AWS A5.5/A5.5M:2014
An American National Standard

Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

American Welding Society®

AWS A5.5/A5.5M:2014
An American National Standard

Approved by the
American National Standards Institute
April 16, 2014

Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

10th Edition

Supersedes AWS A5.5/A5.5M:2006

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

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification prescribes the requirements for classification of low-alloy steel covered electrodes used for shielded metal arc welding. The requirements include chemical composition and mechanical properties of weld metal, weld metal soundness, usability tests of electrodes, and moisture tests of the low-hydrogen electrode covering. Requirements for standard sizes and lengths, marking, manufacturing, and packaging are also included.

Optional supplemental requirements include tests for absorbed moisture in the electrode covering and for diffusible hydrogen in the weld metal.

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

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Foreword

This foreword is not part of AWS A5.5 /A5.5M: 2014, *Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*, but is included for informational purposes only.

This document is the second revision of the A5.5/A5.5M specification 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, AWS A1.1, *Metric Practice Guide for the Welding Industry* , and International Standard ISO 544, *Welding consumables — Technical delivery conditions for welding filler materials — Type of product, dimensions, tolerances and markings* 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 U.S. Customary and SI Units.

This edition includes new filler metal classifications E8015-B2 (reinstated), E9018-B6, E90XX-B23, E90XX-B24, E90XX-B92; E9018-NM2; revised "Rounding Procedure;" references to AWS A5.02/A5.02M:2007 for covered electrode standard sizes, packaging, and physical attributes; the change of E90XX-B9 classifications to E90XX-B91; and changes in procedures for requests for filler metal classifications. Such significant changes are shown in italic font.

Document Development of A5.5/A5.5M

ASTM A316–48T AWS A5.5–48T	*Tentative Specifications for Low-Alloy Steel Arc-Welding Electrodes*
ASTM A316–54T AWS A5.5–54T	*Tentative Specifications for High Tensile and Low-Alloy Steel Covered Arc-Welding Electrodes*
AWS A5.5–58T ASTM A316–58T	*Tentative Specification for Low-Alloy Steel Covered Arc-Welding Electrodes*
AWS A5.5–64T ASTM A316–64T	*Tentative Specification for Low-Alloy Steel Covered Arc-Welding Electrodes*
AWS A5.5–69 ANSI W3.5–1973	*Specification for Low-Alloy Steel Covered Arc-Welding Electrodes*
AWS A5.5–69 Add. 1–77	*1977 Addenda to Specification for Low-Alloy Steel Covered Arc-Welding Electrodes*
ANSI/AWS A5.5–81	*Specification for Low-Alloy Steel Covered Arc-Welding Electrodes*
ANSI/AWS A5.5–96	*Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*
AWS A5.5/A5.5M:2006	*Specification for Low-Alloy 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, 8669 NW 36th St, # 130, Miami, FL 33166.

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1. Scope

1.1 This specification prescribes requirements for the classification of low-alloy steel electrodes for shielded metal arc welding of carbon and low-alloy steels. These electrodes include steel alloys in which no single alloying element exceeds 10.5%.

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 nonmandatory annex Clauses A5 and A10. 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 federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to material properties. The specification designated A5.5 uses U.S. Customary Units; and the specification designated A5.5M uses SI Units. The latter units are shown within brackets [ ] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for sizing of filler metal or packaging or both under A5.5 or A5.5M specification.

2. Normative References

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

2.2 AWS standards[1]:

(1) AWS A3.0M/A3.0, *Standard Welding Terms and Definitions*

(2) AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

(3) AWS A4.4M, *Standard Procedure for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings*

(4) AWS A5.01M/A5.01 (ISO 14344 MOD), *Welding Consumables — Procurement of Filler Metals and Fluxes*

[1] AWS standards are published by the American Welding Society, 8669 NW 36th St, # 130, Miami, FL 33166.

(5) AWS A5.02/A5.02M:2007, *Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*

(6) AWS B4.0, *Standard Methods for Mechanical Testing of Welds*

(7) AWS B4.0M, *Standard Methods for Mechanical Testing of Welds*

2.3 ANSI Standard[2]:

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

2.4 ASTM standards[3]:

(1) ASTM A29/A29M, *Standard Specification for Steel Bars, Carbon and Alloy, Hot-Wrought, General Requirements for*

(2) ASTM A36/A36M, *Standard Specification for Carbon Structural Steel*

(3) ASTM A203/A203M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Nickel*

(4) ASTM A204/A204M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum*

(5) ASTM A242/A242M, *Standard Specification for High-Strength Low-Alloy Structural Steel*

(6) ASTM A283/A283M, *Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates*

(7) ASTM A302/A302M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum, and Manganese-Molybdenum-Nickel*

(8) ASTM A352/A352M, *Standard Specification for Steel Castings, Ferritic and Martensitic, for Pressure-Containing Parts, Suitable for Low-Temperature Service*

(9) ASTM A387/A387M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum*

(10) ASTM A514/A514M, *Standard Specification for High-Yield-Strength, Quenched and Tempered, Alloy Steel Plate, Suitable for Welding*

(11) ASTM A516/A516M, *Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

(12) ASTM A517/A517M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, High-Strength, Quenched and Tempered*

(13) ASTM A533/A533M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered, Manganese-Molybdenum, and Manganese-Molybdenum-Nickel*

(14) ASTM A537/A537M, *Standard Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel*

(15) ASTM A543/A543M, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Quenched and Tempered Nickel-Chromium-Molybdenum*

(16) ASTM A588/A588M, *Standard Specification for High-Strength Low-Alloy Structural Steel with 50 ksi [345 MPa] Minimum Yield Point to 4-in [100-mm] Thick*

(17) ASTM A709/A709M, *Standard Specification for Carbon Structural Steel for Bridges*

(18) ASTM E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

(19) ASTM E350, *Standard Test Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron*

(20) ASTM E1032, *Standard Test Method for Radiographic Examination of Weldments*

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[2] This ANSI standard is published by the American Welding Society, 8669 NW 36th St, # 130, Miami, FL 33166.
[3] ASTM standards are published by ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428–2959.

2.5 ISO standards[4]:

(1) ISO 544, *Welding consumables — Technical delivery conditions for welding filler materials — Type of product, dimensions, tolerances and markings*

(2) ISO 2560, *Welding consumables — Covered electrodes for manual metal arc welding of nonalloy and fine grain steels — Classification*

(3) ISO 3580, *Welding consumables — Covered electrodes for manual metal arc welding of creep-resisting steels — Classification*

(4) ISO 18275, *Welding consumables — Covered electrodes for manual metal arc welding of high-strength steels — Classification*

(5) ISO 80000–1*:2009, Quantities and units — Part 1: General*

2.6 DoD publications[5]

(1) NAVSEA Technical Publication T9074-BD-GIB–010/0300, *Base Materials for Critical Applications: Requirements for Low Alloy Steel Plate, Forgings, Castings, Shapes, Bars, and Heads of HY–80/100/130 and HSLA–80/100*

(2) *MIL-E–22200/1, Military Specification: Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen Medium and High Tensile Steel, As Welded or Stress-Relieved Weld Application*

(3) *MIL-E–22200/10, Military Specification: Electrodes, Welding, Mineral Covered, Iron-Powder, Low-Hydrogen Medium, High Tensile and Higher-Strength Low Alloy Steels*

2.7 API standard[6]

(1) Spec 5L, *Specification for Line Pipe*

3. Classification

3.1 The welding electrodes covered by the A5.5 and A5.5M specifications utilize a classification system, shown in Figure 1, based upon U.S. Customary Units and the International System of Units (SI), respectively, and are classified according to:

(1) Type of current (Table 1)

(2) Type of covering (Table 1)

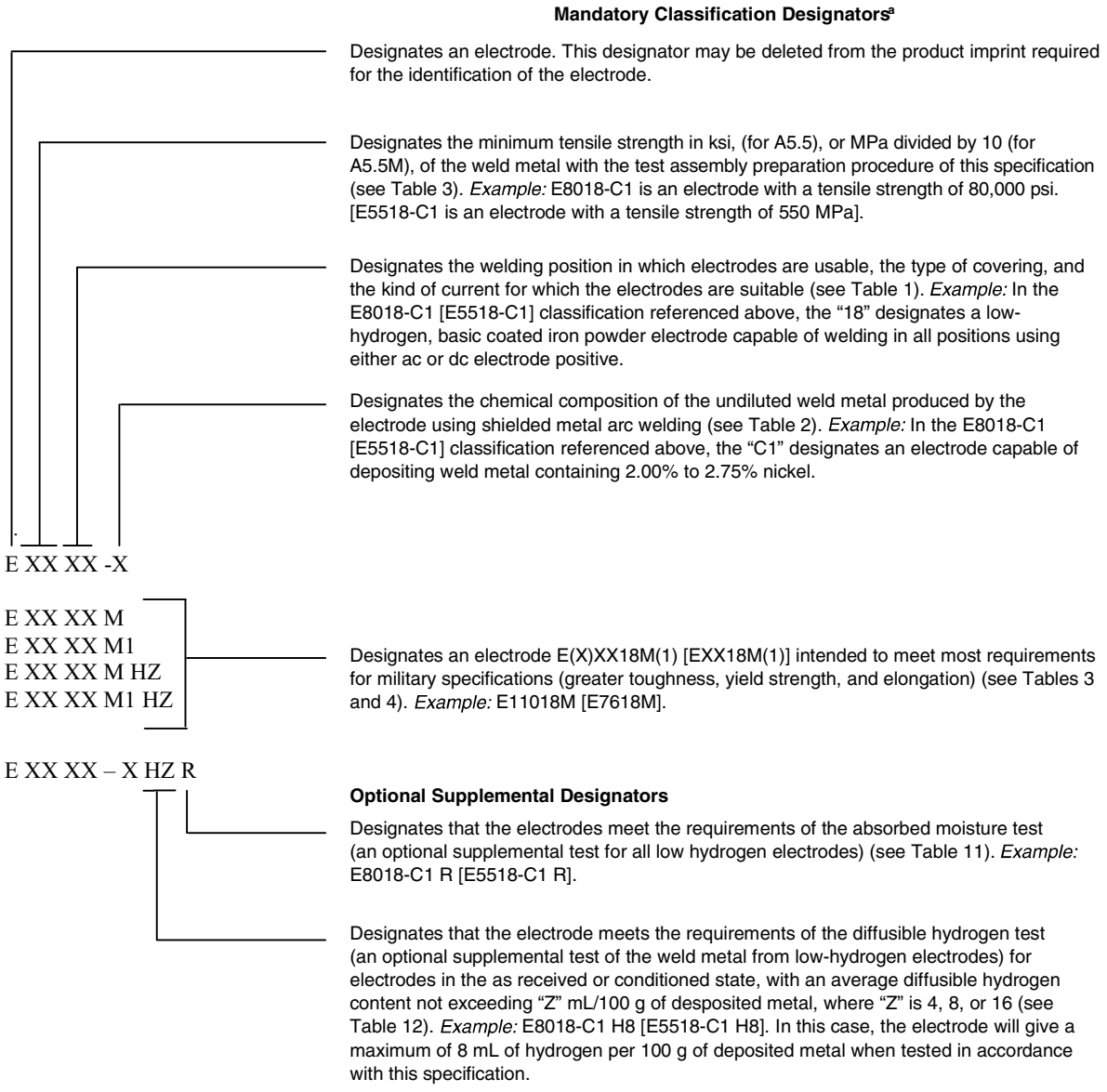
(3) Welding position (Table 1)

(4) Chemical composition of the weld metal (Table 2)

(5) Mechanical properties of the weld metal in the as-welded or postweld heat-treated condition (Tables 3 and 4).

3.2 Material classified under one classification shall not be classified under any other classification in the same specification. However, material may be classified under both A5.5 and A5.5M specifications.

[4] ISO standards are published by the International Organization of Standardization, 1, chemin de la voie-creuse Case postale 56, CH–1211 Genéva, Geneva 20, Switzerland.
[5] DoD standards are published by the Department of Defense (DODSSP), Standardization Documents Order Desk, 700 Robbins Ave, Philadelphia, PA 19111.
[6] API specifications are published by the American Petroleum Institute, 1220 L Street NW, Washington, DC 20005.



[a] The combination of these designators constitutes the electrode classification.

Source: AWS A5.5/A5.5M:2006, Figure 9

Figure 1—Order of Electrode Mandatory and Optional Supplemental Designators

Table 1
Electrode Classification

AWS Classification[a]				
A5.5	A5.5M	Type of Covering	Welding Positions for Classification[b]	Type of Current[c]
E7010-X	E4910-X	High cellulose sodium	F, V, OH, H	dcep
E7011-X	E4911-X	High cellulose potassium	F, V, OH, H	ac or dcep
E7015-X[d,e]	E4915-X[d,e]	Low hydrogen sodium	F, V, OH, H	dcep
E7016-X[d,e]	E4916-X[d,e]	Low hydrogen potassium	F, V, OH, H	ac or dcep
E7018-X[d,e]	E4918-X[d,e]	Low hydrogen potassium, iron powder [f]	F, V, OH, H	ac or dcep
E7020-X	E4920-X	High iron oxide	H-fillets F	ac or dcen ac, dcep, or dcen
E7027-X	E4927-X	High iron oxide, iron powder[f]	H-fillets F	ac or dcen ac, dcep, or dcen
E8010-X	E5510-X	High cellulose sodium	F, V, OH, H	dcep
E8011-G	E5511-G	High cellulose potassium	F, V, OH, H	ac or dcep
E8013-G	E5513-G	High titania potassium	F, V, OH, H	ac, dcep, or dcen
E8015-X[d,e]	E5515-X[d,e]	Low hydrogen sodium	F, V, OH, H	dcep
E8016-X[d,e]	E5516-X[d,e]	Low hydrogen potassium	F, V, OH, H	ac or dcep
E8018-X[d,e]	E5518-X[d,e]	Low hydrogen potassium, iron powder [f]	F, V, OH, H	ac or dcep
E8045-P2[d,e]	E5545-P2[d,e]	Low hydrogen sodium	F, OH, H, V-down	dcep
E9010-G	E6210-G	High cellulose sodium	F, V, OH, H	dcep
E9010-X	E6210-X	High cellulose sodium	F, V, OH, H	dcep
E9011-G	E6211-G	High cellulose potassium	F, V, OH, H	ac or dcep
E9013-G	E6213-G	High titania potassium	F, V, OH, H	ac, dcep, or dcen
E9015-X[d,e]	E6215-X[d,e]	Low hydrogen sodium	F, V, OH, H	dcep
E9016-X[d,e]	E6216-X[d,e]	Low hydrogen potassium	F, V, OH, H	ac or dcep
E9018-X[d,e]	E6218-X[d,e]	Low hydrogen potassium, iron powder [f]	F, V, OH, H	ac or dcep
E9018M[d,e]	E6218M[d,e]	Iron powder, low hydrogen [f]	F, V, OH, H	dcep
E9045-P2[d,e]	E6245-P2[d,e]	Low hydrogen sodium	F, OH, H, V-down	dcep
E10010-G	E6910-G	High cellulose sodium	F, V, OH, H	dcep
E10011-G	E6911-G	High cellulose potassium	F, V, OH, H	ac or dcep
E10013-G	E6913-G	High titania potassium	F, V, OH, H	ac, dcep, or dcen
E10015-X[d,e]	E6915-X[d,e]	Low hydrogen sodium	F, V, OH, H	dcep
E10016-X[d,e]	E6916-X[d,e]	Low hydrogen potassium	F, V, OH, H	ac or dcep
E10018-X[d,e]	E6918-X[d,e]	Low hydrogen potassium, iron powder [f]	F, V, OH, H	ac or dcep
E10018M[d,e]	E6918M[d,e]	Iron powder, low hydrogen [f]	F, V, OH, H	dcep
E10045-P2[d,e]	E6945-P2[d,e]	Low hydrogen sodium	F, OH, H, V-down	dcep
E11010-G	E7610-G	High cellulose sodium	F, V, OH, H	dcep
E11011-G	E7611-G	High cellulose potassium	F, V, OH, H	ac or dcep
E11013-G	E7613-G	High titania potassium	F, V, OH, H	ac, dcep, or dcen
E11015-G[d,e]	E7615-G[d,e]	Low hydrogen sodium	F, V, OH, H	dcep
E11016-G[d,e]	E7616-G[d,e]	Low hydrogen potassium	F, V, OH, H	ac or dcep
E11018-G[d,e]	E7618-G[d,e]	Low hydrogen potassium, iron powder [f]	F, V, OH, H	ac or dcep
E11018M[d,e]	E7618M[d,e]	Iron powder, low hydrogen [f]	F, V, OH, H	dcep
E12010-G	E8310-G	High cellulose sodium	F, V, OH, H	dcep
E12011-G	E8311-G	High cellulose potassium	F, V, OH, H	ac or dcep
E12013-G	E8313-G	High titania potassium	F, V, OH, H	ac, dcep, or dcen
E12015-G[d,e]	E8315-G[d,e]	Low hydrogen sodium	F, V, OH, H	dcep

Table 1 (Continued)
Electrode Classification

AWS Classification[a]				
A5.5	**A5.5M**	**Type of Covering**	**Welding Positions for Classification[b]**	**Type of Current[c]**
E12016-G[d,e]	E8316-G[d,e]	Low hydrogen potassium	F, V, OH, H	ac or dcep
E12018-G[e,e]	E8318-G[d,e]	Low hydrogen potassium, iron powder [f]	F, V, OH, H	ac or dcep
E12018M[d,e]	E8318M[d,e]	Iron powder, low hydrogen [f]	F, V, OH, H	dcep
E12018M1[d,e]	E8318M1[d,e]	Iron powder, low hydrogen [f]	F, V, OH, H	dcep

[a] The letter "X" as used in this table, and elsewhere in this specification, stands for any allowable value of the designator it replaces in the classification. See Figure 1.

