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An American National Standard

Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding

American Welding Society

Approved American National Standard
ANSI

Key Words—Shielded metal arc welding, stainless electrodes, classification, classification tests, electrode identification, electrode packaging, stainless weld metal compositions, welding

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Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding

Supersedes ANSI/AWS A5.4-92

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

Composition and other requirements are specified for more than forty classifications of covered stainless steel welding electrodes. The requirements include general requirements, testing, and packaging. Annex A provides application guidelines and other useful information about the electrodes.

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 A5.4/A5.4M:2006, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*, but is included for informational only.

This document is the first of the A5.4 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 imposition of a radiographic requirement, the deletion of the EXXX-25, E502, E505, and E7Cr classifications, the increase in allowable % silicon content for most classifications, the change from Cb to Nb in several designations, and the addition of nine new classifications (E309H-XX, E316LMn-XX, E409Nb-XX, E430Nb-XX, E2593-XX, E2594-XX, E2595-XX, E3155-XX, and E33-31-XX).

This AWS specification has evolved since the mid 1940s to its present form. The specification for covered stainless steel electrodes, issued in 1946, was prepared by a joint committee of the American Society for Testing and Materials and the American Welding Society. This cooperative effort continued for about 20 years and produced three revisions. The first revision, produced exclusively by the AWS Committee on Filler Metals, was published in 1969.

The current revision represents the ninth revision of the original 1946 document as shown below:

ASTM A298-46T AWS A5.4-46T	*Tentative Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Electrodes*
ASTM A298-48T AWS A5.4-48T	*Tentative Specifications for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Electrodes*
ASTM A298-55T AWS A5.4-55T	*Tentative Specifications for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes*
AWS A5.4-62T ASTM A298-62T	*Tentative Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes*
AWS A5.4-69	*Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes*
AWS A5.4-Add. 1-75	*1975 Addenda to Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes*
AWS A5.4-78	*Specification for Corrosion-Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes*
ANSI/AWS A5.4-81	*Specification for Covered Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Electrodes*
ANSI/AWS A5.4-92	*Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, 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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Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of covered stainless steel electrodes for shielded metal arc welding.[1,2]

The chromium content of weld metal deposited by these electrodes 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.

Note: No attempt has been made to classify all grades of filler metals within the limits of the above scope; only the more commonly used grades have been included.

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 Annex Clauses A5 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*, and applicable state and federal 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 when referring to material properties. The specification with the designation A5.4 uses U.S. Customary Units. The specification A5.4M uses SI Units. The latter are shown in 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 A5.4 or A5.4M specifications.

2. Normative References

2.1 The following AWS standards[3] are referenced in the mandatory section of this document.

1. AWS A5.01, *Filler Metal Procurement Guidelines*
2. AWS A5.5, *Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*
3. AWS B4.0, *Standard Methods for Mechanical Testing of Welds*
4. AWS B4.0M, *Standard Methods for Mechanical Testing of Welds*

2.2 The following ANSI standard is referenced in the mandatory section of this document:

1. ANSI Z49.1,[4] *Safety in Welding, Cutting, and Allied Processes*

2.3 The following ASTM standards[5] are referenced in the mandatory section of this document.

1. ASTM A 36, *Specification for Structural Steel*
2. ASTM A 240, *Specification for Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels*

[1] Due to possible differences in composition, core wire from covered electrodes should not be used as bare filler wire.

[2] Classifications E502, E505, and E7Cr are no longer specified by this document. They are specified in AWS A5.5/A5.5M:2006, designated as follows: E502 as E801X-B6 and E801X-B6L, E505 as E801X-B8 and E801X-B8L, and E7Cr as E801X-B7 and E801X-B7L.

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

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

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

3. ASTM A 285, *Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*

4. ASTM A 515, *Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

5. ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

6. ASTM E 1032, *Standard Test Method for Radiographic Examination of Weldments*

7. ASTM E 353, *Standard Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys*

3. Classification

3.1 The welding electrodes covered by this A5.4/A5.4M specification are classified using the system that is independent of U.S. Customary Units and the International System of Units (SI), and are classified according to:

1. Chemical composition requirements for undiluted weld metal (Table 1)

2. Type of welding current and position of welding (Table 2)

3.2 Materials classified under one classification may be classified under any other classification of this specification provided they meet all the requirements for those classifications, except that a material may not be classified under more than one of the following EXXX-15, EXXX-16, EXXX-17, or EXXX-26 designations. Table 3 lists a number of examples of such dual classification.

Note: The test requirements of this specification establish minimum quality levels which will assure suitability of the electrodes for the usual applications. The guide appended to this specification describes the more common applications and suggests testing procedures for those applications which warrant tests that are beyond those included in this specification.

4. Acceptance

Acceptance[6] of the material shall be in accordance with the provisions of AWS A5.01.

[6] See A3, Acceptance (in Annex A) for further information on acceptance, testing of material shipped and AWS A5.01, *Filler Metal Procurement Guidelines*.

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.[7]

6. Rounding-Off Procedure

For the purposes of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi (1 ksi) for tensile strength for A5.4, or to the nearest 10 MPa for tensile strength for A5.4M, and to the nearest unit in the last right-hand place of figures used in expressing the limiting value for other quantities in accordance with the rounding-off method given in ASTM E 29.

7. Summary of Tests

The tests required for each classification are specified in Table 4. The purpose of these tests is to determine the chemical composition, mechanical properties and soundness of the weld metal, and the usability of the electrodes. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Clause 9, Weld Test Assemblies; Clause 10, Chemical Analysis; Clause 11, Radiographic Test; Clause 12, Tension Test; and Clause 13, Fillet Weld Test.

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. For chemical analysis, retest material may be taken from the original test sample or from a new sample. Retest for chemical analysis 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.

[7] See A4, Certification (in Annex A) for further information concerning certification and the tests called for to meet this requirement.

Table 1
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification	UNS Number[d]	Weight Percent[a, b] C	Cr	Ni	Mo	Nb (Cb) Plus Ta	Mn	Si	P	S	N	Cu	Other
E209-XX	W32210	0.06	20.5–24.0	9.5–12.0	1.5–3.0	—	4.0–7.0	1.00	0.04	0.03	0.10–0.30	0.75	V = 0.10–0.30
E219-XX	W32310	0.06	19.0–21.5	5.5–7.0	0.75	—	8.0–10.0	1.00	0.04	0.03	0.10–0.30	0.75	
E240-XX	W32410	0.06	17.0–19.0	4.0–6.0	0.75	—	10.5–13.5	1.00	0.04	0.03	0.10–0.30	0.75	
E307-XX	W30710	0.04–0.14	18.0–21.5	9.0–10.7	0.5–1.5	—	3.30–4.75	1.00	0.04	0.03	—	0.75	
E308-XX	W30810	0.08	18.0–21.0	9.0–11.0	0.75	—	0.5– 2.5	1.00	0.04	0.03	—	0.75	
E308H-XX	W30810	0.04 –0.08	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E308L-XX	W30813	0.04	18.0–21.0	9.0–11.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E308Mo-XX	W30820	0.08	18.0–21.0	9.0–12.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E308LMo-XX[e]	W30823	0.04	18.0–21.0	9.0–12.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E309-XX	W30910	0.15	22.0–25.0	12.0–14.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E309H-XX	W30910	0.04–0.15	22.0–25.0	12.0–14.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E309L-XX	W30913	0.04	22.0–25.0	12.0–14.0	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E309Nb-XX[f]	W30917	0.12	22.0–25.0	12.0–14.0	0.75	0.70–1.00	0.5–2.5	1.00	0.04	0.03	—	0.75	
E309Mo-XX	W30920	0.12	22.0–25.0	12.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E309LMo-XX[e]	W30923	0.04	22.0–25.0	12.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E310-XX	W31010	0.08–0.20	25.0–28.0	20.0–22.5	0.75	—	1.0–2.5	0.75	0.03	0.03	—	0.75	
E310H-XX	W31015	0.35–0.45	25.0–28.0	20.0–22.5	0.75	—	1.0–2.5	0.75	0.03	0.03	—	0.75	
E310Nb-XX[f]	W31017	0.12	25.0–28.0	20.0–22.0	0.75	0.70–1.00	1.0–2.5	0.75	0.03	0.03	—	0.75	
E310Mo-XX	W31020	0.12	25.0–28.0	20.0–22.0	2.0–3.0	—	1.0–2.5	0.75	0.03	0.03	—	0.75	
E312-XX	W31310	0.15	28.0–32.0	8.0–10.5	0.75	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E316-XX	W31610	0.08	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E316H-XX	W31610	0.04–0.08	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E316L-XX	W31613	0.04	17.0–20.0	11.0–14.0	2.0–3.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E316LMn-XX	W31622	0.04	18.0–21.0	15.0–18.0	2.5–3.5	—	5.0–8.0	0.90	0.04	0.03	0.10–0.25	0.75	
E317-XX	W31710	0.08	18.0–21.0	12.0–14.0	3.0–4.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E317L-XX	W31713	0.04	18.0–21.0	12.0–14.0	3.0–4.0	—	0.5–2.5	1.00	0.04	0.03	—	0.75	
E318-XX	W31910	0.08	17.0–20.0	11.0–14.0	2.0–3.0	6 × C, min to 1.00 max	0.5–2.5	1.00	0.04	0.03	—	0.75	
E320-XX	W88021	0.07	19.0–21.0	32.0–36.0	2.0–3.0	8 × C, min to 1.00 max	0.5–2.5	0.60	0.04	0.03	—	3.0–4.0	

(Continued)

Table 1 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification	UNS Number[d]	Weight Percent[a, b]											
		C	Cr	Ni	Mo	Nb (Cb) Plus Ta	Mn	Si	P	S	N	Cu	Other
E320LR-XX	W88022	0.03	19.0–21.0	32.0–36.0	2.0–3.0	8 × C, min to 0.40 max	1.50–2.50	0.30	0.020	0.015	—	3.0–4.0	
E330-XX	W88331	0.18–0.25	14.0–17.0	33.0–37.0	0.75	—	1.0–2.5	1.00	0.04	0.03	—	0.75	
E330H-XX	W88335	0.35–0.45	14.0–17.0	33.0–37.0	0.75	—	1.0–2.5	1.00	0.04	0.03	—	0.75	
E347-XX	W34710	0.08	18.0–21.0	9.0–11.0	0.75	8 × C, min to 1.00 max	0.5–2.5	1.00	0.04	0.03	—	0.75	
E349-XX	W34910	0.13	18.0–21.0	8.0–10.0	0.35–0.65	0.75–1.20	0.5–25	1.00	0.04	0.03	—	0.75	V = 0.10–0.30 Ti = 0.15 max W = 1.25–1.75
E383-XX	W88028	0.03	26.5–29.0	30.0–33.0	3.2–4.2	—	0.5–2.5	0.90	0.02	0.02	—	0.6–1.5	
E385-XX	W88904	0.03	19.5–21.5	24.0–26.0	4.2–5.2	—	1.0–2.5	0.90	0.03	0.02	—	1.2–2.0	
E409Nb-XX	W40910	0.12	11.0–14.0	0.6	0.75	0.50–1.50	1.0	1.00	0.04	0.03	—	0.75	
E410-XX	W41010	0.12	11.0–13.5	0.7	0.75	—	1.0	0.90	0.04	0.03	—	0.75	
E410NiMo-XX	W41016	0.06	11.0–12.5	4.0–5.0	0.40–0.70	—	1.0	0.90	0.04	0.03	—	0.75	
E430-XX	W43010	0.10	15.0–18.0	0.6	0.75	—	1.0	0.90	0.04	0.03	—	0.75	
E430Nb-XX	W43011	0.10	15.0–18.0	0.6	0.75	0.50–1.50	1.0	1.00	0.04	0.03	—	0.75	
E630-XX	W37410	0.05	16.00–16.75	4.5–5.0	0.75	0.15–0.30	0.25–0.75	0.75	0.04	0.03	—	3.25–4.00	
E16-8-2-XX	W36810	0.10	14.5–16.5	7.5–9.5	1.0–2.0	—	0.5–2.5	0.60	0.03	0.03	—	0.75	
E2209-XX	W39209	0.04	21.5–23.5	8.5–10.5	2.5–3.5	—	0.5–2.0	1.00	0.04	0.03	0.08–0.20	0.75	
E2553-XX	W39553	0.06	24.0–27.0	6.5–8.5	2.9–3.9	—	0.5–1.5	1.00	0.04	0.03	0.10–0.25	1.5–2.5	
E2593-XX	W39593	0.04	24.0–27.0	8.5–10.5	2.9–3.9	—	0.5–1.5	1.00	0.04	0.03	0.08–0.25	1.5–3.0	
E2594-XX	W39594	0.04	24.0–27.0	8.0–10.5	3.5–4.5	—	0.5–2.0	1.00	0.04	0.03	0.20–0.30	0.75	
E2595-XX	W39595	0.04	24.0–27.0	8.0–10.5	2.5–4.5	—	2.5	1.2	0.03	0.025	0.20–0.30	0.4–1.5	W = 0.4–1.0
E3155-XX	W73155	0.10	20.0–22.5	19.0–21.0	2.5–3.5	0.75–1.25	1.0–2.5	1.00	0.04	0.03	—	0.75	Co = 18.5–21.0 W = 2.0–3.0
E33-31-XX	W33310	0.03	31.0–35.0	30.0–32.0	1.0–2.0	—	2.5–4.0	0.9	0.02	0.01	0.3–0.5	0.4–0.8	

[a] Analysis shall be made for the elements for which specific values are shown in the table. If, however, the presence of other elements is indicated in the course of analysis, further analysis shall be made to determine that the total of these other elements, except iron, is not present in excess of 0.50 percent.
[b] Single values are maximum percentages.
[c] Classification suffix -XX may be -15, -16, -17, or -26. See Clause A8 of Annex A for an explanation.
[d] ASTM DS-56H/SAE HS-1086, *Metal & Alloys in the Unified Numbering System.*
[e] E308LMo-XX and E309LMo-XX were formerly named E308MoL-XX and E309MoL-XX, respectively.
[f] E309Nb-XX and E310Nb-XX were formerly named E309Cb-XX and E310Cb-XX. The change was made to conform to the worldwide uniform designation of the element niobium.

