWS A5.28 specification.

3. Acceptance

Acceptance² of the material shall be in accordance with the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.³

4. Certification

By affixing the AWS specification and classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.⁴

5. Units of Measure and Rounding-Off Procedure

5.1 U.S. customary units are the standard units of measure in this specification. The SI units are given as equivalent values to the U.S. customary units. The standard sizes and dimensions in the two systems are not identical and, for this reason, conversion from a standard size or dimension in one system will not always coincide with a standard size or dimension in the other. Suitable

2. See A3. Acceptance (in the Appendix) for further information concerning acceptance, testing of the material shipped, and ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.

3. AWS standards can be obtained from the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.

4. See A4. Certification (in the Appendix) for further information concerning certification and the testing called for to meet this requirement.

Table 1
Chemical Composition Requirements

Composition, Wt % ^{a,b}											Other Elements		
AWS Classification ^a	UNS Number ^b	C	Cr	Ni	Mo	Mn	Si	P	S	N	Cu	Element	Amount
ER209	S20980	0.05	20.5-24.0	9.5-12.0	1.5-3.0	4.0-7.0	0.90	0.03	0.03	0.10-0.30	0.75	V	0.10-0.30
ER218	S21880	0.10	16.0-18.0	8.0-9.0	0.75	7.0-9.0	3.5-4.5	0.03	0.03	0.08-0.18	0.75	—	—
ER219	S21980	0.05	19.0-21.5	5.5-7.0	0.75	8.0-10.0	1.00	0.03	0.03	0.10-0.30	0.75	—	—
ER240	S24080	0.05	17.0-19.0	4.0-6.0	0.75	10.5-13.5	1.00	0.03	0.03	0.10-0.30	0.75	—	—
ER307	S30780	0.04-0.14	19.5-22.0	8.0-10.7	0.5-1.5	3.3-4.75	0.30-0.65	0.03	0.03	—	0.75	—	—
ER308	S30880	0.08	19.5-22.0	9.0-11.0	0.75	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER308H	S30880	0.04-0.08	19.5-22.0	9.0-11.0	0.50	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER308L	S30883	0.03	19.5-22.0	9.0-11.0	0.75	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER308LMo	S30882	0.08	18.0-21.0	9.0-12.0	2.0-3.0	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER308Si	S30881	0.04	18.0-21.0	9.0-12.0	2.0-3.0	1.0-2.5	0.65-1.00	0.03	0.03	—	0.75	—	—
ER308LSi	S30888	0.03	19.5-22.0	9.0-11.0	0.75	1.0-2.5	0.65-1.00	0.03	0.03	—	0.75	—	—
ER309	S30980	0.12	23.0-25.0	12.0-14.0	0.75	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER309L	S30983	0.03	23.0-25.0	12.0-14.0	0.75	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER309Mo	S30982	0.12	23.0-25.0	12.0-14.0	2.0-3.0	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER309LMo	S30986	0.03	23.0-25.0	12.0-14.0	2.0-3.0	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER309Si	S30981	0.12	23.0-25.0	12.0-14.0	0.75	1.0-2.5	0.65-1.00	0.03	0.03	—	0.75	—	—
ER309LSi	S30988	0.03	23.0-25.0	12.0-14.0	0.75	1.0-2.5	0.65-1.00	0.03	0.03	—	0.75	—	—
ER310	S31080	0.08-0.15	25.0-28.0	20.0-22.5	0.75	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER312	S31380	0.15	28.0-32.0	8.0-10.5	0.75	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER316	S31680	0.08	18.0-20.0	11.0-14.0	2.0-3.0	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER316H	S31680	0.04-0.08	18.0-20.0	11.0-14.0	2.0-3.0	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER316L	S31683	0.03	18.0-20.0	11.0-14.0	2.0-3.0	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER316Si	S31681	0.08	18.0-20.0	11.0-14.0	2.0-3.0	1.0-2.5	0.65-1.00	0.03	0.03	—	0.75	—	—
ER316LSi	S31688	0.03	18.0-20.0	11.0-14.0	2.0-3.0	1.0-2.5	0.65-1.00	0.03	0.03	—	0.75	—	—
ER317	S31780	0.08	18.5-20.5	13.0-15.0	3.0-4.0	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER317L	S31783	0.03	18.5-20.5	13.0-15.0	3.0-4.0	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER318	S31980	0.08	18.0-20.0	11.0-14.0	2.0-3.0	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	8 × C min/1.0 max
ER320	N08021	0.07	19.0-21.0	32.0-36.0	2.0-3.0	2.5	0.60	0.03	0.03	—	3.0-4.0	C ^b	8 × C min/1.0 max
ER320LR	N08022	0.025	19.0-21.0	32.0-36.0	2.0-3.0	2.5	0.60	0.03	0.03	—	3.0-4.0	C ^b	8 × C min/0.40 max
ER321	S32180	0.08	18.5-20.5	9.0-10.5	0.75	1.0-2.5	0.30-0.65	0.015	0.02	—	0.75	Ti	9 × C min/1.0 max
ER330	N08331	0.18-0.25	15.0-17.0	34.0-37.0	0.75	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	—	—
ER347	S34780	0.08	19.0-21.5	9.0-11.0	0.75	1.0-2.5	0.30-0.65	0.03	0.03	—	0.75	C ^b	10 × C min/1.0 max
ER347Si	S34788	0.08	19.0-21.5	9.0-11.0	0.75	1.0-2.5	0.65-1.00	0.03	0.03	—	0.75	C ^b	10 × C min/1.0 max
ER383	N08028	0.025	26.5-28.5	30.0-33.0	3.2-4.2	1.0-2.5	0.50	0.02	0.03	—	0.70-1.5	—	—
ER385	N08904	0.025	19.5-21.5	24.0-26.0	4.2-5.2	1.0-2.5	0.50	0.02	0.03	—	1.2-2.0	—	—
ER409	S40900	0.08	10.5-13.5	0.6	0.50	0.8	0.8	0.03	0.03	—	0.75	Ti	10 × C min/1.5 max
ER409Cb	S40940	0.08	10.5-13.5	0.6	0.50	0.8	1.0	0.04	0.03	—	0.75	C ^b	10 × C min/0.75 max
ER410	S41080	0.12	11.5-13.5	0.6	0.75	0.6	0.5	0.03	0.03	—	0.75	—	—
ER410NiMo	S41086	0.06	11.0-12.5	4.0-5.0	0.4-0.7	0.6	0.5	0.03	0.03	—	0.75	—	—

Table 1 (Continued)

AWS Classification ^c	UNS Number ^d	Composition, Wt % ^{a,b}										Other Elements	
		C	Cr	Ni	Mo	Mn	Si	P	S	N	Cu	Element	Amount
ER420	S42080	0.25-0.40	12.0-14.0	0.6	0.75	0.6	0.5	0.03	0.03	—	0.75	—	—
ER430	S43080	0.10	15.5-17.0	0.6	0.75	0.6	0.5	0.03	0.03	—	0.75	—	—
ER446LMo	S44687	0.015	25.0-27.5	—	0.75-1.50	0.4	0.4	0.02	0.02	0.015	—	—	—
ER502 ^e	S50280	0.10	4.6-6.0	0.6	0.45-0.65	0.6	0.5	0.03	0.03	—	—	—	—
ER505 ^e	S50480	0.10	8.0-10.5	0.5	0.8-1.2	0.6	0.5	0.03	0.03	—	0.75	—	—
ER630	S17480	0.05	16.0-16.75	4.5-5.0	0.75	0.25-0.75	0.75	0.03	0.03	—	3.25-4.00	—	0.15-0.30
ER19-10H	S30480	0.04-0.08	18.5-20.0	9.0-11.0	0.25	1.0-2.0	0.30-0.65	0.03	0.03	—	0.75	—	0.05
ER16-8-2	S16880	0.10	14.5-16.5	7.5-9.5	1.0-2.0	1.0-2.0	0.30-0.65	0.03	0.03	—	0.75	—	0.05
ER2209	S39209	0.03	21.5-23.5	7.5-9.5	2.5-3.5	0.50-2.0	0.90	0.03	0.03	0.08-0.20	0.75	—	—
ER2553	S39553	0.04	24.0-27.0	4.5-6.5	2.9-3.9	1.5	1.0	0.04	0.03	0.10-0.25	1.5-2.5	—	—
ER3556	R30556	0.05-0.15	21.0-23.0	19.0-22.5	2.5-4.0	0.50-2.00	0.20-0.80	0.04	0.015	0.10-0.30	—	Co	16.0-21.0
												W	2.0-3.5
												Cb	0.30
												Ta	0.30-1.25
												Al	0.10-0.50
												Zr	0.001-0.10
												La	0.005-0.10
												B	0.02

Notes:

- Analysis shall be made for the elements for which specific values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total, excluding iron, does not exceed 0.50 percent.
- Single values shown are maximum percentages.
- In the designator for composite, stranded, and strip electrodes, the "R" shall be deleted. A designator "C" shall be used for composite and stranded electrodes and a designator "Q" shall be used for strip metal cored or stranded electrode and may not have the same UNS number. Consult ASTM/SAE Uniform Numbering System for the proper UNS Number.
- For special applications, electrodes and rods may be purchased with less than the specified silicon content.
- ASTM/SAE Unified Numbering System for Metals and Alloys.
- Nickel + copper equals 0.5 percent maximum.
- Cr(Nb) may be reported as Cr(Nb) + Ta.
- These classifications also will be included in the next revision of ANSI/AWS A5.28, *Specification for Low Alloy Steel Filler Metals for Gas Shielded Metal Arc Welding*. They will be deleted from ANSI/AWS A5.9 in the first revision following publication of the revised ANSI/AWS A5.28 document.

conversions, encompassing standard sizes of both can be made, however, if appropriate tolerances are applied in each case.

5.2 For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the "nearest unit" in the last right-hand place of figures used in expressing the limiting value in accordance with the rounding-off method given in ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.⁵

Part B

Tests, Procedures, and Requirements

6. Summary of Tests

6.1 Chemical analysis of the solid electrode, rod, or strip is the only test required for classification of the product forms under this specification.

6.2 Chemical analysis of a fused sample of composite or stranded electrode or rod is the only test required for classification of these product forms under this specification.

7. Retest

If the results of the test fail to meet the requirement, the test shall be repeated twice. The results of both retests shall meet the requirement. Material for retest may be taken from the original sample or from a new sample, provided the material is from the same heat or lot. For chemical analysis, retest need be only for those specific elements which failed to meet the test requirement.

8. Chemical Analysis

8.1 A sample of the filler metal or a fused sample shall be prepared for analysis (for example, see Section A5, *Preparation of Samples for Chemical Analysis*).

8.2 The sample shall be analyzed by acceptable analytical methods capable of determining whether the composition meets the requirements of this specification. In case of dispute, the referee method shall be ASTM

5. ASTM standards can be obtained from American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

Standard Method E353, *Chemical Analysis of Stainless, Heat Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys*.

8.3 The results of the analysis shall meet the requirements of Table 1 for the classification of the filler metal under test.

Part C

Manufacture, Identification, and Packaging

9. Method of Manufacture

The welding rods, strip, and electrodes classified according to this specification may be manufactured by any method that will produce material that meets the requirements of this specification.

