AWS A5.9/A5.9M:2006
An American National Standard

Specification for Bare Stainless Steel Welding Electrodes and Rods

American Welding Society

Approved American National Standard
ANSI

Key Words—Composite electrodes, metal cored bare stainless steel rods, duplex stainless steel electrodes, bare solid electrodes, bare solid rods

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Approved by the
American National Standards Institute
May 24, 2006

Specification for Bare Stainless Steel Welding Electrodes and Rods

Supersedes ANSI/AWS A5.9-93

Prepared by the
American Welding Society (AWS) A5 Committee on Filler Metals and Allied Materials

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification prescribes the requirements for classification of solid and composite stainless steel electrodes (both as wire and strip) for gas metal arc welding, submerged arc welding, and other fusion welding processes. It also includes wire and rods for use in gas tungsten arc welding. Classification is based on chemical composition of the filler metal. Additional requirements are included for manufacture, sizes, lengths, and packaging. A guide is appended to the specification as a source of information concerning the classification system employed and the intended use of the stainless steel filler metal.

This specification makes use of both U.S. Customary Units and the International System of Units (SI). Since these are not equivalent, each system must be used independently of the other.

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Foreword

This foreword is not a part of AWS A5.9/5.9M:2006, *Specification for Bare Stainless Steel Welding Electrodes and Rods*, but is included for informational purposes only.

This document is the first of the A5.9 specifications which makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore each system must be used independently of the other, without combining values in any way. In selecting rational metric units the *Metric Practice Guide for the Welding Industry* (AWS A1.1) and International Standard ISO 544, *Welding consumables—Technical delivery conditions for welding filler materials—Type of product, dimensions, tolerances, and marking*, are used where suitable. Tables and figures make use of both U.S. Customary and SI Units, which with the application of the specified tolerances provides for interchangeability of products in both the U.S. Customary and SI Units.

The major changes incorporated in this revision include the deletion of the ER502 and ER505 classifications, new requirements for identification of straight length rods, the change from Cb to Nb in one classification, and the addition of four new classifications (ER316LMn, ER439, ER2594, and ER33-31). New classifications are shown in *italic font*.

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 A5 Committee on Filler Metal and Allied Materials was published in 1969. The current revision is the seventh revision of the original 1953 document as shown below:

ASTM A371-53T AWS A5.9-53T	*Tentative Specifications for Corrosion Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes*
ASTM A371-62T AWS A5.9-62T	*Tentative Specifications for Corrosion Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes*
AWS A5.9-69 ANSI W3.9-1973	*Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes*
AWS A5.9-Add 1-75	*1975 Addenda to Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes*
AWS A5.9-77	*Specification for Corrosion Resisting Chromium and Chromium-Nickel Steel Bare and Composite Metal Cored and Stranded Arc Welding Electrodes and Welding Rods*
AWS A5.9-81	*Specification for Corrosion Resisting Chromium and Chromium-Nickel Steel Bare and Composite Metal Cored and Stranded Welding Electrodes and Welding Rods*
AWS A5.9-93	*Specification for Bare Stainless Steel Welding Electrodes and Rods*

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS A5 Committee on Filler Metals and Allied Materials, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Official interpretations of any of the technical requirements of this standard may only 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.

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Table of Contents

Page No.

List of Tables

List of Figures

Specification for Bare Stainless Steel Welding Electrodes and Rods

1. Scope

1.1 This specification prescribes requirements for the classification of bare stainless steel wire, strip, composite metal cored, and stranded welding electrodes and rods for gas metal arc, gas tungsten arc, submerged arc, and other fusion welding processes. The chromium content of these filler metals is not less than 10.5 percent and the iron content exceeds that of any other element. 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.

1.2 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in Informative Annex Clauses A6 and A11. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*,[1] and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way. The specification designated A5.9 uses U.S. Customary Units; and the specification designated A5.9M uses SI Units. The latter units are shown within brackets [ ] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for sizing of filler metal or packaging or both under A5.9 or A5.9M specification.

2. Normative References

2.1 The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreement based on this AWS standard are encouraged to investigate the possibility of applying the most recent edition of the documents shown below. For undated references, the latest edition of the standard referred to applies.

2.2 The following AWS standard[2] is referenced in the normative sections of this document.

1. AWS A5.01, *Filler Metal Procurement Guidelines*

2.3 The following ANSI standard is referenced in the normative sections of this document.

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

2.4 The following ASTM standards[3] are referenced in the normative sections of this document:

1. ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*
2. ASTM E 353, *Standard Test Methods for Chemical Analysis of Stainless, Heat Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys*

2.5 The following OSHA standard[4] is referenced in the normative sections of this document:

1. OSHA Safety and Health Standards, *29CFR 1910*

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[1] ANSI Z49.1 is published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[2] AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[3] ASTM standards are published by the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

[4] OSHA standards are published by the U.S. Government Printing Office, Washington, DC 20402, and can also be downloaded from www.osha-slc.gov.

3. Classification

3.1 The welding materials covered by this specification are classified according to chemical composition and product form. The first two designators are "ER" for solid wires that may be used as electrodes or rods; "EC" for composite cored or stranded wires; and "EQ" for strip electrodes (see Table 1).