Table 2
Type of Welding Current and Position of Welding

AWS Classification[a]	Welding Current[b]	Welding Position[c]
EXXX(X)-15	dcep	All[d]
EXXX(X)-16	dcep and ac	All[d]
EXXX(X)-17	dcep and ac	All[d]
EXXX(X)-26	dcep and ac	F, H-fillet

[a] See Clause A8, Classification as to Usability, for explanation of positions.
[b] dcep = direct current electrode positive (reverse polarity)
ac = alternating current
[c] The abbreviations F and H-fillet indicate welding positions as follows:
F = Flat
H-fillet = Horizontal fillet
[d] Electrodes 3/16 in [4.8 mm] and larger are not recommended for welding in all positions.

Table 3
Examples of Potentially Occurring Dual Classified Electrodes and Suggested Marking

Primary Classification	Alternate Classification	Suggested Electrode Marking[a]
E308L-XX	E308-XX	E308/E308L-XX
E308H-XX	E308-XX	E308/E308H-XX
E316L-XX	E316-XX	E316/E316L-XX

[a] This abbreviated, suggested marking is permitted only on the electrode (the E may be omitted). All packaging and packing labels and certifications must list the complete classification designation for all classifications intended.

In the event that, during preparation or after completion of any test, it is clearly determined that specified or proper procedures were not followed in preparing the weld test assembly or test specimen(s) 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 specified procedures. In this case the requirement for doubling of the number of test specimens does not apply.

9. Weld Test Assemblies

9.1 One, two, or three weld test assemblies are required depending on electrode diameter as shown in Table 4.

1. The weld pad in Figure 1 for chemical analysis of the undiluted weld metal

2. The groove weld in Figure 2 for Tension and Radiographic tests

3. The fillet weld in Figure 3 for usability of the electrode

Optionally, the sample for chemical analysis may be taken from the reduced section of the fractured tension specimen or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 2 or from the weld pad used for ferrite determination (Figure A.1), thereby avoiding the need to make the weld pad. In the case of dispute, the weld pad of Figure 1 shall be the referee method.

9.2 Preparation of each weld test assembly shall be as prescribed in 9.3, 9.4, and 9.5. Base metal for each assembly shall conform to the following, or an equivalent:

9.2.1 For the chemical analysis pad, the base metal to be used shall be carbon steel, alloy steel, or stainless steel of 0.25 percent carbon maximum for all electrode classifications except E308L, E308LMo, E309L, E309LMo, E316L, E316LMn, E317L, E320LR, E383, E385, E630, E2209, E2593, E2594, E2595, and E33-31. For chemical analysis of these low-carbon classifications, the base metal shall be steel of 0.03 percent maximum carbon. Other steels having a carbon content of 0.25 percent maximum may be used with the further restrictions specified in 10.6.

9.2.2 For the all-weld-metal tension test and radiographic test, the steel to be used shall be of a matching type or either of the following:

1. For E4XX and E630 classifications—Types 410, 430A or 430B

2. For all other classifications—Types 304 or 304L.

Optionally, the steel may conform to one of the following specifications or their equivalents, providing two buttering layers of filler metal as shown in Figure 2A, are deposited in stringer beads using electrodes of the same classification as that being classified: ASTM A 285, ASTM A 36, or ASTM A 515.

9.2.3 For the fillet weld test, the steel to be used shall be of a matching type or shall conform to the following specifications:

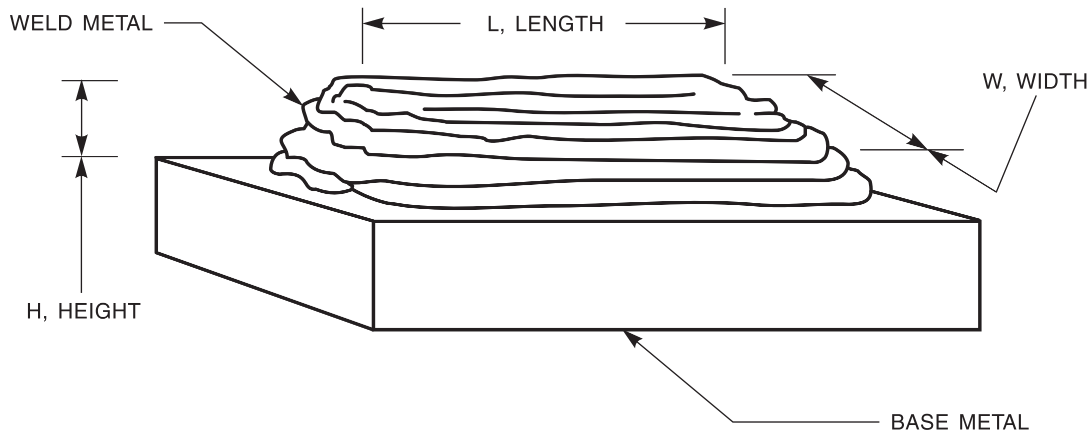
1. For E4XX and E630 classifications—ASTM A 240, Type 410 or Type 430 A or B

2. For all other classifications—ASTM A 240, Type 304 or Type 304L.

Table 4
Tests Required For Classification

Classification	Electrode Diameter in	Electrode Diameter mm	Type of Current[b, c]	Position of Welding[a] Chemical Analysis	Radiographic Test	All Weld Metal Tension Test	Fillet Weld Test
EXXX(X)-15	1/16	1.6	dcep	F	NR	NR	NR
EXXX(X)-15	5/64	2.0	dcep	F	NR	NR	NR
EXXX(X)-15	3/32	2.4	dcep	F	NR	NR	NR
EXXX(X)-15		2.5	dcep	F	NR	NR	NR
EXXX(X)-15	1/8	3.2	dcep	F	F	F	H, V, OH
EXXX(X)-15	5/32	4.0	dcep	F	F	F	H, V, OH
EXXX(X)-15	3/16	4.8	dcep	F	F	F	H
EXXX(X)-15		5.0	dcep	F	F	F	H
EXXX(X)-15	7/32	5.6	dcep	F	F	F	H
EXXX(X)-15		6.0	dcep	F	F	F	H
EXXX(X)-15	1/4	6.4	dcep	F	F	F	H
EXXX(X)-16, -17	1/16	1.6	ac and dcep	F	NR	NR	NR
EXXX(X)-16, -17	5/64	2.0	ac and dcep	F	NR	NR	NR
EXXX(X)-16, -17	3/32	2.4	ac and dcep	F	NR	NR	NR
EXXX(X)-16, -17		2.5	ac and dcep	F	NR	NR	NR
EXXX(X)-16, -17	1/8	3.2	ac and dcep	F	F	F	H, V, OH
EXXX(X)-16, -17	5/32	4.0	ac and dcep	F	F	F	H, V, OH
EXXX(X)-16, -17	3/16	4.8	ac and dcep	F	F	F	H
EXXX(X)-16, -17		5.0	ac and dcep	F	F	F	H
EXXX(X)-16, -17	7/32	5.6	ac and dcep	F	F	F	H
EXXX(X)-16, -17		6.0	ac and dcep	F	F	F	H
EXXX(X)-16, -17	1/4	6.4	ac and dcep	F	F	F	H
EXXX(X)-26	1/16	1.6	ac and dcep	F	NR	NR	NR
EXXX(X)-26	5/64	2.0	ac and dcep	F	NR	NR	NR
EXXX(X)-26	3/32	2.4	ac and dcep	F	NR	NR	NR
EXXX(X)-26		2.5	ac and dcep	F	NR	NR	NR
EXXX(X)-26	1/8	3.2	ac and dcep	F	F	F	H
EXXX(X)-26	5/32	4.0	ac and dcep	F	F	F	H
EXXX(X)-26	3/16	4.8	ac and dcep	F	F	F	H
EXXX(X)-26		5.0	ac and dcep	F	F	F	H
EXXX(X)-26	7/32	5.6	ac and dcep	F	F	F	H
EXXX(X)-26		6.0	ac and dcep	F	F	F	H
EXXX(X)-26	1/4	6.4	ac and dcep	F	F	F	H

[a] The abbreviations F, H, OH, and V indicate welding positions as follows:
F = Flat
H = Horizontal
V = Vertical
OH = Overhead
The abbreviation NR indicates that the test is not required.
[b] ac = alternating current: dcep = direct current, electrode positive (reverse polarity).
[c] Where both alternating and direct current are specified, only ac is required for classification testing.



Electrode Size		Weld Pad Size, minimum						Minimum Distance of Sample from Surface of Base Plate	
		L		W		H			
in	mm	in	mm	in	mm	in	mm	in	mm
1/16	1.6								
5/64	2.0	1-1/2	38	1/2	13	1/2	13	3/8	10
3/32	2.4								
—	2.5								
1/8	3.2								
5/32	4.0	2	50	1/2	13	5/8	16	1/2	13
3/16	4.8								
—	5.0								
7/32	5.6								
—	6.0	2-1/2	64	1/2	13	3/4	19	5/8	16
1/4	6.4								

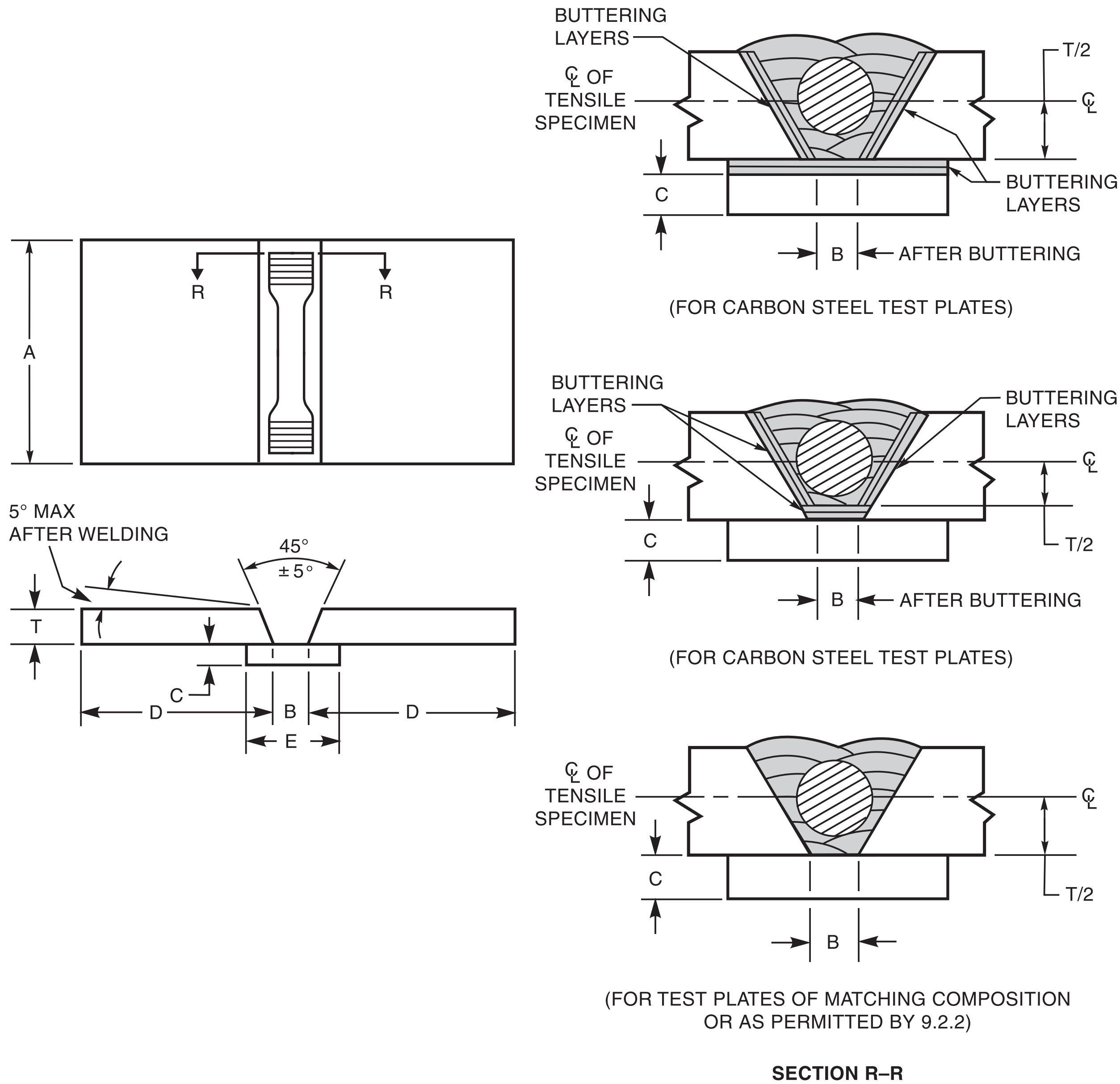
Figure 1—Pad for Chemical Analysis of Undiluted Weld Metal

9.3 Weld Pad. A weld pad shall be prepared as specified in Figure 1 except when one of the alternatives in 9.1 (taking the sample from the broken tension test specimen or from a corresponding location or any location above it in the weld metal in the groove weld in Figure 2 or from the weld pad used for ferrite determination in Figure A.1) is selected. Base metal shall be of any convenient size, of the type specified in 9.2.1. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position, using as short an arc length as practical and at a current as agreed upon between consumer and manufacturer. Multiple layers shall be used to obtain undiluted weld metal. The preheat temperature shall not be less than 60°F [15°C] After depositing each layer, the weld pad shall be immersed in water (temperature unimportant) for approximately 30 seconds. The slag shall be removed after each pass. The completed pad shall be as shown in Figure 1 for each size of the electrode. Testing of the assembly shall be as specified in Clause 10, Chemical Analysis.