[b] The abbreviations, F, V, V-down, OH, H, and H-fillets indicate the welding position; as follows:
F = Flat
H = Horizontal
H-fillets = Horizontal fillets
V = Vertical (For electrodes 3/16 in [5.0 mm] and under, except 5/32 in [4.0 mm] and under for classification E(X)XX15-X, E(X)XX16-X, E(X)XX18-X, and E(X)XX18M(1).
V-down = vertical, with downward progression
OH = overhead (For electrodes 3/16 in [5.0 mm] and under, except 5/32 in [4.0 mm] and under for classifications E(X)XX15-X, E(X)XX16-X, E(X)XX18-X), and E(X)XX18M(1).

[c] The term "dcep" refers to direct current, electrode positive (dc, reverse polarity). The term "dcen" refers to direct current, electrode negative (dc, straight polarity).

[d] Electrodes classified as E(X)XX15-X, E(X)XX16-X, E(X)XX18-X, E(X)XX18M(1) or E(X)XX45-P2 which meet supplemental absorbed moisture requirements in Table 11 may be further identified as shown in Table 11 and Figure 1.

[e] Electrodes classified as E(X)XX15-X, E(X)XX16-X, E(X)XX18-X, E(X)XX18M(1) or E(X)XX45-P2 which produce weld metal that meets the maximum average level of diffusible hydrogen in Table 12 may be further identified as specified in Table 12 and Figure 1.

[f] Use of the term "iron powder" is intended to include other metal powders added to the covering for alloying of the weld metal (See A6.14).

4. Acceptance

Acceptance[7] of the welding electrode shall be in accordance with the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD).

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. [8]

6. Rounding Procedure

For the purpose of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding rules of ASTM E29 or Rule A in Clause B.3 of ISO 80000–1:2009 (the results are the same). If the measured values are obtained by equipment calibrated in units other than those of the specified limit, the measured values shall be converted to the units of the specified limit before rounding. If an average value is to be compared to the specified limit, rounding shall be done only after calculating the average. An observed or calculated value shall be rounded to the nearest 1000 psi (1 ksi) for tensile and yield strength for A5.5; and to the nearest 10 MPa for tensile and

[7] See Clause A3 and AWS A5.01M/A5.01 (ISO 14344 MOD) for further information concerning acceptance and testing of the material shipped.

[8] See Clause A4 for further information concerning certification and the testing called for to meet this requirement.

Table 2
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification[c]		UNS	Weight Percent[a,b]								Additional Elements[e,f]	
A5.5	A5.5M	Number[d]	C	Mn	Si	P	S	Ni	Cr	Mo	Type	Amt.
Carbon-Molybdenum Steel Electrodes												
E7010-A1	E4910-A1	W17010	0.12	0.60	0.40	0.03	0.03	–	–	0.40–0.65	–	–
E7011-A1	E4911-A1	W17011	0.12	0.60	0.40	0.03	0.03	–	–	0.40–0.65	–	–
E7015-A1	E4915-A1	W17015	0.12	0.90	0.60	0.03	0.03	–	–	0.40–0.65	–	–
E7016-A1	E4916-A1	W17016	0.12	0.90	0.60	0.03	0.03	–	–	0.40–0.65	–	–
E7018-A1	E4918-A1	W17018	0.12	0.90	0.80	0.03	0.03	–	–	0.40–0.65	–	–
E7020-A1	E4920-A1	W17020	0.12	0.60	0.40	0.03	0.03	–	–	0.40–0.65	–	–
E7027-A1	E4927-A1	W17027	0.12	1.00	0.40	0.03	0.03	–	–	0.40–0.65	–	–
Chromium-Molybdenum Steel Electrodes												
E8016-B1	E5516-B1	W51016	0.05–0.12	0.90	0.60	0.03	0.03	–	0.40–0.65	0.40–0.65	–	–
E8018-B1	E5518-B1	W51018	0.05–0.12	0.90	0.80	0.03	0.03	–	0.40–0.65	0.40–0.65	–	–
E8015-B2	*E5515-B2*	*W52015*	*0.05–0.12*	*0.90*	*1.00*	*0.03*	*0.03*	–	*1.00–1.50*	*0.40–0.65*	–	–
E8016-B2	E5516-B2	W52016	0.05–0.12	0.90	0.60	0.03	0.03	–	1.00–1.50	0.40–0.65	–	–
E8018-B2	E5518-B2	W52018	0.05–0.12	0.90	0.80	0.03	0.03	–	1.00–1.50	0.40–0.65	–	–
E7015-B2L	E4915-B2L	W52115	0.05	0.90	1.00	0.03	0.03	–	1.00–1.50	0.40–0.65	–	–
E7016-B2L	E4916-B2L	W52116	0.05	0.90	0.60	0.03	0.03	–	1.00–1.50	0.40–0.65	–	–
E7018-B2L	E4918-B2L	W52118	0.05	0.90	0.80	0.03	0.03	–	1.00–1.50	0.40–0.65	–	–
E9015-B3	E6215-B3	W53015	0.05–0.12	0.90	1.00	0.03	0.03	–	2.00–2.50	0.90–1.20	–	–
E9016-B3	E6216-B3	W53016	0.05–0.12	0.90	0.60	0.03	0.03	–	2.00–2.50	0.90–1.20	–	–
E9018-B3	E6218-B3	W53018	0.05–0.12	0.90	0.80	0.03	0.03	–	2.00–2.50	0.90–1.20	–	–
E8015-B3L	E5515-B3L	W53115	0.05	0.90	1.00	0.03	0.03	–	2.00–2.50	0.90–1.20	–	–
E8018-B3L	E5518-B3L	W53118	0.05	0.90	0.80	0.03	0.03	–	2.00–2.50	0.90–1.20	–	–
E8015-B4L	E5515-B4L	W53415	0.05	0.90	1.00	0.03	0.03	–	1.75–2.25	0.40–0.65	–	–
E8016-B5	E5516-B5	W51316	0.07–0.15	0.40–0.70	0.30–0.60	0.03	0.03	–	0.40–0.60	1.00–1.25	V	0.05
E8015-B6	E5515-B6	W50215	0.05–0.10	1.0	0.90	0.03	0.03	0.40	4.0–6.0	0.45–0.65	–	–
E8016-B6	E5516-B6	W50216	0.05–0.10	1.0	0.90	0.03	0.03	0.40	4.0–6.0	0.45–0.65	–	–
E8018-B6	E5518-B6	W50218	0.05–0.10	1.0	0.90	0.03	0.03	0.40	4.0–6.0	0.45–0.65	–	–
E9018-B6	*E6218-B6*	W50219	*0.05–0.10*	*1.0*	*0.90*	*0.03*	*0.03*	*0.40*	*4.0–6.0*	*0.45–0.65*	–	–

Table 2 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification[c]			Weight Percent[a,b]								Additional Elements[e,f]	
A5.5	A5.5M	UNS Number[d]	C	Mn	Si	P	S	Ni	Cr	Mo	Type	Amt.
E8015-B6L	E5515-B6L	W50205	0.05	1.0	0.90	0.03	0.03	0.40	4.0–6.0	0.45–0.65	–	–
E8016-B6L	E5516-B6L	W50206	0.05	1.0	0.90	0.03	0.03	0.40	4.0–6.0	0.45–0.65	–	–
E8018-B6L	E5518-B6L	W50208	0.05	1.0	0.90	0.03	0.03	0.40	4.0–6.0	0.45–0.65	–	–
E8015-B7	E5515-B7	W50315	0.05–0.10	1.0	0.90	0.03	0.03	0.40	6.0–8.0	0.45–0.65	–	–
E8016-B7	E5516-B7	W50316	0.05–0.10	1.0	0.90	0.03	0.03	0.40	6.0–8.0	0.45–0.65	–	–
E8018-B7	E5518-B7	W50318	0.05–0.10	1.0	0.90	0.03	0.03	0.40	6.0–8.0	0.45–0.65	–	–
E8015-B7L	E5515-B7L	W50305	0.05	1.0	0.90	0.03	0.03	0.40	6.0–8.0	0.45–0.65	–	–
E8016-B7L	E5516-B7L	W50306	0.05	1.0	0.90	0.03	0.03	0.40	6.0–8.0	0.45–0.65	–	–
E8018-B7L	E5518-B7L	W50308	0.05	1.0	0.90	0.03	0.03	0.40	6.0–8.0	0.45–0.65	–	–
E8015-B8	E5515-B8	W50415	0.05–0.10	1.0	0.90	0.03	0.03	0.40	8.0–10.5	0.85–1.20	–	–
E8016-B8	E5516-B8	W50416	0.05–0.10	1.0	0.90	0.03	0.03	0.40	8.0–10.5	0.85–1.20	–	–
E8018-B8	E5518-B8	W50418	0.05–0.10	1.0	0.90	0.03	0.03	0.40	8.0–10.5	0.85–1.20	–	–
E8015-B8L	E5515-B8L	W50405	0.05	1.0	0.90	0.03	0.03	0.40	8.0–10.5	0.85–1.20	–	–
E8016-B8L	E5516-B8L	W50406	0.05	1.0	0.90	0.03	0.03	0.40	8.0–10.5	0.85–1.20	–	–
E8018-B8L	E5518-B8L	W50408	0.05	1.0	0.90	0.03	0.03	0.40	8.0–10.5	0.85–1.20	–	–
E9015-B23	*E6215-B23*										*W*	*1.50–2.00*
											V	*0.15–0.30*
											Nb	*0.02–0.10*
E9016-B23	*E6216-B23*	K20857	*0.04–0.12*	*1.00*	*0.60*	*0.015*	*0.015*	*0.50*	*1.9–2.9*	*0.30*	*B*	*0.006*
E9018-B23	*E6218-B23*										*Al*	*0.04*
											Cu	*0.25*
											N	*0.05*
											V	*0.15–0.30*
											Nb	*0.02–0.10*
E9015-B24	*E6215-B24*										*Ti*	*0.10*
E9016-B24	*E6216-B24*	*K20885*	*0.04–0.12*	*1.00*	*0.60*	*0.020*	*0.015*	*0.50*	*1.9–2.9*	*0.80–1.20*	*B*	*0.006*
E9018-B24	*E6218-B24*										*Al*	*0.04*
											Cu	*0.25*
											N	*0.07*

Table 2 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification[c]			Weight Percent[a,b]								Additional Elements[e,f]	
A5.5	A5.5M	UNS Number[d]	C	Mn	Si	P	S	Ni	Cr	Mo	Type	Amt.
E9015-B91[g,h]	*E6215-B91*[g,h]	W50425									V	0.15–0.30
											Cu	0.25
E9016-B91[g,h]	*E6216-B91*[g,h]	W50426	0.08–0.13	1.20	0.30	0.01	0.01	0.80	8.0–10.5	0.85–1.20	Al	0.04
E9018-B91[g,h]	*E6218-B91*[g,h]	W50428									Nb	0.02–0.10
											N	0.02–0.07
											W	*1.50–2.00*
											V	*0.15–0.30*
E9015-B92[g]	*E6215-B92*[g]										*Nb*	*0.02–0.08*
E9016-B92[g]	*E6216-B92*[g]	*W59016*	*0.08–0.15*	*1.20*	*0.60*	*0.020*	*0.015*	*1.00*	*8.0–10.0*	*0.30–0.70*	*B*	*0.006*
E9018-B92[g]	*E6218-B92*[g]										*Al*	*0.04*
											Cu	*0.25*
											N	*0.03–0.08*
					Nickel Steel Electrodes							
E8016-C1	E5516-C1	W22016	0.12	1.25	0.60	0.03	0.03	2.00–2.75	–	–	–	–
E8018-C1	E5518-C1	W22018	0.12	1.25	0.80	0.03	0.03	2.00–2.75	–	–	–	–
E7015-C1L	E4915-C1L	W22115	0.05	1.25	0.50	0.03	0.03	2.00–2.75	–	–	–	–
E7016-C1L	E4916-C1L	W22116	0.05	1.25	0.50	0.03	0.03	2.00–2.75	–	–	–	–
E7018-C1L	E4918-C1L	W22118	0.05	1.25	0.50	0.03	0.03	2.00–2.75	–	–	–	–
E8016-C2	E5516-C2	W23016	0.12	1.25	0.60	0.03	0.03	3.00–3.75	–	–	–	–
E8018-C2	E5518-C2	W23018	0.12	1.25	0.80	0.03	0.03	3.00–3.75	–	–	–	–
E7015-C2L	E4915-C2L	W23115	0.05	1.25	0.50	0.03	0.03	3.00–3.75	–	–	–	–
E7016-C2L	E4916-C2L	W23116	0.05	1.25	0.50	0.03	0.03	3.00–3.75	–	–	–	–
E7018-C2L	E4918-C2L	W23118	0.05	1.25	0.50	0.03	0.03	3.00–3.75	–	–	–	–
E8016-C3	E5516-C3	W21016	0.12	0.40–1.25	0.80	0.03	0.03	0.80–1.10	0.15	0.35	V	0.05
E8018-C3	E5518-C3	W21018	0.12	0.40–1.25	0.80	0.03	0.03	0.80–1.10	0.15	0.35	V	0.05
E7018-C3L	E4918-C3L	W20918	0.08	0.40–1.40	0.50	0.03	0.03	0.80–1.10	0.15	0.35	V	0.05
E8016-C4	E5516-C4	W21916	0.10	1.25	0.60	0.03	0.03	1.10–2.00	–	–	–	–
E8018-C4	E5518-C4	W21918	0.10	1.25	0.80	0.03	0.03	1.10–2.00	–	–	–	–
E9015-C5L	E6215-C5L	W25018	0.05	0.40–1.00	0.50	0.03	0.03	6.00–7.25	–	–	–	–

Table 2 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification[c]			Weight Percent[a,b]								Additional Elements[e,f]	
A5.5	A5.5M	UNS Number[d]	C	Mn	Si	P	S	Ni	Cr	Mo	Type	Amt.
Nickel-Molybdenum Steel Electrodes												
E8018-NM1	E5518-NM1	W21118	0.10	0.80–1.25	0.60	0.02	0.02	0.80–1.10	0.10	0.40–0.65	V Cu Al	0.02 0.10 0.05
E9018-NM2	*E6218-NM2*	*W21119*	*0.04–0.15*	*0.50–1.60*	*0.70*	*0.02*	*0.02*	*1.40–2.10*	*0.20*	*0.20–0.50*	*V* *Cu* *Al*	*0.05* *0.10* *0.05*
Manganese-Molybdenum Steel Electrodes												
E8018-D1	E5518-D1	W18118	0.12	1.00–1.75	0.80	0.03	0.03	0.90	–	0.25–0.45	–	–
E9015-D1	E6215-D1	W19015	0.12	1.00–1.75	0.60	0.03	0.03	0.90	–	0.25–0.45	–	–
E9018-D1	E6218-D1	W19018	0.12	1.00–1.75	0.80	0.03	0.03	0.90	–	0.25–0.45	–	–
E10015-D2	E6915-D2	W10015	0.15	1.65–2.00	0.60	0.03	0.03	0.90	–	0.25–0.45	–	–
E10016-D2	E6916-D2	W10016	0.15	1.65–2.00	0.60	0.03	0.03	0.90	–	0.25–0.45	–	–
E10018-D2	E6918-D2	W10018	0.15	1.65–2.00	0.80	0.03	0.03	0.90	–	0.25–0.45	–	–
E8016-D3	E5516-D3	W18016	0.12	1.00–1.80	0.60	0.03	0.03	0.90	–	0.40–0.65	–	–
E8018-D3	E5518-D3	W18018	0.12	1.00–1.80	0.80	0.03	0.03	0.90	–	0.40–0.65	–	–
E9018-D3	E6218-D3	W19118	0.12	1.00–1.80	0.80	0.03	0.03	0.90	–	0.40–0.65	–	–
General Low-Alloy Steel Electrodes												
E(X)XX10-G[i]	EXX10-G[i]	–	–	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min.[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]
E(X)XX11-G[i]	EXX11-G[i]	–	–	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min.[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]
E(X)XX13-G[i]	EXX13-G[i]	–	–	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]
E(X)XX15-G[i]	EXX15-G[i]	–	–	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]
E(X)XX16-G[i]	EXX16-G[i]	–	–	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min.[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]
E(X)XX18-G[i]	EXX18-G[i]	–	–	1.00 min.[j]	0.80 min.[j]	0.03	0.03	0.50 min.[j]	0.30 min.[j]	0.20 min.[j]	V Cu	0.10 min.[j] 0.20 min.[j]