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

4. Acceptance

Acceptance[5] of the material shall be in accordance with the provisions of AWS A5.01.

5. 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.[6]

6. Rounding-Off Procedure

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 E 29.

7. Summary of Tests

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

7.2 Chemical analysis of a fused sample of composite or stranded electrode, rod, or strip, is the only test required for classification of these product forms under this specification. See Annex Clause A5, Preparation of Samples for Chemical Analysis.

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Material for retest may be taken from the original test sample or from a new sample. Retest need be only for those specific elements that failed to meet the test requirement.

If the results of one or both retests fail to meet the requirement, the material under test shall be considered as not meeting the requirements of this specification for that classification.

In the event that, during preparation or after completion of any test, it is clearly determined that prescribed or proper procedures were not followed in preparing the samples or in conducting the test, the test shall be considered invalid, without regard to whether the test was actually completed, or whether test results met, or failed to meet, the requirement. That test shall be repeated, following proper prescribed procedures. In this case the requirement for doubling of the number of test samples does not apply.

9. Chemical Analysis

9.1 A sample of the filler metal, or the stock from which it is made in the case of solid electrodes or rods, or a fused sample shall be prepared for analysis. See Annex Clause A5, Preparation of Samples for Chemical Analysis, for several possible methods.

9.2 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 E 353.

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

10. 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.

11. Standard Sizes and Shapes

11.1 Standard sizes for 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.

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

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[5] See Annex Clause A3, Acceptance for further information concerning acceptance, testing of the material shipped, and AWS A5.01.

[6] See Annex Clause A4, Certification for further information concerning certification and the testing called for to meet this requirement.

Table 1
Chemical Composition Requirements[a]

AWS Classification[d]	UNS Number[f]	Composition, Wt-%[b, c]										Other Elements	
		C	Cr	Ni	Mo	Mn	Si[e]	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	3.30–4.75	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	—	—
ER308Si	S30881	0.08	19.5–22.0	9.0–11.0	0.75	1.0–2.5	0.65–1.00	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	—	—
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	—	—
ER308Mo	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	—	—
ER308LMo	S30886	0.04	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	—	—
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	—	—
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	—	—
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	—	—
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	—	—
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	—	—
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	—	—
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	—	—
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	—	—
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	—	—
ER316LMn	*S31682*	*0.03*	*19.0–22.0*	*15.0–18.0*	*2.5–3.5*	*5.0–9.0*	*0.30–0.65*	*0.03*	*0.03*	*0.10–0.20*	*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	Nb[h]	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	Nb[h]	8 × C min/1.0 max
ER320LR	N08022	0.025	19.0–21.0	32.0–36.0	2.0–3.0	1.5–2.0	0.15	0.015	0.02	—	3.0–4.0	Nb[h]	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	0.03	0.03	—	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	Nb[h]	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	Nb[h]	10 × C min/1.0 max

(Continued)

Table 1 (Continued)
Chemical Composition Requirements[a]

AWS Classification[d]	UNS Number[f]	Composition, Wt-%[b, c]										Other Elements	
		C	Cr	Ni	Mo	Mn	Si[e]	P	S	N	Cu	Element	Amount
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	—	0.70–1.50	—	—
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
ER409Nb[i]	S40940	0.08	10.5–13.5	0.6	0.50	0.8	1.0	0.04	0.03	—	0.75	Nb[h]	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	—	—
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	—	—
ER439	*S43035*	*0.04*	*17.0–19.0*	*0.6*	*0.5*	*0.8*	*0.8*	*0.03*	*0.03*	—	*0.75*	*Ti*	*10 × C min/1.1 max*
ER446LMo	S44687	0.015	25.0–27.5	[g]	0.75–1.50	0.4	0.4	0.02	0.02	0.015	[g]	—	—
ER630	S17480	0.05	16.00–16.75	4.5–5.0	0.75	0.25–0.75	0.75	0.03	0.03	—	3.25–4.00	Nb[h]	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	Nb[h] Ti	0.05 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	—	—
ER2209	S39209	0.03	21.5–23.5	7.5–9.5	2.5–3.5	0.50–2.00	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	—	—
ER2594	*S32750*	*0.03*	*24.0–27.0*	*8.0–10.5*	*2.5–4.5*	*2.5*	*1.0*	*0.03*	*0.02*	*0.20–0.30*	*1.5*	*W*	*1.0*
ER33–31	*R20033*	*0.015*	*31.0–35.0*	*30.0–33.0*	*0.5–2.0*	*2.00*	*0.50*	*0.02*	*0.01*	*0.35–0.60*	*0.3–1.2*		
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 W Nb Ta Al Zr La B	16.0–21.0 2.0–3.5 0.30 0.30–1.25 0.10–0.50 0.001–0.100 0.005–0.100 0.02

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[a] Classifications ER502 and ER505 have been discontinued. Classifications EB6 and ER80S-B6, which are similar to ER502, have been added to AWS A5.23 and A5.28, respectively. EB8 and ER80S-B8, which are similar to ER505, have been added to AWS A5.23 and AWS A5.28, respectively.

[b] 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.

[c] Single values shown are maximum percentages.