10. Standard Sizes and Shapes

10.1 Standard sizes of filler metal (except strip electrodes) in the different package forms (straight lengths, coils with support, coils without support, and spools) shall be as shown in Table 2.

10.2 Standard sizes for strip electrodes in coils shall be as shown in Table 3.

11. Finish and Uniformity

11.1 All filler metal shall have a smooth finish that is free from slivers, depressions, scratches, scale, seams, laps (exclusive of the longitudinal joint in metal cored filler metal) and foreign matter that would adversely affect the welding characteristics, the operation of the welding equipment, or the properties of the weld metal.

11.2 Each continuous length of filler metal shall be from a single heat or lot of material and welds, when present, shall have been made so as not to interfere with the uniform, uninterrupted feeding of the filler metal on automatic and semiautomatic equipment.

11.3 Core ingredients in metal cored filler metal shall be distributed with sufficient uniformity throughout the length of the electrode so as not to adversely affect the performance of the electrode or the properties of the weld metal.

11.4 The slit edges of strip electrodes shall be free from burrs exceeding five percent of the strip thickness.

Table 2
Standard Wire Sizes of Electrodes and Rods^a

Form	Diameter			Tolerance			
				Solid		Composite	
	in.	mm		in.	mm	in.	mm
Welding rods in straight lengths ^b	0.045		1.1	±0.001	±0.03	±0.002	±0.05
	1/16	(0.063)	1.6				
	5/64	(0.078)	2.0				
	3/32	(0.094)	2.4	±0.002	±0.05	±0.003	±0.05
	1/8	(0.125)	3.2				
	5/32	(0.156)	4.0				
	3/16	(0.187)	4.8				
Filler metals in coils with or without support	0.045		1.1	±0.001	±0.03	±0.002	±0.05
	1/16	(0.063)	1.6				
	5/64	(0.078)	2.0				
	3/32	(0.094)	2.4				
	7/64	(0.109)	2.8	±0.002	±0.05	±0.002	±0.08
	1/8	(0.125)	3.2				
	5/32	(0.156)	4.0				
	3/16	(0.187)	4.8				
	1/4	(0.250)	6.4				
Filler metal wound on 8 or 12 in. (200 or 300 mm) O.D. spools	0.030		0.8				
	0.035		0.9	±0.001	±0.03	±0.002	±0.05
	0.045		1.1				
	1/16	(0.063)	1.6				
	5/64	(0.078)	2.0	±0.002	±0.05	±0.003	±0.08
	3/32	(0.094)	2.4				
	7/64	(0.109)	2.8				
Filler metal wound on 4 in. (100 mm) O.D. spools	0.020		0.5				
	0.025		0.6				
	0.030		0.8	±0.001	±0.03	±0.002	±0.05
	0.035		0.9				
	0.045		1.1				

Notes:

a. Dimension, tolerances, and package forms other than those shown shall be as agreed upon between purchaser and supplier.

b. Length shall be 36 in. +0, -1/2 in. (900 mm + 15, -0 mm)

Table 3
Standard Sizes of Strip Electrodes^{a, b}

Width		Thickness	
in.	mm	in.	mm
1.18	30	0.020	0.5
2.36	60	0.020	0.5
3.54	90	0.020	0.5
4.72	120	0.020	0.5

Notes:

- a. Other sizes shall be as agreed upon between purchaser and supplier.
 b. Strip electrodes shall not vary more than ± 0.008 in. (± 0.20 mm) in width and more than ± 0.002 in. (± 0.05 mm) in thickness.

12. Standard Package Forms

12.1 Standard package forms are straight lengths, coils with support, coils without support, and spools. Standard package dimensions and weights for each form are shown in Table 4.

12.2 Package forms, sizes, and weights other than those shown in Table 4 shall be as agreed between purchaser and supplier.

12.3 The liners in coils with support shall be designed and constructed to prevent distortion of the coil during normal handling and use, and shall be clean and dry enough to maintain the cleanliness of the filler metal.

12.4 Spools shall be designed and constructed to prevent distortion of the filler metal during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal (see Figures 1 and 2).

12.5 Net weights shall be within ± 10 percent of the nominal weight.

13. Winding Requirements

13.1 The filler metal shall be wound so that kinks, waves, sharp bends, or wedging are not encountered, leaving the filler metal free to unwind without restriction. The outside end of the filler metal (the end with which welding is to begin) shall be identified so it can be readily located and shall be fastened to avoid unwinding.

13.2 The cast and helix of all filler metal in coils and spools shall be such that the filler metal will feed in an uninterrupted manner in automatic and semiautomatic equipment.

13.3 The cast and helix of drawn, solid filler metal on 4 in. (100 mm) spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

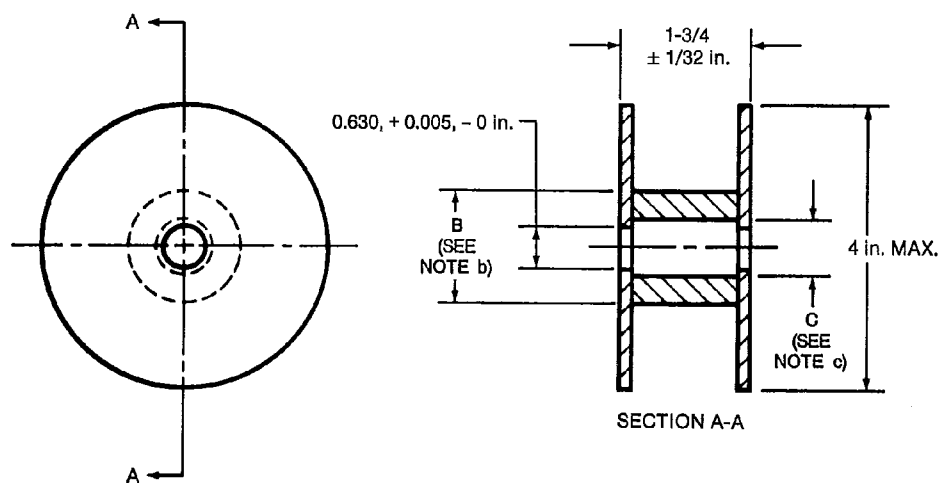
- (1) Form a circle not less than 2.5 in. (65 mm) nor more than 15 in. (380 mm) in diameter

Table 4
Standard Package Dimensions and Weights^a

Product Form	Spool or Coil Diameter ^b		Strip Width ^b		Nominal Weight	
	in.	mm	in.	mm	lbs	kg
Welding Rods in Straight Lengths	NA	NA	NA	NA	10, 50	4.5, 23
Spools	4	100	NA	NA	1-1/2, 2-1/2	0.7, 1.1
	8	200	NA	NA	10	4.5
	12	300	NA	NA	25	11.4
	14	350	NA	NA	50	22.8
Coil with Support ^c	12	300	NA	NA	25, 50, 60	11, 23, 27
Strip Electrode	12	300	1.18	30	60	27.5
	12	300	2.36	60	60	27.5
	12	300	3.54	90	120	55
	12	300	4.72	120	120	55

Notes:

- a. Net weights shall be within $\pm 10\%$ of the nominal weight.
 b. NA is "not applicable".
 c. Weight of coils without support shall be as specified by the purchaser.



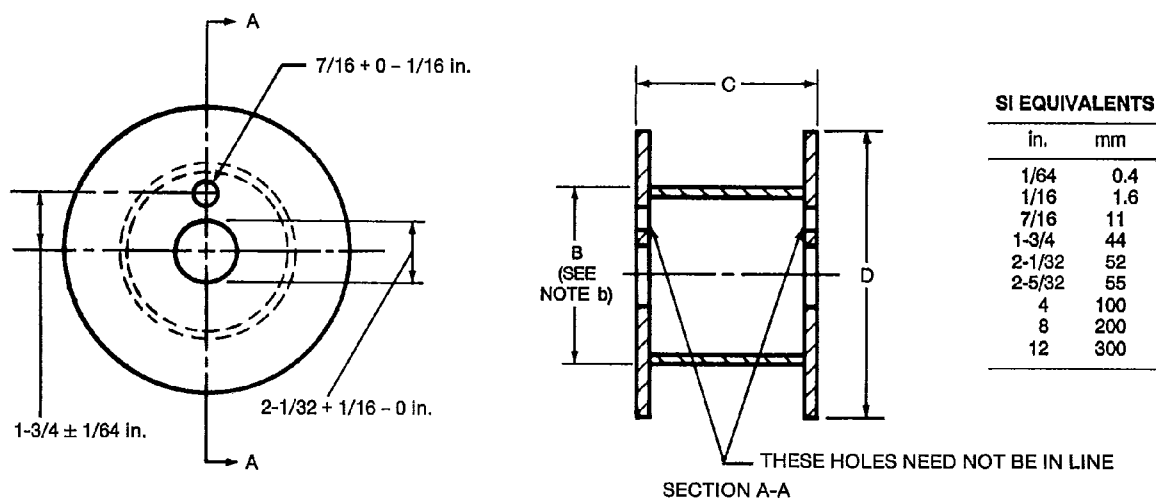
SI EQUIVALENTS

in.	mm
0.005	0.13
1/32	0.8
0.630	16
1-3/4	45
4	102

Notes:

- All dimensions are in inches.
- Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the filler metals.
- Dimension C, inside diameter of barrel, shall be such that swelling of the barrel or misalignment of the barrel and flanges will not result in the inside diameter of the barrel being less than the inside diameter of the flanges.

Figure 1—Standard 4 in. (100 mm) Diameter Spool Dimensions



SI EQUIVALENTS

in.	mm
1/64	0.4
1/16	1.6
7/16	11
1-3/4	44
2-1/32	52
2-5/32	55
4	100
8	200
12	300

Notes:

- All dimensions are in inches.
- Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the filler metals.

Figure 2—Standard 8 and 12 in. (200 and 300 mm) Diameter Spool Dimensions

Dimensions, in.		
Spool size	C	D, maximum
8	2-5/32 ± 1/32	8
12	4 ± 1/16	12

(2) Rise above the flat surface no more than 1/2 in. (13 mm) at any location

13.4 The cast and helix of drawn solid filler metal on 8 in. (200 mm) spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

(1) Form a circle not less than 8 in. (200 mm) nor more than 50 in. (1.3 m) in diameter

(2) Rise above the flat surface no more than 1 in. (25 mm) at any location

13.5 The cast and helix of drawn, solid filler metal on 12 in. and 14 in. (300 and 350 mm) spools shall be such that a specimen long enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will do the following:

(1) Form a circle not less than 15 in. (380 mm) in diameter and not more than 50 in. (1.3 m) in diameter

(2) Rise above the flat surface no more than 1 in. (25 mm) at any location

13.6 The edge of the strip electrodes (camber) shall not deviate from a straight line by more than 0.5 in. (12.5 mm) in any 8 ft. (2.5 m) in length.

14. Filler Metal Identification

14.1 The product information and the precautionary information required in Section 16, Marking of Packages, shall also appear on each coil and each spool.

14.2 Coils without support shall have a tag containing this information securely attached to the inside end of the coil.

14.3 Coils with support shall have the information securely affixed in a prominent location on the support.

14.4 Spools shall have the information securely affixed in a prominent location on the outside of one flange of the spool.