Table 2 (Continued)
Chemical Composition Requirements for Undiluted Weld Metal

AWS Classification[c]			Weight Percent[a,b]								Additional Elements[e,f]	
A5.5	A5.5M	UNS Number[d]	C	Mn	Si	P	S	Ni	Cr	Mo	Type	Amt.
E7020-G	E4920-G	–	–	1.00 min. [j]	0.80 min. [j]	0.03	0.03	0.50 min. [j]	0.30 min. [j]	0.20 min. [j]	V Cu	0.10 min. [j] 0.20 min. [j]
E7027-G	E4927-G	–	–	1.00 min. [j]	0.80 min. [j]	0.03	0.03	0.50 min. [j]	0.30 min. [j]	0.20 min. [j]	V Cu	0.10 min. [j] 0.20 min. [j]
Military-Similar Electrodes												
E9018M[k]	E6218M[k]	W21218	0.10	0.60–1.25	0.80	0.030	0.030	1.40–1.80	0.15	0.35	V	0.05
E10018M[k]	E6918M[k]	W21318	0.10	0.75–1.70	0.60	0.030	0.030	1.40–2.10	0.35	0.25–0.50	V	0.05
E11018M[k]	E7618M[k]	W21418	0.10	1.30–1.80	0.60	0.030	0.030	1.25–2.50	0.40	0.25–0.50	V	0.05
E12018M[k]	E8318M[k]	W22218	0.10	1.30–2.25	0.60	0.030	0.030	1.75–2.50	0.30–1.50	0.30–0.55	V	0.05
E12018M1[k]	E8318M1[k]	W23218	0.10	0.80–1.60	0.65	0.015	0.012	3.00–3.80	0.65	0.20–0.30	V	0.05
Pipeline Steel Electrodes												
E7010-P1	E4910-P1	W17110	0.20	1.20	0.60	0.03	0.03	1.00	0.30	0.50	V	0.10
E8010-P1	E5510-P1	W18110	0.20	1.20	0.60	0.03	0.03	1.00	0.30	0.50	V	0.10
E9010-P1	E6210-P1	W19110	0.20	1.20	0.60	0.03	0.03	1.00	0.30	0.50	V	0.10
E8018-P2	E5518-P2	W18218	0.12	0.90–1.70	0.80	0.03	0.03	1.00	0.20	0.50	V	0.05
E9018-P2	E6218-P2	W19218	0.12	0.90–1.70	0.80	0.03	0.03	1.00	0.20	0.50	V	0.05
E8045-P2	E5545-P2	W18245	0.12	0.90–1.70	0.80	0.03	0.03	1.00	0.20	0.50	V	0.05
E9045-P2	E6245-P2	W19245	0.12	0.90–1.70	0.80	0.03	0.03	1.00	0.20	0.50	V	0.05
E10045-P2	E6945-P2	W10245	0.12	0.90–1.70	0.80	0.03	0.03	1.00	0.20	0.50	V	0.05
Weathering Steel Electrodes												
E7018-W1	E4918-W1	W20018	0.12	0.40–0.70	0.40–0.70	0.025	0.025	0.20–0.40	0.15–0.30	–	V Cu	0.08 0.30–0.60
E8018-W2	E5518-W2	W20118	0.12	0.50–1.30	0.35–0.80	0.03	0.03	0.40–0.80	0.45–0.70	–	Cu	0.30–0.75

[a] Single values are maxima, except where specified otherwise.

[b] Weld metal shall be analyzed for those elements for which specific values are shown. Other elements listed without specified values shall be reported, if intentionally added. The total of these latter unspecified elements and all other elements not intentionally added shall not exceed 0.50%.

[c] The suffixes A1, B3, C3, etc. designate the chemical composition of the electrode classification.

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

[e] *Analysis for boron is required to be reported for any weld metal if it has been intentionally added or is known to be present at levels greater than 0.0010%.*

[f] *Analysis for cobalt is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.20%.*

[g] *Mn + Ni shall be 1.40% max.*

[h] *The E90XX-B91 [E62XX-B91] classifications were formerly classified as E90XX-B9 [E62XX-B9] in AWS A5.5/A5.5M:2006.*

[i] The letters "(X)XX" ["XX"] used in the classification designations for all electrodes in this table stand for the various tensile strength levels (70, 80, 90, 100, 110, and 120 ksi [49, 55, 62, 69, 76, and 83 MPa x 10]), of weld metals.

[j] In order to meet the alloy requirements of the "G" group, the undiluted weld metal shall have the minimum of at least one of the elements listed in this table. Additional chemical requirements may be agreed upon between the purchaser and supplier.

[k] These classifications are intended to be similar to types of electrodes covered by military specifications MIL-E–22200/1 and MIL-E–22200/10.

Table 3
Tension Test Requirements[a,b]

AWS Classification[c]		Tensile Strength		Yield Strength, At 0.2% Offset		Elongation	
A5.5	A5.5M	ksi	MPa	ksi	MPa	Percent	Postweld Condition[d]
E7010-P1	E4910-P1	70	490	60	415	22	AW
E7010-A1	E4910-A1	70	490	57	390	22	PWHT
E7010-G	E4910-G	70	490	57	390	22	AW or PWHT
E7011-A1	E4911-A1	70	490	57	390	22	PWHT
E7011-G	E4911-G	70	490	57	390	22	AW or PWHT
E7015-X	E4915-X	70	490	57	390	22	PWHT
E7015-B2L	E4915-B2L	75	520	57	390	19	PWHT
E7015-G	E4915-G	70	490	57	390	22	AW or PWHT
E7016-X	E4916-X	70	490	57	390	22	PWHT
E7016-B2L	E4916-B2L	75	520	57	390	19	PWHT
E7016-G	E4916-G	70	490	57	390	22	AW or PWHT
E7018-X	E4918-X	70	490	57	390	22	PWHT
E7018-B2L	E4918-B2L	75	520	57	390	19	PWHT
E7018-C3L	E4918-C3L	70	490	57	390	22	AW
E7018-W1	E4918-W1	70	490	60	415	22	AW
E7018-G	E4918-G	70	490	57	390	22	AW or PWHT
E7020-A1	E4920-A1	70	490	57	390	22	PWHT
E7020-G	E4920-G	70	490	57	390	22	AW or PWHT
E7027-A1	E4927-A1	70	490	57	390	22	PWHT
E7027-G	E4927-G	70	490	57	390	22	AW or PWHT
E8010-P1	E5510-P1	80	550	67	460	19	AW
E8010-G	E5510-G	80	550	67	460	19	AW or PWHT
E8011-G	E5511-G	80	550	67	460	19	AW or PWHT
E8013-G	E5513-G	80	550	67	460	16	AW or PWHT
E8015-X	E5515-X	80	550	67	460	19	PWHT
E8015-B3L	E5515-B3L	80	550	67	460	17	PWHT
E8015-G	E5515-G	80	550	67	460	19	AW or PWHT
E8016-X	E55516-X	80	550	67	460	19	PWHT
E8016-C3	E5516-C3	80	550	68 to 80[e]	470 to 550[e]	24	AW
E8016-C4	E5516-C4	80	550	67	460	19	AW
E8016-G	E5516-G	80	550	67	460	19	AW or PWHT
E8018-X	E5518-X	80	550	67	460	19	PWHT
E8018-B3L	E5518-B3L	80	550	67	460	17	PWHT
E8018-C3	E5518-C3	80	550	68 to 80[e]	470 to 550[e]	24	AW
E8018-C4	E5518-C4	80	550	67	460	19	AW
E8018-NM1	E5518-NM1	80	550	67	460	19	AW
E8018-P2	E5518-P2	80	550	67	460	19	AW
E8018-W2	E5518-W2	80	550	67	460	19	AW
E8018-G	E5518-G	80	550	67	460	19	AW or PWHT
E8045-P2	E5545-P2	80	550	67	460	19	AW
E9010-P1	E6210-P1	90	620	77	530	17	AW
E9010-G	E6210-G	90	620	77	530	17	AW or PWHT
E9011-G	E6211-G	90	620	77	530	17	AW or PWHT
E9013-G	E6213-G	90	620	77	530	14	AW or PWHT
E9015-X	E6215-X	90	620	77	530	17	PWHT
E9015-G	E6215-G	90	620	77	530	17	AW or PWHT
E9016-X	E6216-X	90	620	77	530	17	PWHT
E9016-G	E6216-G	90	620	77	530	17	AW or PWHT
E9018M	E6218M	90	620	78 to 90[e]	540 to 620[e]	24	AW
E9018-NM2	*E6218-NM2*	*90*	*620*	*77*	*530*	*17*	*PWHT*
E9018-P2	E6218-P2	90	620	77	530	17	AW

Table 3 (Continued)
Tension Test Requirements[a,b]

AWS Classification[c]		Tensile Strength		Yield Strength, At 0.2% Offset		Elongation	
A5.5	A5.5M	ksi	MPa	ksi	MPa	Percent	Postweld Condition[d]
E9018-X	E6218-X	90	620	77	530	17	PWHT
E9018-G	E6218-G	90	620	77	530	17	AW or PWHT
E9045-P2	E6245-P2	90	620	77	530	17	AW
E10010-G	E6910-G	100	690	87	600	16	AW or PWHT
E10011-G	E6911-G	100	690	87	600	16	AW or PWHT
E10013-G	E6913-G	100	690	87	600	13	AW or PWHT
E10015-X	E6915-X	100	690	87	600	16	PWHT
E10015-G	E6915-G	100	690	87	600	16	AW or PWHT
E10016-X	E6916-X	100	690	87	600	16	PWHT
E10016-G	E6916-G	100	690	87	600	16	AW or PWHT
E10018M	E6918M	100	690	88 to 100[e]	610 to 690[e]	20	AW
E10018-X	E6918-X	100	690	87	600	16	PWHT
E10018-G	E6918-G	100	690	87	600	16	AW or PWHT
E10045-P2	E6945-P2	100	690	87	600	16	AW
E11010-G	E7610-G	110	760	97	670	15	AW or PWHT
E11011-G	E7611-G	110	760	97	670	15	AW or PWHT
E11013-G	E7613-G	110	760	97	670	13	AW or PWHT
E11015-G	E7615-G	110	760	97	670	15	AW or PWHT
E11016-G	E7616-G	110	760	97	670	15	AW or PWHT
E11018-G	E7618-G	110	760	97	670	15	AW or PWHT
E11018M	E7618M	110	760	98 to 110[e]	680 to 760[e]	20	AW
E12010-G	E8310-G	120	830	107	740	14	AW or PWHT
E12011-G	E8311-G	120	830	107	740	14	AW or PWHT
E12013-G	E8313-G	120	830	107	740	11	AW or PWHT
E12015-G	E8315-G	120	830	107	740	14	AW or PWHT
E12016-G	E8316-G	120	830	107	740	14	AW or PWHT
E12018-G	E8318-G	120	830	107	740	14	AW or PWHT
E12018M	E8318M	120	830	108 to 120[e]	745 to 830[e]	18	AW
E12018M1	E8318M1	120	830	108 to 120[e]	745 to 830[e]	18	AW

[a] See Table 5 for sizes to be tested.
[b] Single values are minima, except as otherwise specified.
[c] The letter suffix "X" as used in this table represents the suffixes (A1, B1, B2, etc.) which are tested in the PWHT condition only.
[d] "AW" signifies as-welded, which may or may not be aged, at the manufacturer's option (see 12.2). "PWHT" signifies postweld heat treated as specified in 9.4.1.1 and in Table 7, except that the "G" designated classifications, marked as "AW or PWHT" in this table, may have weld metal tested with or without PWHT as agreed upon between the purchaser and supplier.
[e] For 3/32 in [2.5 mm] electrodes, the upper value for the yield strength may be 5 ksi [35 MPa] higher than the indicated value.

yield strength for A5.5M; and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities. The rounded results shall fulfill the requirements for the classification under test.

7. Summary of Tests

The tests required for each classification are specified in Table 5. The purpose of these tests is to determine the chemical composition, mechanical properties, and soundness of the weld metal; the usability of the electrode; and the moisture content of the low-hydrogen electrode covering. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Clauses 9 through 15. The supplemental tests for absorbed moisture (see Clause 16) and for diffusible hydrogen (see Clause 17) are not required for classification of the low-hydrogen electrodes (see Note i of Table 5).

Table 4
Charpy V-Notch Impact Requirements

AWS Classification		Limits for 3 out of 5 Specimens[a,b,c]	
A5.5	**A5.5M**	**Average, min.[d]**	**Single Value, min.[d]**
E7018-W1 E8018-W2	E4918-W1 E5518-W2	20 ft•lbf at 0°F [27 J at –20°C]	15 ft•lbf at 0°F [20 J at –20°C]
E12018M1	E8318M1	50 ft•lbf at 0°F [67 J at –20°C]	40 ft•lbf at 0°F [54 J at –20°C]
E7010-P1 E8010-P1 E8018-P2 E8045-P2 E9010-P1 E9018-P2 *E9018-NM2* [e] E9045-P2 E10045-P2	E4910-P1 E5510-P1 E5518-P2 E5545-P2 E6210-P1 E6218-P2 *E6218-NM2* [e] E6245-P2 E6945-P2	20 ft•lbf at –20°F [27 J at –30°C]	15 ft•lbf at –20°F [20 J at –30°C]
E8018-NM1 E8016-C3 E8018-C3	E5518-NM1 E5516-C3 E5518-C3	20 ft•lbf at –40°F [27 J at –40°C]	15 ft•lbf at –40°F [20 J at –40°C]
E8016-D3, E8018-D1 E8018-D3, E9015-D1 E9018-D1, E9018-D3 E10015-D2, E10016-D2 E10018-D2	E5516-D3, E5518-D1 E5518-D3, E6215-D1 E6218-D1, E6218-D3 E6915-D2, E6916-D2 E6918-D2	20 ft•lbf at –60°F [e] [27 J at –50°C]	15 ft•lbf at –60°F [e] [20 J at –50°C]
E7018-C3L E8016-C4, E8018-C4 E9018M, E10018M E11018M, E12018M	E4918-C3L E5516-C4, E5518-C4 E6218M, E6918M E7618M, E8318M	20 ft•lbf at –60°F [27 J at –50°C]	15 ft•lbf at –60°F [20 J at –50°C]
E8016-C1 E8018-C1	E5516-C1 E5518-C1	20 ft•lbf at –75°F [e] [27 J at –60°C]	15 ft•lbf at –75°F [e] [20 J at –60°C]
E7015-C1L E7016-C1L E7018-C1L E8016-C2 E8018-C2	E4915-C1L E4916-C1L E4918-C1L E5516-C2 E5518-C2	20 ft•lbf at –100°F [e] [27 J at –75°C]	15 ft•lbf at –100°F [e] [20 J at –75°C]
E7015-C2L E7016-C2L E7018-C2L	E4915-C2L E4916-C2L E4918-C2L	20 ft•lbf at –150°F [e] [27 J at –100°C]	15 ft•lbf at –150°F [e] [20 J at –100°C]
E9015-C5L	E6215-C5L	20 ft•lbf at –175°F [e] [27 J at –115°C]	15 ft•lbf at –175°F [e] [20 J at –115°C]
EXXXX-A1 EXXXX-BX EXXXX-BXL E(X)XXXX-G		Not specified	

[a] *The test temperature for the five specimens shall be at or below the temperature listed. The actual temperature used shall be listed on the certification documentation when issued.*

[b] Both the highest and the lowest test values obtained shall be disregarded in computing the average value. Two of the three remaining values shall equal or exceed the minimum average value listed; one of these three remaining values may be lower than minimum average value, but shall not be less than the minimum single value listed. The average of the three remaining values shall not be less than the minimum average value listed.

[c] *Impact test specimens are tested without thermal treatment, except as noted.*

[d] Impact test values shall be recorded to "nearest whole unit" of energy absorbed in accordance with the rounding method specified in Clause 6.