[d] 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 electrodes. For example, ERXXX designates a solid wire and EQXXX designates a strip electrode of the same general analysis, and the same UNS number. However, ECXXX designates a composite metal cored or stranded electrode and may not have the same UNS number. Consult SAE HS-1086/ASTM DS-56, *Metals & Alloys in the Unified Numbering System*, for the proper UNS number.

[e] For special applications, electrodes and rods may be purchased with less than the specified silicon content.

[f] SAE HS-1086/ASTM DS-56, *Metals & Alloys in the Unified Numbering System.*

[g] Nickel + copper equals 0.5 percent maximum.

[h] Nb may be reported as Nb + Ta.

Table 2
Standard Wire Sizes of Electrodes and Rods[a]

	Diameter[a]			Tolerance[a]			
				Solid		Composite	
Form	in		mm	in	mm	in	mm
Welding rods in straight lengths[b]	0.045		1.1[c]	±0.001	±0.03	±0.002	±0.05
	—		1.2				
	1/16	(0.063)	1.6	±0.002	±0.05	±0.003	±0.08
	5/64	(0.078)	2.0				
	3/32	(0.094)	2.4				
	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[c]	±0.001	±0.03	±0.002	±0.05
	—		1.2				
	1/16	(0.063)	1.6	±0.002	±0.05	±0.003	±0.08
	5/64	(0.078)	2.0				
	3/32	(0.094)	2.4				
	7/64	(0.109)	2.8				
	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, 12, or 14 in (200, 300, or 350 mm) O.D. spools	0.030		0.8	±0.001	±0.03	±0.002	±0.05
	0.035		0.9				
	0.045		1.1[c]				
	—		1.2				
	1/16	(0.063)	1.6	±0.002	±0.05	±0.003	±0.08
	5/64	(0.078)	2.0				
	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	±0.001	±0.03	±0.002	±0.05
	0.025		0.6				
	0.030		0.8				
	0.035		0.9				
	0.045		1.1[c]				
	—		1.2				

[a] Dimensions, 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].

[c] Metric size not shown in ISO 544.

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

[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. Finish and Uniformity

12.1 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.

12.2 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.

12.3 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.

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

13. Standard Package Forms

13.1 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.

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

13.3 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.

13.4 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 Figure 1).

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

14. Winding Requirements

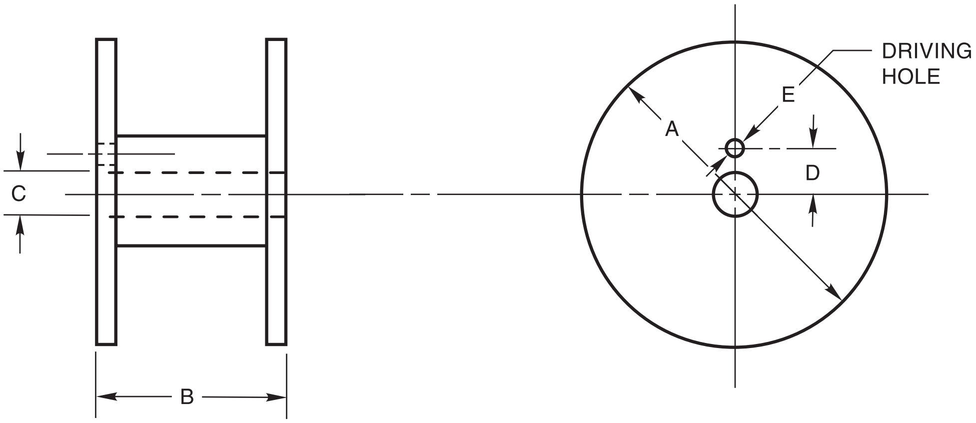
14.1 The filler metal shall be wound so that kinks, waves, sharp bends, or wedging are not encountered, leaving the filler metal free to unwind without restriction. The outside end of the filler metal (the end with which welding is to begin) shall be identified so it can be readily located and shall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

14.2 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.

Table 4
Standard Package Dimensions and Weights[a]

	Spool or Coil Diameter		Strip Width		Nominal Weight	
Product Form	in	mm	in	mm	lbs	kg
Welding Rods in Straight Lengths	—	—	—	—	10, 50	4.5, 23
Spools	4	100	—	—	1-1/2, 2-1/2	0.7, 1.1
	8	200	—	—	10	4.5
	12	300	—	—	25, 33	11.4, 15
	14	350	—	—	50	22.8
Coil with Support[b]	12	300	—	—	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

[a] Net weights shall be within ±10% of the nominal weight.
[b] Weight of coils without support shall be as specified by the purchaser.



		DIMENSIONS							
		4 in [100 mm]		8 in [200 mm]		12 in [300 mm]		14 in [350 mm]	
	Spools	in	mm	in	mm	in	mm	in	mm
A	Diameter, max (Note 4)	4.0	102	8.0	203	12	305	14	355
B	Width Tolerance	1.75 ±0.03	46 +0, –2	2.16 ±0.03	56 +0, –3	4.0 ±0.06	103 +0, –3	4.0 ±0.06	103 +0, –3
C	Diameter Tolerance	0.63 +0.01, –0	16 +1, –0	2.03 +0.06, –0	50.5 +2.5, –0	2.03 +0.06, –0	50.5 +2.5, –0	2.03 +0.06, –0	50.5 +2.5, –0
D	Distance between Axes Tolerance	— —	— —	1.75 ±0.02	44.5 ±0.5	1.75 ±0.02	44.5 ±0.5	1.75 ±0.02	44.5 ±0.5
E	Diameter (Note 3) Tolerance	— —	— —	0.44 +0, –0.06	10 +1, –0	0.44 +0, –0.06	10 +1, –0	0.44 +0, –0.06	10 +1, –0