14.5 Identification of each straight length welding rod is not required by this specification but may be done as agreed upon between the purchaser and supplier.

15. Packaging

Filler metal shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

16. Marking of Packages

16.1 The following product information (as a minimum) shall be legibly marked so as to be visible from the outside of each unit package:

- (1) AWS specification and classification number (year of issue may be excluded)
- (2) Supplier's name and trade designation
- (3) Size and net weight
- (4) Lot, control, or heat number

16.2 The following precautionary information (as a minimum) shall be prominently displayed in legible print on all packages of welding material, including individual unit packages enclosed within a larger package:

WARNING

Protect yourself and others.

Read and understand this information.

FUMES AND GASES can be dangerous to your health.

ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can kill.

- Before use, read and understand the manufacturer's instructions, Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch live electrical parts.
- See American National Standard Z49.1, *Safety in Welding and Cutting*, published by the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135; OSHA Safety and Health Standards, 29CFR 1910, available from the U.S. Government Printing Office, Washington, D.C. 20402.

DO NOT REMOVE THIS INFORMATION

Appendix

Guide to Specification for Bare Stainless Steel Welding Electrodes and Rods

(This Appendix is not a part of ANSI/AWS A5.9-93, *Specification for Bare Stainless Steel Welding Electrodes and Rods*, but is included for information purposes only.)

A1. Introduction

A1.1 This guide is intended to provide both the supplier and the purchaser of bare stainless steel welding electrodes and welding rods of the types covered by this specification with a means of production control and a basis of acceptance through mutually acceptable, sound, standard requirements.

A1.2 This guide has been prepared as an aid to prospective users of the bare stainless steel welding electrodes and welding rods of the types covered by the specification in determining the classification best suited for a particular application, with due consideration to the requirements for that application.

A1.3 For definitions of bare electrodes, composite metal cored electrodes, and composite stranded electrodes, see "electrode" in ANSI/AWS A3.0, *Standard Welding Terms and Definitions*. For purposes of this specification, composite metal cored rods are defined by composite metal cored electrodes and composite stranded rods are defined by composite stranded electrodes, except for the basic differences between welding electrode and welding rod as defined by ANSI/AWS A3.0.

A1.4 In some cases, the composition of bare filler metal classified in this specification may differ from that of core wire used for the corresponding classification of covered electrodes classified in ANSI/AWS A5.4, *Spec-*

ification for Covered Stainless Steel Electrodes for Shielded Metal Arc Welding. Caution, therefore, should be exercised regarding the use of core wire from a covered electrode as bare filler metal.

A2. Classification System

A2.1 The chemical composition of the filler metal is identified by a series of numbers and, in some cases, chemical symbols, the letters L, H, and LR, or both. Chemical symbols are used to designate modifications of basic alloy types, e.g., ER308Mo. The letter "H" denotes carbon content restricted to the upper part of the range that is specified for the standard grade of the specific filler metal. The letter "L" denotes carbon content in the lower part of the range that is specified for the corresponding standard grade of filler metal. The letters "LR" denote low residuals (see A8.30).

A2.1.1 The first two designators may be "ER" for solid wires that may be used as electrodes or rods; or they may be "EC" for composite cored or stranded wires; or they may be "EQ" for strip electrodes.

A2.1.2 The three digit number such as 308 in ER308 designates the chemical composition of the filler metal.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*, as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of ANSI/AWS A5.01. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing the supplier normally conducts on material of that classification, as specified in Schedule F, Table 1, of the ANSI/AWS A5.01. Testing in accordance with any other schedule in that table shall be specifically required by the purchase order. In such cases, acceptance of the material shipped shall be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been made. The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance System" in ANSI/AWS A5.01.

A5. Preparation of Samples for Chemical Analysis

A5.1 Solid Bare Electrodes and Rod. Preparation of a chemical analysis sample from solid, bare welding electrodes and rods presents no technical difficulties. Such filler metal may be subdivided for analysis by any convenient method with all samples or chips representative of the lot of filler metal.

A5.2 Composite Metal Cored or Stranded Electrodes

A5.2.1 Gas tungsten arc welding with argon gas shielding may be used to melt a button (or slug) of sufficient size for analytical use.

A5.2.2 Gas metal arc welding with argon gas shielding also may be used to produce a homogeneous deposit for analysis. In this case, the weld pad is similar to that used to prepare a sample of filler metal deposited by covered electrodes.

A5.2.3 Both processes must be utilized in such a manner that no dilution of the base metal or mold occurs to contaminate the fused sample. Copper molds often are used to minimize the effects of dilution by the base metal or mold.

A5.2.4 Special care must be exercised to minimize such dilution effects when testing low carbon filler metals.

A5.3 Preparation of a fused sample by gas tungsten arc welding using argon shielding gas will transfer essentially all of the components through the arc. Some slight loss in carbon may occur, but such loss will never be greater than would be encountered in an actual welding operation, regardless of process (see A7.9.1). Non-metallic ingredients, when present in the core, will form a slag on top of the deposit which must be removed and discarded.

A5.4 The sample of fused filler metal must be large enough to provide the amount of undiluted material required by the chemist for analysis. No size or shape of deposited pads has been specified because these are immaterial if the deposit is truly undiluted.

A5.5 A sample made using the composite-type filler metal which has been fused in a copper mold should be undiluted since there will be essentially no admixture with base metal.

A5.6 Assurance that an undiluted sample is being obtained from the chosen size of pad at the selected distance above the base metal can be obtained by analyzing chips removed from successively lower layers of the pad. Layers which are undiluted will all have the same chemical composition. Therefore, the determination of identical compositions for two successive layers of deposited filler metal will provide evidence that the last layer is undiluted. Layers diluted by mild steel base metal will be low in chromium and nickel. Particular attention should be given to carbon when analyzing Type 308L, 308LSi, 308LMo, 309L, 309LSi, 309LMo, 316L, 316LSi, 317L, 320LR, 383, 385, 446LMo, 2209, or 2553 weld metal deposited using either solid or metal cored electrodes or rods. Because of carbon pick-up, the undiluted layers in a pad built on high-carbon base metal begin a considerable distance above the base.

A6. Ventilation During Welding

A6.1 Five major factors govern the quantity of fumes to which welders and welding operators can be exposed during welding:

- (1) Dimensions of the space in which welding is done (with special regard to the height of the ceiling)
- (2) Number of welders and welding operators working in the space
- (3) Rate of evolution of fumes, gases, or dust, according to the materials and processes involved
- (4) The proximity of the welders or welding operators to the fumes as they issue from the welding zone, and to the gases and dusts in the space in which they are working
- (5) The ventilation provided to the space in which the welding is done

A6.2 American National Standard Z49.1, *Safety in Welding and Cutting* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is particularly drawn to the section of that document related to Health Protection and Ventilation.

A7. Ferrite in Weld Deposits

A7.1 Ferrite is known to be very beneficial in reducing the tendency for cracking or fissuring in weld metals; however, it is not essential. Millions of pounds of fully austenitic weld metal have been used for years and provided satisfactory service performance. Generally, ferrite is helpful when the welds are restrained, the joints are large, and when cracks or fissures adversely affect service performance. Ferrite increases the weld strength level. Ferrite may have a detrimental effect on corrosion resistance in some environments. It also is generally regarded as detrimental to toughness in cryogenic service, and in high-temperature service where it can transform into the brittle sigma phase.

A7.2 Ferrite can be measured on a relative scale by means of various magnetic instruments. However, work by the Subcommittee for Welding of Stainless Steel of the High Alloys Committee of the Welding Research Council (WRC) established that the lack of a standard calibration procedure resulted in a very wide spread of readings on a given specimen when measured by different laboratories. A specimen averaging 5.0 percent ferrite based on the data collected from all the laboratories was measured as low as 3.5 percent by some and as high as 8.0 percent by others. At an average of 10 percent, the spread was 7.0 to 16.0 percent. In order to substantially reduce this problem, the WRC Subcommittee published on July 1, 1972, *A Calibration Procedure for Instruments to Measure the Delta Ferrite Content of Austenitic*

Stainless Steel Weld Metal.¹ In 1974, the AWS extended this procedure and prepared AWS A4.2, *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal*. All instruments used to measure the ferrite content of AWS classified stainless electrode products were to be traceable to this AWS standard.

A7.3 The WRC Subcommittee also adopted the term *Ferrite Number (FN)* to be used in place of percent ferrite, to clearly indicate that the measuring instrument was calibrated to the WRC procedure. The Ferrite Number, up to 10 FN, is to be considered equal to the "percent ferrite" term previously used. It represents a good average of commercial U.S. and world practice on the "percent ferrite". Through the use of standard calibration procedures, differences in readings due to instrument calibration are expected to be reduced to about ± 5 percent, or at the most, ± 10 percent of the measured ferrite value.

A7.4 In the opinion of the WRC Subcommittee, it has been impossible, to date, to accurately determine the true absolute ferrite content of weld metals.

A7.5 Even on undiluted pads, ferrite variations from pad to pad must be expected due to slight changes in welding and measuring variables. On a large group of pads from one heat or lot and using a standard pad welding and preparation procedure plus or minus two sigma values indicate that 95 percent of the tests are expected to be within a range of approximately ± 2.2 FN at about 8 FN. If different pad welding and preparation procedures are used, these variations will increase.

A7.6 Even larger variations may be encountered if the welding technique allows excessive nitrogen pickup, in which case the ferrite can be much lower than it should be. High nitrogen pickup can cause a typical 8 FN deposit to drop to 0 FN. A nitrogen pickup of 0.10 percent will typically decrease the FN by about 8.

A7.7 Plate materials tend to be balanced chemically to have an inherently lower ferrite content than matching weld metals. Weld metal diluted with plate metal will usually be somewhat lower in ferrite than the undiluted weld metal, though this does vary depending on the amount of dilution and the composition of the base metal.

A7.8 The welding process used and the welding conditions and technique have a significant influence on the chemical composition and the ferrite content of the weld deposit in many instances. These influences must be

1. Welding Research Council, 345 East 47th Street, New York, NY 10017.

considered by the user if the weld deposit must meet specific chemical or Ferrite Number limits. The purpose of A7.9.1 through A7.9.3 is to present some general information on the effect of various welding processes on the chemical composition and the ferrite content of weld deposits made with filler metal classified in this specification.

A7.9 The chemical composition of a given weld deposit has the capability of providing an approximately predictable Ferrite Number for the deposit, as described in A7.13 with the limitations discussed here. However, important changes in the chemical compositions can occur from wire to deposit as described in A7.9.1 through A7.9.4.

A7.9.1 Gas Tungsten Arc Welding. This welding process involves the least change in the chemical composition from wire to deposit, and hence produces the smallest difference between the ferrite content calculated from the wire analysis and that measured on the deposit. There is some loss of carbon in gas tungsten arc welding - about half of the carbon content above 0.02 percent. Thus, a wire of 0.06 percent carbon will typically produce a deposit of 0.04 percent carbon. There is also some nitrogen pickup—a gain of 0.02 percent. The change in other elements is not significant in the undiluted weld metal.