[e] *These classifications are tested in the postweld heat treated condition, as specified in 9.4.1.1 and in Table 7.*

Table 5
Required Tests[a]

AWS Classification[b]			Electrode Size[c]		Welding Position for Test Assembly				
A5.5	A5.5M	Type of Current[d]	in	mm	Chemical Analysis[e]	Soundness Test & All Weld Metal Tension Test[f, g]	Impact Test[h]	Fillet Weld Test[i, j]	Moisture Test[k]
E7010-X	E4910-X	dcep	3/32, 1/8	2.5, 3.2	NR[m]	NR[m]	NR	NR[m]	NR
E8010-X	E5510-X		5/32	4.0	F	F	NR	V, OH	NR
E9010-X	E6210-X		3/16	5.0	NR[m]	F	NR	V, OH	NR
E10010-G	E6910-G		7/32	–	NR[m]	NR[m]	NR	NR[m]	NR
E11010-G	E7610-G		1/4	6.0	F	F	NR	H	NR
E12010-G	E8310-G								
E7011-X	E4911-X	ac and dcep	3/32, 1/8	2.5, 3.2	NR[m]	NR[m]	NR	NR[m]	NR
E8011-G	E5511-G		5/32	4.0	F	F	NR	V, OH	NR
E9011-G	E6211-G		3/16	5.0	NR[m]	F	NR	V, OH	NR
E10011-G	E6911-G		7/32	–	NR[m]	NR[m]	NR	NR[m]	NR
E11011-G	E7611-G		1/4	6.0	F	F	NR	H	NR
E12011-G	E8311-G								
E8013-G	E5513-G	ac, dcen, and dcep	3/32, 1/8	2.5, 3.2	NR[m]	NR[m]	NR	NR[m]	NR
E9013-G	E6213-G		5/32	4.0	F[l]	F[l]	NR	V, OH	NR
E10013-G	E6913-G		3/16	5.0	NR[m]	F[l]	NR	V, OH	NR
E11013-G	E7613-G								
E12013-G	E8313-G								
E7015-X	E4915-X	dcep	3/32, 1/8	2.5, 3.2	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E8015-X	E5515-X		5/32	4.0	F	F	F	V, OH	Req'd
E9015-X	E6215-X		3/16	5.0	NR[m]	F	F	H	NR[m]
E10015-X	E6915-X		7/32	–	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E11015-G	E7615-G		1/4	6.0	F	F	F	H	Req'd
E12015-G	E8315-G								
E7016-X	E4916-X	ac and dcep	3/32, 1/8	2.5, 3.2	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E8016-X	E5516-X		5/32	4.0	F	F	F	V, OH	Req'd
E9016-X	E6216-X		3/16	5.0	NR[m]	F	F	H	NR[m]
E10016-X	E6916-X		7/32	–	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E11016-G	E7616-G		1/4	6.0	F	F	F	H	Req'd
E12016-G	E8316-G								

Table 5 (Continued)
Required Tests[a]

AWS Classification[b]			Electrode Size[c]		Welding Position for Test Assembly				
A5.5	A5.5M	Type of Current[d]	in	mm	Chemical Analysis[e]	Soundness Test & All Weld Metal Tension Test[f, g]	Impact Test[h]	Fillet Weld Test[i, j]	Moisture Test[k]
E8045-P2	E5545-P2	dcep	3/32, 1/8	2.5, 3.2	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E9045-P2	E6245-P2	dcep	5/32	4.0	F	F	F	V-down, OH	Req'd
E10045-P2	E6945-P2	dcep	–	4.5	F	F	F	V-down, OH	Req'd
E7018-X	E4918-X	ac and dcep							
E8018-X	E5518-X	ac and dcep	3/32, 1/8	2.5, 3.2	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E9018-X	E6218-X	ac and dcep	5/32	4.0	F	F	F	V, OH	Req'd
E10018-X	E6918-X	ac and dcep	3/16	5.0	NR[m]	F	F	H	NR[m]
E11018-G	E7618-G	ac and dcep	7/32	–	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E12018-G	E8318-G	ac and dcep	1/4	6.0	F	F	F	H	Req'd
E7020-X	E4920-X	For H-fillets: ac and dcen. For flat position: ac, dcen, and dcep	1/8	3.2	NR[m]	NR[m]	NR[m]	NR[m]	NR
			5/32	4.0	F[l]	F[l]	NR	H	NR
			3/16	5.0	NR[m]	F[l]	NR	H	NR
E7027-X	E4927-X		7/32	–	NR[m]	NR[m,n]	NR	NR[m]	NR
			1/4	6.0	F[l]	F[l,n]	NR	H	NR
			5/16	8.0	NR[m]	F[l,n]	NR	NR	NR
E9018M	E6218M	dcep	3/32, 1/8	2.5, 3.2	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E10018M	E6918M	dcep	5/32	4.0	F	F	F	V, OH	Req'd
E11018M	E7618M	dcep	3/16	5.0	NR[m]	F	F	H	NR[m]
E12018M	E8318M	dcep	7/32	–	NR[m]	NR[m]	NR[m]	NR[m]	NR[m]
E12018M1	E8318M1	dcep	1/4	6.0	F	F	F	H	Req'd

[a] NR means "not required."
[b] The letter suffix "X" as used in this table is defined in Note a of Table 1.
[c] Electrodes manufactured in sizes not shown shall be tested to the requirement of the nearest standard size.
[d] The abbreviations, F, H, H-fillets, V, V-down, and OH, are defined in Note b of Table 1. The terms "dcep" and "dcen" are defined in Note c of Table 1.
[e] See Clause 10.
[f] See Clause 11.
[g] See Clause 12.
[h] See Clause 13. Impact tests are required for classifications listed in Table 4.
[i] Progression for tests performed in the vertical position shall be upward, except for E(X)XX10-X electrodes which may be tested in either upward or downward progression and the E(X)XX45-P2, which is tested vertically down only.
[j] See Clause 14.
[k] The moisture test given in Clause 15 is the required test for measurement of moisture content of the covering. The absorbed moisture test, in Clause 16, and the diffusible hydrogen test, in Clause 17, are supplemental tests required only when their corresponding optional supplemental designators are to be used with the classification designators.
[l] When dcep and dcen are specified, only dcen need be tested.
[m] Standard electrode sizes not requiring this specific test can be classified provided at least two other sizes of that classification have passed the tests required for them, or the size to be classified meets specification requirements by having been tested in accordance with Clauses 8 through either 13, 14, 15, or 16, depending on the electrode being classified.
[n] Electrodes longer than 18 in [450 mm] will require a double length test assembly in accordance with Note 1 of Figure 3, to ensure uniformity of the entire electrode.

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. Specimens for retest may be taken from the original test assembly or from a new test assembly. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement. If the results of one or both retests fail to meet the requirement, the material under test shall be considered as not meeting the requirements of this specification for that classification.

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

9. Weld Test Assemblies

9.1 One or more of the following four weld test assemblies are required for classification testing. They are:

(1) The weld pad in Figure 2 for chemical analysis of the weld metal

(2) The groove weld in Figure 3 for mechanical properties and soundness of the weld metal for all classifications except E(X)XX18M(1)

(3) The fillet weld in Figure 4 for the usability of the electrode

(4) The groove weld in Figure 5, an alternate to (2) above, for mechanical properties and soundness of the weld metal for E(X)XX18M(1) electrodes.

The sample for chemical analysis may be taken from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 3 or 5, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be the referee method.

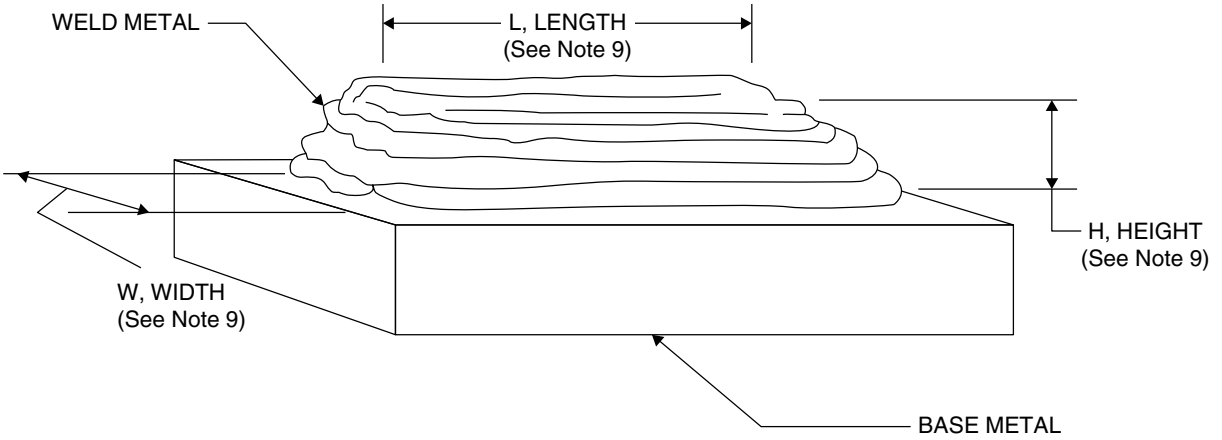
9.2 Preparation of each weld test assembly shall be as prescribed in 9.3 through 9.5. The base metal for each assembly shall be as required in Table 6 and shall meet the requirements of the ASTM specification shown there or an equivalent specification. Electrodes other than low-hydrogen electrodes shall be tested without conditioning.[9] Low-hydrogen electrodes, if they have not been adequately protected against moisture pickup in storage, shall be held at a temperature within the range 500°F to 800°F [260°C to 430°C] for a minimum of one hour prior to testing. Testing of assemblies shall be as prescribed in Clauses 10 through 14.

9.3 Weld Pad. A weld pad shall be prepared as specified in Figure 2, 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 3 or 5) is selected. Base metal of any convenient size, of the type specified in Table 6, shall be used as the base for the weld pad. 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 with multiple layers to obtain undiluted weld metal. The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 300°F [150°C]. The slag shall be removed after each pass. The pad may be quenched in water between passes. The dimensions of the completed pad shall be as shown in Figure 2. Testing of this assembly shall be as specified in Clause 10.

9.4 Groove Weld

9.4.1 Mechanical Properties and Soundness. A test assembly shall be prepared and welded as specified in Figure 3 or 5 using matching base material (see Table 6) with no buttering, or non-matching base material (see Table 6) buttered as shown in Figure 3(B), of thickness specified in Figure 3 or 5. Preheat and interpass temperatures shall be as specified in Table 7. Testing of this assembly shall be as specified in Clauses 11, 12, and 13. The assembly shall be tested in the as-welded condition or the postweld heat treated condition as specified in Table 3, except for the E(X)XXXX-G

[9] Conditioning can be considered to be any special preparation or procedure, such as baking the electrode, which the user would not normally practice.



Notes:
1. Base metal of any convenient size, of the type specified in Table 6, shall be used as the base for the weld pad.
2. The surface of the base metal on which the filler metal is to be deposited shall be clean.
3. The pad shall be welded in the flat position with successive layers to obtain undiluted weld metal.
4. One pad shall be welded for each type of current shown in Table 5 except for those classifications identified by note l in Table 5.
5. The number and size of the beads will vary according to the size of the electrode and the width of the weave, as well as the amperage employed. The width of each weld pass in each weld layer shall be no more than 2–1/2 times the diameter of the core wire.
6. The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 300°F [150°C].
7. The slag shall be removed after each pass.
8. The test assembly may be quenched in water between passes to control interpass temperature.
9. The minimum completed pad size shall be at least four layers in height (H) with length (L) and width (W) sufficient to perform analysis. The sample for analysis shall be taken from weld metal that is at least the following distance above the original base metal surface:

Electrode Size		Minimum Distance From Surface of Base Plate	
in	mm	in	mm
3/32	2.5	1/4	6
1/8 5/32 3/16	3.2 4.0 4.5, 5.0	5/16	8
7/32 1/4 5/16	— 6.0 8.0	3/8	10

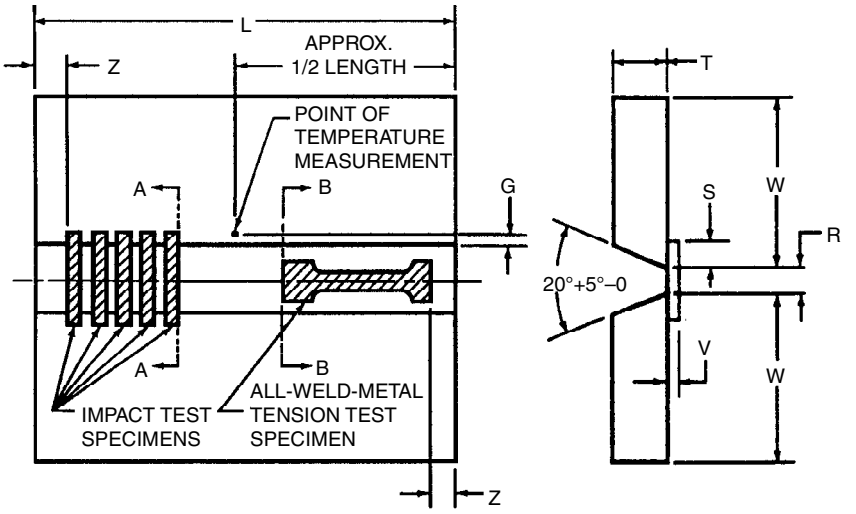
Figure 2—Pad for Chemical Analysis of Undiluted Weld Metal

classifications, which, when Postweld Heat Treatment (PWHT) is required, shall be tested in the postweld heat treated condition agreed upon between the purchaser and supplier (see Note b of Table 7).

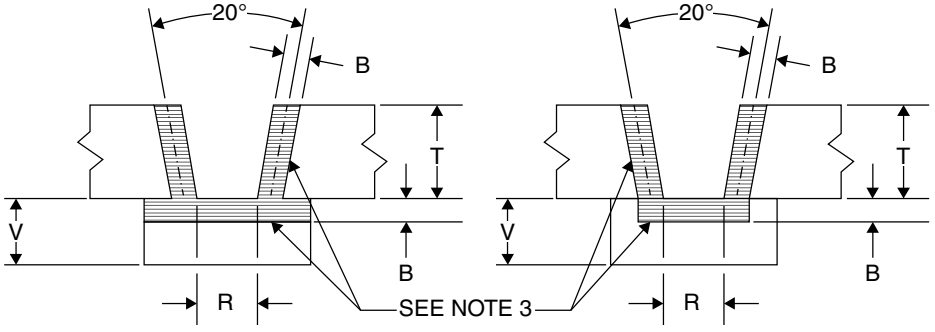
9.4.1.1 When PWHT is required, the heat treatment shall be applied to the assembly before specimens for mechanical testing are removed. This heat treatment may be applied either before or after the radiographic examination.

9.4.1.2 The temperature of the test assembly shall be raised in a suitable furnace, at the rate of 150°F to 500°F [85°C to 280°C] per hour until the postweld heat treatment temperature specified in Table 7, for the electrode classification, is attained. This temperature shall be maintained for the time specified in Table 7 (–0, +15 minutes).

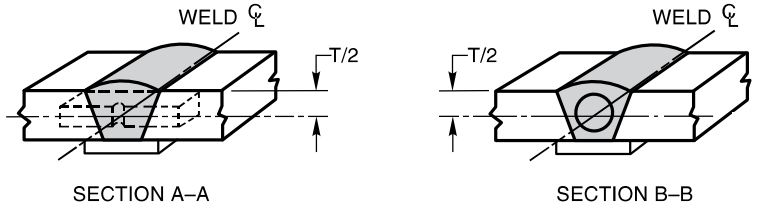
9.4.1.3 The test assembly shall then be allowed to cool in the furnace, at a rate not greater than 350°F [200°C] per hour, and may be removed from the furnace when the temperature of the furnace has reached 600°F [300°C] and allowed to cool in still air.



(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



(B) GROOVE PREPARATION OF TEST PLATE FOR NON-MATCHING BASE MATERIALS



(C) ORIENTATION AND LOCATION OF IMPACT TEST SPECIMEN

(D) LOCATION OF ALL-WELD-METAL TENSION TEST SPECIMEN

Figure 3—Groove Weld Test Assembly for Mechanical Properties and Soundness of Weld Metal Produced by Using All Electrode Classifications Except E(X)XX18M(1)

Dimension	Description	A5.5, in	A5.5M, mm
B	Butter Layer Thickness, min.	1/8	3
G	Offset from groove edge	1/4 to 1/2	6 to 13
L	Length, min. (See Note 1)	10	250
S	Backing overlap, min.	1/4	6
V	Backing thickness, min.	1/4	6
W	Width, min.	5	125
Z	Discard, min.	1	25

Electrode Size		T, Nominal (Plate Thickness)		R (see Note 11) (Root Opening)		Passes per Layer	Total Layers
in	mm	in	mm	in	mm		
3/32	2.5	1/2	12	3/8	10	2	Not specified
1/8	3.2	1/2	12	1/2	13	2	5 to 7
5/32	4.0	3/4	20	5/8	16	2	7 to 9
3/16	4.5, 5.0	3/4	20	3/4	19	2	6 to 8
7/32	–	3/4	20	7/8	22	2	6 to 8
1/4	6.0	1	25	1	25	2	9 to 11
5/16	8.0	1–1/4	30	1–1/8	28	2	10 to 12

Notes:
1. For electrodes longer than 18 in [450 mm], a 20 in [500 mm] long test assembly shall be welded.
2. Base metal shall be as specified in Table 6. For other base metal which does not closely match the composition of the deposit of the electrode under test, the edges of the groove and the contacting face of the backing shall be surfaced as shown, using any size of an electrode having the same composition or classification as the electrode being tested, before welding the joint.
3. The surfaces to be welded shall be clean.
4. Prior to welding, the assembly may be preset to yield a welded joint sufficiently flat to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint within 5 degrees of plane. A completed welded test assembly that is more than 5 degrees out of plane shall be discarded. Straightening of the test assembly is prohibited.
5. Welding shall be in the flat position, using each type of current specified in Table 5 except for classifications identified by Note l in Table 5.
6. The preheat and interpass temperature shall be as specified in Table 7 for the classification being tested.
7. For electrode size larger than 1/8 in [3.2 mm] the joint root may be seal welded with 3/32 or 1/8 in [2.5 or 3.2 mm] electrodes using stringer beads.
8. In addition to the stops and starts at the ends, each pass shall contain a stop and start in between the ends.
9. The completed weld shall be at least flush with the surface of the test plate.
10. The test assemblies shall be postweld heat treated as specified in Table 7 for the classification being tested.
11. Tolerance for root opening is –0, + 1/16 in [–0, + 1 mm].