9.4 Groove Weld for Mechanical Properties and Soundness

9.4.1 A test assembly shall be prepared and welded as specified in 9.4.1.1, 9.4.1.2, Figure 2, and the All Weld Metal Tension Test and/or Radiographic Test columns of Table 4 using base material of the appropriate type as specified in 9.2.2. Preheat and interpass temperatures shall be as specified in Table 5. Testing of this assembly shall be as specified in Clause 11, Radiographic Test and Clause 12, Tension Test.

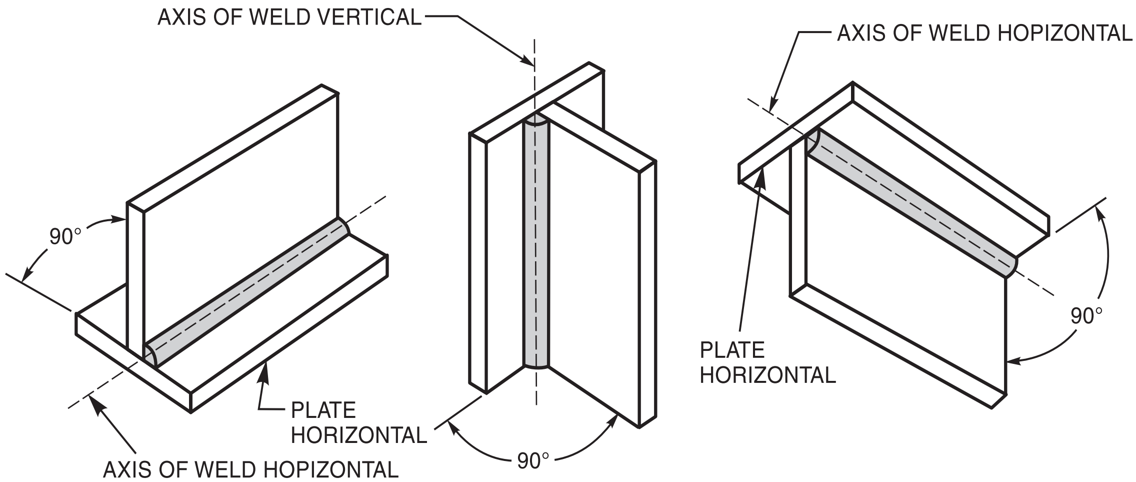
9.4.1.1 The plates shall be welded in the flat position, and they shall be preset or sufficiently restrained during welding to prevent warping more than 5 degrees. A test plate that has warped more than 5 degrees shall be discarded. Test assemblies shall not be straightened.



Electrode Diameter		Dimensions of Test Assembly					
		T[a]	A, min.[b]	B[c]	C, min.	D, min.	E, min.
in	1/8	1/2	3-1/2	1/4	3/16	3-1/2	1
mm	3.2	12	90	6.5	5	90	25
in	5/32 to 1/4 incl.	3/4	5-1/2	1/2	1/4	3-1/2	1
mm	4.0 to 6.4 incl.	20	140	12	6.5	90	25

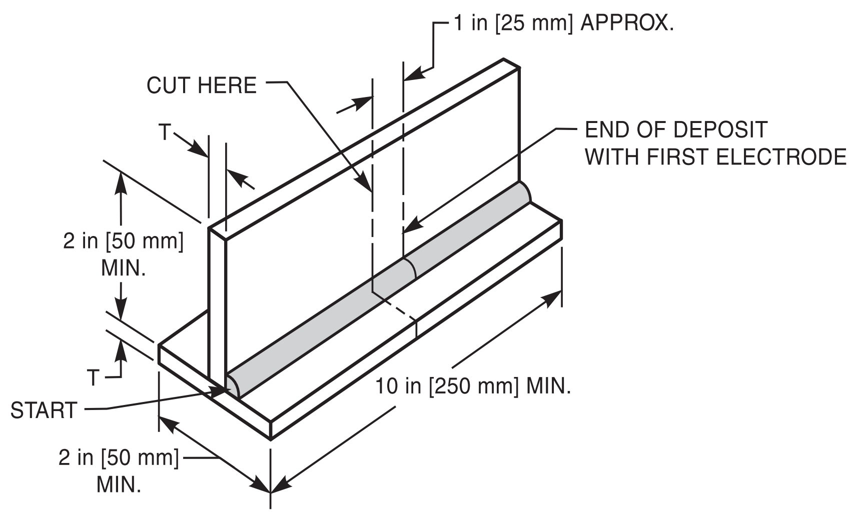
[a] For the radiographic test either 1/2 in [12 mm] or 3/4 in [20 mm] plate thickness may be used.
[b] Minimum length must be 8 in [200 mm] if being used for radiographic test.
[c] Tolerance shall be +1/8 in [3 mm], –0.

Figure 2—Groove Weld Assembly for Tension and Radiographic Tests for Electrodes 1/8 in [3.2 mm] Diameter and Larger



(a) HORIZONTAL FILLET WELDS (b) VERTICAL FILLET WELDS (c) OVERHEAD FILLET WELDS

(A) POSITIONS OF TEST PLATES FOR WELDING FILLET-WELD TEST SPECIMENS



(B) PREPARATION OF FILLET-WELD TEST ASSEMBLY

Electrode Diameter		Plate Thickness, T		Position of Welding	Maximum Fillet Size	
in	mm	in	mm		in	mm
1/8	3.2	1/4	6	V	1/4	6.5
				H and OH	3/16	5
1/8[a]	3.2[a]	3/8	10	V	3/8	10
				H and OH	1/4	6.5
5/32	4.0	3/8	10	V	5/16	8
				H and OH	1/4	6.5
5/32[a]	4.0[a]	1/2	12	V	1/2	13
				H and OH	5/16	8
3/16	4.8 or 5.0	3/8	10	H	5/16	8
7/32	5.6	3/8	10	H	3/8	10
1/4	6.0 or 6.4	3/8	10	H	3/8	10

[a]For EXXX-17 electrodes only.

Figure 3—Fillet Weld Test Assembly

Table 5
Welding Conditions for Preparation of the Groove Weld

AWS Classification	Preheat and Interpass Temperature Minimum °F	Minimum °C	Maximum °F	Maximum °C
E409Nb E410NiMo E430 E430Nb E630	300	150	500	260
E410	400	200	600	315
All Others	60	15	300	150

9.4.1.2 The test assembly shall be within the temperature ranges specified in Table 5 before starting each pass, including depositing of any buttering layer, as measured on the assembly at a distance of 1 in [25 mm] from the weld at the midlength of the test plate.

If, after any pass, the maximum temperature specified is exceeded, plates shall be allowed to cool in air (do not cool in water) to a temperature within the range shown.

The assembly shall be tested in the as-welded or postweld heat-treated condition as specified in Table 6.

9.5 Fillet Weld

9.5.1 A test assembly shall be prepared and welded as shown in Figure 3, using base metal of the appropriate type specified in 9.2.3. The welding position and conditions shall be as specified in the fillet weld column of Table 4 for the different electrode sizes and classifications. Testing of the assembly shall be as specified in Clause 13, Fillet Weld Test.

9.5.2 In preparing the two plates forming the test assembly, the standing member (web) shall have one edge prepared throughout its entire length so that when the web is set upon the base plate (flange), which shall be straight and flat, there will be intimate contact along the entire length of the joint.

9.5.3 A single-pass fillet weld shall be deposited on one side of the joint. The first electrode shall be continuously consumed to within the maximum permissible stub length of 2 in [50 mm]. Additional electrodes, if necessary, shall then be used to complete the weld for the full length of the joint, consuming each electrode completely as stated above, insofar as permitted by the length of the assembly.

9.5.4 When welding in the vertical position, the welding shall progress upward.

10. Chemical Analysis

10.1 The top surface of the weld pad described in 9.3 and shown in Figure 1 shall be removed and discarded and a sample for analysis shall be obtained from the underlying metal by any appropriate mechanical means. The sample shall be free of slag.

10.2 Weld pads, which are too hard for sample removal in the as-welded condition, may be given an annealing heat treatment.

10.3 Alternatively, the sample taken from the reduced section of the fractured tension specimen or from the groove weld (see 9.1) may be prepared for analysis by any suitable mechanical means. A sample taken from the weld pad used for ferrite determination (A6.9.1 through A6.9.4) shall be taken after draw filing, or grinding, and the height above the base plate for sample removal shall be consistent with the requirements of Figure 1 for the standard weld pad.

10.4 The sample shall be analyzed by accepted analytical methods. In case of dispute, the referee method shall be ASTM E 353.

10.5 The results of the analysis shall meet the requirements of Table 1 for the classification of the electrode under test.

10.6 If steel base metal other than those that have 0.03 percent maximum carbon are used for the low carbon electrodes,[8] the sample shall come from material above the eighth layer.

11. Radiographic Test

11.1 When required in Table 4 the groove weld described in 9.4 and shown in Figure 2, shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth and flush with the original surfaces (except as noted) of the base metal or with a uniform reinforcement not exceeding 3/32 in [2.5 mm]. It is permitted

[8] Low-carbon electrodes are as follows: E308L, E308LMo, E309L, E309LMo, E316L, E316LMn, E317L, E320LR, E383, E385, E630, E2209, E2593, E2594, E2595, and E33-31.

Table 6
All-Weld-Metal Mechanical Property Requirements

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.

on both sides of the test assembly to remove base metal to a depth of 1/16 in [1.5 mm] nominal below the original base metal surface in order to facilitate backing and/or buildup removal. Thickness of the weld metal shall not be reduced by more than 1/16 in [1.5 mm] less than the normal base metal thickness. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

11.2 The weld shall be radiographed in accordance with ASTM E 1032. The quality level of inspection shall be 2-2T.

11.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows:

1. no cracks, no incomplete fusion and no incomplete penetration.

2. no slag in excess of the following

   a. in any 6 in [150 mm] length of the 1/2 in [12 mm] thick test assembly: no individual slag inclusion longer than 7/32 in [5.6 mm] and a maximum total length of 7/16 in [11 mm] for all slag inclusions

   b. in any 6 in [150 mm] length of the 3/4 in [20 mm] thick test assembly: no individual slag inclusion in excess of 9/32 in [7.1 mm] and a maximum total length of 15/32 in [12 mm] for all slag inclusions

In evaluating the radiograph, 1 in [25 mm] of the weld on each end of the test assembly shall be disregarded.

3. no rounded indications in excess of those permitted by the radiographic standards in Figure 5A, or 5B as applicable.

11.3.1 A rounded indication is an indication (on the radiograph) whose length is no more than three times its width. Rounded indications may be circular or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present. The indications may be porosity, or slag inclusions.

11.3.2 Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded. Test assemblies with indications in excess of the sizes permitted in the radiographic standards do not meet the requirements of this specification.

12. Tension Test

12.1 One all-weld metal round tension specimen as specified in the Tension Test section of AWS B4.0 or AWS B4.0M shall be machined from the groove weld described in 9.4 and shown in Figure 2. For a test plate thickness of 1/2 in [12 mm], the all-weld-metal tension test specimen shall have a nominal diameter of 0.250 in [6.25 mm]. For a test plate thickness of 3/4 in [20 mm], the all-weld-metal tension test specimen shall have a nominal diameter of 0.500 [12.5 mm]. For all plate thickness, the gage length-to-diameter ratio shall be 4:1.

12.2 The specimen shall be tested in the manner described in the tension test section of AWS B4.0 or AWS B4.0M.

12.3 The results of the tension test shall meet the requirements specified in Table 6.

13. Fillet Weld Test

13.1 The fillet weld test, when required in Table 4, shall be made in accordance with 9.5 and Figure 3. The entire face of the completed fillet weld shall be examined visually. The weld shall be free from cracks or other open defects that would affect the strength of the weld. After the visual examination, a cross section shall be taken from the portion of the weld made with the first electrode at approximately 1 in [25 mm] from the end of that weld bead, as shown in Figure 3. The cross-sectional surface shall be polished and etched, and then examined as required in 13.2.

13.2 Scribe lines shall be placed on the prepared surface, as shown in Figure 4, and the leg length and the convexity shall be determined to the nearest 1/64 in [0.5 mm] by actual measurement.

13.2.1 The fillet weld shall have complete fusion to the joint root.

13.2.2 Both legs of the fillet weld shall be equal in length within 1/16 in [1.5 mm].

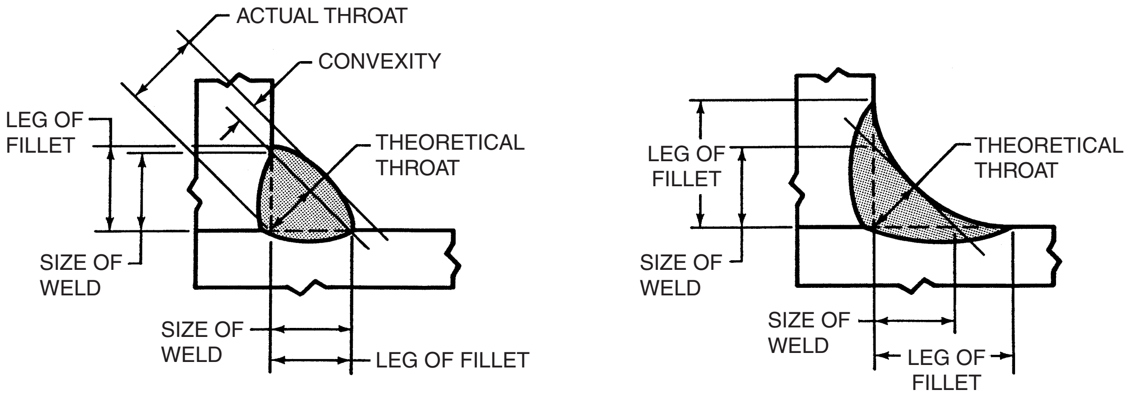
13.2.3 Convexity of the fillet weld shall be within the limits shown in Figure 4.

13.2.4 The fillet weld shall show no evidence of cracks.

13.2.5 The fillet weld shall be reasonably free from undercutting, overlap, trapped slag, and porosity.

14. Method of Manufacture

The welding electrodes classified according to this specification may be manufactured by any method that will produce electrodes conforming to the requirements of this specification.