Notes:

1. Outside diameter of barrel shall be such as to permit feeding of the filler metals.
2. Inside diameter of the barrel shall be such that swelling of the barrel or misalignment of the barrel and flanges will not result in the inside of the diameter of the barrel being less than the inside diameter of the flanges.
3. Holes are provided on each flange, but they need not be aligned. No driving holes required for 4 in [100 mm] spools.
4. Metric dimensions and tolerances conform to ISO 544 except that “A” specifies ± tolerances on the nominal diameter, rather than a plus tolerance only, which is shown here as a maximum.

Figure 1—Dimensions of 4, 8, 12, and 14 in [100, 200, 300, and 350 mm] Standard Spools

14.2.1 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

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

14.2.2 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

14.2.3 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

14.3 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] length.

15. Filler Metal Identification

15.1 The product information and the precautionary information required in Clause 17, Marking of Packages, shall also appear on each coil and each spool.

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

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

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

15.5 *Each bare straight filler rod shall be durably marked with identification traceable to the unique product type of the manufacturer or supplier. Suitable methods of identification could include stamping, coining, embossing, imprinting, flag-tagging, or color coding. (If color coding is used, the choice of color shall be as agreed between supplier and purchaser and the color shall be identified on the packaging.) When the AWS classification designation is used, the "ER" may be omitted; for example "308L" for classification ER308L. Additional identification shall be as agreed upon between the purchaser and supplier.*

16. Packaging

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

17. Marking of Packages

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

17.2 The appropriate precautionary information[7] given in ANSI Z49.1, latest edition (as a minimum) shall be prominently displayed in legible print on all packages including individual unit packages within a larger package.

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[7] Typical examples of "warning labels" are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.

Annex A (Informative)

Guide to Specification for Bare Stainless Steel Welding Electrodes and Rods

This annex is not a part of AWS A5.9/A5.9M:2006, *Specification for Bare Stainless Steel Welding Electrodes and Rods,* but is included for informational 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 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 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 AWS A5.4, *Specification for 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 A8.31).

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- or four-digit number, such as 308 in ER308, designates the nominal chemical composition of the filler metal.

A2.2 An international system for designating welding filler metals has been published by the International Standards Organization (ISO) prepared by the International Institute of Welding (IIW), ISO 14343. Table A.1 shows the designations for stainless steel bare filler metals along with the corresponding grades in this specification.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01, *Filler Metal Procurement Guidelines*, as the specification

Table A.1
Comparison of Classifications in ISO 14343[a]

AWS A5.9/A5.9M[b]	ISO 14343A	ISO 14343B[c]
ER209		
ER218		
ER219		
ER240		
ER307		SS307
ER308		SS308
ER308H		SS308H
ER308L	19 9 L	SS308L
ER308Mo	20 10 3	SS308Mo
ER308LMo		SS308LMo
ER308Si		SS308Si
ER308LSi	19 9 L Si	SS308LSi
ER309	22 12 H	SS309
ER309L	23 12 L	SS309L
ER309Mo		SS309Mo
ER309LMo	23 12 2 L	SS309LMo
ER309Si		SS309Si
ER309LSi	23 12 L Si	SS309LSi
ER310	25 20	SS310
ER312	29 9	SS312
ER316		SS316
ER316H	19 12 3 H	SS316H
ER316L	19 12 3 L	SS316L
ER316LMn	*20 16 3 Mn N L*	
ER316Si		SS316Si
ER316LSi	19 12 3 LSi	SS316LSi
ER317		SS317
ER317L	18 15 3 L	SS317L
ER318	19 12 3 Nb	SS318
ER320		SS320
ER320LR		SS320LR
ER321		SS321
ER330	18 36 H	SS330
ER347	19 9 Nb	SS347
ER347Si	19 9 Nb Si	SS347Si
ER383	27 31 4 Cu L	SS383
ER385	20 25 5 Cu L	SS385
ER409		SS409
ER409Nb		SS410Nb
ER410	13	SS410
ER410NiMo	13 4	SS410NiMo
ER420		SS420
ER430	17	SS430
ER439		
ER446LMo		
ER630		SS630
ER19-10H	19 9 H	SS19-10H
ER16-8-2	16 8 2	SS16-8-2
ER2209	22 9 3 N L	SS2209
ER2553		
ER2594	*25 9 4 N L*	
ER33-31		
ER3556		

[a] The requirements for the equivalent classifications shown are not necessarily identical in every respect.

[b] The classification designator "R" shall be replaced by "Q" for strip, and by "C" for tubular composite metal cored electrodes.

[c] The first "S" in the classification designator shall be replaced by "B" for strip, and by "T" for tubular composite metal cored electrodes.

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 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 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 Program" in 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 Other processes that melt a sample under a vacuum or inert atmosphere that results in a cast button (slug) may be used to produce a specimen for analysis.

A5.2.3 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.