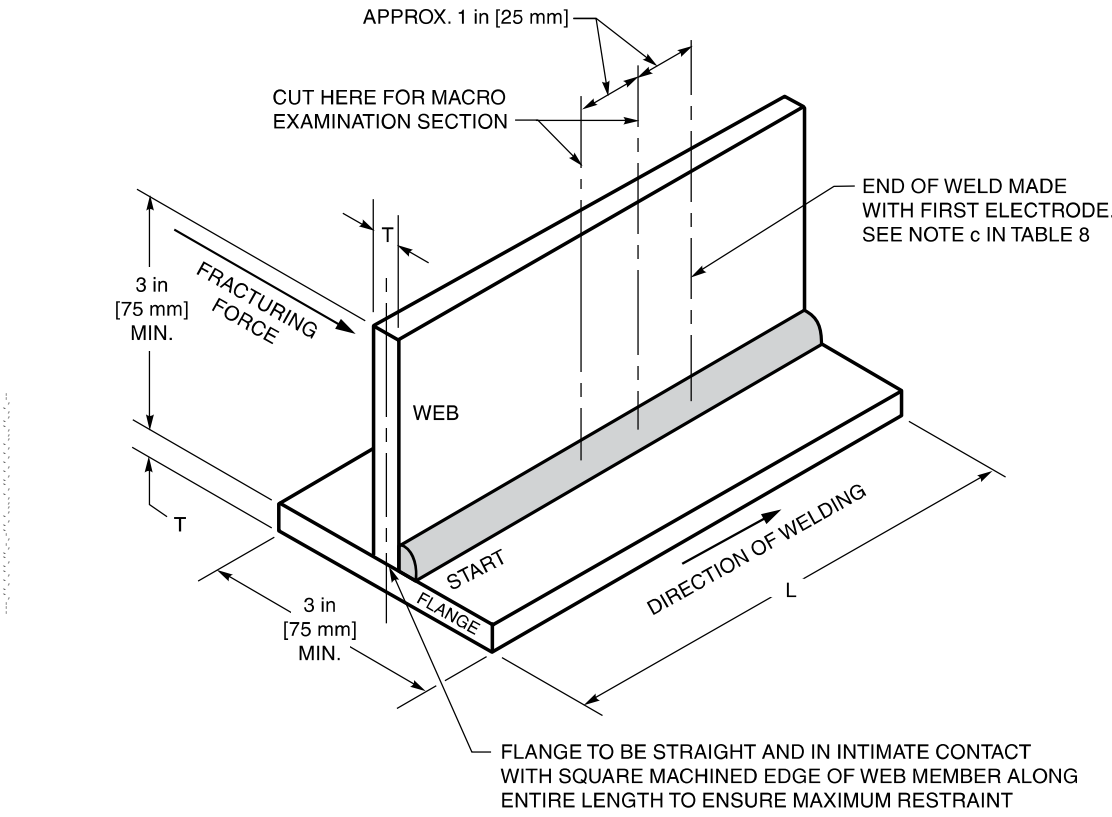
Source of Details A, C and D: AWS A5.1/A5.1M:2004 ERRATA, Figure 2.

Figure 3 (Continued)—Groove Weld Test Assembly for Mechanical Properties and Soundness of Weld Metal Produced by Using All Electrode Classifications Except E(X)XX18M(1)

9.5 Fillet Weld. One or more test assemblies shall be prepared and welded as specified in Table 5 and shown in Figure 4 using base metal of the appropriate type specified in Table 6. The welding positions shall be as specified in Table 8 and Figure 6 according to the size and classification of the electrode. Testing of the assembly shall be as specified in Clause 14.

10. Chemical Analysis

10.1 The sample for analysis shall be taken from weld metal produced with the electrode. The sample shall be taken from a weld pad or the reduced section of the fractured tension test specimen, or from a corresponding location (or any location above it) in the groove weld in Figure 3 or 5. Areas where arc starts or craters exist shall be avoided.



Notes:
1. See Table 8 for values of T and L.
2. Base metal shall be as specified in Table 6.
3. The surfaces to be welded shall be clean.
4. One assembly shall be welded for each position specified in Table 8 and shown in Figure 6 using each type of current and polarity specified in Table 5.
5. The preheat shall be 60°F [15°C] minimum.
6. A single pass fillet weld shall be made on one side of the joint. The first electrode shall be consumed to a stub length of no greater than 2 in [50 mm].
7. Progression in the vertical position shall be upwards, except for E(X)XX10-X electrodes, which may be tested in either upwards or downwards progression, and the E(X)XX45-P2, which is tested vertically down only.
8. Weld cleaning shall be limited to slag chipping, brushing and needle scaling. Grinding or filing of the final weld surface is prohibited.
9. The tests shall be conducted without postweld heat treatment.

Source: AWS A5.5/A5.5M:2006, Figure 3.

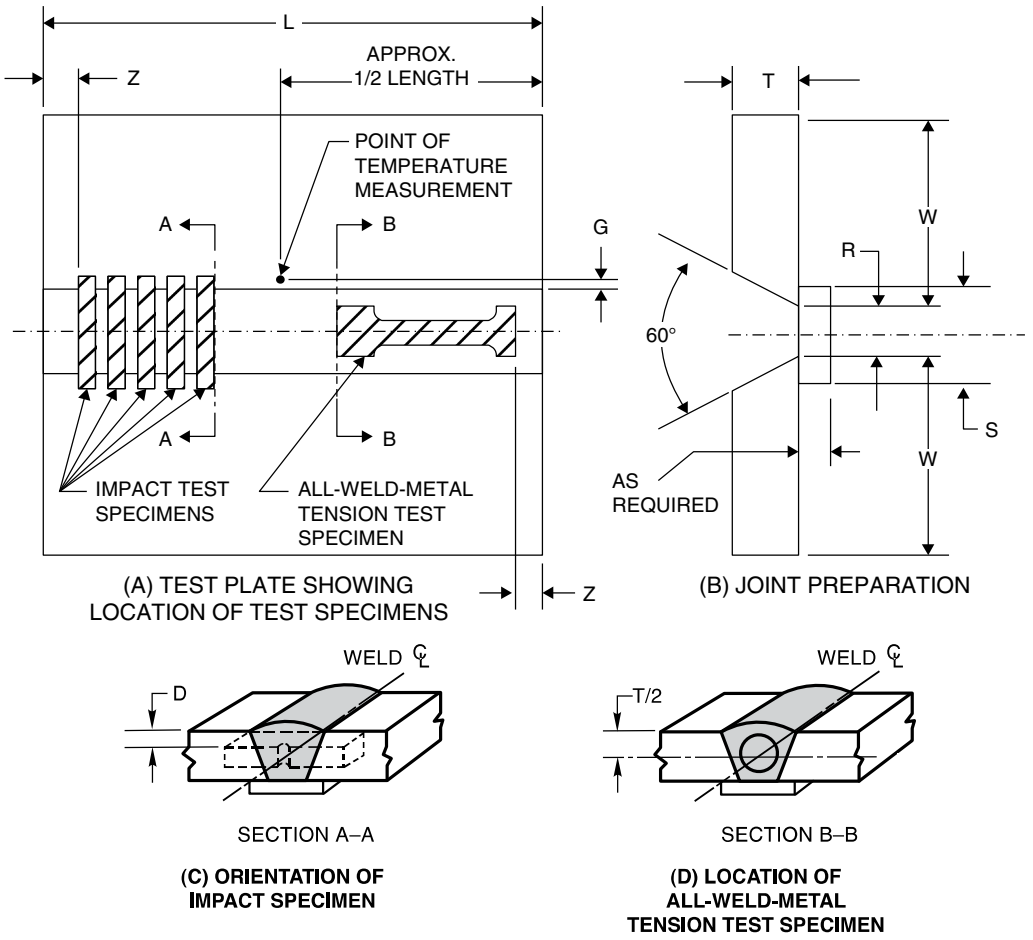
Figure 4—Fillet Weld Test Assembly

The top surface of the pad described in 9.3 and shown in Figure 2 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 and shall be taken from metal that is at least the minimum distance from the original base metal surface as specified in Figure 2.

The sample from the reduced section of the fractured tension test specimen, or from a corresponding location (or any location above it) in the groove weld in Figure 3 or 5, shall be prepared for analysis by any suitable mechanical means.

10.2 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM E350.

10.3 The results of the analysis shall meet the requirements of Table 2 for the classification of the electrode under test.



Dimension	Description	A5.5, in	A5.5M, mm
G	Offset from groove edge	1/4 to 1/2	6 to 13
L	Length, min.	10	250
S	Backing width, min.	1	25
D	Specimen location, nominal	1/16	1.6
W	Width, min.	5	125
Z	Discard, min.	1	25

Electrode Size		T (Min. Plate Thickness)		R (Max. Root Opening)		Number of Layers	
in	mm	in	mm	in	mm	Min.	Max.
3/32	2.5	1/2	12	1/4	6	See note 1	
1/8	3.2	1/2	12	1/4	6	See note 1	
5/32	4.0	3/4	20	1/2	13	7	9
3/16	5.0	3/4	20	1/2	13	7	9
7/32	–	3/4	20	1/2	13	7	8
1/4	6.0	1	25	1/2	13	9	11

Figure 5—Groove Weld Test Assembly for Mechanical Properties and Soundness of Weld Metal Produced by Using E(X)XX18M(1)

Notes:
1. Pass and layer sequence shall be reported.
2. Base metal shall be as specified in Table 6.
3. The surfaces to be welded shall be clean.
4. Prior to welding, the assembly may be preset to yield a welded joint sufficiently flat to facilitate removal of the test specimens. As an alternative, restraint or a combination of restraint and presetting may be used to keep the welded joint within 5 degrees of plane. A completed weld test assembly that is more than 5 degrees out of plane shall be discarded. Straightening of the test assembly is prohibited.
5. Welding shall be performed in the flat position using the type of current specified in Table 5 for the classification.
6. The preheat and interpass temperature shall be that specified in Table 7 for the classification being tested.
7. Layers should be approximately 1/8 in [3 mm] thick with each layer being started at the finishing end of the preceding layer.
8. The weld shall be made with stringer beads or with maximum weave no wider than 2–1/2 times the diameter of the core wire.
9. The completed weld shall have a reinforcement of standard proportions, 1/32 in [0.8 mm] minimum; 1/8 in [3.2 mm] maximum. For electrodes larger than 1/8 in [3.2 mm], the root beads may be made with 3/32 in or 1/8 in [2.5 mm or 3.2 mm] electrodes.
10. The number of layers pertains specifically to minimum plate thicknesses. Use of thicker plates may increase the number of layers.

Figure 5 (Continued)—Groove Weld Test Assembly for Mechanical Properties and Soundness of Weld Metal Produced by Using E(X)XX18M(1)

11. Radiographic Test

11.1 When required in Table 5, the groove weld described in 9.4.1 and shown in Figure 3 or 5 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 of the base metal or with a reasonably uniform reinforcement not exceeding 3/32 in [2.5 mm]. It is permitted 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 nominal 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 E1032. 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, and

(2) no slag inclusions longer than 1/4 in [6.5 mm] or 1/3 of the thickness of the weld, whichever is greater, or no groups of slag inclusions in line that have an aggregate length greater than the thickness of the weld in a length 12 times the thickness of the weld, except when the distance between the successive inclusions exceeds six times the length of the longest inclusion in the group, and

(3) no rounded indications in excess of those permitted by the radiographic standards in Figure 7A or Figure 7B according to the grade specified in Table 9.

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

11.4 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 indication may be porosity or slag. Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded. Test assemblies with indications larger than the large indications permitted in the radiographic standards do not meet the requirements of this specification.

12. Tension Test

12.1 One all-weld-metal tension test 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 Clause 9 and shown in Figure 3 or 5. For specimens machined from 3/4 in [20 mm] or thicker weld assemblies, the all-weld-metal tension test shall have a nominal diameter of 0.500 in

Table 6
Base Metal for Weld Test Assemblies

	Base Metal	
AWS Classification	**ASTM Specification Number[a]**	**UNS Number[b]**
EXXXX-A1	A204 Grade A	K11820
EXXXX-B1	A387 Grade 2	K12143
EXXXX-B2, EXXXX-B2L, EXXXX-B5	A387 Grade 11	K11789
EXXXX-B3, EXXXX-B3L, EXXXX-B4L	A387 Grade 22 or 22L	K21590
EXXXX-B6, EXXXX-B6L, EXXXX-B7, EXXXX-B7L	A387 Grade 5	S50200
EXXXX-B8, EXXXX-B8L	A387 Grade 9	K90941
EXXXX-B23, EXXXX-B24	A29 Grade 1015 or 1020; A283 Grade A, B, C, or D; A36; A131 Grade B (Buttering required)[d]	G10150, G10200, K01400, K01702, K02401, K02801, K02702, K02600 K02102
EXXXX-*B91*	A387 Grade 91	K90901, S50460
EXXXX-B92	*A387 Grade 92*	*K90901, K92460*
EXXXX-C1, EXXXX-C1L	A537 Class 1 or 2; A203 Grade A or B	K12437 K21703, K22103
EXXXX-C2, EXXXX-C2L	A203, Grade D or E	K31718, K32018
EXXXX-C3, EXXXX-C3L	A516 Grade 60, 65, or 70; A537 Class 1 or 2	K02100, K02403, K02700, K12437
EXXXX-NM1	A302 Grade C or D; A533 Type B or C	K12039, K12054, K12539, K12554
EXXXX-D1, E(X)XXXX-D2, EXXXX-D3	A302 Grade A or B	K12021, K12022
EXXXX-NM2, E(X)XX18M	A514, A517, A543 Type B or C; NAVSEA Technical Publication T9074-BD-GIB–010/0300 HY80 or HY100	K11630, K42339 K31820, K32045
E12018M1 [E8318M1]	NAVSEA Technical Publication T9074-BD-GIB–010/0300 HY100	K32045
EXX10-P1, EXX18-P2, E(X)XX45-P2 EXX10-G electrodes intended for pipe welding	API 5L X pipe steel [c]	–
EXX18-W1, EXX18-W2	A588 Grade A, B, or C; A709 Grade 50W	K11947, K12043, K11538
All except E(X)XX18M(1)	A29 Grade 1015 or 1020; A283 Grade A, B, C, or D (Buttering required)[d]	G10150, G10200, K01400, K01702, K02401, K02702
All	A36; A131 Grade B (Buttering required)[d]	K02600, K02102

[a] Steel specifications providing compositions that are equivalent to those shown in other national and international specifications are acceptable.
[b] SAE HS–1086/ASTM DS–56, *Metals & Alloys in the Unified Numbering System*.
[c] Grade shall be appropriate for electrode classification strength level.
[d] Carbon steel base metal does not require buttering when used for fillet weld test assemblies.