Measured Fillet Weld Size[a]		Maximum Convexity[b]	
in	mm	in	mm
1/8	3.0	3/64	1.0
9/64	3.5	3/64	1.0
5/32	4.0	3/64	1.0
11/64	4.5	3/64	1.0
3/16	5.0	1/16	1.5
13/64	5.0	1/16	1.5
7/32	5.5	1/16	1.5
15/64	6.0	1/16	1.5
1/4	6.5	1/16	1.5
17/64	6.5	1/16	1.5
9/32	7.0	1/16	1.5
19/64	7.5	1/16	1.5
5/16	8.0	5/64	2.0
21/64	8.5	5/64	2.0
11/32	8.5	5/64	2.0
23/64	9.0	5/64	2.0
3/8	9.5	5/64	2.0

[a] Size of fillet weld = leg length of largest inscribed isosceles right triangle.
[b] Fillet weld size, convexity, and leg lengths of fillet welds shall be determined by actual measurement (nearest 1/64 in [0.5 mm]) on a section laid out with scribed lines shown.

Figure 4—Fillet Weld Test Specimen

15. Standard Sizes and Lengths

Standard sizes (diameter of the core wire), standard lengths and tolerances of electrodes shall be as shown in Table 7.

16. Core Wire and Covering

16.1 The core wire and covering shall be free of defects that would interfere with uniform deposition of the weld metal.

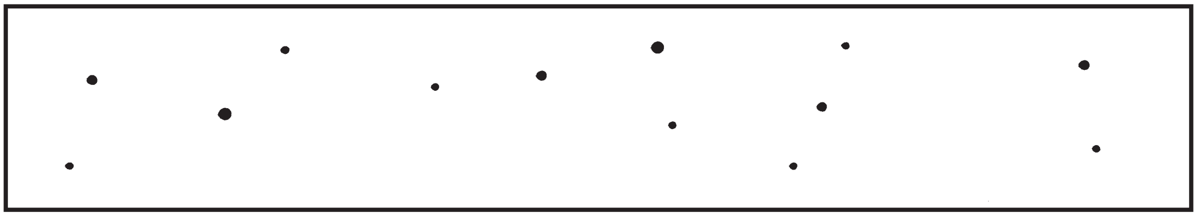
16.2 The core wire and the covering shall be concentric to the extent that the maximum core-plus-one-covering dimension does not exceed the minimum core-plus-one-covering dimension by more than the following:

1. Seven percent of the mean dimension in sizes 3/32 in [2.5 mm] and smaller

2. Five percent of the mean dimension in sizes 1/8 in [3.2 mm] and 5/32 in [4.0 mm]

3. Four percent of the mean dimension in sizes 3/16 in [4.8 mm] and larger

The concentricity may be measured by any suitable means.



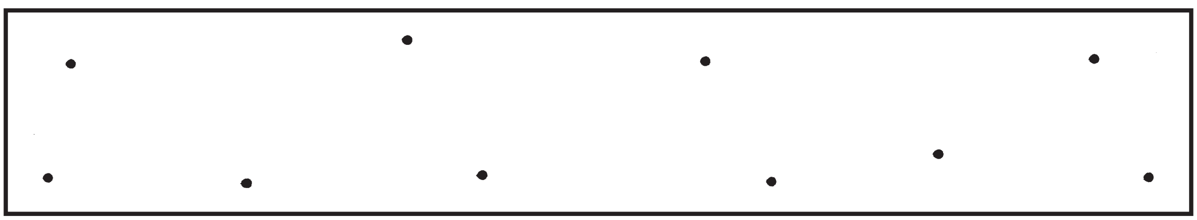
(A) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in TO 1/16 in [0.4 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 13 WITH THE FOLLOWING RESTRICTIONS:

MAXIMUM NUMBER OF LARGE 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 2.
MAXIMUM NUMBER OF MEDIUM 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 4.
MAXIMUM NUMBER OF SMALL 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 7.

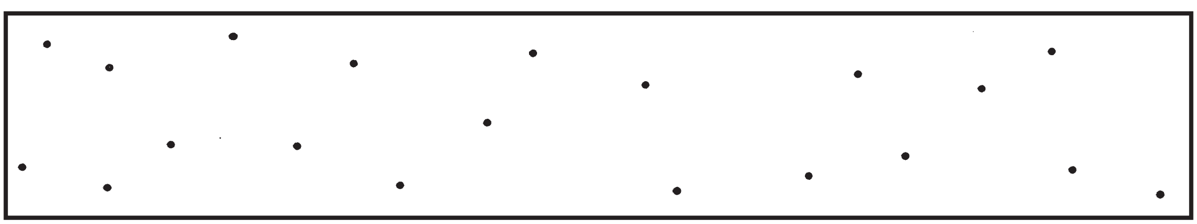
(B) LARGE ROUNDED INDICATIONS

SIZE 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 6.



(C) MEDIUM ROUNDED INDICATIONS

SIZE 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 10.

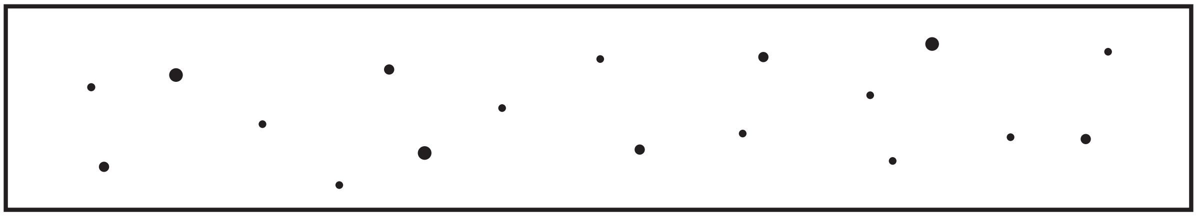


(D) SMALL ROUNDED INDICATIONS

SIZE 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 20.

Notes:
1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrications.

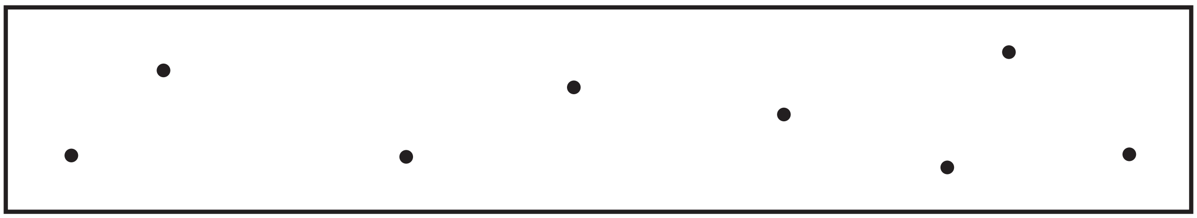
Figure 5A—Rounded Indication Standards for Radiograph Test—1/2 in [12 mm] Plate



(A) ASSORTED ROUNDED INDICATIONS

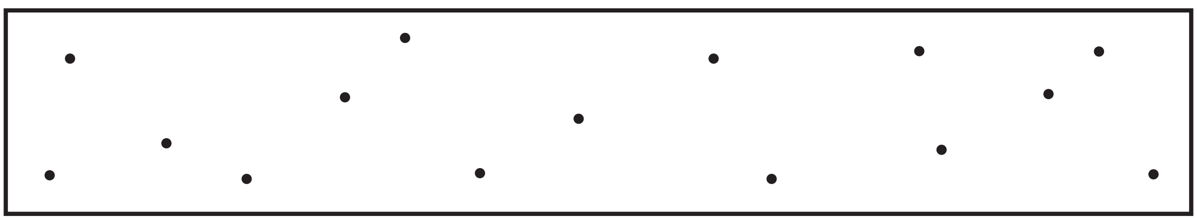
SIZE 1/64 in TO 1/16 in [0.4 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 18 WITH THE FOLLOWING RESTRICTIONS:

MAXIMUM NUMBER OF LARGE 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 5.
MAXIMUM NUMBER OF SMALL 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 10.



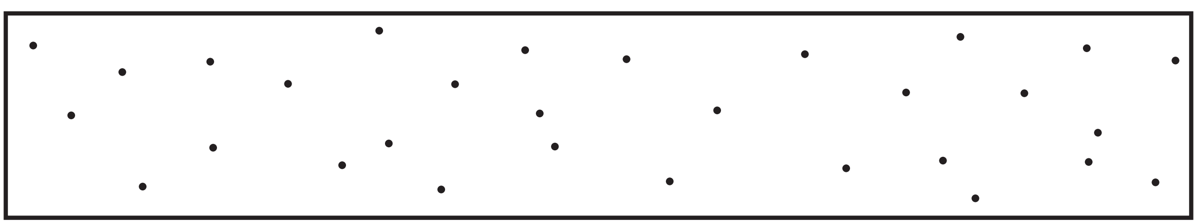
(B) LARGE ROUNDED INDICATIONS

SIZE 3/64 in TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 8.



(C) MEDIUM ROUNDED INDICATIONS

SIZE 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 15.



(D) SMALL ROUNDED INDICATIONS

SIZE 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 30.

Notes:
1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrications.

Figure 5B—Rounded Indication Standards for Radiograph Test—3/4 in [20 mm] Plate

Table 7
Standard Sizes and Lengths

Electrode Size (Diameter of Core Wire)[a]		Standard Lengths[b,c]	
in	mm	in	mm
1/16	1.6	9, 10	225, 250
5/64	2.0	9, 10	225, 250
3/32	2.4[e]	9, 10, 12, 14[d]	225, 250, 300, 350[d]
	2.5	9, 10, 12, 14[d]	225, 250, 300, 350[d]
1/8	3.2	14, 18[d]	350, 450[d]
5/32	4.0	14, 18[d]	350, 450[d]
3/16	4.8[e]	14, 18[d]	350, 450[d]
	5.0	14, 18[d]	350, 450[d]
7/32	5.6[e]	14, 18[d]	350, 450[d]
	6.0	14, 18[d]	350, 450[d]
1/4	6.4[e]	14, 18[d]	350, 450[d]

[a] Tolerance on the diameter shall be ±0.002 in [±0.05 mm].
[b] Tolerance on length shall be ±1/4 in [±6 mm].
[c] Other sizes and lengths shall be as agreed upon between purchaser and supplier.
[d] These lengths are intended only for the EXXX-26 type.
[e] These sizes are not standard in ISO 544.

17. Exposed Core

17.1 The grip end of each electrode shall be bare (free of covering) for a distance of not less than 1/2 in [12 mm], nor more than 1-1/4 in [30 mm] for electrodes 5/32 in [4.0 mm] and smaller, and not less than 3/4 in [19 mm], nor more than 1-1/2 in [38 mm] for electrodes 3/16 in [4.8 mm] and larger, to provide for electrical contact with the electrode holder.

17.2 The arc end of each electrode shall be sufficiently bare and the covering sufficiently tapered to permit easy striking of the arc. The length of the bare portion (measured from the end of the core wire to the location where the full cross section of the covering is obtained) shall not exceed 1/8 in [3 mm] or the diameter of the core wire, whichever is less. Electrodes with chipped coverings near the arc end, baring the core wire no more than the lesser of 1/4 in [6 mm] or twice the diameter of the core wire, meet the requirements of this specification, provided no chip uncovers more than 50 percent of the circumference of the core.

18. Electrode Identification

All electrodes shall be identified as follows:

18.1 At least one imprint of the electrode classification shall be applied to the electrode covering starting within 2-1/2 in [65 mm] of the grip end of the electrode. The prefix letter "E" in the electrode classification may be omitted from the imprint.

18.2 The numbers and letters of the imprint shall be of bold block type and of a size large enough to be legible.

18.3 The ink used for imprinting shall provide sufficient contrast with the electrode covering so that, in normal use, the numbers and letters are legible both before and after welding.

19. Packaging

19.1 Electrodes shall be suitably packaged to protect them from damage during shipment and storage under normal conditions.

19.2 Standard package weights shall be as agreed between purchaser and supplier.

20. Marking of Packages

20.1 The following product information (as a minimum) shall be legibly marked on the outside of each unit package:

1. AWS specification and classification designations (year of issue may be excluded)

2. Supplier's name and trade designation

3. Standard size and net weight

4. Lot, control, or heat number

20.2 The appropriate precautionary information[9] as given in ANSI Z49.1, latest edition (as a minimum), or its equivalent, shall be prominently displayed in legible print on all packages of electrodes, including individual unit packages enclosed within a larger package.

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

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Annex A (Informative)

Guide to AWS Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding

This annex is not a part of AWS A5.4/A5.4M:2006, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding,* but is included for informational only.

A1. Introduction

The purpose of this guide is to correlate the electrode classifications with their intended applications so the specification can be used effectively. Appropriate base metal specifications or welding processes are referred to whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the materials or welding processes for which each welding material is suitable.

A2. Classification System

A2.1 The system for identifying the electrode classification in this specification follows the standard pattern used in other AWS filler metal specifications. The prefix letter "E" at the beginning of each classification designation stands for electrode. The first three digits designate the classification as to its composition. (Occasionally, a number of digits other than three is used and letters may follow the digits to indicate a specific composition.) The last two digits designate the classification as to usability with respect to position of welding and type of current as described in A8. The smaller sizes of EXXX(X)-15, EXXX(X)-16, or EXXX(X)-17 electrodes up to and including 5/32 in [4.0 mm] included in this specification are used in all welding positions.

A2.1.1 The mechanical tests measure strength and ductility. In corrosive and high temperature applications where there may be no load-carrying or pressure-retaining requirement, mechanical properties are often of lesser importance than the corrosion and heat resisting properties. These mechanical test requirements, however, provide an assurance of freedom from weld metal flaws, such as check cracks and serious dendritic segregation which, if present, may cause failure in service.