A7.9.2 Gas Metal Arc Welding. For this process, typical carbon losses are low, only about one quarter those of the gas tungsten arc welding process. However, the typical nitrogen pick up is much higher than in gas tungsten arc welding, and it should be estimated at about 0.04 percent (equivalent to about 3 or 4 FN loss) unless specific measurements on welds for a particular application establish other values. Nitrogen pickup in this process is very dependent upon the welding technique and may go as high as 0.15 percent or more. This may result in little or no ferrite in the weld deposits of filler metals such as ER308 and ER309. Some slight oxidation plus volatilization losses may occur in manganese, silicon, chromium, nickel, and molybdenum contents.

A7.9.3 Submerged Arc Welding. Submerged arc welds show variable gains, losses of alloying elements, or both depending on the flux used. All fluxes produce some changes in the chemical composition as the electrode is melted and deposited as weld metal. Some fluxes deliberately add alloying elements such as columbium (niobium) and molybdenum; others are very active in the sense that they deplete significant amounts of certain elements that are readily oxidized, such as chromium. Other fluxes are less active and may contain small amounts of alloys to offset any losses and thereby, produce a weld deposit with a chemical composition close to the compo-

sition of the electrode. If the flux is active or alloyed, changes in the welding conditions, particularly voltage, will result in significant changes in the chemical composition of the deposit. Higher voltages produce greater flux/metal interactions and, for example, in the case of an alloy flux, greater alloy pickup.

A7.9.4 When close control of ferrite content is required, the effects of a particular flux/electrode combination should be evaluated before any production welding is undertaken due to the effects as shown in Table A1.

A7.10 Bare filler metal wire, unlike covered electrodes, cannot be adjusted for ferrite content by means of further alloy additions by the electrode producer, except through the use of flux in the submerged arc welding process. Thus, if specific FN ranges are desired, they must be obtained through wire chemistry selection. This is further complicated by the changes in the ferrite content from wire to deposit caused by the welding process and techniques, as previously discussed.

A7.11 In the 300 series filler metals, the compositions of the bare filler metal wires in general tend to cluster around the midpoints of the available chemical ranges. Thus, the potential ferrite for the 308, 308L, and 347 wires is approximately 10 FN, for the 309 wire approximately 12 FN, and for the 316 and 316L wires approximately 5 FN. Around these midpoints, the ferrite contents may be ± 7 FN or more, but the chemical compositions of these filler metals will still be within the chemical limits specified in this specification.

Table A1
Variations of Alloying Elements
for Submerged Arc Welding

Element	Typical Change From Wire to Deposit
Carbon	Varies. On "L" grades usually a gain: +0.01 to +0.02 percent; on regular grades usually a loss: up to -0.02 percent
Silicon	Usually a gain: +0.3 to +0.6 percent
Chromium	Usually a loss unless a deliberate addition is made to the flux: -0.5 to -3.0 percent
Nickel	Little change unless a deliberate addition is made to the flux
Manganese	Varies: -0.5 to +0.5 percent
Molybdenum	Little change unless a deliberate addition is made to the flux
Columbium (Niobium)	Usually a loss unless a deliberate addition: -0.2 to -0.5 percent

A7.12 In summary, the ferrite potential of a filler metal afforded by this chemical composition will, except for a few instances in submerged arc welding, be modified downward in the deposit due to changes in the chemical composition which are caused by the welding process and the technique used.

A7.13 The ferrite content of welds may be calculated from the chemical composition of the weld deposit. This can be done from one of several constitution diagrams. These are the WRC-1988 Diagram (Figure A1), the Espy Diagram (Figure A2), and the DeLong Diagram (Figure A3). There may be a wide range of results obtained from one diagram to another. The following paragraphs give some explanation of the differences among these diagrams and their recommended applications.

A7.13.1 WRC-1988 Diagram² (Figure A1) predicts ferrite in Ferrite Number (FN). This diagram is the newest of the diagrams mentioned. Studies within the WRC Subcommittee on Welding Stainless Steel and within Commission II of the International Institute of Welding show a closer agreement between measured and predicted ferrite using this diagram than when using the DeLong Diagram. It should be noted that predictions of the WRC-1988 Diagram are independent of silicon and manganese contents because these elements were not found to have statistically significant effects. The WRC-1988 Diagram is preferred for "300" series stainless steels and for duplex stainless alloys. It may not be applicable to compositions having greater than 0.2 percent of nitrogen and greater than 10 percent of manganese.

A7.13.2 Espy Diagram³ (Figure A2) calculates the percent ferrite rather than FN of deposits of the "200" series (see A2.1) having manganese levels up to 15 percent and nitrogen contents up to 0.35 percent (nitrogen strengthened austenitic stainless steels).

A7.13.3 DeLong Diagram⁴, Figure A3, is a modified Schaeffler Diagram⁵ predicting the Ferrite Number (FN) up to a maximum of 18 FN. The diagram includes the nitrogen level into the calculation to predict the FN. The DeLong modifications to the Schaeffler Diagram provide a better correlation between the calculated and measured ferrite content of the weld metal; therefore, the Schaeffler Diagram is not shown in this specification.

The new WRC-1988 Diagram (see A7.13.1) is the most accurate and preferred diagram for predicting the ferrite in "300" series stainless steel weld metals. Future publications of this specification may not include the DeLong Diagram.

A7.13.4 The differences between measured and calculated ferrite are somewhat dependent on the ferrite level of the deposit, increasing as the ferrite level increases. The agreement between the calculated and measured ferrite values is also strongly dependent on the quality of the chemical analysis. Variations in the results of the chemical analyses encountered from laboratory to laboratory can have significant effects on the calculated ferrite value, changing it as much as 4 to 8 FN. Cooling rate has a significant effect on the actual ferrite content and is one reason for the variations between calculated and measured ferrite of weld metal.

A8. Description and Intended Use of Filler Metals

A8.1 ER209. The nominal composition (wt.%) of this classification is 22 Cr, 11 Ni, 5.5 Mn, 2 Mo, and 0.20 N. Filler metals of this classification are most often used to weld UNS S20910 base metal. This alloy is a nitrogen-strengthened, austenitic stainless steel exhibiting high strength and good toughness over a wide range of temperature. Weldments in the as-welded condition made using this filler metal are not subject to carbide precipitation. Nitrogen alloying reduces the tendency for carbon diffusion and thereby increases resistance to intergranular corrosion.

The ER209 filler metal has sufficient total alloy content for use in welding dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on mild steel for corrosion applications when used with the gas metal arc welding process.

The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.2 ER218. The nominal composition (wt.%) of this classification is 17 Cr, 8.5 Ni, 8 Mn, 4 Si, and 0.13 N. Filler metals of this classification are most often used to weld UNS S21800 base metals. This alloy is a nitrogen-strengthened austenitic stainless steel exhibiting high strength and good toughness over a wide range of temperature. Nitrogen alloying in this base composition results in significant improvement in wear resistance in particle-to-metal and metal-to-metal (galling) applications when compared to the more conventional austenitic stainless steels such as Type 304. The ER218 filler metal has sufficient total alloy content for use in welding dissimilar alloys like mild steel and the stainless steels,

2. McCowan, C. N., Siewert, T. A. and Olson, D. L. "Stainless steel weld metal: prediction of ferrite." Bulletin 342. New York: Welding Research Council, April 1989.

3. Espy, R. H. "Weldability of nitrogen-strengthened stainless steels." *Welding Journal* 61(5): 149S-156S, 1982.

4. DeLong, W. T. 1974 Adams Lecture: "Ferrite in austenitic stainless steel weld metal." *Welding Journal* 53 (7): 273-S-286-S, July 1974.