Table 7
Preheat, Interpass, and Postweld Heat Treatment Temperatures

AWS Classification		Preheat and Interpass Temperature		Postweld Heat Treatment Temperature		Postweld Heat Treatment Time[a]
A5.5	A5.5M	°F	°C	°F	°C	Hour(s)
E7010-A1	E4910-A1					
E7011-A1	E4911-A1					
E7015-A1	E4915-A1					
E7016-A1	E4916-A1					
E7018-A1	E4918-A1					
E7020-A1	E4920-A1					
E7027-A1	E4927-A1					
E8018-D1	E5518-D1	200 to 225	95 to 110	1150 ± 25	620 ± 15	1
E9015-D1	E6215-D1					
E9018-D1	E6218-D1					
E10015-D2	E6915-D2					
E10016-D2	E6916-D2					
E10018-D2	E6918-D2					
E8016-D3	E5516-D3					
E8018-D3	E5518-D3					
E9018-D3	E6218-D3					
E8016-B1	E5516-B1					
E8018-B1	E5518-B1					
E8015-B2	E5515-B2					
E8016-B2	E5516-B2					
E8018-B2	E5518-B2					
E7015-B2L	E4915-B2L					
E7016-B2L	E4916-B2L					
E7018-B2L	E4918-B2L	325 to 375	160 to 190	1275 ± 25	690 ± 15	1
E9015-B3	E6215-B3					
E9016-B3	E6216-B3					
E9018-B3	E6218-B3					
E8015-B3L	E5515-B3L					
E8018-B3L	E5518-B3L					
E8015-B4L	E5515-B4L					
E8016-B5	E5516-B5					
E8015-B6	E5515-B6					
E8016-B6	E5516-B6					
E8018-B6	E5518-B6					
E9018-B6	*E6218-B6*					
E8015-B6L	E5515-B6L					
E8016-B6L	E5516-B6L					
E8018-B6L	E5518-B6L	350 to 450	180 to 230	1375 ± 25	740 ± 15	1
E8015-B7	E5515-B7					
E8016-B7	E5516-B7					
E8018-B7	E5518-B7					
E8015-B7L	E5515-B7L					
E8016-B7L	E5516-B7L					
E8018-B7L	E5518-B7L					
E8015-B8	E5515-B8					
E8016-B8	E5516-B8					
E8018-B8	E5518-B8	400 to 500	200 to 250	1375 ± 25	740 ± 15	1
E8015-B8L	E5515-B8L					
E8016-B8L	E5516-B8L					
E8018-B8L	E5518-B8L					

Table 7 (Continued)
Preheat, Interpass, and Postweld Heat Treatment Temperatures

AWS Classification		Preheat and Interpass Temperature		Postweld Heat Treatment Temperature		Time[a]
A5.5	A5.5M	°F	°C	°F	°C	Hour(s)
E9015-B23	*E6215-B23*					
E9016-B23	*E6216-B23*					
E9018-B23	*E6218-B23*					
E9015-B24	*E6215-B24*	*350 to 475*	*180 to 250*	*1365 ± 25*	*740 ± 15*	*2*
E9016-B24	*E6216-B24*					
E9018-B24	*E6218-B24*					
E9015-*B91*	E6215-*B91*					
E9016-*B91*	E6216-*B91*					
E9018-*B91*	E6218-*B91*	400 to 600	200 to 315	1400 ± 25	760 ± 15	2
E9015-B92	*E6215-B92*					
E9016-B92	*E6216-B92*					
E9018-B92	*E6218-B92*					
E8016-C1	E5516-C1					
E8018-C1	E5518-C1					
E7015-C1L	E4915-C1L					
E7016-C1L	E4916-C1L					
E7018-C1L	E4918-C1L	200 to 225	95 to 110	1125 ± 25	605 ± 15	1
E8016-C2	E5516-C2					
E8018-C2	E5518-C2					
E7015-C2L	E4915-C2L					
E7016-C2L	E4916-C2L					
E7018-C2L	E4918-C2L					
E9015-C5L	E6215-C5L	200 to 250	95 to 120	1075 ± 25	580 ± 15	1
E9018-NM2	*E6218-NM2*	*200 to 225*	*95 to 110*	*1125 ± 25*	*605 ± 15*	*8*
E8010-G	E5510-G					
E8011-G	E5511-G					
E8013-G	E5513-G					
E9010-G	E6210-G					
E9011-G	E6211-G					
E9013-G	E6213-G					
E10010-G	E6910-G					
E10011-G	E6911-G	*See Note c*		See Note c		
E10013-G	E6913-G					
E11010-G	E7610-G					
E11011-G	E7611-G					
E11013-G	E7613-G					
E12010-G	E8310-G					
E12011-G	E8311-G					
E12013-G	E8313-G					

Table 7 (Continued)
Preheat, Interpass, and Postweld Heat Treatment Temperatures

AWS Classification		Preheat and Interpass Temperature		Postweld Heat Treatment Temperature		Postweld Heat Treatment Time[a]
A5.5	A5.5M	°F	°C	°F	°C	Hour(s)
E7010-G	E4910-G					
E7011-G	E4911-G					
E7015-G	E4915-G					
E7016-G	E4916-G					
E7018-G	E4918-G					
E7020-G	E4920-G					
E7027-G	E4927-G					
E8015-G	E5515-G					
E8016-G	E5516-G					
E8018-G	E5518-G					
E9015-G	E6215-G	See Note b		See Note b		
E9016-G	E6216-G					
E9018-G	E6218-G					
E10015-G	E6915-G					
E10016-G	E6916-G					
E10018-G	E6918-G					
E11015-G	E7615-G					
E11016-G	E7616-G					
E11018-G	E7618-G					
E12015-G	E8315-G					
E12016-G	E8316-G					
E12018-G	E8318-G					
E7010-P1	E4910-P1					
E7018-C3L	E4918-C3L					
E7018-W1	E4918-W1					
E8016-C3	E5516-C3					
E8018-C3	E5518-C3					
E8016-C4	E5516-C4					
E8018-C4	E5518-C4					
E8018-NM1	E5518-NM1					
E8018-W2	E5518-W2					
E8018-P2	E5518-P2	200 to 250	95 to 120	Not Specified[c]		
E8045-P2	E5545-P2					
E9018-P2	E6218-P2					
E9045-P2	E6245-P2					
E9018M	E6218M					
E10018M	E6918M					
E10045-P2	E6945-P2					
E11018M	E7618M					
E12018M	E8318M					
E12018M1	E8318M1					
E8010-P1	E5510-P1	325 to 375	160 to 190	Not Specified[c]		
E9010-P1	E6210-P1					

[a] Postweld heat treat at specified time, –0, +15 minutes.

[b] *The need for, and specific values for preheat and interpass temperatures, and postweld heat treatment conditions of weld test assemblies made with "G" electrodes shall be as agreed upon between the purchaser and supplier.*

[c] Postweld heat treatment is not required for those classifications listed as "as-welded" in Table 3.

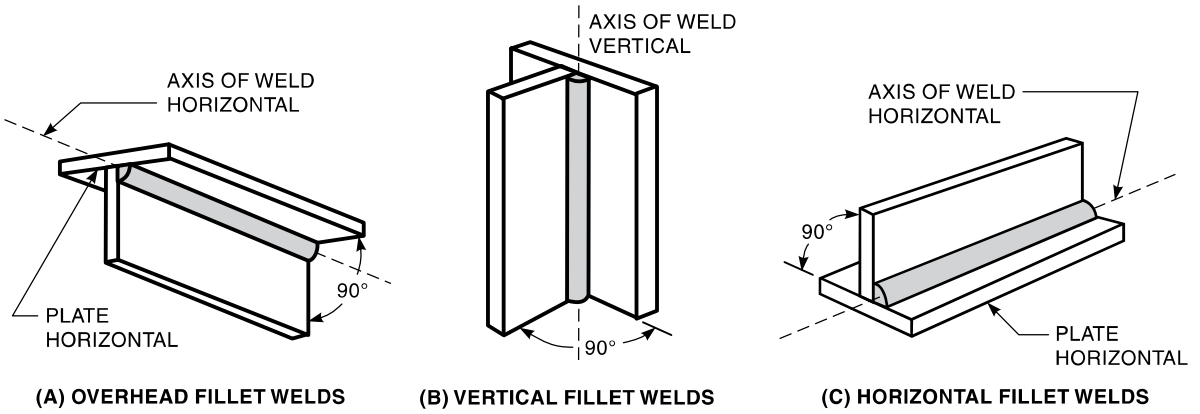
Table 8
Requirements for Preparation of Fillet Weld Test Assemblies

AWS Classification[a]		Electrode				Plate Size[b]				Position of Welding	Size of Fillet Weld	
		Size		Length		Thickness (T)		Length (L) min.[c]				
A5.5	A5.5M	in	mm	in	mm	in	mm	in	mm		in	mm
E(X)XX10-X E(X)XX11-X	EXX10-X EXX11-X	3/32	2.5	12	300	1/8	3	10	250	V, OH	5/32 max.	4.0 max.
		1/8	3.2	14	350	1/4	6	12	300	V, OH	3/16 max.	5.0 max.
		5/32	4.0	14	350	3/8	10	12	300	V, OH	1/4 max.	6.0 max.
		3/16	5.0	14	350	3/8	10	12	300	V, OH	5/16 max.	8.0 max.
		7/32	–	14 or 18	350 or 450	1/2	12	12 or 16	300 or 400	H	1/4 min.	6.0 min.
		1/4	6.0	18	450	1/2	12	16	400	H	1/4 min	6.0 min.
E(X)XX13-X	EXX13-X	3/32	2.5	12	300	1/8	3	10	250	V, OH	5/32 max.	4.0 max.
		1/8	3.2	14	350	1/4	6	12	300	V, OH	3/16 max.	5.0 max.
		5/32	4.0	14	350	3/8	10	12	300	V, OH	1/4 max.	6.0 max.
		3/16	5.0	14	350	3/8	10	12	300	V, OH	3/8 max.	10.0 max.
		7/32	–	14 or 18	350 or 450	1/2	12	12 or 16	300 or 400	H	1/4 min	6.0 min.
E(X)XX15-X E(X)XX16-X E(X)XX18M(1) E(X)XX18-X	EXX15-X EXX16-X EXX18M(1) EXX18-X	3/32	2.5	12 or 14	300 or 350	1/8	3	10 or 12	250 or 300	V, OH	3/16 max.	5.0 max.
		1/8	3.2	14	350	1/4	6	12	300	V, OH	1/4 max.	6.0 max.
		5/32	4.0	14	350	3/8	10	12	300	V, OH	5/16 max.	8.0 max.
		3/16	5.0	14	350	3/8	10	12	300	H	3/16 min.	5.0 min..
		7/32	–	14 or 18	350 or 450	1/2	12	12 or 16	300 or 400	H	1/4 min.	6.0 min.
		1/4	6.0	18	450	1/2	12	16	400	H	5/16 min.	8.0 min.
E7020-X E7027-X	E4920-X E4927-X	1/8	3.2	14	350	1/4	6	12	300	H	1/8 min.	3.0 min.
		5/32	4.0	14	350	3/8	10	12	300	H	3/16 min.	5.0 min.
		3/16	5.0	14 or 18	350 or 450	3/8	10	12 or 16	300 or 400	H	1/4 min.	6.0 min.
		7/32	–	18 or 28	450 or 700	1/2	12	16 or 26	400 or 650	H	1/4 min.	6.0 min.
		1/4	6.0	18 or 28	450 or 700	1/2	12	16 or 26	400 or 650	H	5/16 min.	8.0 min.
		5/16	8.0	18 or 28	450 or 700	1/2	12	16 or 26	400 or 650	H	5/16 min.	8.0 min.
E(X)XX45-P2	EXX45-P2	3/32	2.5	14	350	1/8	3	10 or 12	250 or 300	V-down, OH	3/16 max.	5.0 max.
		1/8	3.2	14	350	1/4	6	12	300	V-down, OH	1/4 max.	6.0 max.
		5/32	4.0	14	350	3/8	10	12	300	V-down, OH	5/16 max.	8.0 max.
		—	4.5	14	350	3/8	10	12	300	V-down, OH	1/4 min.	6.0 min.

[a] The letters "(X)XX" ["XX"] used in the classification designations in this table represent the various strength levels, 70, 80, 90, 100, 110, and 120 [49, 55, 62, 69, 76, and 83], of the weld metal. The letter suffix "X" as used in this table is defined in Note a of Table 1.

[b] See Figure 4.

[c] A starting tab, or a longer test assembly shall be used to ensure that the end of the first bead is more than 4 in [100 mm] from the end of the test assembly.



Source: AWS A5.5/A5.5M:2006, Figure 5.

Figure 6—Welding Positions for Fillet Weld Test Assemblies

Table 9
Radiographic Soundness Requirements

AWS Classification[a]		
A5.5	**A5.5M**	**Radiographic Standard[b,c]**
E(X)XX15-X	EXX15-X	
E(X)XX16-X	EXX16-X	
E(X)XX18-X	EXX18-X	Grade 1
E7020-X	E4920-X	
E(X)XX18M(1)	EXX18M(1)	
E(X)XX45-P2	EXX45-P2	
E(X)XX10-X	EXX10-X	
E(X)XX11-X	EXX11-X	
E(X)XX13-G	EXX13-G	Grade 2
E7027-X	E4927-X	

[a] The letters "(X)XX" ["XX"] used in the classification designations in this table stand for the various strength levels 70, 80, 90, 100, 110, and 120 [49, 55, 62, 69, 76, and 83] of electrodes. The letter suffix "X" as used in this table stands for the suffixes A1, B1, B2, etc. (see Table 2).

[b] See Figure 7.

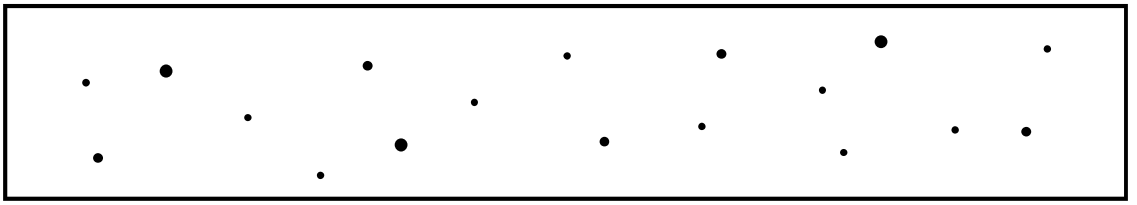
[c] The radiographic soundness obtainable under actual industrial conditions employed for various electrode classifications is discussed in A6.11.1 in Annex A.

[12.5 mm]. For specimens machined from 1/2 in [12 mm] thick weld assemblies, the all-weld-metal tension test specimen shall have a nominal diameter of 0.250 in [6.5 mm]. The nominal gauge length-to-diameter ratio shall be 4:1 in each case.

12.2 After machining, but before testing, tension test specimens to be tested in the as-welded condition may be aged at 200°F to 220°F [90°C to 105°C] for up to 48 hours, then allowed to cool to room temperature. If the specimen is aged, that fact, together with the manner of aging, shall be recorded on the test certificate. Refer to A6.3 for a discussion on the purpose of aging. The purchaser may, by mutual agreement with the supplier, have the thermal aging of specimens prohibited for all mechanical testing done to Schedule I or J of AWS A5.01M/A5.01 (ISO 14344 MOD).

12.3 The aged and unaged specimens shall be tested in the manner described in the Tension Test section of AWS B4.0 or AWS B4.0M.

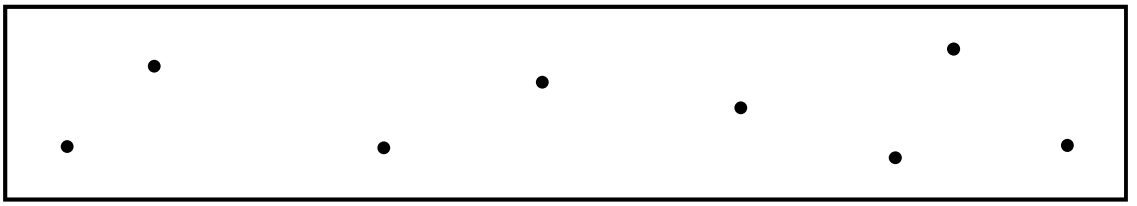
12.4 Results of the tension test shall meet the requirements specified in Table 3.



(A) ASSORTED ROUNDED INDICATIONS

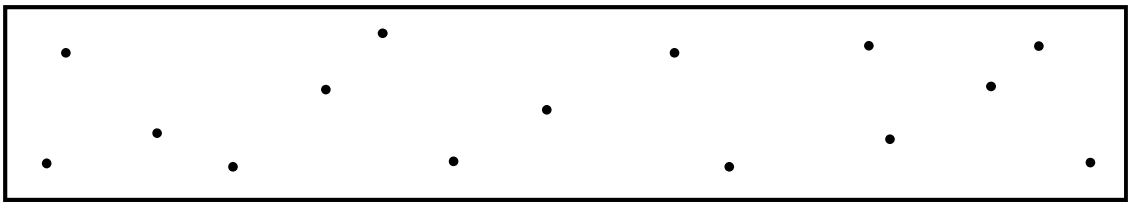
SIZE: 1/64 in [0.4 mm] TO 1/16 in [1.6 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 18, WITH THE FOLLOWING RESTRICTIONS:

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



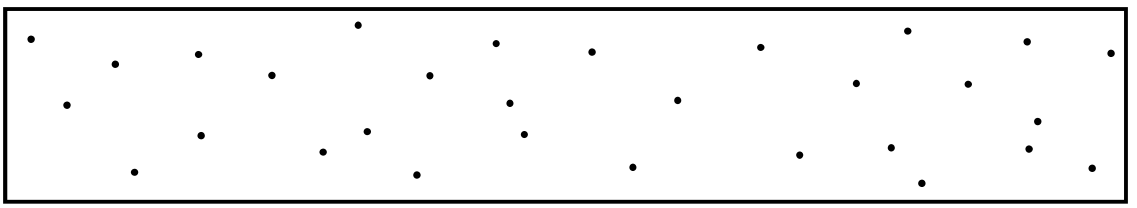
(B) LARGE ROUNDED INDICATIONS

SIZE: 3/64 in [1.2 mm] TO 1/16 in [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 [0.8 mm] TO 3/64 in [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

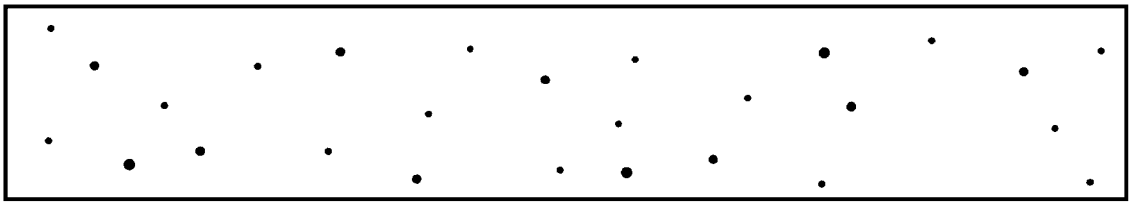
SIZE: 1/64 in [0.4 mm] TO 1/32 in [0.8 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 30.

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 specially 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 fabrication.
3. Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded.

Source: AWS A5.1/A5.1M:2004, ERRATA, Figure 7 on page 16.