A5.2.4 These methods 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.

A5.2.5 Special care must be exercised to minimize such dilution effects when testing low carbon filler metals.

A5.3 Preparation of the fused sample by gas tungsten arc welding using argon shielding gas will transfer essentially all of the components. 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). Nonmetallic 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, 316LMn, 316LSi, 317L, 320LR, 383, 385, 439, 446LMo, 2209, 2553, 2594, or 33-31 weld metal deposited using either 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 ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes* (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*.[8] 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 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 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.

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[8] WRC documents are published by Welding Research Council, P.O. Box 201547, Shaker Heights, OH 44120.

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 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 common arc 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 undiluted 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 A7.9.3.

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 undiluted 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, and chromium contents.

A7.9.3 Submerged Arc Welding. Submerged arc welds show variable gains or 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 niobium (columbium) 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 composition 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. 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 A.2.

A7.10 Bare solid filler metal wire, unlike covered electrodes and bare composite cored wires, 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 chemical composition selection. This is further complicated by the changes in the ferrite content

Table A.2
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 non-L 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.
Niobium	Usually a loss, unless a deliberate addition is made to the flux: –0.1 to –0.5 percent.

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.

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 best be done using the WRC-1992 Diagram[9] (see Figure A.1). Many earlier diagrams have been proposed and found useful. These may be reviewed in handbooks and other references.

A7.13.1 The WRC-1992 Diagram 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 the closest agreement between measured and predicted ferrite using this diagram. It should be noted that predictions of the WRC-1992 Diagram are independent of silicon and manganese contents because these elements were not found to have statistically significant effects. The WRC 1992 Diagram is preferred for "300" series stainless steels and for duplex stainless steels. It may not be applicable to compositions having greater than 1% Si.

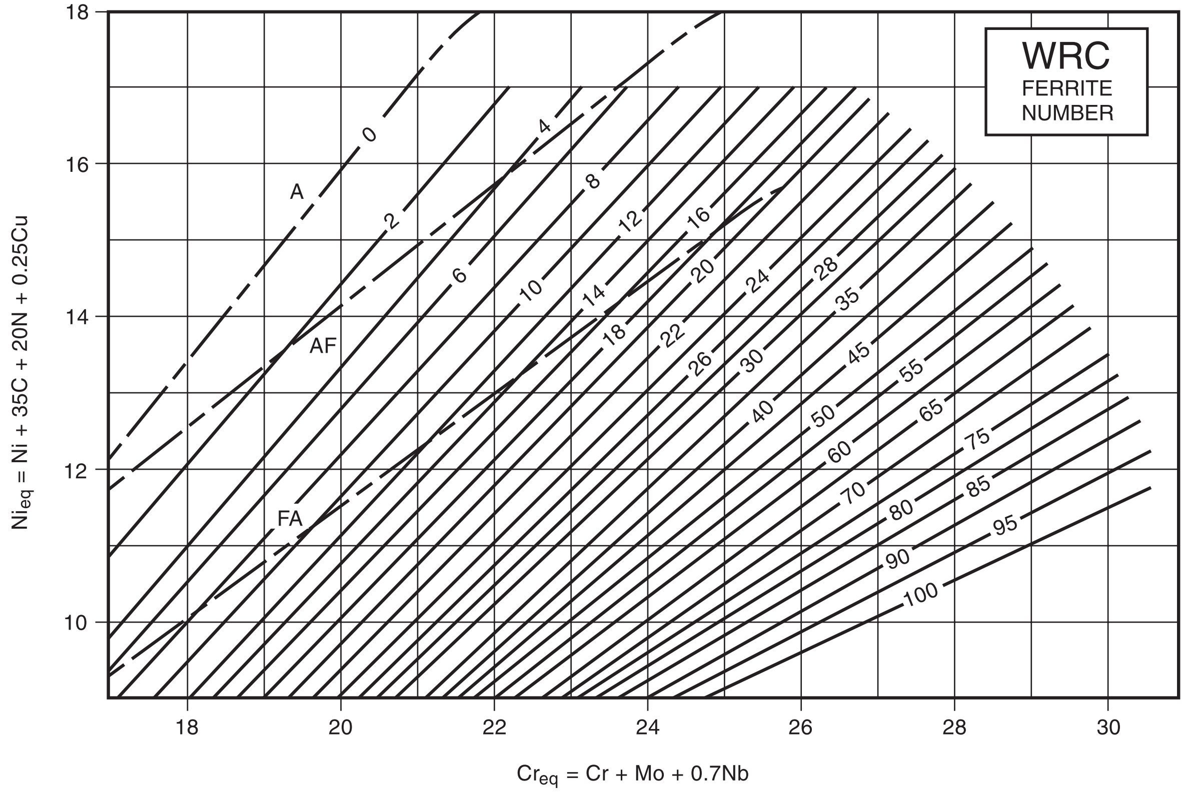

Figure A.1—WRC-1992 Diagram for Stainless Steel Weld Metal

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[9] Kotecki, D. J., and Siewert, T. A. 1992. WRC-1992 Constitution Diagram for Stainless Steel Weld Metals: A modification of the WRC-1988 Diagram. *Welding Journal* 71(5): 171-s to 178-s.