5. Schaeffler, A. E. *Metal Progress* 56: 680-680B.

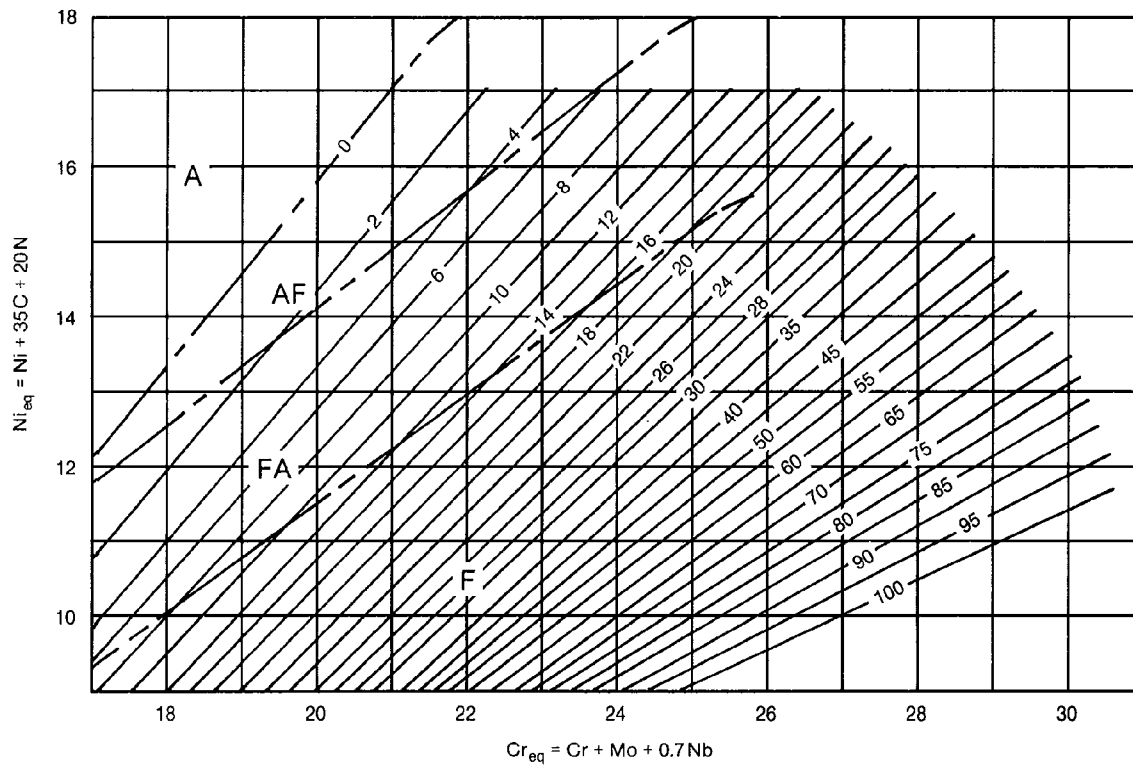


Figure A1—WRC-1988 Diagram for Stainless Steel Weld Metal

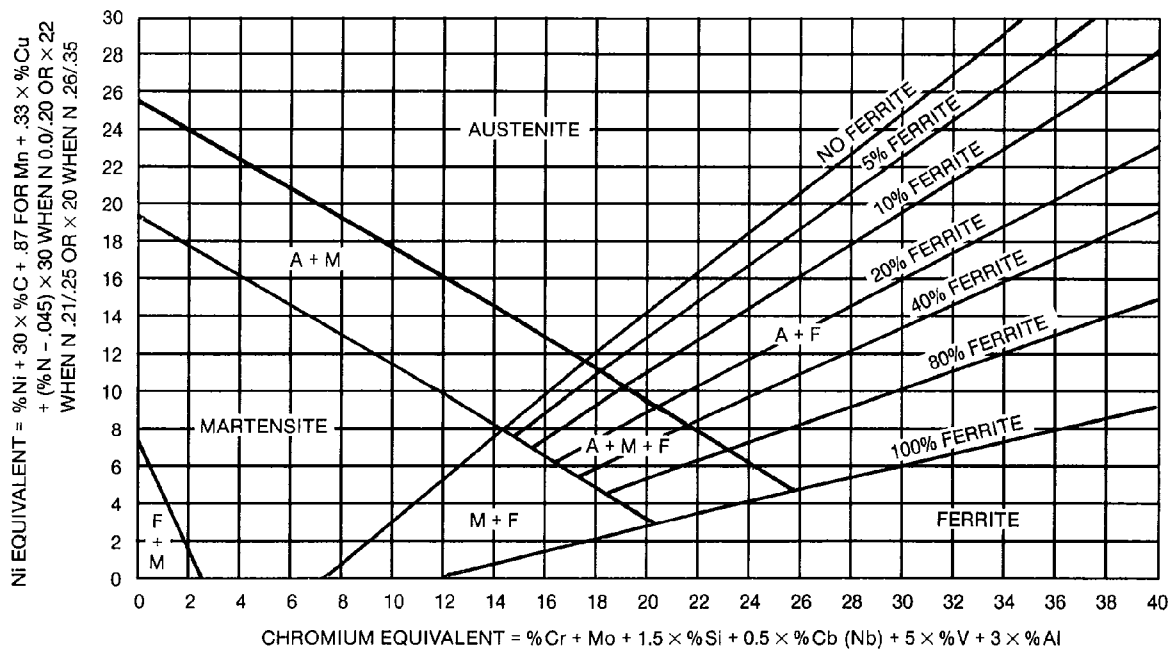
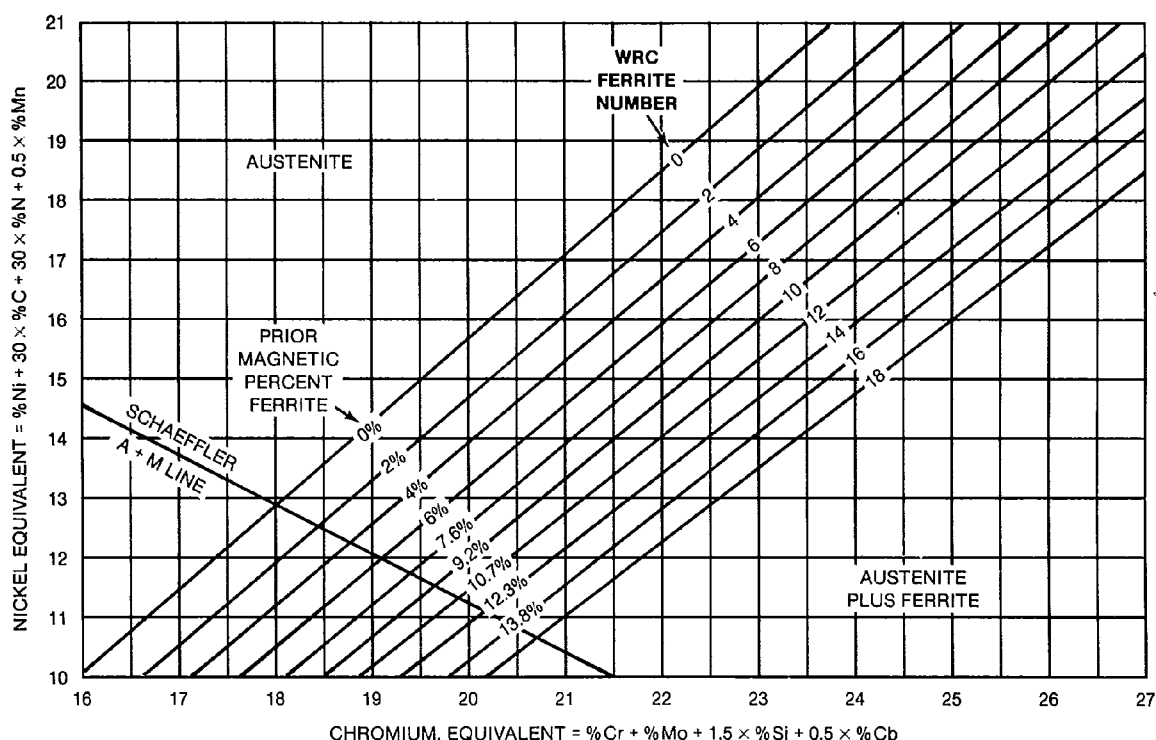


Figure A2—Espy Percent Ferrite Diagram for Stainless Steel Weld Metal



Calculate the nickel and chromium equivalents from the weld metal analysis. If nitrogen analysis of the weld metal is not available, assume 0.06% for GTA and covered electrode, or 0.08% for GMA weld metals. If the chemistry is accurate the diagram predicts the WRC Ferrite Number within plus or minus 3 in approximately 90% of the tests for the 308, 309, 316 and 317 families.

Figure A3—DeLong (FN) Diagram for Stainless Steel Weld Metal

and also for direct overlay on mild steel for corrosion and wear applications when used with the gas metal arc process. The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.3 ER219. The nominal composition (wt.%) of this classification is 20 Cr, 6 Ni, 9 Mn, and 0.20 N. Filler metals of this classification are most often used to weld UNS S21900 base metals. This alloy is a nitrogen-strengthened austenitic stainless steel exhibiting high strength and good toughness over a wide range of temperatures.

Weldments made using this filler metal are not subject to carbide precipitation in the as-welded condition. Nitrogen alloying reduces the tendency for intergranular carbide precipitation in the weld area by inhibiting carbon diffusion and thereby increases resistance to intergranular corrosion.

The ER219 filler metal has sufficient total alloy content for use in joining dissimilar alloys like mild steel and the stainless steels, and also for direct overlay on

mild steel for corrosive applications when used with the gas metal arc welding process. The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.4 ER240. The nominal composition (wt.%) of this classification is 18 Cr, 5 Ni, 12 Mn, and 0.20 N. Filler metal of this classification is most often used to weld UNS S24000 and UNS S24100 base metals. These alloys are nitrogen-strengthened austenitic stainless steels exhibiting high strength and good toughness over a wide range of temperatures. Significant improvement of wear resistance in particle-to-metal and metal-to-metal (galling) applications is a valuable characteristic when compared to the more conventional austenitic stainless steels such as Type 304. Nitrogen alloying reduces the tendency toward intergranular carbide precipitation in the weld area by inhibiting carbon diffusion thereby reducing the possibility for intergranular corrosion. Nitrogen alloying also improves resistance to pitting and crevice corrosion in aqueous chloride-containing media. In addition, weldments in Type 240 exhibit improved resistance

to transgranular stress corrosion cracking in hot aqueous chloride-containing media. The ER240 filler metal has sufficient total alloy content for use in joining dissimilar alloys like mild steel and the stainless steels and also for direct overlay on mild steel for corrosion and wear applications when used with the gas metal arc process. The gas tungsten arc, plasma arc, and electron beam processes are not suggested for direct application of this filler metal on mild steel.

A8.5 ER307. The nominal composition (wt.%) of this classification is 21 Cr, 9.5 Ni, 4 Mn, 1 Mo. Filler metals of this classification are used primarily for moderate-strength welds with good crack resistance between dissimilar steels such as austenitic manganese steel and carbon steel forgings or castings.

A8.6 ER308. The nominal composition (wt.%) of this classification is 21 Cr, 10 Ni. Commercial specifications for filler and base metals vary in the minimum alloy requirements; consequently, the names 18-8, 19-9, and 20-10 are often associated with filler metals of this classification. This classification is most often used to weld base metals of similar composition, in particular, Type 304.

A8.7 ER308H. This classification is the same as ER308, except that the allowable carbon content has been restricted to the higher portion of the 308 range. Carbon content in the range of 0.04-0.08 provides higher strength at elevated temperatures. This filler metal is used for welding 304H base metal.

A8.8 ER308L. This classification is the same as ER308, except for the carbon content. Low carbon (0.03 percent max) in this filler metal reduces the possibility of intergranular carbide precipitation. This increases the resistance to intergranular corrosion without the use of stabilizers such as columbium (niobium) or titanium. Strength of this low-carbon alloy, however, is less than that of the columbium (niobium)-stabilized alloys or Type 308H at elevated temperatures.

A8.9 ER308LSi. This classification is the same as ER308L, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of a lower silicon content weld metal.

A8.10 ER308Mo. This classification is the same as ER308, except for the addition of molybdenum. It is used for welding ASTM CF8M stainless steel castings and matches the base metal with regard to chromium, nickel, and molybdenum contents. It may be used for

welding wrought materials such as Type 316 (UNS31600) stainless when a ferrite content in excess of that attainable with the ER316 classification is desired.

A8.11 ER308LMo. This classification is used for welding ASTM CF3M stainless steel castings and matches the base metal with regard to chromium, nickel, and molybdenum contents. It may be used for welding wrought materials such as Type 316L stainless when a ferrite in excess of that attainable with ER316L is desired.

A8.12 ER308Si. This classification is the same as ER308, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding processes (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld metal, the crack sensitivity of the weld is somewhat higher than that of a lower silicon content weld metal.

A8.13 ER309. The nominal composition (wt.%) of this classification is 24 Cr, 13 Ni. Filler metals of this classification are commonly used for welding similar alloys in wrought or cast form. Occasionally, they are used to weld Type 304 and similar base metals where severe corrosion conditions exist requiring higher alloy weld metal. They are also used in dissimilar metal welds, such as joining Type 304 to carbon steel, welding the clad side of Type 304 clad steels, and applying stainless steel sheet linings to carbon steel shells.

A8.14 ER309L. This classification is the same as ER309, except for the carbon content. Low carbon (0.03 percent max) in this filler metal reduces the possibility of intergranular carbide precipitation. This increases the resistance to intergranular corrosion without the use of stabilizers such as columbium (niobium) or titanium. Strength of this low-carbon alloy, however, may not be as great at elevated temperatures as that of the columbium (niobium)-stabilized alloys or ER309.

A8.15 ER309Si. This classification is the same as ER309, except for higher silicon content. This improves the usability of the filler metal in the gas metal arc welding processes (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld metal deposit, the crack sensitivity of the weld is somewhat higher than that of a lower silicon content weld metal.

A8.16 ER309Mo. This classification is the same as ER309 except for the addition of 2.0 to 3.0 percent molybdenum to increase its pitting corrosion resistance in halide-containing environments. The primary application for this filler metal is surfacing of base metals to improve their corrosion resistance. The ER309Mo is used to achieve a single-layer overlay with a chemical composition similar to that of a 316 stainless steel. It is

also used for the first layer of multilayer overlays with filler metals such as ER316 or ER317 stainless steels. Without the first layer of 309Mo, elements such as chromium and molybdenum might be reduced to unacceptable levels in successive layers by dilution from the base metal. Other applications include the welding of molybdenum-containing stainless steel linings to carbon steel shells, the joining of carbon steel base metals which had been clad with a molybdenum-containing stainless steel, and the joining of dissimilar base metals such as carbon steel to Type 304 stainless steel.