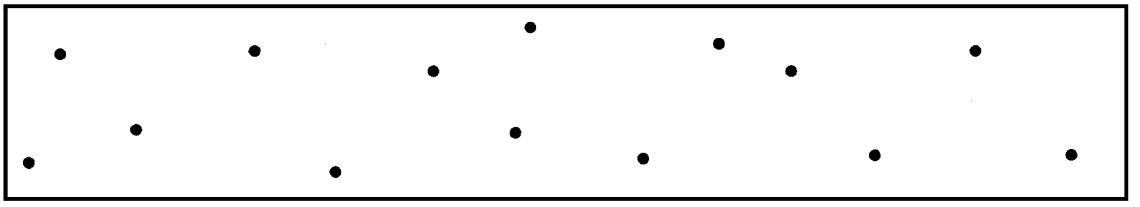
Figure 7A—Radiographic Acceptance Standards for Rounded Indications (Grade 1)



(A) ASSORTED ROUNDED INDICATIONS

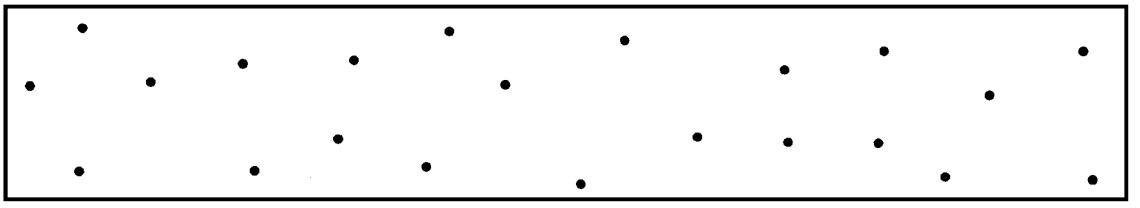
SIZE: 1/64 in [0.4 mm] TO 5/64 in [2.0 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 27, WITH THE FOLLOWING RESTRICTIONS:

MAXIMUM NUMBER OF LARGE (1/16 in [1.6 mm] TO 5/64 in [2.0 mm] IN DIAMETER OR IN LENGTH) INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM (3/64 in [1.2 mm] TO 1/16 in [1.6 mm] IN DIAMETER OR IN LENGTH) INDICATIONS = 8.
MAXIMUM NUMBER OF SMALL (1/64 in [0.4 mm] TO 3/64 in [1.2 mm] IN DIAMETER OR IN LENGTH) INDICATIONS = 16.



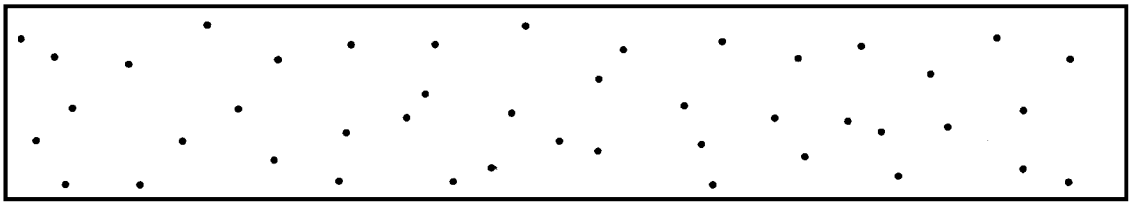
(B) LARGE ROUNDED INDICATIONS

SIZE: 1/16 in [1.6 mm] TO 5/64 in [2.0 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 14.



(C) MEDIUM ROUNDED INDICATIONS

SIZE: 3/64 in [1.2 mm] TO 1/16 in [1.6 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 22.



(D) SMALL ROUNDED INDICATIONS

SIZE: 1/64 in [0.4 mm] TO 3/64 in [1.2 mm] IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 44.

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 specially 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 fabrication.
3. Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded.

Source: AWS A5.1/A5.1M:2004, ERRATA, Figure 7 on page 17.

Figure 7B—Radiographic Acceptance Standards for Rounded Indications (Grade 2)

13. Impact Test

13.1 Five full-size Charpy V-notch impact test specimens, as specified in the Fracture Toughness Test section of AWS B4.0 or AWS B4.0M, shall be machined from the test assembly shown in Figure 3 or 5, for those classifications for which impact testing is required in Table 5. The Charpy V-notch specimens shall have the notched surface and the struck surface parallel with each other within 0.002 in [0.05 mm]. The other two surfaces of the specimen shall be square with the notched or struck surfaces within 10 minutes of a degree. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.

The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at a minimum 50X magnification on either a shadowgraph or metallograph. The correct location of the notch shall be verified by etching before or after machining.

13.2 The five specimens shall be tested in accordance with the Fracture Toughness Test section of AWS B4.0 or AWS B4.0M. *The test temperature shall be at or below the temperature specified in Table 4 for the classification under test. The actual temperature used shall be listed on the certification documentation when issued.*

13.3 In evaluating the test results, the lowest and the highest values obtained shall be disregarded. Two of the remaining three values shall equal or exceed the specified 20 ft·lbf [27 J] energy level. One of the three may be lower, but not lower than the single value indicated in Table 4, and the average of the three shall not be less than the required average energy level.

14. Fillet Weld Test

14.1 The fillet weld test, when required in Table 5, shall be made in accordance with the requirements of 9.5 and Figure 4. The entire face of the completed fillet shall be examined visually. It shall be free of cracks, overlap, slag, and porosity, and shall be substantially free of undercut. An infrequent short undercut up to 1/32 in [0.8 mm] in depth shall be allowed. After the visual examination, a specimen containing approximately 1 in [25 mm] of the weld (in the lengthwise direction) shall be prepared as shown in Figure 4. One cross-sectional surface of the specimen shall be polished, etched, and then examined as required in 14.2.

14.2 Scribe lines shall be placed on the prepared surface, as shown in Figure 8, and the leg lengths and convexity of the fillet shall be determined to the nearest 1/64 in [0.5 mm] by actual measurement (see Figure 8). These dimensions shall meet the requirements in Table 8 for fillet size, and Table 10 for convexity and permissible difference in the length of the legs.

14.3 The remaining two sections of the test assembly shall be broken longitudinally through the fillet weld by a force exerted as shown in Figure 9. When necessary, to facilitate fracture through the fillet, one or more of the following procedures may be used:

(1) A reinforcing bead, as shown in Figure 9A, may be added to each leg of the weld.

(2) The position of the web on the flange may be changed, as shown in Figure 9B.

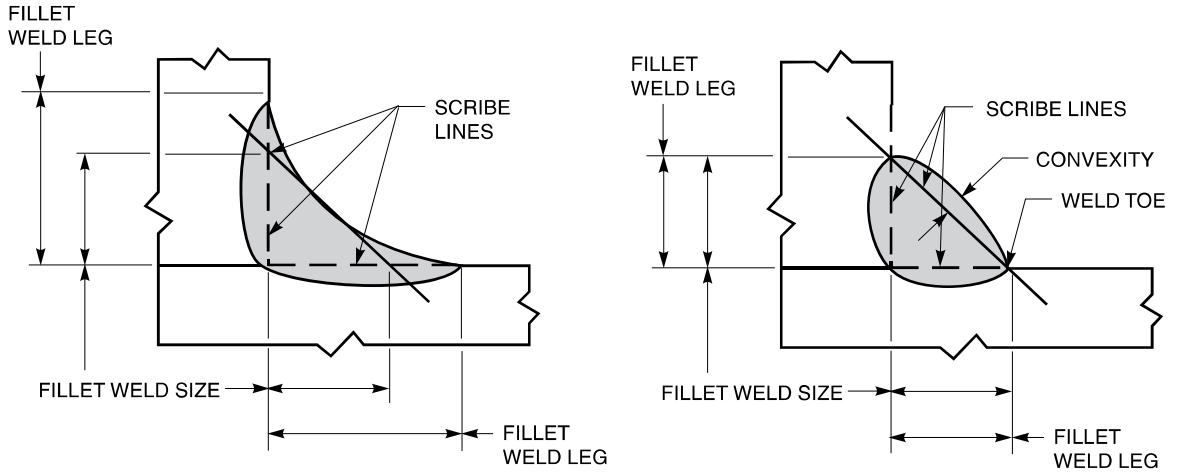
(3) The face of the fillet may be notched, as shown in Figure 9C.

Tests in which the weld metal pulls out of the base metal during bending are invalid. Specimens in which this occurs shall be replaced, specimen for specimen, and the test completed. In this case, the doubling of specimens required for retest in Clause 8, does not apply.

14.4 The fractured surfaces shall be visually examined without magnification. The fracture surface shall be free of cracks. Incomplete fusion at the weld root shall not be greater than 20% of the total length of the weld. There shall be no continuous length of incomplete fusion greater than 1 in [25 mm] as measured along the weld axis, except for electrodes of E(X)XX13-G classifications. Fillet welds made with electrodes of these classifications may exhibit incomplete penetration through the entire weld length. They may also exhibit incomplete fusion, which shall at no point exceed 25% of the smaller leg of the fillet weld.

15. Moisture Test

15.1 The moisture content of the covering of the electrode, when required in Table 5, shall be determined by any suitable method. In case of dispute, the method described in AWS A4.4M shall be the referee method.



(A) CONCAVE FILLET WELD **(B) CONVEX FILLET WELD**

Notes:
1. Fillet weld size is the leg lengths of the largest isosceles right triangle that can be inscribed within the fillet weld cross section.
2. Convexity is the maximum distance from the face of a convex fillet weld perpendicular to a line joining the weld toes.
3. Fillet weld leg is the distance from the joint root to the toe of the fillet weld.

Source: AWS A5.5/A5.5M:2006, Figure 7.

Figure 8—Dimensions of Fillet Welds

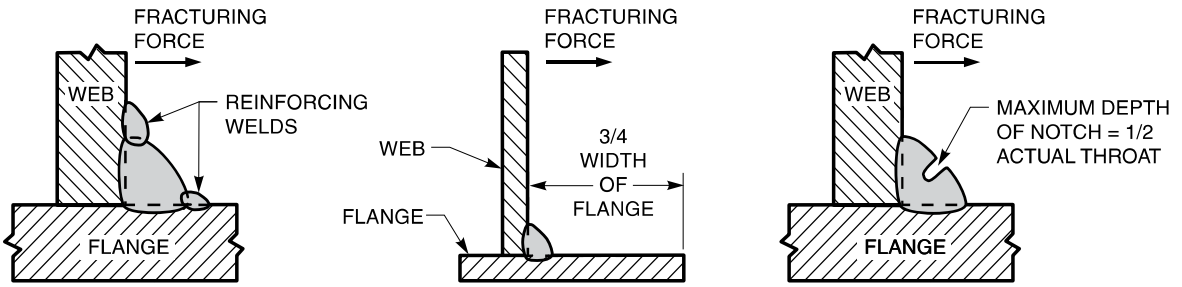
Table 10
Dimensional Requirements for Fillet Weld Usability Test Specimens

Measured Fillet Weld Size		Maximum Convexity		Maximum Difference Between Fillet Weld Legs	
in	mm	in	mm	in	mm
1/8, or less	3.0, or less	3/64	1.0	1/32	1.0
9/64	3.5	3/64	1.0	3/64	1.0
5/32	4.0	3/64	1.0	3/64	1.0
11/64	4.5	1/16	1.5	1/16	1.5
3/16	5.0	1/16	1.5	1/16	1.5
13/64	5.0	1/16	1.5	5/64	2.0
7/32	5.5	1/16	1.5	5/64	2.0
15/64	6.0	1/16	1.5	3/32	2.5
1/4	6.5	1/16	1.5	3/32	2.5
17/64	6.5	1/16	1.5	7/64	3.0
9/32	7.0	1/16	1.5	7/64	3.0
19/64	7.5	5/64	2.0	1/8	3.0
5/16	8.0	5/64	2.0	1/8	3.0
21/64	8.5	5/64	2.0	9/64	3.5
11/32	8.5	5/64	2.0	9/64	3.5
23/64	9.0	5/64	2.0	5/32	4.0
3/8, or more	9.5, or more	5/64	2.0	5/32	4.0

15.2 The electrodes shall be tested without conditioning, unless the manufacturer recommends otherwise. If the electrodes are conditioned, that fact, along with the method used for conditioning, and the time and temperature involved in the conditioning, shall be noted on the test record. The moisture content shall not exceed the limit specified in Table 11, for the classification under test.

16. Absorbed Moisture Test

16.1 In order for a low-hydrogen electrode to be designated as low-moisture-absorbing, with the "R" suffix designator, sufficient electrodes shall be exposed to an environment of 80° F [27 °C] and 80% relative humidity (RH) for a period of not less than 9 hours by any suitable method. In case of dispute, the exposure method described in 16.2 through 16.6 shall



Source: AWS A5.5/A5.5M:2006, Figure 8.

Figure 9—Alternate Methods for Facilitating Fracture of the Fillet Weld

Table 11
Moisture Content Limits for Low-Hydrogen Electrode Coverings

AWS Electrode Designation[a]		Limit of Moisture Content, % by weight max.	
A5.5	**A5.5M**	**As-Received or Reconditioned[b]**	**As-Exposed[c]**
E70XX-X, E70XX-X HZ	E49XX-X, E49XX-X HZ	0.4	Not specified
E70XX-X R, E70XX-X HZ R	E49XX-X R, E49XX-X HZ R	0.3	0.4
E80XX-X, E80XX-X HZ	E55XX-X, E55XX-X HZ	0.2	Not specified
E80XX-X R, E80XX-X HZ R	E55XX-X R, E55XX-X HZ R	0.2	0.4
E90XX-X, E90XX-X HZ E9018M, E9018M HZ	E62XX-X, E62XX-X HZ E6218M, E6218M HZ	0.15	Not specified
E90XX-X R, E90XX-X HZ R E9018M R, E9018M HZ R	E62XX-X R, E62XX-X HZ R E6218M R, E6218M HZ R	0.15	0.4
E100XX-X, E100XX-X HZ E10018M, E10018M HZ	E69XX-X, E69XX-X HZ E6918M, E6918M HZ	0.15	Not specified
E100XX-X R, E100XX-X HZ R E10018M R, E10018M HZ R	E69XX-X R, E69XX-X HZ R E6918M R, E6918M HZ R	0.15	0.4
E110XX-G, E110XX-G HZ E11018M, E11018M HZ	E76XX-G, E76XX-G HZ E7618M, E7618M HZ	0.15	Not specified
E110XX-G R, E110XX-G HZ R E11018M R, E11018M HZ R	E76XX-G R, E76XX-G HZ R E7618M R, E7618M HZ R	0.15	0.4
E120XX-G, E120XX-G HZ E12018M, E12018M HZ	E83XX-G, E83XX-G HZ E8318M, E8318M HZ	0.15	Not specified
E120XX-G R, E120XX-G HZ R E12018M R, E12018M HZ R	E83XX-G R, E83XX-G HZ R E8318M R, E8318M HZ R	0.15	0.4
E12018M1, E12018M1 HZ	E8318M1, E8318M1 HZ	0.10	Not specified
E12018M1 R, E12018M1 HZ R	E8318M1 R, E8318M1 HZ R	0.10	0.4

[a] See Clause 16, Figure 1, and Table 12.
[b] As-received or reconditioned electrode coverings shall be tested as specified in Clause 15.
[c] As-exposed electrode coverings shall be treated with a moist environment as specified in 16.2 through 16.6 before being tested as specified in 16.1.

be the referee method. The moisture content of the electrode covering on the low-moisture-absorbing, low-hydrogen electrode {E(X)XX15-X R; E(X)XX16-X R; E(X)XX18-X R; E(X)XX45-P2 R; and E(X)XX18M(1) R} shall be determined by any suitable method. In case of dispute, the method described in AWS A4.4M shall be the referee method for the determination of moisture content. The moisture content of the exposed covering shall not exceed the maximum specified moisture content for the designated electrode and classification in Table 11.

16.2 An electrode sample of the smallest and largest sizes of "R" designated electrodes shall be exposed. If the electrodes are conditioned prior to exposure, that fact, along with the method used for conditioning, and the time and temperature involved in conditioning, shall be noted on the test record. Conditioning of electrodes after exposure is not permitted.

16.3 The electrode sample shall be exposed in a suitably calibrated and controlled environmental chamber for 9 hours minimum at 80 °F, +5 °F, –0 °F, [27 °C, +3 °C, –0 °C,] and 80%, +5%, –0% relative humidity (RH).

16.4 The environmental chamber shall meet the following design requirements:

(1) The apparatus shall be an insulated humidifier that produces the temperature of adiabatic saturation through regenerative evaporation or vaporization of water.

(2) The apparatus shall have an average air speed within the envelope of air surrounding the covered electrode of 100 fpm to 325 fpm [0.5 m/s to 1.7 m/s].

(3) The apparatus shall have a drip-free area where the covered electrode up to 18 in [450 mm] in length can be positioned with length as perpendicular as practical to the general air flow.

(4) The apparatus shall have a calibrated means of continuously measuring and recording the dry bulb temperature and either the wet bulb temperature or the differential between the dry bulb and wet bulb temperature over the period of time required.

(5) The apparatus shall have airspeed of at least 900 fpm [4.5 m/s] over the wet bulb sensor unless the wet bulb sensor can be shown to be insensitive to air speed or has a known correction factor that will provide for an adjusted wet bulb reading equal to the temperature of adiabatic saturation.

(6) The apparatus shall have the wet bulb sensor located on the suction side of the fan so that there is an absence of heat radiation on the sensor.