A7.13.2 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[10]

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, 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

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[10] ERXXX can be ECXXX or EQXXX. See Table 1 note d.

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 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 process (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.

A8.8 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.

A8.9 ER308L. This classification is the same as ER308, except for the carbon content. Low carbon (0.03 percent maximum) 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 niobium or titanium. Strength of this low-carbon alloy, however, is less than that of the niobium-stabilized alloys or Type 308H at elevated temperatures.

A8.10 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.

A8.11 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.

A8.12 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.

A8.13 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 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 process (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.

A8.15 ER309L. This classification is the same as ER309, except for the carbon content. Low carbon (0.03 percent maximum) 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 niobium or titanium. Strength of this low-carbon alloy, however, may not be as great at elevated temperatures as that of the niobium-stabilized alloys or ER309.

A8.16 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 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 lower silicon content weld metal.

A8.17 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.

A8.18 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 pickup 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.

A8.19 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 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.

A8.23 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.

A8.24 ER316L. This classification is the same as ER316, except for the carbon content. Low carbon (0.03 percent maximum) 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 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 niobium-stabilized alloys or Type ER316H.

A8.25 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.

***A8.26 ER316LMn.** The nominal composition (wt-%) of this classification is 19 Cr, 15 Ni, 7 Mn, 3 Mo, and 0.2 N. This is a fully austenitic alloy with a typical ferrite content of 0.5 FN maximum. One of the primary uses of this filler metal is for the joining of similar and dissimilar cryogenic steels for applications down to –452°F (–269°C). This filler metal also exhibits good corrosion resistance in acids and seawater, and is particularly suited for corrosion conditions found in urea synthesis plants. It is also non-magnetic. The high Mn-content of the alloy helps to stabilize the austenitic microstructure and aids in hot cracking resistance.*

A8.27 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.

A8.28 ER317L. This classification is the same as ER317, except for the carbon content. Low carbon (0.03 percent maximum) 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 niobium or titanium. This low-carbon alloy, however, may not be as strong at elevated temperature as the niobium-stabilized alloys or Type 317.

A8.29 ER318. This composition is identical to ER316, except for the addition of niobium. 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.

A8.30 ER320. The nominal composition (wt.-%) of this classification is 20 Cr, 34 Ni, 2.5 Mo, 3.5 Cu, with 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 niobium is available for repairing castings which do not contain niobium, but with this modified composition, solution annealing is required after welding.

A8.31 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 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.

A8.32 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 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.

A8.33 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-sulfur 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.

A8.34 ER347. The nominal composition (wt.-%) of this classification is 20 Cr, 10 Ni, with Nb added as a stabilizer. The addition of niobium 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 Nb or Ti. Although Nb is the stabilizing element usually specified in Type 347 alloys, it should be recognized that tantalum (Ta) is also present. Ta and 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.

A8.35 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.

A8.36 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 sulfuric 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.

A8.37 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 sulfuric 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.

A8.38 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.

A8.39 ER409Nb. This classification is the same as ER409, except that 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.

A8.40 ER410. This 12 Cr alloy (wt.-%) is an air-hardening steel. Preheat and postweld heat 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.

A8.41 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-gauge 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.

A8.42 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.

A8.43 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.

A8.44 ER439. *This is an 18 Cr (wt. %) alloy that is stabilized with titanium. ER439 provides improved oxidation and corrosion resistance over ER409 in similar applications. Applications are the same as those of ER409 filler metals where thin stock is fabricated into exhaust system components.*

A8.45 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.

A8.46 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 A 564 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 as-welded; welded and precipitation hardened; or welded, solution treated, and precipitation hardened.

A8.47 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, 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 [540°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 Annex Clause A10, Special Tests, should be included in application testing.

A8.48 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.

A8.49 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 chromium such as UNS S31803 and S32205. 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 UNS S32550 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 ER2594. *The nominal composition (wt. %) of this classification is 25.5 Cr, 9.2 Ni, 3.5 Mo, 0.25 N. The sum of the Cr + 3.3(Mo + 0.5 W) + 16 N, known as the Pitting Resistance Equivalent Number (*PRE_N*), is at least 40, thereby allowing the weld metal to be called a ‘superduplex stainless steel.’ This number is a semi-quantitative indicator of resistance to pitting in aqueous chloride-containing environments. It is designed for the welding of superduplex stainless steels UNS S32750 and 32760 (wrought), and UNS J93380, J93404(cast). It can also be used for the welding of UNS S32550, J93370, J93372 when not subject to sulfurous or sulfuric acids in service. It can also be used for the welding of carbon and low alloy steels to duplex stainless steels as well as to weld ‘standard’ duplex stainless steel such as UNS S32205 and J92205 especially for root runs in pipe.*

A8.52 ER33-31. *The nominal composition (wt.-%) of this classification is 33 Cr, 31Ni, 1.6 Mo. The filler metal is used for welding nickel-chromium-iron alloy (UNS R20033) to itself and to carbon steel, and for weld overlay on boiler tubes. The weld metal is resistant to high temperature corrosive environments of coal fired power plant boilers.*

A8.53 ER3556. The nominal composition (wt.-%) of this classification is 31 Fe, 20 Ni, 22 Cr, 18 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 by spray transfer is approximately 1/8 to 3/16 in [3.2 to 4.8 mm]. Short circuiting transfer can be used to weld material as thin as 1/16 in [1.6 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.