A8.17 ER309LMo. This classification is the same as an ER309Mo except for a lower maximum carbon content (0.03%). Low-carbon contents in stainless steels reduce the possibility of chromium carbide precipitation and thereby increase weld metal resistance to intergranular corrosion. The ER309LMo is used in the same type of applications as the ER309Mo, but where excessive pick-up of carbon from dilution by the base metal, where intergranular corrosion from carbide precipitation, or both are factors to be considered in the selection of the filler metal. In multilayer overlays, the low carbon ER309LMo is usually needed for the first layer in order to achieve low carbon contents in successive layers with filler metals such as ER316L or ER317L.

A8.18 ER309LSi. This classification is the same as ER309L, except for higher silicon content. This improves the usability of the filler metal in the gas metal arc welding processes (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of a lower silicon content weld metal.

A8.19 ER310. The nominal composition (wt.%) of this classification is 26.5 Cr, 21 Ni. Filler metal of this classification is most often used to weld base metals of similar composition.

A8.20 ER312. The nominal composition (wt.%) of this classification is 30 Cr, 9 Ni. Filler metal of this classification was originally designed to weld cast alloys of similar composition. It also has been found to be valuable in welding dissimilar metals such as carbon steel to stainless steel, particularly those grades high in nickel. This alloy gives a two-phase weld deposit with substantial percentages of ferrite in an austenite matrix. Even with considerable dilution by austenite-forming elements such as nickel, the microstructure remains two-phase and thus highly resistant to weld metal cracks and fissures.

A8.21 ER316. The nominal composition (wt.%) of this classification is 19 Cr, 12.5 Ni and 2.5 Mo. This filler metal is used for welding Type 316 and similar alloys. It has been used successfully in certain applications involving special base metals for high-temperature service.

The presence of molybdenum provides creep resistance at elevated temperatures and pitting resistance in a halide atmosphere.

Rapid corrosion of ER316 weld metal may occur when the following three factors co-exist:

(1) The presence of a continuous or semicontinuous network of ferrite in the weld metal microstructure

(2) A composition balance of the weld metal giving a chromium-to-molybdenum ratio of less than 8.2 to 1

(3) Immersion of the weld metal in a corrosive medium. Attempts to classify the media in which accelerated corrosion will take place by attack on the ferrite phase have not been entirely successful. Strong oxidizing and mildly reducing environments have been present where a number of corrosion failures were investigated and documented. The literature should be consulted for latest recommendations.

A8.22 ER316H. This filler metal is the same as ER316, except that the allowable carbon content has been restricted to the higher portion of the 316 range. Carbon content in the range of 0.04 to 0.08 wt.% provides higher strength at elevated temperatures. This filler metal is used for welding 316H base metal.

A8.23 ER316L. This classification is the same as ER316, except for the carbon content. Low carbon (0.03 percent max.) in this filler metal reduces the possibility of intergranular chromium carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as columbium (niobium) or titanium. This filler metal is primarily used for welding low-carbon molybdenum-bearing austenitic alloys. This low-carbon alloy, however, is not as strong at elevated temperature as the columbium (niobium)-stabilized alloys or Type ER316H.

A8.24 ER316LSi. This classification is the same as ER316L, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity is somewhat higher than that of a lower silicon content weld metal.

A8.25 ER316Si. This classification is the same as ER316, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of a lower silicon content weld metal.

A8.26 ER317. The nominal composition (wt.%) of this classification is 19.5 Cr, 14 Ni, 3.5 Mo, somewhat higher than ER316. It is usually used for welding alloys of similar composition. ER317 filler metal is utilized in

severely corrosive environments where crevice and pitting corrosion are of concern.

A8.27 ER317L. This classification is the same as ER317, except for the carbon content. Low carbon (0.03 percent max) in this filler metal reduces the possibility of intergranular carbide precipitation. This increases the resistance to intergranular corrosion without the use of stabilizers such as columbium (niobium) or titanium. This low-carbon alloy, however, may not be as strong at elevated temperature as the columbium (niobium)-stabilized alloys or Type 317.

A8.28 ER318. This composition is identical to ER316, except for the addition of columbium (niobium). Colum-bium (niobium) provides resistance to intergranular chromium carbide precipitation and thus increased resistance to intergranular corrosion. Filler metal of this classification is used primarily for welding base metals of similar composition.

A8.29 ER320. The nominal composition (wt.%) of this classification is 20 Cr, 34 Ni, 2.5 Mo, 3.5 Cu with Cb(Nb) added to provide resistance to intergranular corrosion. Filler metal of this classification is primarily used to weld base metals of similar composition for applications where resistance to severe corrosion involving a wide range of chemicals, including sulfuric and sulfurous acids and their salts, is required. This filler metal can be used to weld both castings and wrought alloys of similar composition without postweld heat treatment. A modification of this classification without columbium (niobium) is available for repairing castings which do not contain columbium (niobium), but with this modified composition, solution annealing is required after welding.

A8.30 ER320LR (Low Residuals). This classification has the same basic composition as ER320; however, the elements C, Si, P, and S are specified at lower maximum levels and the Cb (Nb) and Mn are controlled at narrower ranges. These changes reduce the weld metal hot cracking and fissuring (while maintaining the corrosion resistance) frequently encountered in fully austenitic stainless steel weld metals. Consequently, welding practices typically used for austenitic stainless steel weld metals containing ferrite can be used in bare filler metal welding processes such as gas tungsten arc and gas metal arc. ER320LR filler metal has been used successfully in submerged arc overlay welding, but it may be prone to cracking when used for joining base metal by the submerged arc process. ER320LR weld metal has a lower minimum tensile strength than ER320 weld metal.

A8.31 ER321. The nominal composition (wt.%) of this classification is 19.5 Cr, 9.5 Ni with titanium added. The titanium acts in the same way as columbium (niobium)

in Type 347 in reducing intergranular chromium carbide precipitation and thus increasing resistance to intergranular corrosion. The filler metal of this classification is used for welding chromium-nickel stainless steel base metals of similar composition, using an inert gas shielded process. It is not suitable for use with the submerged arc process because only a small portion of the titanium will be recovered in the weld metal.

A8.32 ER330. The nominal composition (wt.%) of this classification is 35.5 Ni, 16 Cr. Filler metal of this type is commonly used where heat and scale resisting properties above 1800°F (980°C) are required, except in high-sulphur environments, as these environments may adversely affect elevated temperature performance. Repairs of defects in alloy castings and the welding of castings and wrought alloys of similar composition are the most common applications.

A8.33 ER347. The nominal composition (wt.%) of this classification is 20 Cr, 10 Ni with Cb(Nb) added as a stabilizer. The addition of Cb(Nb) reduces the possibility of intergranular chromium carbide precipitation and thus susceptibility to intergranular corrosion. The filler metal of this classification is usually used for welding chromium-nickel stainless steel base metals of similar composition stabilized with either Cb(Nb) or Ti. Although Cb(Nb) is the stabilizing element usually specified in Type 347 alloys, it should be recognized that tantalum (Ta) is also present. Ta and Cb(Nb) are almost equally effective in stabilizing carbon and in providing high-temperature strength. If dilution by the base metal produces a low ferrite or fully austenitic weld metal, the crack sensitivity of the weld may increase substantially.

A8.34 ER347Si. This classification is the same as ER347, except for the higher silicon content. This improves the usability of the filler metal in the gas metal arc welding process (see A9.2). If the dilution by the base metal produces a low ferrite or fully austenitic weld, the crack sensitivity of the weld is somewhat higher than that of a lower silicon content weld metal.

A8.35 ER383. The nominal composition (wt.%) of this classification is 27.5 Cr, 31.5 Ni, 3.7 Mo, and 1 Cu. Filler metal of this classification is used to weld UNS N08028 base metal to itself, or to other grades of stainless steel. ER383 filler metal is recommended for sulphuric and phosphoric acid environments. The elements C, Si, P, and S are specified at low maximum levels to minimize weld metal hot cracking and fissuring (while maintaining the corrosion resistance) frequently encountered in fully austenitic stainless steel weld metals.

A8.36 ER385. The nominal composition (wt.%) of this classification is 20.5 Cr, 25 Ni, 4.7 Mo, and 1.5 Cu. ER385 filler metal is used primarily for welding of

ASTM B625, B673, B674, and B677 (UNS N08904) materials for the handling of sulphuric acid and many chloride containing media. ER385 filler metal also may be used to join Type 317L material where improved corrosion resistance in specific media is needed. ER385 filler metal may be used for joining UNS N08904 base metals to other grades of stainless steel. The elements C, S, P, and Si are specified at lower maximum levels to minimize weld metal hot cracking, and fissuring (while maintaining corrosion resistance) frequently encountered in fully austenitic weld metals.

A8.37 ER409. This 12 Cr alloy (wt.%) differs from Type 410 material because it has a ferritic microstructure. The titanium addition forms carbides to improve corrosion resistance, increase strength at high temperature, and promote the ferritic microstructure. ER409 filler metals may be used to join matching or dissimilar base metals. The greatest usage is for applications where thin stock is fabricated into exhaust system components.

A8.38 ER409Cb. This classification is the same as ER409 except that columbium (niobium) is used instead of titanium to achieve similar results. Oxidation losses across the arc generally are lower. Applications are the same as those of ER409 filler metals.

A8.39 ER410. This 12 Cr alloy (wt.%) is an air-hardening steel. Preheat and postheat treatments are required to achieve welds of adequate ductility for many engineering purposes. The most common application of filler metal of this type is for welding alloys of similar composition. It is also used for deposition of overlays on carbon steels to resist corrosion, erosion, or abrasion.

A8.40 ER410NiMo. The nominal composition (wt.%) of this classification is 12 Cr, 4.5 Ni, 0.55 Mo. It is primarily designed for welding ASTM CA6NM castings or similar material, as well as light gage 410, 410S, and 405 base metals. Filler metal of this classification is modified to contain less chromium and more nickel to eliminate ferrite in the microstructure as it has a deleterious effect on mechanical properties. Final postweld heat treatment should not exceed 1150°F (620°C), as higher temperatures may result in rehardening due to untempered martensite in the microstructure after cooling to room temperature.

A8.41 ER420. This classification is similar to ER410, except for slightly higher chromium and carbon contents. ER420 is used for many surfacing operations requiring corrosion resistance provided by 12 percent chromium along with somewhat higher hardness than weld metal deposited by ER410 electrodes. This increases wear resistance.

A8.42 ER430. This is a 16 Cr (wt.%) alloy. The composition is balanced by providing sufficient chromium to

give adequate corrosion resistance for the usual applications, and yet retain sufficient ductility in the heat-treated condition. (Excessive chromium will result in lower ductility.) Welding with filler metal of the ER430 classification usually requires preheating and postweld heat treatment.

Optimum mechanical properties and corrosion resistance are obtained only when the weldment is heat treated following the welding operation.

A8.43 ER446LMo. The nominal composition (wt.%) of this classification (formerly listed as ER26-1) is 26 Cr, 1 Mo. It is used for welding base metal of the same composition with inert gas shielded welding processes. Due to the high purity of both base metal and filler metal, cleaning of the parts before welding is most important. Complete coverage by shielding gas during welding is extremely important to prevent contamination by oxygen and nitrogen. Nonconventional gas shielding methods (leading, trailing, and back shielding) often are employed.