A2.1.2 It is recognized that for certain applications, supplementary tests may be required. In such cases, additional tests to determine specific properties, such as corrosion resistance, scale resistance, or strength at elevated temperatures, may be required as agreed upon between supplier and purchaser (see A9).

A2.2 Request for New Classification

1. When a new classification that is different from those in this specification achieves commercial significance, the manufacturer, or the user, of this new classification may request that a classification be established for it and that it be included in this specification.

2. A request to establish a new classification must be a written request, and it needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials or the Subcommittee on Stainless Steel Filler Metals to determine whether the new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. In particular, the request needs to include:

a. All classification requirements as given for existing classifications, such as chemical composition ranges, mechanical property requirements, and usability test requirements.

b. Any testing conditions for conducting the tests used to demonstrate that the product meets the classification requirements. (It would be sufficient, for example, to state that welding conditions are the same as for other classifications.)

c. Information on Description and Intended Use, which parallels that for existing classifications, for that section of the annex.

A request for a new classification without the above information will be considered incomplete. The Secretary will return the request to the requestor for further information.

3. The request should be sent to the Secretary of the Committee on Filler Metals and Allied Materials at AWS Headquarters. Upon receipt of the request, the Secretary will:

a. Assign an identifying number to the request. This number will include the date the request was received.

b. Confirm receipt of the request and give the identification number to the person who made the request.

c. Send a copy of the request to the Chair of the Committee on Filler Metals and Allied Materials, and to the Chair of the Subcommittee on Stainless Steel Filler Metals.

d. File the original request.

e. Add the request to the log of outstanding requests.

4. All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairs of the Committee and the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a timely manner and the Secretary shall report these to the Chair of the Committee on Filler Metals and Allied Materials for action.

5. The Secretary shall include a copy of the log of all requests pending and those completed during the preceding year with the agenda for each Committee on Filler Metals and Allied Materials meeting. Any other publication of requests that have been completed will be at the option of the American Welding Society, as deemed appropriate.

A2.3 International Classification System. Table A.1 shows the classifications of welding filler metals in ISO 3581:2003 corresponding to those in this specification. In accordance with the generic system being adopted in many ISO specifications, the initial letter "E" designates a covered electrode, and the letter "S" the alloy system. The subsequent designators follow the AWS system. This system applies to classifications in ISO 3581B. The designations used in Europe for the closely corresponding classifications in ISO 3581A appear in Table A.1.

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 states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, must 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 is normally conducted 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 must be specifically required by the purchase order. In such cases, acceptance of the material shipped will 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 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 conducted. 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, *Filler Metal Procurement Guidelines*.

A5. Ventilation

A5.1 Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators are exposed during welding. They are:

1. Dimensions of the space in which the welding is done (with special regard to the height of the ceiling)

2. Number of welders and welding operators working in that space

Table A.1
Comparison of Classification in ISO 3581:2003

AWS A5.4/A5.4M	ISO 3581A	ISO 3581B
E209	—	ES209
E219	—	ES219
E240	—	ES240
E307	E18 9 Mn Mo	ES307
E308	E19 9	ES308
E308H	E19 9 H	ES308H
E308L	E19 9 L	ES308L
E308Mo	E20 10 3	ES308Mo
E308LMo	—	ES308LMo
E309	E22 12	ES309
E309H	—	ES309H
E309L	E22 12 L	ES309L
E309Nb	E23 12 Nb	ES309Nb
E309Mo	—	ES309Mo
E309LMo	E23 12 2 L	ES309LMo
E310	E25 20	ES310
E310H	E25 20H	ES310H
E310Nb	—	ES310Nb
E310Mo	—	ES310Mo
E312	E29 9	ES312
E316	E19 12 2	ES316
E316H	—	ES316H
E316L	E19 12 3 L	ES316L
E316LMn	E20 16 3 Mn N L	ES316LMn
E317	—	ES317
E317L	—	ES317L
E318	E 19 2 3 Nb	ES318
E320	—	ES320
E320LR	—	ES320LR
E330	E18 36	ES330
E330H	—	ES330H
E347	E19 9 Nb	ES347
E349	—	ES349
E409Nb	—	ES409Nb
E410	E13	ES410
E410NiMo	E13 4	ES410NiMo
E430	E17	ES430
E430Nb	—	ES430Nb
E630	—	ES630
E16-8-2	E16 8 2	ES16-8-2
E2209	E22 9 3 N L	ES2209
E2553	—	ES2553
E2593	E25 9 3 Cu N L	—
E2594	E25 9 4 N L	—
E2595	—	—
E3155	—	—
E33-31	—	—

3. Rate of evolution of fumes, gases, or dust, according to the materials and processes used

4. The proximity of the welders or welding operators to the fumes, as these fumes 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

A5.2 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 drawn particularly to the section on Ventilation in that document.

A6. Ferrite in Weld Deposits

A6.1 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.

A6.2 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, *Calibration Procedure for Instruments to Measure the Delta Ferrite Content of Austenitic Stainless Steel Weld Metal.*[10] In 1974, the American Welding Society extended this procedure and prepared AWS A4.2, *Standard Procedure 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 are to be traceable to this AWS standard.

A6.3 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.

A6.4 In the opinion of the WRC Subcommittee, it has been impossible, to date, to accurately determine the true absolute ferrite content of weld metals.

A6.5 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, 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.

A6.6 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.

A6.7 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.

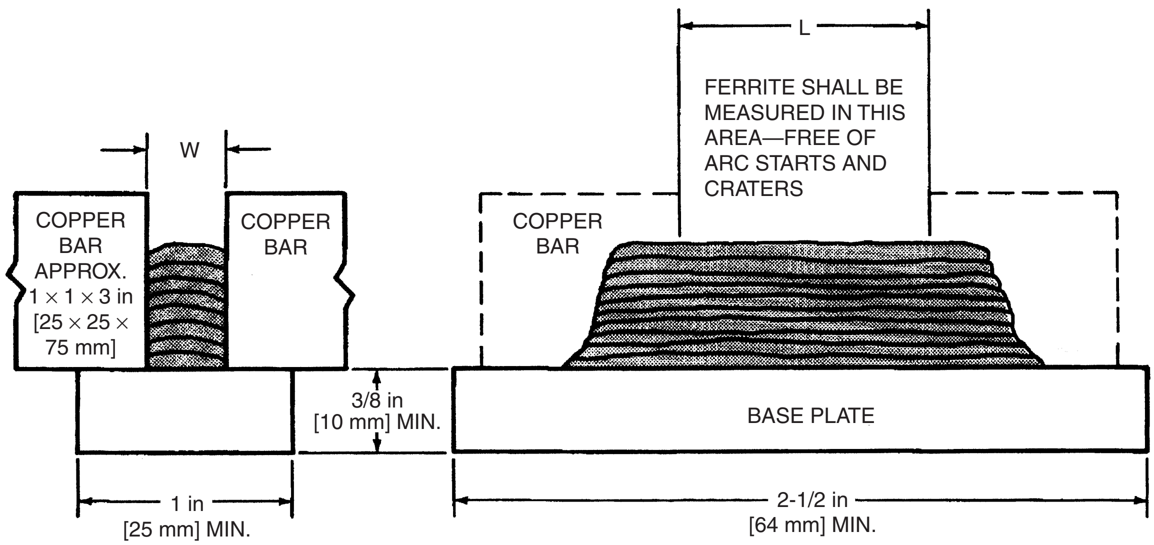
A6.8 In the E3XX classifications, many types such as E310, E310Mo, E310Nb, E316LMn, E320, E320LR, E330, E383, E385, and E3155, and E31-33 are fully austenitic. The E316 group can be made with little or no ferrite and generally is used in that form because it has better corrosion resistance in certain media. It also can be obtained in a higher ferrite form, usually over 4 FN, if

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

desired. Many of the other E3XX classifications can be made in low ferrite versions, but commercial practice usually involves ferrite control above 4 FN. Because of composition limits covering these grades and various manufacturing limits, most lots will be under 10 FN and they are unlikely to go over 15 FN, E308LMo and E309L can have ferrite levels in excess of 15 FN. E16-8-2 generally is controlled at a low ferrite level, under 5 FN; E309LMo, E312, E2209, E2553, E2593, and E2594, and E2595 generally are quite high in ferrite, usually over 20 FN.

A6.9 When it is desired to measure ferrite content, the following procedure is recommended to minimize variation in measured ferrite content and avoid false low or false high values.

A6.9.1 Weld pads as detailed in Figure A.1 are prepared as described in A6.9.2 through A6.9.4. The base plate should be Type 301, 302, or 304 conforming to ASTM Specification A 167 or A 240. Carbon steel may be used provided that the weld pad is built up to the minimum height specified in A 6.9.2.



Electrode Size		Welding Current Amperes[a]	Approximate Dimensions of Deposit			
			Width, W		Length, L	
in	mm	-15,-16,-17, -26	in	mm	in	mm
1/16	1.6	35–50	0.25	6.5	1-1/4	32
5/64	2.0	45–60	0.25	6.5	1-1/4	32
3/32	2.4, 2.5	65–90	0.3	7.5	1-1/2	38
1/8	3.2	90–120	0.4	10	1-1/2	38
5/32	4.0	120–150	0.5	13	1-1/2	38
3/16	4.8, 5.0	160–200	0.6	15	1-1/2	38
7/32	5.6	200–240	0.7	18	1-1/2	38
	6.0	220–260	0.7	18	1-1/2	38
1/4	6.4	240–280	0.7	18	1-1/2	38

[a] Recommended welding current will vary widely depending on the type of core wire employed. Consult the manufacturer for specific recommendations. Welding current used to produce the test specimen should be reported.

Figure A.1—Weld Pad for Ferrite Test

A6.9.2 The weld pad should be built up between two copper bars laid parallel on the base plate by depositing single weld bead layers, one on top of the other to a minimum height of 1/2 in [13 mm]. The spacing between the copper bars for the size of the electrode being tested should be as specified in Figure A.1. An optional welding fixture is shown in Figure A.2. If carbon steel is used as the base plate, the weld pad should be built up to a minimum height of 5/8 in [16 mm].

A6.9.3 Typical welding currents used for the size of the electrode being tested are shown in Figure A.1. The arc length should be as short as practicable. The weld bead layers may be deposited with a weave, if necessary, to fill the space between the copper bars. The arc should not be allowed to impinge on the copper bars. The welding direction should be alternated from pass to pass. The weld stops and starts should be located at the ends of the weld buildup. Each pass should be cleaned prior to depositing the next weld bead. The maximum interpass temperatures should be 200°F [95°C]. Between passes, the weld pad may be cooled by quenching in water not sooner than 20 seconds after the completion of each pass. The last pass should be air cooled to below 800°F [430°C] prior to quenching in water.

A6.9.4 The completed weld pad when the anticipated ferrite is 30 FN or less should be draw filed to provide sufficient finished surface to make the required ferrite readings. Draw filing should be performed with a 14 in [360 mm] mill bastard file held on both sides of the weld with the long axis of the file perpendicular to the long axis of the weld. (Other methods of surface preparation have been shown to result in work hardening and/or overheating, causing false measurements.) Files should either be new or should have been used only on austenitic stainless steel. Filing should be accomplished by smooth draw filing strokes (one direction only) along the length of the weld while applying a firm downward pressure. Cross filing, i.e., filing in two different directions,

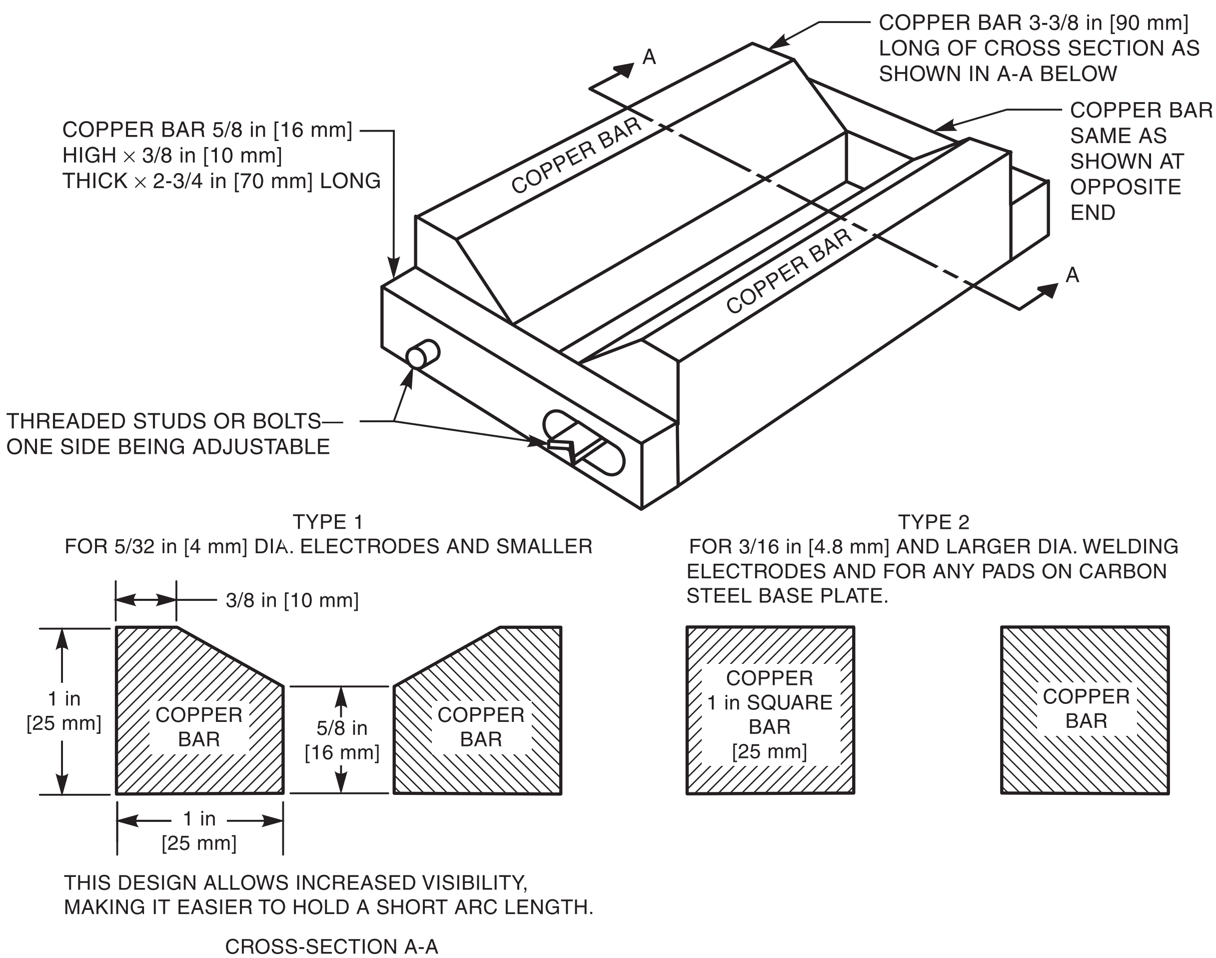


Figure A.2—Optional Welding Fixture for Welding Ferrite Test Pads

should not be permitted. The finished surface should be smooth with all traces of weld ripple removed and should be continuous in length where measurements are to be taken. The width of the prepared surface should not be less than 1/8 in [3 mm]. For anticipated ferrite levels greater than 30 FN, the surface should be ground with successfully finer abrasives to 600 grit or finer. Care should be taken during grinding to prevent overheating or burning. The completed weld pad should have the surface prepared so that it is smooth with all traces of weld ripple removed and should be continuous in length where measurements are to be taken. This can be accomplished by any suitable means providing the surface is not heated in excess during the machining operation (excessive heating may affect the final ferrite reading). The width of the prepared surface should not be less than 1/8 in [3 mm].