Strip cladding is conducted with either the submerged arc or electroslag welding process. Although electroslag welding does not involve an arc, except for initiation, it uses identical strip feeding equipment, controls, and power sources. Voltage and flux composition control whether the process is submerged arc or electroslag. The electroslag process is widely used because of its ability to deposit weld metal with low dilution.

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 (HAZ) 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.

A10.1.1 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 G 4, *Standard Method for Conducting Corrosion Tests in Plant Equipment*, or ASTM A 262, *Standard Practices for Detecting Susceptibility to Intergranular Attack in Austenitic Stainless Steels*, or ASTM G 48, *Standard Test Methods for Pitting and Crevice Corrosion Resistance of Stainless Steels and Related Alloys by Use of Ferric Chloride Solution*.

A10.2 Tests for Mechanical Properties. The tensile properties, bend ductility, and soundness of welds produced 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 that 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 AWS A5.4/A5.4M, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*, are shown in Table A.3. For a discussion of impact

Table A.3
All-Weld-Metal Mechanical Property Requirements from AWS A5.4/A5.4M:2006

AWS Classification	Tensile Strength, min ksi	Tensile Strength, min MPa	Elongation min. Percent	Heat Treatment
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
E308LMo-XX[a]	75	520	35	None
E309-XX	80	550	30	None
E309H-XX	80	550	30	None
E309L-XX	75	520	30	None
E309Nb-XX[a]	80	550	30	None
E309Mo-XX	80	550	30	None
E309LMo-XX[a]	75	520	30	None
E310 -XX	80	550	30	None
E310H-XX	90	620	10	None
E310Nb-XX[a]	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
E316LMn-XX	80	550	20	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
E409Nb-XX	65	450	20	d
E410-XX	75	520	20	b
E410NiMo-XX	110	760	15	c
E430-XX	65	450	20	d
E430Nb-XX	65	450	20	d
E630-XX	135	930	7	e
E16-8-2-XX	80	550	35	None
E2209-XX	100	690	20	None
E2553-XX	110	760	15	None
E2593-XX	110	760	15	None
E2594-XX	110	760	15	None
E2595-XX	110	760	15	None
E3155-XX	100	690	20	None
E33-31-XX	105	720	25	None

[a] E308LMo-XX, E309LMo-XX, E309Nb-XX, and E310Nb-XX were formerly named E308MoL-XX, E309MoL-XX, E309Cb-XX, and E310Cb-XX, respectively. The change was made to conform to the worldwide uniform designation of the element niobium.

[b] Heat to 1350°F to 1400°F [730°C to 760°C], hold for one hour (–0, +15 minutes), furnace cool at a rate not to exceeding 200°F [110°C] per hour to 600°F [315°C] and air cool to ambient.

[c] Heat to 1100°F to 1150°F [595°C to 620°C], hold for one hour (–0, +15 minutes), and air cool to ambient.

[d] Heat to 1400°F to 1450°F [760°C to 790°C], hold for two hours (–0, +15 minutes), furnace cool at a rate not exceeding 100°F [55°C] per hour to 1100°F [595°C] and air cool to ambient.

[e] Heat to 1875°F to 1925°F [1025°C to 1050°C], hold for one hour (–0, +15 minutes), and air cool to ambient, and then precipitation harden at 1135°F to 1165°F [610°C to 630°C], hold for four hours (–0, +15 minutes), and air cool to ambient.

Table A.4
Discontinued Classifications

Discontinued Classification	Last Published
ER26-1[a]	1981
ER502[b]	1993
ER505[c]	1993
ER409Cb[d]	1993

[a] This classification was not really discontinued, but was changed to ER446LMo.
[b] This electrode classification was transferred to the AWS A5.28 specification where it is classified as ER80S-B6, and to the AWS A5.23 specification where it is classified as EB6.
[c] This electrode classification was transferred to the AWS A5.28 specification where it is classified as ER80S-B8, and to the AWS A5.23 specification where it is classified as EB8.
[d] This classification was not really discontinued, but was changed to ER409Nb to reflect the adoption of Nb for niobium instead of Cb for columbium.

properties for cryogenic applications, see Annex A8 of 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 AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds.*

A11. General Safety Considerations

A11.1 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in Annex Clause A6. Safety and health information is available from other sources, including, but not limited to Safety and Health Fact Sheets listed in A11.3, ANSI Z49.1 *Safety in Welding, Cutting, and Allied Processes*,[11] and applicable federal and state regulations. ANSI Z49.1 can be downloaded and printed from the AWS website at http://www.aws.org.