A8.44 ER502. The nominal composition (wt.%) of this classification is 5 Cr and 0.50 Mo. It is used for welding material of similar composition, usually in the form of pipe or tubing. The alloy is an air-hardening material, and therefore, when welding with this filler metal, preheating and postweld heat treatment are required.

A8.45 ER505. The nominal composition (wt.%) of this classification is 9 Cr, 1 Mo. Filler metal of this classification is used for welding base metal of similar composition, usually in the form of pipe or tubing. The alloy is an air-hardening material, and therefore, when welding with this filler metal, preheating and postweld heat treatment are required.

A8.46 ER630. The nominal composition (wt.%) of this classification is 16.4 Cr, 4.7 Ni, 3.6 Cu. The composition is designed primarily for welding ASTM A564 Type 630 and some other precipitation-hardening stainless steels. The composition is modified to prevent the formation of ferrite networks in the martensitic microstructure which have a deleterious effect on mechanical properties. Dependent on the application and weld size, the weld metal may be used either as-welded, welded and precipitation hardened, or welded, solution treated, and precipitation hardened.

A8.47 ER16-8-2. The nominal composition (wt.%) of this classification is 15.5 Cr, 8.5 Ni, 1.5 Mo. Filler metal of this classification is used primarily for welding stainless steel such as types 16-8-2, 316, and 347 for high-pressure, high-temperature piping systems. The weld deposit usually has a Ferrite Number no higher than 5 FN. The deposit also has good hot-ductility properties which offer greater freedom from weld or crater cracking

even under restraint conditions. The weld metal is usable in either the as-welded condition or solution-treated condition. This filler metal depends on a very carefully balanced chemical composition to develop its fullest properties. Corrosion tests indicate that the 16-8-2 weld metal may have less corrosion resistance than 316 base metal, depending on the corrosive media. Where the weldment is exposed to severe corrodants, the surface layers should be deposited with a more corrosion-resistant filler metal.

A8.48 ER19-10H. The nominal composition (wt.%) of this classification is 19 Cr, 10 Ni and similar to ER308H except that the chromium content is lower and there are additional limits on Mo, Nb(Cb), and Ti. This lower limit of Cr and additional limits on other Cr equivalent elements allows a lower ferrite range to be attained. A lower ferrite level in the weld metal decreases the chance of sigma embrittlement after long-term exposure at temperatures in excess of 1000°F (°C). This filler metal should be used in conjunction with welding processes and other welding consumables which do not deplete or otherwise significantly change the amount of chromium in the weld metal. If used with submerged arc welding, a flux that neither removes nor adds chromium to the weld metal is highly recommended.

This filler metal also has the higher carbon level required for improved creep properties in high-temperature service. The user is cautioned that actual weld application qualification testing is recommended in order to be sure that an acceptable weld metal carbon level is obtained. If corrosion or scaling is a concern, special testing, as outlined in Section A10, Special Tests, should be included in application testing.

A8.49 ER2209. The nominal composition (wt.%) of this classification is 22.5 Cr, 8.5 Ni, 3 Mo, 0.15 N. Filler metal of this classification is used primarily to weld duplex stainless steels which contain approximately 22 percent of chromium such as UNS S31803. Deposits of this alloy have "duplex" microstructures consisting of an austenite-ferrite matrix. These stainless steels are characterized by high tensile strength, resistance to stress corrosion cracking, and improved resistance to pitting.

A8.50 ER2553. The nominal composition (wt.%) of this classification is 25.5 Cr, 5.5 Ni, 3.4 Mo, 2 Cu, 0.2 N. Filler metal of this classification is used primarily to weld duplex stainless steels which contain approximately 25 percent chromium. Deposits of this alloy have a "duplex" microstructure consisting of an austenite-ferrite matrix. These stainless steels are characterized by high tensile strength, resistance to stress corrosion cracking, and improved resistance to pitting.

A8.51 ER3556. The nominal composition (wt.%) of this classification is 29 Fe, 21 Ni, 22 Cr, 18.5 Co, 3 Mo,

2.5 W (UNS R30556). Filler metal of this classification is used for welding 31 Fe, 20 Ni, 22 Cr, 18 Co, 3 Mo, 2.5 W (UNS R30556) base metal to itself, for joining steel to other nickel alloys, and for surfacing steel by the gas tungsten arc, gas metal arc, and plasma arc welding processes. The filler metal is resistant to high-temperature corrosive environments containing sulfur. Typical specifications for 31 Fe, 20 Ni, 22 Cr, 18 Co, 3 Mo, 2.5 W base metal are ASTM B435, B572, B619, B622, and B626, UNS number R30556.

A9. Usability

A9.1 When welding stainless steels with the gas tungsten arc process, direct current electrode negative (dcen) is preferred. For base metal up to 1/16 in. (1.6 mm) thick, argon is the preferred shielding gas because there is less tendency to melt through these lighter thicknesses. For greater thicknesses, or for automatic welding, mixtures of helium and argon are recommended because of the greater penetration and better surface appearance. Argon gas for shielding may also be used and will give satisfactory results in most cases, but a somewhat higher amperage will be required. For information on the effects of higher silicon, see A9.2 and the classification of interest.

A9.2 When using the gas metal arc welding process in which the filler metal is employed as an electrode, direct current electrode positive (dcep) is most commonly used. The shielding gas for spray transfer is usually argon, with or without minor additions of oxygen. For short circuiting transfer, shielding gases composed of helium plus additions of oxygen and carbon dioxide often are used. The minimum thickness that can be welded is approximately 1/8 to 3/16 in. (3.2 to 4.8 mm). However, thinner sections can be joined if a backing is used. The higher silicon levels improve the washing and wetting behavior of the weld metal. For instance, for increases from 0.30 to 0.65 percent silicon, the improvement is pronounced; for increases from 0.65 to 1.0 percent silicon, further improvement is experienced but is less pronounced.

A9.3 For submerged arc welding, direct current electrode positive (dcep) or alternating current (ac) may be used. Basic or neutral fluxes are generally recommended in order to minimize silicon pickup and the oxidation of chromium and other elements. When welding with fluxes that are not basic or neutral, electrodes having a silicon content below the normal 0.30 percent minimum may be desired for submerged arc welding. Such active fluxes may contribute some silicon to the weld metal. In this case, the higher silicon does not significantly improve the washing and wetting action of the weld metal.

A9.4 The strip cladding process closely resembles conventional submerged arc welding, except that a thin,

consumable strip electrode is substituted for the conventional wire. Thus, the equipment consists of conventional submerged arc units with modified contact tips and feed rolls. Normal power sources with a minimum output of 750 amperes are used. If submerged arc equipment is available, then the same feeding motor, gear box, flux handling system, wire spool, and controls used to feed wire electrodes can be used for strip surfacing. The only difference in most cases is a strip welding head and "bolt-on" adaptor plate.

Strip surfacing is generally carried out using direct current supplied either from a generator or from a rectifier. Power sources with either constant voltage or drooping characteristics are used routinely.

A constant-voltage power source is preferable, however, generator or rectifier type can be connected in parallel to produce higher current for specific applications. The use of direct current electrode positive (dcep) yields somewhat better edge shape and a more regular deposit surface.

A10. Special Tests

A10.1 Corrosion or Scaling Tests. Tests of joint specimens have the advantage that the joint design and welding procedure can be made identical to that being used in fabrication. They have the disadvantage of testing the combined properties of the weld metal, the heat-affected zone of the base metal, and the unaffected base metal. Furthermore, it is difficult to obtain reproducible data if a difference exists between the corrosion or oxidation rates of the various metal structures (weld metal, heat-affected zone, and unaffected base metal). Test samples cannot be readily standardized if welding procedure and joint design are to be considered variables. Joint specimens for corrosion tests should not be used for qualifying the filler metal, but may be used for qualifying welding procedures using approved materials. Special corrosion or scale resisting tests which are pertinent to the intended application may be conducted as agreed upon between the purchaser and supplier. This section is included for the guidance of those who desire to specify such special tests.

A10.2 The heat treatments, surface finish, and marking of the specimens prior to testing should be in accordance with standard practices for tests of similar alloys in the wrought or cast forms. The testing procedure should correspond to ASTM G4, *Standard Method for Conducting Corrosion Tests in Plant Equipment*, or ASTM A262, *Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels*.

A10.3 Tests for Mechanical Properties. The tensile properties, bend ductility, and soundness of welds pro-

duced using filler metal which conforms with this specification are frequently determined during welding procedure qualification. For cryogenic applications, impact properties of welds are required. It should be realized that the variables in the process, such as current, voltage, and welding speed; variables in the shielding medium, such as the gas mixture or flux; variables in the manual dexterity of the welder; and variables in the composition of the base metal influence the results which may be obtained. When properly controlled, however, these filler metals will give sound welds under widely varying conditions with tensile strength and ductility similar to that obtained by the covered arc welding electrodes.

Tensile and elongation requirements for weld metal deposited by shielded metal arc welding (covered) electrodes specified in ANSI/AWS A5.4, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*, are shown in Table A2. For a discussion of impact properties for cryogenic applications, see Appendix A8 of ANSI/AWS A5.4. Note that the impact properties of welds made with bare filler metals in the GTAW or GMAW processes are usually superior to those produced with the SMAW or SAW processes. When supplementary tests for mechanical properties are specified, the procedures should be in accordance with the latest edition of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

A11. Safety Considerations

A11.1 Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

When welding overhead or in confined spaces, ear plugs to prevent weld spatter from entering the ear canal should be worn. In addition, goggles or equivalent should be worn to give added eye protection. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance has been spilled on clothing, a change to clean, fire-resistant clothing should be made before working with open arcs or flame. Aprons, cape-sleeves, leggings, and shoulder covers with bibs designed for welding service should be used. Where welding or cutting of unusually

Table A2
Tensile Requirements for All-Weld-Metal from ANSI/AWS A5.4-92

AWS Classification	Tensile Strength, min		Elongation min Percent	Heat Treatment
	ksi	MPa		
E209-XX	100	690	15	None
E219-XX	90	620	15	None
E240-XX	100	690	15	None
E307-XX	85	590	30	None
E308-XX	80	550	35	None
E308H-XX	80	550	35	None
E308L-XX	75	520	35	None
E308Mo-XX	80	550	35	None
E308MoL-XX	75	520	35	None
E309-XX	80	550	30	None
E309L-XX	75	520	30	None
E309Cb-XX	80	550	30	None
E309Mo-XX	80	550	30	None
E309MoL-XX	75	520	30	None
E310-XX	80	550	30	None
E310H-XX	90	620	10	None
E310Cb-XX	80	550	25	None
E310Mo-XX	80	550	30	None
E312-XX	95	660	22	None
E316-XX	75	520	30	None
E316H-XX	75	520	30	None
E316L-XX	70	490	30	None
E317-XX	80	550	30	None
E317L-XX	75	520	30	None
E318-XX	80	550	25	None
E320-XX	80	550	30	None
E320LR-XX	75	520	30	None
E330-XX	75	520	25	None
E330H-XX	90	620	10	None
E347-XX	75	520	30	None
E349-XX	100	690	25	None
E383-XX	75	520	30	None
E385-XX	75	520	30	None
E410-XX	75	450	20	a
E410NiMo-XX	110	760	15	c
E430-XX	65	450	20	d
E502-XX	60	420	20	b
E505-XX	60	420	20	b
E630-XX	135	930	7	e
E16-8-2-XX	80	550	35	None
E7Cr-XX	60	420	20	b
E2209-XX	100	690	20	None
E2553-XX	110	760	15	None