A6.9.5 A total of at least six ferrite readings should be taken on the finished surface along the longitudinal axis of the weld pad with an instrument calibrated in accordance with the procedures specified in AWS A4.2M, *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal* (latest edition). The readings obtained should be averaged to a single value.

A6.10 The ferrite content of welds may be calculated from the chemical composition of the weld deposit. This can be done from the WRC-1992 Diagram (Figure A.3).

A6.10.1 The WRC-1992 Diagram[11] (Figure A.3) predicts the ferrite content in Ferrite Number (FN). It is a slight modification of the WRC-1988 Diagram[12] to take into account the effect of copper as originally proposed by Lake. Studies within the WRC Subcommittee on Welding of Stainless Steel and within Commission II of

[11] 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.

[12] McCowan, C. N., Siewert, T. A., and Olson, D. L. 1989. WRC Bulletin 342, *Stainless Steel Weld Metal: Prediction of Ferrite Content*. Welding Research Council, New York, NY.

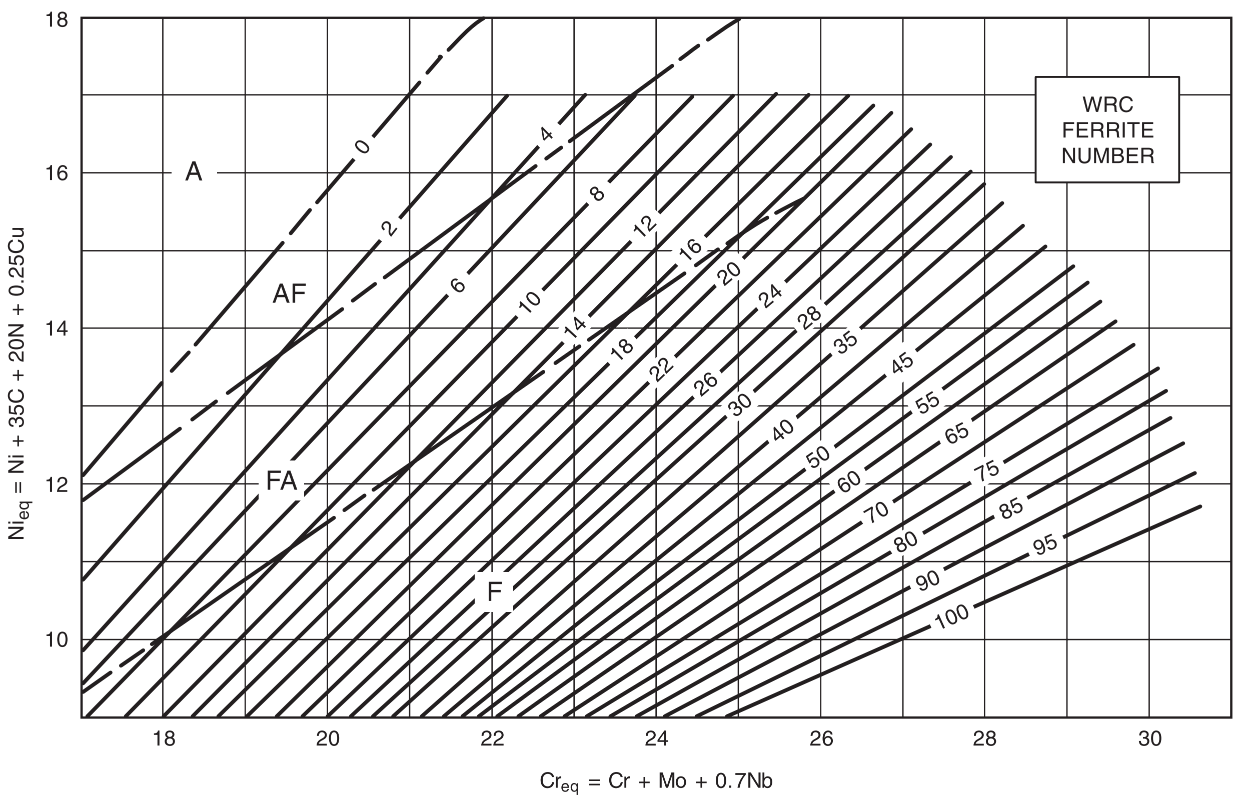


Figure A.3—WRC-1992 (FN) Diagram for Stainless Steel Weld Metal

the International Institute of Welding show a closer agreement between measured and predicted ferrite contents using the WRC-1988 Diagram than when using the previously used DeLong Diagram. The WRC-1992 Diagram may not be applicable to compositions having greater than 0.3 percent nitrogen, one percent silicon or greater than ten percent manganese. For stainless steel compositions not alloyed with Cu, the predictions of the 1988 and 1992 diagrams are identical.

A6.10.2 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.

A7. Description and Intended Use of Filler Metals

A7.1 E209. The nominal composition (wt. %) of this weld metal is 22 Cr, 11 Ni, 5.5 Mn, 2 Mo, and 0.20 N. Electrodes of this composition are most often used to weld AISI Type 209 (UNS S20910) base metals. The alloy is a nitrogen-strengthened austenitic stainless steel exhibiting high strength with good toughness over a wide range of temperatures. Nitrogen alloying reduces the tendency for intergranular carbide precipitation in the weld area by inhibiting carbon diffusion and thereby increasing resistance to intergranular corrosion. Nitrogen alloying coupled with the molybdenum content provides superior resistance to pitting and crevice corrosion in aqueous chloride-containing media. Type E209 electrodes have 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 applications.

A7.2 E219. The nominal composition (wt. %) of this weld metal is 20 Cr, 6 Ni, 9 Mn, and 0.20 N. Electrodes of this composition are most often used to weld AISI Type 219 (UNS S21900) base metals. This alloy is a nitrogen-strengthened austenitic stainless steel exhibiting high strength with good toughness over a wide range of temperatures. Nitrogen alloying reduces the tendency for intergranular carbide precipitation in the weld area by inhibiting carbon diffusion, and thereby increases resistance to intergranular corrosion. Nitrogen alloying also improves resistance to pitting and crevice corrosion in aqueous chloride containing media. The E219 electrodes have 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 applications.

A7.3 E240. The nominal composition (wt. %) of this weld metal is 18 Cr, 5 Ni, 12 Mn, and 0.20 N. Electrodes of this composition are most often used to weld AISI Type 240 and 241 base metals. These alloys are nitrogen-strengthened austenitic stainless steels exhibiting high strength with good toughness over a wide range of temperatures. Significant improvement in resistance to wear in particle-to-metal and metal-to-metal (galling) applications is a desirable characteristic when compared to the more conventional austenitic stainless steels like Type 304. Nitrogen alloying reduces the tendency for intergranular carbide precipitation in the weld area by inhibiting carbon diffusion and thereby increasing resistance to intergranular corrosion. Nitrogen alloying also improves resistance to pitting and crevice corrosion in aqueous chloride-containing media. In addition, weldments in Alloys AISI 240 and AISI 241 when compared to Type 304, exhibit improved resistance to transgranular stress corrosion cracking in hot aqueous chloride-containing media. The E240 electrodes have 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.

A7.4 E307. The nominal composition (wt.%) of this weld metal is 19.8 Cr, 9.8 Ni, 4 Mn and 1 Mo. Electrodes of this composition 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.

A7.5 E308. The nominal composition (wt. %) of this weld metal is 19.5 Cr, and 10 Ni. Electrodes of this composition are most often used to weld base metal of similar composition such as AISI Types 301, 302, 304, and 305.

A7.6 E308H. These electrodes are the same as E308 except that the allowable weld metal carbon content has been restricted to eliminate the lowest carbon levels. Carbon content in the range of 0.04 to 0.08 percent provides higher tensile and creep strengths at elevated temperatures. These electrodes are used for welding Type 304H base metal. Weld metal ferrite content is normally targeted for 5 FN to minimize the effect of sigma embrittlement in high-temperature service.

A7.7 E308L. The composition of the weld metal is the same as E308, except for the carbon content. The 0.04 percent maximum carbon content of weld metal deposited by these electrodes reduces the possibility of intergranular carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. A carbon content of 0.04 percent maximum has been shown to be adequate in weld metal, even though it is recognized that similar base metal specifications require a 0.03 percent limitation. This low-carbon alloy, however, is not as strong at elevated temperature as E308H or E347.

A7.8 E308Mo. These electrodes are the same as E308, except for the addition of molybdenum. E308Mo electrodes are recommended for welding ASTM CF8M stainless steel castings, as they match the base metal with regard to chromium, nickel, and molybdenum. They may also be used for welding wrought materials such as Type 316 stainless when increased ferrite is desired beyond that attainable with E316 electrodes.

A7.9 E308LMo. These electrodes are recommended for welding ASTM CF3M stainless steel castings, as they match the base metal with regard to chromium, nickel, and molybdenum. E308LMo electrodes may also be used for welding wrought materials such as Type 316L stainless when increased ferrite is desired beyond that attainable with E316L electrodes.

A7.10 E309. The nominal composition (wt. %) of this weld metal is 23.5 Cr, 13 Ni with carbon levels allowed up to 0.15 percent and typical ferrite levels from 3 to 20 FN. Electrodes of this composition are used for welding similar compositions in wrought or cast form. They are also used for welding dissimilar steels, such as joining Type 304 to carbon or low-alloy steel, welding the clad side of Type 304-clad steels, making the first layer of a 308 weld cladding and applying stainless steel sheet linings to carbon steel shells. Embrittlement or cracking can occur if these dissimilar steel welds are subjected to a postweld heat treatment or to service above 700ºF [370ºC]. Occasionally, they are used to weld Type 304 and similar base metals where severe corrosion conditions exist requiring higher alloy weld metal. Essentially, there are two electrodes contained within this specification, E309H and E309L, and for critical applications their use is encouraged. See below for their specific applications.

A7.11 E309H. These electrodes are the same as E309, except that the allowable weld metal carbon content has been restricted to eliminate the lowest carbon levels. The carbon restriction will provide higher tensile and creep strengths at elevated temperatures. This together with a typical ferrite content of about 6 FN make these electrodes suitable for the welding of 24 Cr 12 Ni wrought and cast steels designed for corrosion and oxidation resistance. High carbon castings to ACI's HH grade should be welded with an electrode that is similar to the casting composition.

A7.12 E309L. The composition of this weld metal is the same as that deposited by E309 electrodes, except for the lower carbon content. The 0.04 percent maximum carbon content of these weld deposits ensures a higher ferrite content than the E309H, usually greater than 8 FN and reduces the possibility of intergranular carbide precipitation. This thereby increases the resistance to intergranular corrosion without the use of niobium (columbium). E309L deposits are not as strong at elevated temperature as the niobium-stabilized alloy or E309H deposits. E309L electrodes are commonly used for welding dissimilar steels, such as joining Type 304 to mild or low-alloy steel, welding the clad side of Type 304-clad steels, welding the first layer of E308L weld cladding and applying stainless steel sheet linings to carbon steel. Embrittlement or cracking can occur if these dissimilar steel welds are subjected to a post weld heat treatment or to service above 700ºF [370ºC]. If postweld heat treatment of the carbon steel is essential, the total procedure, welding and heat treatment, should be proven prior to implementation.

A7.13 E309Nb. The composition of this weld metal is the same as Type 309, except for the addition of niobium and a reduction in the carbon limit. The niobium provides resistance to carbide precipitation and thus increases intergranular corrosion resistance, and also provides higher strength in elevated-temperature service. E309Nb electrodes are used also for welding Type 347 clad steels or for the overlay of carbon steel.

A7.14 E309Mo. The composition of this weld metal is the same as that deposited by E309 electrodes, except for the addition of molybdenum and a small reduction in the carbon limit. These electrodes are used for welding Type 316 clad steels or for the overlay of carbon steels.

A7.15 E309LMo. The composition of this weld metal is the same as that deposited by E309Mo electrodes, except for the restricted carbon content. The lower carbon content of the weld metal reduces the possibility of intergranular corrosion and increases the ferrite content. This in turn reduces the potential for solidification cracking when deposited onto carbon or low alloy steels.

A7.16 E310. The nominal composition (wt. %) of this weld metal is 26.5 Cr, 21 Ni. Electrodes of this composition are most often used to weld base metals of similar composition.