A11.2 The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A11.3 AWS Safety and Health Fact Sheets Index (SHF)[12]

No.	**Title**
1	*Fumes and Gases*
2	*Radiation*
3	*Noise*
4	*Chromium and Nickel in Welding Fume*
5	*Electric Hazards*
6	*Fire and Explosion Prevention*
7	*Burn Protection*
8	*Mechanical Hazards*
9	*Tripping and Falling*
10	*Falling Objects*
11	*Confined Space*
12	*Contact Lens Wear*
13	*Ergonomics in the Welding Environment*
14	*Graphic Symbols for Precautionary Labels*
15	*Style Guidelines for Safety and Health Documents*
16	*Pacemakers and Welding*
17	*Electric and Magnetic Fields (EMF)*
18	*Lockout/Tagout*
19	*Laser Welding and Cutting Safety*
20	*Thermal Spraying Safety*
21	*Resistance Spot Welding*
22	*Cadmium Exposure from Welding & Allied Processes*
23	*California Proposition 65*
24	*Fluxes for Arc Welding and Brazing: Safe Handling and Use*
25	*Metal Fume Fever*
26	*Arc Viewing Distance*
27	*Thoriated Tungsten Electrodes*
28	*Oxyfuel Safety: Check Valves and Flashback Arrestors*
29	*Grounding of Portable and Vehicle Mounted Welding Generators*
30	*Cylinders: Safe Storage, Handling, and Use*

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[11] ANSI Z49.1 is published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

[12] AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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Annex B (Informative)

Guidelines for the Preparation of Technical Inquiries

This annex is not a part of AWS A5.9/5.9M:2006, *Specification for Bare Stainless Steel Welding Electrodes and Rods*, but is included for informational purposes only.

B1. Introduction

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

B2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

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

B2.1 Scope. Each inquiry shall address one single provision of the standard unless the point of the inquiry involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the inquiry along with the edition of the standard that contains the provision(s) the inquirer is addressing.

B2.2 Purpose of the Inquiry. The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be to obtain an interpretation of a standard's requirement or to request the revision of a particular provision in the standard.

B2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to understand the point of the inquiry. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annex) that bear on the inquiry shall be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry shall provide technical justification for that revision.

B2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry or provide the wording for a proposed revision, if this is what the inquirer seeks.

B3. Interpretation of Provisions of the Standard

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

B4. Publication of Interpretations

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

B5. Telephone Inquiries

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

B6. AWS Technical Committees

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

AWS Filler Metal Specifications by Material and Welding Process

	OFW	SMAW	GTAW GMAW PAW	FCAW	SAW	ESW	EGW	Brazing
Carbon Steel	A5.2	A5.1	A5.18	A5.20	A5.17	A5.25	A5.26	A5.8, A5.31
Low-Alloy Steel	A5.2	A5.5	A5.28	A5.29	A5.23	A5.25	A5.26	A5.8, A5.31
Stainless Steel		A5.4	A5.9, A5.22	A5.22	A5.9	A5.9	A5.9	A5.8, A5.31
Cast Iron	A5.15	A5.15	A5.15	A5.15				A5.8, A5.31
Nickel Alloys		A5.11	A5.14		A5.14			A5.8, A5.31
Aluminum Alloys		A5.3	A5.10					A5.8, A5.31
Copper Alloys		A5.6	A5.7					A5.8, A5.31
Titanium Alloys			A5.16					A5.8, A5.31
Zirconium Alloys			A5.24					A5.8, A5.31
Magnesium Alloys			A5.19					A5.8, A5.31
Tungsten Electrodes			A5.12					
Brazing Alloys and Fluxes								A5.8, A5.31
Surfacing Alloys	A5.21	A5.13	A5.21	A5.21	A5.21			
Consumable Inserts			A5.30					
Shielding Gases			A5.32	A5.32			A5.32	

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AWS Filler Metal Specifications and Related Documents

Designation	Title
FMC	*Filler Metal Comparison Charts*
IFS	*International Index of Welding Filler Metal Classifications*
UGFM	*User's Guide to Filler Metals*
A4.2M (ISO 8249 MOD)	*Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content Austenitic and Duplex Ferritic-Austenitic 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*
A4.4M	*Standard Procedures for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings*
A5.01	*Filler Metal Procurement Guidelines*
A5.1/A5.1M	*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/A5.3M	*Specification for Aluminum and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding*
A5.4/A5.4M	*Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*
A5.5/A5.5M	*Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*
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/A5.8M	*Specification for Filler Metals for Brazing and Braze Welding*
A5.9/A5.9M	*Specification for Bare Stainless Steel Welding Electrodes and Rods*
A5.10/A5.10M	*Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods*
A5.11/A5.11M	*Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding*
A5.12/A5.12M	*Specification for Tungsten and Tungsten-Alloy Electrodes for Arc Welding and Cutting*
A5.13	*Specification for Surfacing Electrodes for Shielded Metal Arc Welding*
A5.14/A5.14M	*Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods*
A5.15	*Specification for Welding Electrodes and Rods for Cast Iron*
A5.16/A5.16M	*Specification for Titanium and Titanium Alloy Welding Electrodes and Rods*
A5.17/A5.17M	*Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*
A5.18/A5.18M	*Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*
A5.19	*Specification for Magnesium Alloy Welding Electrodes and Rods*
A5.20/A5.20M	*Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*
A5.21	*Specification for Bare Electrodes and Rods for Surfacing*
A5.22	*Specification for Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding*
A5.23/A5.23M	*Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*
A5.24/A5.24M	*Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods*
A5.25/A5.25M	*Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding*
A5.26/A5.26M	*Specification for Carbon and Low-Alloy Steel Electrodes for Electrogas Welding*
A5.28/A5.28M	*Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*
A5.29/A5.29M	*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*
A5.32/A5.32M	*Specification for Welding Shielding Gases*

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