Notes:

- Heat to 1350 to 1400°F (730 to 760°C), hold for one hour, furnace cool at a rate of 100°F (60°C) per hour to 600°F (315°C) and air cool to ambient.
- Heat to 1550 to 1600°F (840 to 870°C), hold for two hours, furnace cool at a rate not exceeding 100°F (55°C) per hour to 1100°F (595°C) and air cool to ambient.
- Heat to 1100 to 1150°F (595 to 620°C), hold for one hour, and air cool to ambient.
- Heat to 1400 to 1450°F (760 to 790°C), hold for two hours, furnace cool at a rate not exceeding 100°F (55°C) per hour to 1100°F (595°C) and air cool to ambient.
- Heat to 1875 to 1925°F (1025 to 1050°C), hold for one hour, and air cool to ambient, and then precipitation harden at 1135 to 1165°F (610 to 630°C), hold for four hours, and air cool to ambient.

thick base metal is involved, sheet metal shields should be used for extra protection. Mechanization of highly hazardous processes or jobs should be considered. Other personnel in the work area should be protected by the use of noncombustible screens or by the use of appropriate protection as described in the previous paragraph. Before leaving a work area, hot workpieces should be marked to alert other persons of this hazard. No attempt should be made to repair or disconnect electrical equipment when it is under load. Disconnection under load produces arcing of the contacts and may cause burns or shock, or both. (*Note: Burns can be caused by touching hot equipment such as electrode holders, tips, and nozzles. Therefore, insulated gloves should be worn when these items are handled, unless an adequate cooling period has been allowed before touching.*) The following sources are for more detailed information on personal protection:

(1) ANSI/ASC Z49.1, *Safety in Welding and Cutting*, published by the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, FL 33135.

(2) *Code of Federal Regulations*, Title 29 Labor, Chapter XVII, Part 1910, OSHA General Industry Standards available from the U.S. Government Printing Office, Washington, DC 20402.

(3) ANSI/ASC Z41.1, *Safety-Toe Footwear*, American National Standards Institute, 11 West 42 Street, 13th Floor, New York, NY 10036.

A11.2 Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

All electrical equipment and the workpieces should be grounded. The workpiece lead is not a ground lead. It is used only to complete the welding circuit. A separate connection is required to ground the workpiece.

The correct cable size should be used, since sustained overloading will cause cable failure and result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous arcs and sparks. Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity. To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber soled shoes, or stand on a dry board or insulated platform. Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used. Open circuit voltage should be avoided. When several welders are working with arcs of different polar-

ities, or when a number of alternating current machines are being used, the open circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

In case of electric shock, the power should be turned OFF. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. If the victim is not breathing, cardiopulmonary resuscitation (CPR) should be administered as soon as contact with the electrical source is broken. A physician should be called and CPR continued until breathing has been restored, or until a physician has arrived. Electrical burns are treated as thermal burns; that is, clean, cold (iced) compresses should be applied. Contamination should be avoided; the area should be covered with a clean, dry dressing; and the patient should be transported to medical assistance.

Recognized safety standards such as ANSI/ASC Z49.1, *Safety in Welding and Cutting*, and the NFPA No. 70, *National Electrical Code*, available from National Fire Protection Association, Batterymarch Park, Quincy, MA 02269, should be followed.

A11.3 Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles which originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Management, welders, and other personnel alike should be aware of the effects of these fumes and gases. The amount and composition of these fumes and gases depend upon the composition of the filler metal and base metal, welding process, current level, arc length, and other factors.

The possible effects of over exposure range from irritation of eyes, skin, and respiratory system to more severe complications. Effects may occur immediately or at some later time. Fumes can cause symptoms such as nausea, headaches, dizziness, and metal fume fever. The possibility of more serious health effects exists when especially toxic materials are involved. In confined spaces, the shielding gases and fumes might displace breathing air and cause asphyxiation. One's head should always be kept out of the fumes. Sufficient ventilation, exhaust at the arc, or both, should be used to keep fumes and gases from your breathing zone and the general area.

In some cases, natural air movement will provide enough ventilation. Where ventilation may be questionable, air sampling should be used to determine if corrective measures should be applied.

More detailed information on fumes and gases produced by the various welding processes may be found in the following:

(1) The permissible exposure limits required by OSHA can be found in *Code of Federal Regulations*, Title 29, Chapter XVII Part 1910. The OSHA General Industry Standards are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402.

(2) The recommended threshold limit values for these fumes and gases may be found in *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*, published by the American Conference of Governmental Industrial Hygienists (ACGIH), 6550 Glenway Avenue, Building D-5, Cincinnati, OH 45211.

(3) The results of an AWS-funded study are available in a report entitled, *Fumes and Gases in the Welding Environment*, available from the American Welding Society.

A11.4 Radiation. Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. One should become acquainted with the effects of this radiant energy.

Radiant energy may be ionizing (such as x-rays), or non-ionizing (such as ultraviolet, visible light, or infrared). Radiation can produce a variety of effects such as skin burns and eye damage, depending on the radiant energy's wavelength and intensity, if excessive exposure occurs.

A11.4.1 Ionizing Radiation. Ionizing radiation is produced by the electron beam welding process. It is ordinarily controlled within acceptance limits by use of suitable shielding enclosing the welding area.

A11.4.2 Non-Ionizing Radiation. The intensity and wavelengths of non-ionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base metal composition, fluxes, and any coating or plating on the base metal. Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc when used properly), laser welding and torch welding, cutting, brazing, or soldering can produce quantities of non-ionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by non-ionizing radiant energy from welding include the following measures:

(1) One should not look at welding arcs except through welding filter plates which meet the requirements of ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, published by American National Standards Institute, 11 West 42 Street, 13th Floor, New York, NY 10036. Transparent welding curtains are not intended as welding filter plates, but rather are intended to protect a passerby from incidental exposure.

(2) Exposed skin should be protected with adequate gloves and clothing as specified in ANSI/ASC Z49.1, *Safety in Welding and Cutting*, published by American Welding Society.

(3) Reflections from welding arcs should be avoided, and all personnel should be protected from intense reflections. (Note: Paints using pigments of substantially zinc oxide or titanium dioxide have a lower reflectance for ultraviolet radiation.)

(4) Screens, curtains, or adequate distance from aisles, walkways, etc., should be used to avoid exposing passersby to welding operations.

(5) Safety glasses with UV protective side shields provide some beneficial protection from ultraviolet radiation produced by welding arcs.

A11.4.3 Ionizing radiation information sources include the following:

(1) American Welding Society. ANSI/AWS F2.1, *Recommended Safe Practices for Electron Beam Welding and Cutting*, available from the American Welding Society.

(2) Manufacturer's product information literature.

A11.4.4 The following include non-ionizing radiation information sources:

(1) Hinrichs, J. F. "Project committee on radiation-summary report". *Welding Journal*, January, 1978.

(2) National Technical Information Service. *Non-ionizing radiation protection special study no. 42-0053-77, evaluation of the potential hazards from actinic ultraviolet radiation generated by electric welding and cutting arcs*. Springfield, VA: National Technical Information Service. ADA-033768.

(3) ———. *Non-ionizing radiation protection special study no. 42-0312-77, evaluation of the potential retina hazards from optical radiation generated by electrical welding and cutting arcs*. Springfield, VA: National Technical Information Service. ADA-043023.

(4) Moss, C. E. and Murray, W. E. "Optical radiation levels produced in gas welding, torch brazing, and oxygen cutting." *Welding Journal*, September 1979.

(5) "Optical radiation levels produced by air-carbon arc cutting processes." *Welding Journal*, March 1980.

(6) American National Standards Institute. ANSI/ASC Z136.1, *Safe use of lasers*. New York: American National Standards Institute.

(7) American Welding Society. ANSI/ASC Z49.1, *Safety in welding and cutting*. Miami, FL: American Welding Society.

(8) American National Standards Institute. ANSI/ASC Z87.1, *Practice for occupational and educational eye and face protection*. New York: National Standards Institute.

(9) Moss, C. E. "Optical radiation transmission levels through transparent welding curtains." *Welding Journal*, March 1979.

AWS Filler Metal Specifications and Related Documents

AWS Designation	Title
FMC	Filler Metal Comparison Charts
A4.2	Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Austenitic-Ferritic Stainless Steel Weld Metal
A4.3	Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding
A5.01	Filler Metal Procurement Guidelines
A5.1	Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding
A5.2	Specification for Carbon and Low Alloy Steel Rods for Oxyfuel Gas Welding
A5.3	Specification for Aluminum and Aluminum Alloy Electrodes for Shielded Metal Arc Welding
A5.4	Specification for Stainless Steel Welding Electrodes for Shielded Metal Arc Welding
A5.5	Specification for Low Alloy Steel Covered Arc Welding Electrodes
A5.6	Specification for Covered Copper and Copper Alloy Arc Welding Electrodes
A5.7	Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes
A5.8	Specification for Filler Metals for Brazing and Braze Welding
A5.9	Specification for Bare Stainless Steel Welding Electrodes and Rods
A5.10	Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods
A5.11	Specification for Nickel and Nickel Alloy Welding Electrodes for Shielded Metal Arc Welding
A5.12	Specification for Tungsten and Tungsten Alloy Electrodes for Arc Welding and Cutting
A5.13	Specification for Solid Surfacing Welding Rods and Electrodes
A5.14	Specification for Nickel and Nickel Alloy Bare Welding Electrodes and Rods
A5.15	Specification for Welding Electrodes and Rods for Cast Iron
A5.16	Specification for Titanium and Titanium Alloy Welding Electrodes and Rods
A5.17	Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding
A5.18	Specification for Carbon Steel Filler Metals for Gas Shielded Arc Welding
A5.19	Specification for Magnesium Alloy Welding Electrodes and Rods
A5.20	Specification for Carbon Steel Electrodes for Flux Cored Arc Welding
A5.21	Specification for Composite Surfacing Welding Rods and Electrodes
A5.22	Specification for Flux Cored Corrosion-Resisting Chromium and Chromium-Nickel Steel Electrodes
A5.23	Specification for Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
A5.24	Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods
A5.25	Specification for Carbon and Low Alloy Steel Electrodes and Fluxes for Electroslag Welding
A5.26	Specification for Carbon and Low Alloy Steel Electrodes for Electrogas Welding
A5.27	Specification for Copper and Copper Alloy Rods for Oxyfuel Gas Welding
A5.28	Specification for Low Alloy Steel Filler Metals for Gas Shielded Arc Welding
A5.29	Specification for Low Alloy Steel Electrodes for Flux Cored Arc Welding
A5.30	Specification for Consumable Inserts
A5.31	Specification for Fluxes for Brazing and Braze Welding

For ordering information, contact the Order Department, American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135. Phone: 1-800-334-9353.