A7.17 E310H. The composition of this weld metal is the same as that deposited by E310 electrodes, except that carbon ranges from 0.35 to 0.45 percent. These electrodes are used primarily for welding or repairing high-alloy heat and corrosion-resistant castings of the same general composition which are designated as Type HK by the Alloy Castings Institute. The alloy has high strength at temperatures over 1700°F [930°C]. It is not recommended for high-sulfur atmospheres or where severe thermal shock is present. Long time exposure to temperatures in the approximate range of 1400°F to 1600°F [760°C to 870°C] may induce formation of sigma and secondary carbides which may result in reduced corrosion resistance, reduced ductility, or both. The composition of this electrode should not be confused with the stainless steel wrought alloy 310H which has a lower carbon content of 0.04–0.10 percent.

A7.18 E310Nb. The composition of this weld metal is the same as that deposited by E310 electrodes, except for the addition of niobium and a reduction in carbon limit. These electrodes are used for the welding of heat-resisting castings, Type 347 clad steels, or the overlay of carbon steels.

A7.19 E310Mo. The composition of this weld metal is the same as that deposited by E310 electrodes, except for the addition of molybdenum and a reduction in carbon limit. These electrodes are used for the welding of heat-resisting castings, Type 316 clad steels, or for the overlay of carbon steels.

A7.20 E312. The nominal composition (wt. %) of this weld metal is 30 Cr, 9 Ni. These electrodes were originally designed to weld cast alloys of similar composition. They have been found to be valuable in welding dissimilar metals, especially if one of them is a stainless steel, high in nickel. This alloy gives a two-phase weld deposit with substantial amounts of ferrite in an austenitic 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. Applications should be limited to service temperature below 800°F [420°C] to avoid formation of secondary brittle phases.

A7.21 E316. The nominal composition (wt. %) of this weld metal is 18.5 Cr, 12.5 Ni, 2.5 Mo. These electrodes are used for welding Type 316 and similar alloys. They have been used successfully in certain applications involving special base metals for high-temperature service. For these high-temperature applications in the past, the carbon level would have been about 0.06%. For similar current or future applications, the use of E316H would ensure similar carbon levels. The presence of molybdenum provides creep resistance and increased ductility at elevated temperatures. Rapid corrosion of Type 316 weld metal may occur when the following three factors coexist:

1. The presence of a continuous or semi continuous 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.

A7.22 E316H. These electrodes are the same as E316, except that the allowable weld metal carbon content has been restricted to eliminate the lowest carbon levels. Carbon content in the range of 0.04 to 0.08 percent provides higher tensile and creep strengths at elevated temperatures. These electrodes are used for welding 316H base metal.

A7.23 E316L. This composition is the same as E316, except for the carbon content. The 0.04 percent maximum carbon content of weld metal deposited by these electrodes reduces the possibility of intergranular carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. These electrodes are used principally for welding low-carbon, molybdenum-bearing austenitic alloys. Tests have shown that 0.04 percent carbon limit in the weld metal gives adequate protection against intergranular corrosion in most cases. This low-carbon alloy, however, is not as strong at elevated temperatures as Type E316H. This classification with maximum ferrite content of 2 FN has traditionally been the choice for welding Types 304 and 316 stainless steels for cryogenic service at temperatures down to –452°F [–269°C].

A7.24 E316LMn. The nominal composition (wt. %) of this weld metal is 19.5 Cr, 16.5 Ni, 6.5 Mn, 3 Mo, 0.2 N. This is normally a fully austenitic alloy with a maximum ferrite content of 0.5 FN. In critical applications for cryogenic and corrosion resistant service, the purchaser should specify the maximum ferrite allowable. One of the primary uses of this electrode is for the joining of similar and dissimilar cryogenic steels for applications down to –452°F [–269°C]. Similar steels include stainless steels such as UNS S30453 and S31653. This electrode also exhibits good corrosion resistance in acids and seawater, and is particularly suited to the corrosion conditions found in urea synthesis plants. It is also nonmagnetic. The high Mn-content of the alloy helps to stabilize the austenitic microstructure and aids in hot cracking resistance.

A7.25 E317. The alloy content of weld metal deposited by these electrodes is somewhat higher than that of Type

E316 electrodes, particularly in molybdenum. These electrodes are usually used for welding alloys of similar composition and are utilized in severely corrosive environments (such as those containing halogens) where crevice and pitting corrosion are of concern.

A7.26 E317L. The composition of this weld metal is the same as that deposited by E317 electrodes, except for the carbon content. The 0.04 percent maximum carbon content of weld metal deposited by these electrodes reduces the possibility of intergranular carbide precipitation and thereby increases the resistance to intergranular corrosion without the use of stabilizers such as niobium or titanium. This low-carbon alloy, however, is not as strong at elevated temperatures as the niobium-stabilized alloys or the standard Type 317 weld metal with higher carbon content.

A7.27 E318. The composition of this weld metal is the same as that deposited by E316 electrodes, except for the addition of niobium. Niobium provides resistance to intergranular carbide precipitation and thus increased resistance to intergranular corrosion. These electrodes are used primarily for welding base metals of similar composition.

A7.28 E320. The nominal composition (wt. %) of this weld metal is 20 Cr, 34 Ni, 2.5 Mo, 3.5 Cu, with Nb added to improve resistance to intergranular corrosion. These electrodes are primarily used to weld base metals of similar composition for applications where resistance to severe corrosion is required for a wide range of chemicals including sulfuric and sulfurous acids and their salts. These electrodes can be used to weld both castings and wrought alloys of similar compositions without postweld heat treatment.

A modification of this grade without niobium, not classified herein, is available for repairing castings which do not contain niobium. With this modified composition, solution annealing is required after welding.

A7.29 E320LR (Low Residuals). Weld metal deposited by E320LR electrodes has the same basic composition as that deposited by E320 electrodes; however, the elements C, Si, P, and S are specified at lower maximum levels, and Nb and Mn are controlled within narrower ranges. These changes reduce the weld metal fissuring (while maintaining the corrosion resistance) frequently encountered in fully austenitic stainless steel weld metals. Consequently, welding practices typically used to deposit ferrite-containing austenitic stainless steel weld metals can be used. Type 320LR weld metal has a lower minimum tensile strength than Type 320 weld metal.

A7.30 E330. The nominal composition (wt. %) of this weld metal is 35 Ni, 15.5 Cr. These electrodes are commonly used where heat- and scale-resisting properties above 1800°F [980°C] are required. However, high-sulfur environments may adversely affect performance at elevated temperature. Repairs of defects in alloy castings and the welding of castings and wrought alloys of similar compositions are the most common applications.

A7.31 E330H. The composition of this weld metal is the same as that deposited by E330 electrodes, except that carbon ranges from 0.35 to 0.45 percent. These electrodes are used primarily for the welding and repairing of high-alloy heat and corrosion-resistant castings of the same general composition which are designated HT by the Alloy Castings Institute. This composition can be used to 2100°F [1150°C] in oxidizing atmospheres and at 2000°F [1090°C] in reducing atmospheres. However, high-sulfur environments may adversely affect performance at elevated temperature.

A7.32 E347. The nominal composition (wt. %) of this weld metal is 19.5 Cr, 10 Ni with Nb or Nb plus Ta added as a stabilizer. Either of these additions reduces the possibility of intergranular chromium carbide precipitation and thus increases resistance to intergranular corrosion.

These electrodes are usually used for welding chromium-nickel alloys of similar compositions stabilized either with niobium or titanium. Electrodes depositing titanium as a stabilizing element are not commercially available because titanium is not readily transferred across the arc in shielded metal arc welding. Although niobium is the stabilizing element usually specified in Type 347 alloys, it should be recognized that tantalum also is present. Tantalum and niobium are almost equally effective in stabilizing carbon and in providing high-temperature strength. This specification recognizes the usual commercial practice of reporting niobium as the sum of niobium plus tantalum. If dilution by the base metal produces a low-ferrite or fully austenitic weld metal deposit, crack sensitivity of the weld may increase substantially.

Some applications, especially those involving high-temperature service, are adversely affected if the ferrite content is too high. Consequently, a high ferrite content should not be specified unless tests prove it to be absolutely necessary.

A7.33 E349. The normal composition (wt. %) of this weld metal is 19.5 Cr, 9 Ni, 1 Nb, 0.5 Mo, 1.4 W. These electrodes are used for welding steels of similar composition such as AISI Type 651 or 652. The combination of niobium, molybdenum, and tungsten with chromium and nickel gives good high-temperature rupture strength. The chemical composition of the weld metal results in an appreciable content of ferrite which increases the crack resistance of the weld metal.

A7.34 E383. The nominal composition (wt. %) of this weld metal is 28 Cr, 31.5 Ni, 3.7 Mo, 1 Cu. These electrodes are used to weld base metal of a similar composition to itself and to other grades of stainless steel. Type E383 weld 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.

A7.35 E385. The nominal composition (wt. %) of this weld metal is 20.5 Cr, 25 Ni, 5 Mo, 1.5 Cu. These electrodes are used primarily for welding of Type 904L materials for the handling of sulfuric acid and many chloride-containing media. Type E385 electrodes also may be used to join Type 317L material where improved corrosion resistance in specific media is needed. E385 electrodes also can be used for joining Type 904L base metal to other grades of stainless. The elements C, Si, P, and S 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.

A7.36 E409Nb. The composition of this weld metal is very similar to that deposited by E410 electrodes, except that niobium has been added which produces a ferritic microstructure with fine grains. These electrodes are used for the welding of ferritic stainless steels such as Types 405 and 409. They are also used for the second and/or additional layers in the welding of Type 410 clad stainless steel and for the overlay of carbon and low alloy steels. Preheat and postweld heat treatments are required to achieve welds of adequate ductility for many engineering purposes. This weld deposit cannot be expected to develop the strength and hardness of a fully hardened martensitic stainless steel alloy such as Type 410.

A7.37 E410. This 12 Cr alloy is an air-hardening steel. Preheat and postheat treatments are required to achieve welds of adequate ductility for many engineering purposes. The most common application of these electrodes is for welding alloys of similar compositions. They are also used for surfacing of carbon steels to resist corrosion, erosion, or abrasion.

A7.38 E410NiMo. These electrodes are used for welding ASTM CA6NM (CA-6NM) castings or similar materials, as well as light-gauge Type 410, 410S, and 405 base metals. Weld metal deposited by these electrodes is modified to contain less chromium and more nickel than weld metal deposited by E410 electrodes. The objective is to eliminate ferrite in the microstructure, as ferrite has a deleterious effect on mechanical properties of this alloy. Final postweld heat treatment should not exceed 1150°F [620°C]. Higher temperatures may result in rehardening due to untempered martensite in the microstructure after cooling to room temperature.

A7.39 E430. The weld metal deposited by these electrodes contains between 15 and 18 Cr (wt. %). 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 to meet the mechanical requirements of the specification. (Excessive chromium will result in lowered ductility.) Welding with E430 electrodes usually requires preheat and postheat. Optimum mechanical properties and corrosion resistance are obtained only when the weldment is heat treated following the welding operation.

A7.40 E430Nb. The composition of this weld metal is the same as that deposited by E430 electrodes, except for the addition of niobium. The weld deposit is a ferritic microstructure with fine grains. Preheat and postweld heat treatments are required to achieve welds of adequate ductility for many engineering purposes. These electrodes are used for the welding of Type 430 stainless steel. They are also used for the first layer in the welding of Type 405 and 410 clad steels.

A7.41 E630. The nominal composition (wt. %) of these electrodes is 16.4 Cr, 4.7 Ni, 3.6 Cu. These electrodes are primarily designed for welding ASTM A 564, Type 630, and some other precipitation-hardening stainless steels. The weld metal is modified to prevent the formation of ferrite networks in the martensite microstructure which could have a deleterious effect on mechanical properties. Dependent on the application and weld size, the weld metal may be used either as-welded, welded and precipitation hardened, or welded, solution treated and precipitation hardened.

A7.42 E16-8-2. The nominal composition (wt. %) of this weld metal is 15.5 Cr, 8.5 Ni, 1.5 Mo. These electrodes are 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 relative freedom from weld or crater cracking even under high-restraint conditions. The weld metal is usable in either the as-welded or solution-treated condition. These electrodes depend on a very carefully balanced chemical composition to develop their fullest properties. Corrosion tests indicate that Type 16-8-2 weld metal may have less corrosion resistance than Type 316 base metal depending on the corrosive media. Where the weldment is exposed to severely corrosive agents, the surface layers should be deposited with a more corrosion-resistant weld metal.

A7.43 E2209. The nominal composition (wt. %) of this weld metal is 22.5 Cr, 9.5 Ni, 3 Mo, 0.15 N. Electrodes of this composition are used primarily to weld duplex stainless steels which contain approximately 22 percent of chromium. Weld metal deposited by these electrodes has "duplex" microstructure consisting of an austenite-ferrite matrix. Weld metal deposited by E2209 electrodes combines increased tensile strength with improved resistance to pitting corrosive attack and to stress corrosion cracking. If postweld annealing is required this weld metal will require a higher annealing temperature than that required by the duplex base metal.

A7.44 E2553. The nominal composition (wt. %) of this weld metal is 25.5 Cr, 7.5 Ni, 3.4 Mo, 2 Cu and 0.17 N. These electrodes are used primarily to weld duplex stainless steels which contain approximately 25 percent of chromium. Weld metal deposited by these electrodes has a "duplex" microstructure consisting of an austenite-ferrite matrix. Weld metal deposited by E2553 electrodes combines increased tensile strength with improved resistance to pitting corrosive attack and to stress corrosion cracking.

A7.45 E2593. The nominal composition (wt. %) of this weld metal is 25 Cr, 9.5 Ni, 3.4 Mo, 2.5 Cu and 0.2 N. These electrodes are used primarily to weld duplex stainless steels which contain approximately 25 percent chromium. Weld metal deposited by these electrodes has a "duplex" microstructure consisting of an austenite-ferrite matrix. Weld metal deposited by E2593 electrodes combines increased tensile strength with improved resistance to pitting corrosive attack and to stress corrosion cracking. If postweld annealing is required this weld metal will require a higher annealing temperature than that required by the E2553 classification or the duplex base metal.

A7.46 E2594. The nominal composition (wt. %) of this weld metal is 25.5 Cr, 10 Ni, 4 Mo, and 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 Type 2507 super-duplex stainless steels UNS S32750 (wrought) and UNS J93404 (cast), and similar compositions. 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 steels such as Type 2205 although the weld metal impact toughness may be inferior to that from E2209 electrodes. If post weld annealing is required this weld metal will require a higher annealing temperature than that required by the duplex base metal.

A7.47 E2595. The nominal composition (wt. %) of this weld metal is 25.5 Cr, 9 Ni, 3.8 Mo, 0.7 Cu, 0.7 W, and 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 S32550, S32750, and S32760 (wrought), and UNS J93370, J93380, J93404, CD4MCuN (cast), and similar compositions. 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 S31803 and UNS S32205.

A7.48 E3155. The nominal chemical composition of this weld metal is 21.25 Cr, 19.75 Co, 20 Ni, 3.0 Mo, 2.5 W. These electrodes are used primarily for welding parts fabricated from material of similar or dissimilar composition, particularly when the weld zone is required to have corrosion and heat resistance comparable to that of the parent metal. It is used in aerospace applications including tailpipes and tail cones, afterburner parts, exhaust manifolds, combustion chambers, turbine blades, buckets, and nozzles. Its high-temperature properties are inherent and are not dependent upon age hardening.

A7.49 E33-31 The nominal chemical composition (wt. %) of weld metal produced by electrodes of this classification is 31 Ni, 32 Fe, 33 Cr, 1.6 Mo, and low carbon. The filler materials are used for welding nickel-chromium-iron alloy (UNS R20033) to itself, and to weld to carbon steel. The ASTM specifications for this alloy are B 625, B 649, B 366, B 472, B 564, B 619, B 622, and B 626. The electrodes are generally used in the flat position.

A8. Classification as to Usability

A8.1 Four basic usability classifications are provided in this specification, as shown in Table 2.

A8.2 The type of covering applied to a core wire to make a shielded metal arc welding electrode typically determines the usability characteristics of the electrode. The following discussion of covering types is based upon terminology commonly used by the industry; no attempt has been made to specifically define the composition of the different covering types.

A8.3 Usability Designation -15. The electrodes are usable with dcep (electrode positive) only. While use with alternating current is sometimes accomplished, they are not intended to qualify for use with this type of current. Electrode sizes 5/32 in [4.0 mm] and smaller may be used in all positions of welding.

A8.4 Usability Designation -16. The covering for these electrodes generally contains readily ionizing elements, such as potassium, in order to stabilize the arc for welding with alternating current. Electrode sizes 5/32 in [4.0 mm] and smaller may be used in all positions of welding.

A8.5 Usability Designation -17. The covering of these electrodes is a modification of the -16 covering in that considerable silica replaces some of the titania of the -16 covering. Since both the -16 and the -17 electrode coverings permit ac operation, both covering types were classified as -16 in the past because there was no classification alternative until the 1992 revision of AWS A5.4. However, the operational differences between the two types have become significant enough to warrant a separate classification.

On horizontal fillet welds, electrodes with a -17 covering tend to produce more of a spray arc and a finer rippled weld-bead surface than do those with the -16 coverings. A slower freezing slag of the -17 covering also permits improved handling characteristics when employing a drag technique. The bead shape on horizontal fillets is typically flat to concave with -17 covered electrodes as compared to flat to slightly convex with -16 covered electrodes. When making fillet welds in the vertical position with upward progression, the slower freezing slag of the -17 covered electrodes requires a slight weave technique to produce the proper bead shape. For this reason, the minimum leg- size fillet that can be properly made with a -17 covered electrode is larger than that for a -16 covered electrode. While these electrodes are designed for all-position operation, electrode sizes 3/16 in [4.8 mm] and larger are not recommended for vertical or overhead welding.

A8.6 Usability Designation -26. This designation is for those electrodes that are designed for flat and horizontal fillet welding and that have limited out of position characteristics. In practice most of these electrodes give higher deposition rates than their all-positional counterparts owing to their thicker coatings that contain higher levels of metal powders. The thicker coating gives larger fillet welds that are typically flat to concave. It also reduces the effects of core wire overheating, making 18 inch long electrodes possible for the larger electrodes, even with stainless steel core wire. Higher currents are usually required to achieve the necessary penetration compared to the all-positional types.

The slag system of these electrodes is similar to those of the -16 and -17 designations. The resulting slag may be more fluid and even slower freezing than that from electrodes with a -17 designation. Core wire compositions are typically either Type 304L stainless steel or low carbon mild steel. Electrodes with the latter tend to have thicker coatings to accommodate the necessary alloys in order to attain the required weld metal composition. Such electrodes require even higher currents to compensate for the additional coating to be melted and the lower resistance of the core wire.

Electrodes with the -26 designation are recommended for welding only in the flat and horizontal fillet positions. The manufacturer's suggested operating currents should be consulted. Out of position welding may be possible with electrode sizes up to 1/8 in [3.2 mm] diameter.

A9. Special Tests

A9.1 Corrosion or Scaling Resistance Tests

A9.1.1 Although welds made with electrodes covered by this specification are commonly used in corrosion-resisting or heat-resisting applications, it is not practical to require tests for corrosion or scale resistance on welds or weld metal specimens. Such special tests which are pertinent to the intended application may be conducted as agreed upon between supplier and purchaser. This section is included for the guidance of those who desire to specify such special tests.

A9.1.2 Corrosion or scaling tests of joint specimens have the advantage that the joint design and welding procedure can be made identical to those being used in fabrication. They have the disadvantage of being a test of the combined properties of the weld metal, the heat-affected zone of the base metal, and the unaffected base metal. Furthermore, it is difficult to obtain reproducible data if a difference exists between the corrosion or oxidation rates of the various metal structures (weld metal, heat-affected zone, and unaffected base metal). Test samples cannot be readily standardized if welding procedure and joint design are to be considered variables. Joint specimens for corrosion tests should not be used for qualifying the electrode but may be used for qualifying welding procedures using approved materials.

A9.1.3 All-weld-metal specimens for testing corrosion or scale resistance are prepared by following the procedure outlined for the preparation of pads for chemical analysis (see Clause 10). The pad size should be at least 3/4 in [19 mm] in height by 2-1/2 in [65 mm] wide by 1 + 5/8n in [25 + 16n mm] long, where "n" represents the number of specimens required from the pad. Specimens measuring 1/2 × 2 × 1/4 in [13 × 50 × 6.4 mm] are machined from the top surface of the pad in such a way that the 2 in [50 mm] dimension of the specimen is parallel to the 2-1/2 in [65 mm] width dimension of the pad and the 1/2 in [13 mm] dimension is parallel to the length of the pad.

A9.1.4 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 the 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*.

A9.2 Mechanical Properties Tests for Dissimilar Metal Welds

A9.2.1 Tests for mechanical properties of joint specimens may be desired when the intended application involves the welding of dissimilar metals. Procedures for the mechanical testing of such joints should be in accordance with the latest edition of AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds*.

A9.2.2 Tests of joint specimens may be influenced by the properties of the base metal and welding procedures and may not provide adequate tests of the weld metal. Such tests should be considered as tests for qualifying welding procedures using approved materials rather than tests for qualifying the electrodes.

A9.2.3 Where fabrication codes require tests of welds in heat-treated conditions other than those specified in Table 6, all-weld-metal tests of heat-treated specimens may be desired. For the preparation of such specimens, the procedures outlined in Clause 12, Tension Test and Clause 13, Fillet Weld Test, should be followed.

A9.3 Impact Property Tests for Welds Intended for Cryogenic Service

A9.3.1 Fully austenitic stainless steel weld metals are known to possess excellent toughness at cryogenic temperatures such as –320°F [–196°C]. To ensure freedom from brittle failure, Section VIII of the ASME *Boiler and Pressure Vessel Code* requires weldments intended for cryogenic service be qualified by Charpy V-notch testing. The criterion for acceptability is the attainment of a lateral expansion opposite the notch of not less than 15 mils (0.015 in) [0.38 mm] for each of three specimens.

A9.3.2 Austenitic stainless steel weld metals usually are not fully austenitic but contain some delta ferrite. Delta ferrite is harmful to cryogenic toughness. However, fully austenitic weld metal has a greater susceptibility to hot cracking (see A6). It has been found that such weld metals require judicious compositional balances to meet the 15 mils [0.38 mm] lateral expansion criterion even at moderately low temperatures such as –150°F [–100°C].

A9.3.3 Electrode classifications which can be used if special attention is given to the weld deposit composition content to maximize toughness are E308L-XX, E316L-XX, and E316LMn-XX. Published studies of the effect of composition changes on weldment toughness properties for these types have shown the following:

A9.3.3.1 Both carbon and nitrogen contents have strong adverse effects on weld metal toughness so that their contents should be minimized. Low-carbon weld metals with nitrogen content below 0.06 percent are preferred.

A9.3.3.2 Nickel appears to be the only element whose increased content in weld metal improves weld metal toughness.

A9.3.3.3 Delta ferrite is harmful; therefore, minimizing ferrite in weld metal (3 FN maximum) is recommended. Weld metal free of ferrite (fully austenitic) is preferred; the more austenitic, the better.

A9.3.3.4 Fully austenitic E316L weld metal appears to be the preferred composition because of the ease in achieving ferrite-free weld metal, while compositionally conforming to AWS A5.4 and retaining crack resistance.

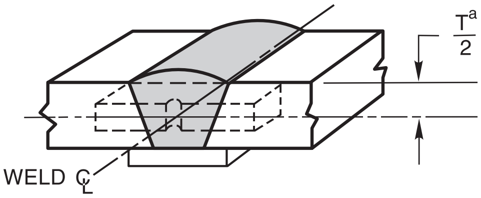
A9.3.3.5 Lime-covered, typically the -15 classification type, electrodes tend to produce weldments having slightly superior lateral expansion values for Charpy V-notch impact specimens than titania-covered, typically -16, -17, and -26 classification type, electrodes when weld metal composition factors are essentially the same. This appears to be due to two factors:

A9.3.3.5.1 Lime-covered SMAW electrodes usually provide better protection from nitrogen incursion into the weld metal than that provided by titania-covered electrodes. Nitrogen, as noted above, has significantly adverse effects on weld toughness.

A9.3.3.5.2 Lime-covered SMAW electrodes appear to produce weld metals of lower oxygen levels and inclusion population, i.e., cleaner weld metal, or both. The above suggestions are particularly important when the intended application involves very-low temperatures such as –320°F [–196°C].

A9.3.4 Limited SMAW electrode weld metal data have indicated that welding in the vertical position, as compared to flat position welding, does not reduce toughness properties, providing good operator's technique is employed.

A9.3.5 Where cryogenic service below –150°F [–100°C] is intended, it is recommended that each lot of electrodes be qualified with Charpy V-notch impact tests. When such tests are required, the test specimens must be taken from a test plate prepared in accordance with Figure 2. The impact specimens must be located in the test plate as shown in Figure A.4. The specimens must be prepared and tested in accordance with the impact test sections of the latest edition of AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds*. The test temperature must be selected on the basis of intended service.



Note: Specimen size to be in accordance with AWS B4.0 or AWS B4.0M, *Standard Methods for Mechanical Testing of Welds.*

[a] If buttering is used in preparation of the test plate (see Figure 2) the T/2 dimension may need to be reduced to assure that none of the buttering becomes part of the notch area of the impact specimen.

Figure A.4—Orientation and Location of Optional Impact Specimen

A10. Discontinued Classifications

Some classifications have been discontinued, from one revision of this specification to another. This results either from changes in commercial practice or changes in the classification system used in the specification. The Classifications that have been discontinued are listed in Table A.2 along with the year in which they were last included in this specification.

Table A.2
Discontinued Classifications[a]

AWS Classification	Last A5.4 Publication Date
EXXX-25	1948, 1992[b]
EXXX-26	1948[c]
E308ELC-XX	1955[d]
E316ELC-XX	1955[d]
E502-XX	1992[e]
E505-XX	1992[f]
E7Cr-XX	1992[g]
E308MoL-XX	1992[h]
E309MoL-XX	1992[h]
E309Cb-XX 1992[i]	1992[i]
E310Cb-XX	1992[i]

[a] See A10, Discontinued Classifications (in Annex A).
[b] The -25 classifications were discontinued with the publication of the 1955 edition of A5.4, included again in the 1992 edition, and then discontinued again in the 2006 edition.
[c] The -26 classifications were discontinued with the publication of the 1955 edition of A5.4 and then were included again in the 1992 edition.
[d] Starting with the 1962 edition of A5.4, the designator suffix for the low carbon classifications was changed from "ELC" to "L." Thus the E308ELC-XX and E316ELC-XX classifications were not really discontinued; they became E308L-XX and E316L-XX, respectively.
[e] This classification was transferred to ANSI/AWS A5.5 in 1996 with the new designation E801X-B6 and E801X-B6L.
[f] This classification was transferred to ANSI/AWS A5.5 in 1996 with the new designation E801X-B8 and E801X-B8L.
[g] This classification was transferred to ANSI/AWS A5.5 in 1996 with the new designation E801X-B7and E801X-B7L.
[h] These two classifications were not really discontinued but were changed to E308LMo-XX and E309LMo-XX to reflect that the "L" for low carbon is the principal modifying suffix.
[i] These two classifications were not really discontinued but were changed to E309Nb-XX and E310Nb-XX to reflect the adoption of Nb for niobium instead of Cb for columbium.

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 A5. 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*,[13] and applicable federal and state regulations.

A11.2 Safety and Health Fact Sheets. 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.

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

A11.3 AWS Safety and Health Fact Sheets Index (SHF)[14]

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*

[14] 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 A5.4/A5.4M:2006, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*, 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 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/A4.2	*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	*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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