16.5 The exposure procedure shall be as follows:

(1) The electrode sample taken from previously unopened packages, or from a reconditioned lot, shall be heated to a temperature, –0 °F, +10 °F [–0 °C, +6 °C] above the dew point of the chamber at the time of loading.

(2) The electrode sample shall be loaded into the chamber without delay after the packages are opened.

(3) The electrodes shall be placed in the chamber in a vertical or horizontal position on 1 in [25 mm] centers, with the length of the electrode as perpendicular as practical to the general air flow.

(4) Time, temperature, and humidity shall be continuously recorded for the period that the electrodes are in the chamber.

(5) Counting of the exposure time shall start when the required temperature and humidity in the chamber are established.

(6) At the end of the exposure time, the electrodes shall be removed from the chamber and a sample of the electrode covering taken for moisture determination as specified in Clause 15.

16.6 The manufacturer shall control other test variables which are not defined, but which must be controlled to ensure a greater consistency of results.

17. Diffusible Hydrogen Test

17.1 The smallest and largest sizes of an electrode to be identified by an optional supplemental diffusible hydrogen designator shall be tested according to one of the methods given in AWS A4.3. Based upon the average value of test results that satisfy the requirements of Table 12, the appropriate diffusible hydrogen designator may be added at the end of the classification.

Table 12
Diffusible Hydrogen Requirements for Weld Metal and Optional Supplemental Designators

AWS Classification	Diffusible Hydrogen Designator[a]	Diffusible Hydrogen Content Average, Maximum[b] $mL(H_2)/100$ g Deposited Metal
E(X)XX15-X, E(X)XX16-X,	H16	*16*
E(X)XX18-X, E(X)XX18M(1),	H8	*8*
or E(X)XX45-P2	H4	*4*

[a] Diffusible hydrogen testing of low-hydrogen electrode classifications is only required when the diffusible hydrogen designator is added to the classification as specified in Figure 1. See Clause 17.
[b] The lower average diffusible hydrogen levels (H8 and H4) may not be available in all low-hydrogen classifications.

17.2 Testing shall be done without conditioning of the electrode, unless the manufacturer recommends otherwise. If the electrodes are conditioned, that fact, along with the method used for conditioning, and the time and temperature involved in the conditioning, shall be noted on the test record.

17.3 For purposes of certifying compliance with diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of ten (10) grains of moisture/lb [1.43 g/kg] of dry air at the time of welding. [10]

17.4 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification, provided the actual test results satisfy the diffusible hydrogen requirements for the applicable designator. Likewise, if the actual test results for an electrode meet the requirements for the lower or lowest hydrogen designator, as specified in Table 12, the electrode also meets the requirements for all higher hydrogen designators in Table 12 without need to retest.

18. Method of Manufacture

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

19. Standard Sizes and Lengths

Standard sizes (diameter of the core wire) and lengths of electrodes and their respective tolerances are specified in 3.1 of AWS A5.02/A5.02M:2007, and shown in Table 13.

20. Core Wire and Covering

Requirements for the core wire and covering, including concentricity requirements, are specified in 3.2 of AWS A5.02/A5.02M:2007.

21. Exposed Core

***21.1** Requirements for the grip end of each electrode are specified in 3.3.1 of AWS A5.02/A5.02M:2007.*

***21.2** Requirements for the arc end of each electrode are specified in 3.3.2 of AWS A5.02/A5.02M:2007.*

[10] See A8.1.4 in Annex A.

Table 13
Standard Sizes and Lengths

Standard Size, (Core Wire Diameter[d])			Standard Length[a,b,c]			
			All Classifications except E7020-Al [E4920-A1], E7020-G [E4920-G], E7027-Al [E4927-A1], and E7027-G [E4927-G]		E7020-Al [E4920-A1], E7020-G [E4920-G], E7027-Al [E4927-A1], and E7027-G [E4927-G]	
in	in	mm	in	mm	in	mm
3/32[e]	*(0.093)*	—	12 or 14	300 or 350	12	300
—	*(0.098)*	*2.5*[e]	12 or 14	300 or 350	12	300
1/8	*(0.125)*	*3.2*	14	350	14	350
5/32	*(0.156)*	*4.0*	14	350	14	350
—	*(0.177)*	*4.5*[e]	14	350	—	—
3/16	*(0.187)*	—	14	350	14 or 18	350 or 450
—	*(0.197)*	*5.0*	14	350	14 or 18	350 or 450
7/32[e]	*(0.218)*	—	14 or 18	350 or 450	18 or 28	450 or 700
—	*(0.236)*	*6.0*	14 or 18	350 or 450	18 or 28	450 or 700
1/4[e]	*(0.250)*	—	18	450	18 or 28	450 or 700
5/16[e]	*(0.312)*	*8.0*[e]	—	—	18 or 28	450 or 700

[a] Tolerance on the length shall be ± 1/4 in [±10 mm].
[b] In all cases, end gripping is standard.
[c] Other lengths are acceptable and shall be as agreed upon between the purchaser and supplier.
[d] Tolerance on the core wire diameter shall be ± 0.002 in [±0.05 mm]. Electrodes produced in sizes other than those shown may be classified. Please see Note c of Table 5.
[e] These diameters are not manufactured in all electrode classifications (See Table 5).

22. Electrode Identification

22.1 *All electrodes shall be identified (imprinted) as specified in 3.4.1 to 3.4.4 of AWS A5.02/A5.02M:2007.*

22.2 *In lieu of imprinting, electrodes may be identified by the alternate method specified as option 2 in 3.4.5 of AWS A5.02/A5.02M:2007.*

23. Packaging

Electrodes shall be packaged as specified in 3.5.1 and 3.5.2 of AWS A5.02/A5.02M:2007. In addition, E(X)XX18M(1) electrodes shall be packaged in hermetically sealed containers. These hermetically sealed containers shall be capable of passing the test specified in 3.5.3.1 of AWS A5.02/A5.02M:2007.

24. Marking of Packages

24.1 *The product information specified in 3.6 of AWS A5.02/A5.02M:2007 (as a minimum) shall be legibly marked on the outside of each unit package.*

24.2 *The appropriate precautionary information*[11] *as given in ANSI Z49.1 (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.*

[11] Typical example "warning labels" *and precautionary information* are shown in figures in ANSI Z49.1 for some common or specific consumables using certain processes.

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Annex A (*Informative*)
Guide to AWS Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding

This annex is not part of AWS A5.5/A5.5M: 2014, *Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*, but is included for informational purposes 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 are referred to whenever that can be done and when it would be helpful. Such references are intended as examples rather than complete listings of the base metals for which each filler metal 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 stands for electrode. The first two (or three) digits, 70 (or 110) [49 (or 76)], for example, designate tensile strength of at least 70 (or 110) ksi [490 (or 760) MPa] of the weld metal, welded and postweld heat treated (if required) in accordance with the test assembly preparation section of this specification. The third (or fourth) digit designates position usability that will allow satisfactory welds to be produced with the electrode.

Thus, the "1," as in E7018-C2L (or E11018M) [E4918-C2L (or E7618M)], means that the electrode is usable in all positions (flat, horizontal, vertical, and overhead). The "2," as in E7020-A1 [E4920-A1], designates that the electrode is suitable for use in the flat position and for making fillet welds in the horizontal position. The "4," as in E8045-P2 [E5545-P2] designates that the electrode is usable in the flat, horizontal, and overhead positions, and is especially suitable for vertical welding with downward progression. The last two digits taken together designate the type of current with which the electrode can be used and the type of covering on the electrode, as listed in Table 1.

With the exception of the military-similar electrodes (i.e., E(X)XX18M(1)), the classifications in this specification also include a suffix designator, separated by a hyphen from the tensile strength and usability designators. This composition designator, such as A1, B3, or W1, immediately identifies the classification as different from those in AWS A5.1/A5.1M, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.* The composition designator identifies the chemical composition of the weld metal as specified in Table 2. For example, an "A1" composition designator identifies the electrode as one that produces carbon-molybdenum steel weld metal, when the electrode is deposited using shielded metal arc welding.

A2.2 Optional designators are also used in this specification in order to identify electrodes that have met the mandatory classification requirements and certain supplementary requirements as agreed upon between the purchaser and supplier. Certain low-hydrogen electrodes may have optional designators. An optional supplemental designator "HZ" following the composition designator indicates an average diffusible hydrogen content of not more than "Z" mL/100 g of deposited metal when tested in the "as-received" or conditioned state in accordance with AWS A4.3. Electrodes that are designated as meeting the lower or lowest hydrogen limits, as specified in Table 12, are also understood to be able to meet any higher hydrogen limits even though these are not necessarily designated along with the electrode classification. Therefore, as an

example, an electrode designated as "H4" also meets "H8" and "H16" requirements without being designated as such. See Clause 17, Figure 1, and Table 12.

A letter "R" is a designator used with the low-hydrogen electrode classifications. It is used to identify electrodes that have been exposed to a humid environment for a given length of time and tested for moisture absorption in addition to the standard moisture test required for classification of hydrogen electrodes. See Clause 16, and Note d to Table 1, as well as Figure 1 and Table 11.

A2.3 "G" Classification

A2.3.1 This specification includes filler metals classified as E(X)XXXX-G. The "G" indicates that the filler metal is of a *general* classification. It is *general* because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent, in establishing this classification, is to provide a means by which filler metals that differ in one respect or another (chemical composition, for example) from all other classifications (meaning that the composition of the filler metal—in the case of the example—does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow useful filler metal, one that otherwise would have to await a revision of the specification, to be classified immediately, under the existing specification. This means, then, that two filler metals, each bearing the same "G" classification, may be quite different in some certain respect (chemical composition, again, for example).

A2.3.2 The point of difference (although not necessarily the amount of difference) referred to above will be readily apparent from the use of the words "not required" and "not specified" in the specification. The use of these words is as follows:

Not Specified is used in those areas of the specification that refer to the results of some particular test. It indicates that the requirements for that test are not specified for that particular classification.

Not Required is used in those areas of the specification that refer to the test that must be conducted in order to classify a filler metal. It indicates that the test is not required because the requirements for the test have not been specified for that particular classification.

Restating the case, when a requirement is not specified, it is not necessary to conduct the corresponding test in order to classify filler metal to that classification. When a purchaser wants the information provided by that test, in order to consider a particular product of that classification for a certain application, the purchaser will have to arrange for that information with the supplier of that product. The purchaser will have to establish with that supplier just what the testing procedure and the acceptance requirements are to be, for that test. The purchaser may want to incorporate that information (via AWS A5.01M/A5.01 (ISO 14344 MOD)) in the purchase order.

A2.3.3 ***Request for Filler Metal Classification***

(1) When a filler metal cannot be classified other than as a "G" classification, a manufacturer may request that a new classification be established. The manufacturer shall do this using the following procedure:

If a manufacturer elects to use a "G" classification, the Committee on Filler Metals and Allied Materials recommends that the manufacturer still request that a new classification be established, as long as the filler metal is commercially available.

(2) A request to establish a new filler metal classification must be submitted in writing. The request needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials and the relevant Subcommittee to determine whether a new classification or the modification of an existing classification is more appropriate, or if neither is necessary. In particular, the request needs to include:

(a) *Declaration that the new classification will be offered for sale commercially;*

(b) All classification requirements as given for existing classifications, such as, chemical composition ranges, mechanical property requirements, and usability test requirements;

(c) Any conditions for conducting the tests used to demonstrate that the filler metal meets the classification requirements (It would be sufficient, for example, to state that welding conditions are the same as for other classifications);

(d) Information on Descriptions and Intended Use, which parallels that for existing classifications (for that clause of the Annex);

(e) *Actual test data for all tests required for classification according to the requirements of the specification for a minimum of two production heats/lots must be provided. In addition, if the specification is silent regarding mechanical*

properties, test data submitted shall include appropriate weld metal mechanical properties from a minimum of two production heats/lots.

A request for a new classification without the above information listed in (a) through (e) will be considered incomplete. The Secretary will return the request to the requester for further information.

(3) *In order to comply with the AWS Policy on Patented Items, Trademarks, and Restraint of Trade, if the proposed new classification is patented, if a patent is pending for it, or if there is any intention to apply for a patent, the requester shall disclose this. The affected classification shall be identified in all drafts and eventually the published standard. The requester shall also provide written assurance to AWS that:*

i. No patent rights will be enforced against anyone using the patent to comply with the standard;

or

ii. The owner will make licenses available to anyone wishing to use the patent to comply with the standard, without compensation or for reasonable rates, with reasonable terms and conditions demonstrably free of any unfair competition.

The status for the patent shall be checked before publication of the document and the patent information included in the document will be updated as appropriate.

Neither AWS, nor the Committee on Filler Metals and Allied Materials, nor the relevant Subcommittee is required to consider the validity of any patent or patent application.

(4) 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 the Chair of the particular Subcommittee involved.

(d) File the original request.

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

(5) All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requester of the status of the request, with copies to the Chairs of the Committee and of the Subcommittee. Requests still outstanding after 18 months shall be considered not to be 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.

(6) 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.

A2.4 International Classification System

An international system for designating welding filler metals has been developed by ISO. A complete series of ISO standards for filler metals and allied materials, including the vast majority of AWS classifications, but not all, has now been published. Some of these ISO standards have a single way of classification, like AWS standards. A number of the ISO standards dealing with steels are cohabitation standards. A cohabitation standard specifies two parallel systems, roughly corresponding to the European system (the "A" side) and the AWS system (the "B" side). In each case, the "B" side is identical, or close to, the AWS designation. Annex Table A1 shows the classifications and designations, appearing in ISO specifications, equivalent to filler metal classifications included in this specification.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01M/A5.01 (ISO 14344 MOD), as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, needs to be clearly stated in the purchase order, according to the provisions of AWS A5.01M/A5.01 (ISO 14344 MOD). In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing the supplier normally conducts on material of that classification, as specified in Schedule

Table A1
Comparison of Classifications

ISO						AWS	
2560A[a]	**2560B[a]**	**3580A[b]**	**3580B[b]**	**18275A[c]**	**18275B[c]**	**A5.5**	**A5.5M**
Carbon-Molybdenum Steel Electrodes							
E38xMo	E49xx–1M3	EMo x	E49xx-MM3			E70xx-A1	E49xx-A1
Manganese-Molybdenum Steel Electrodes							
	E55xx–3M2					E80xx-D1	E55xx-D1
					E69xx–4M2	E100xx-D2	E69xx-D2
				E550xMnMo	E62xx–3M3	E90xx-D3	E62xx-D3
Chromium-Molybdenum Steel Electrodes							
		ECrMo0.5	E55xx-CM			E80xx-B1	E55xx-B1
		ECrMo1	E55xx–1CM			E80xx-B2	E55xx-B2
		ECrMo1L	E55xx–1CML			E70xx-B2L	E49xx-B2L
		ECrMo2	E62xx–2C1M			E90xx-B3	E62xx-B3
		ECrMo2L	E55xx–2C1ML			E80xx-B3L	E55xx-B3L
			E55xx–2CM1L			E80xx-B4L	E55xx-B4L
			E55xx-C1M			E80xx-B5	E55xx-B5
		ECrMo5	E55xx–5CM			E80xx-B6	E55xx-B6
		ECrMo5	*E62xx–5CM*			*E90xx-B6*	*E62xx-B6*
			E55xx–5CML			E80xx-B6L	E55xx-B6L
			E55xx–7CM			E80xx-B7	E55xx-B7
			E55xx–7CML			E80xx-B7L	E55xx-B7L
		ECrMo9	E55xx–9C1M			E80xx-B8	E55xx-B8
			E55xx–9C1ML			E80xx-B8L	E55xx-B8L
		—	—			*E90xx-B23*	*E62xx-B23*
		—	—			*E90xx-B24*	*E62xx-B24*
		ECrMo91	E62xx–9C1MV			E90xx-*B91*	E62xx-*B91*
		—	—			*E90xx-B92*	*E62xx-B92*
Nickel Steel Electrodes							
	E55xx-N5					E80xx-C1	E55xx-C1
	E49xx-N5					E70xx-C1L	E49xx-C1L
	E55xx-N7					E80xx-C2	E55xx-C2
	E49xx-N7					E70xx-C2L	E49xx-C2L
E38x1Ni	E55xx-N2					E80xx-C3	E55xx-C3
	E49xx-N2					E70xx-C3L	E49xx-C3L
	E55xx-N3					E80xx-C4	E55xx-C4
	E6215-N13L					E90xx-C5L	E62xx-C5L
Nickel-Molybdenum Steel Electrodes							
E38x1NiMo	E55xx-N2M3					E80xx-NM1	E55xx-NM1
—	—					*E90xx-NM2*	*E62xx-NM2*
Military-Similar Electrodes							
E550x1,5NiMo	E6218-N3M1					E9018M	E6218M
	E6918-N3M2					E10018M	E6918M
				E69xMn2NiCrMo	E7618-N4CM2	E11018M	E7618M
				E69xMn2Ni1CrMo	E8318-N4C2M2	E12018M	E8318M
						E12018M1	E8318M1
Weathering Alloy Steel Electrodes							
	E49xx-NCC2					E7018-W1	E4918-W1
	E55xx-NCC1					E8018-W2	E5518-W2

[a] ISO 2560, *Welding consumables — Covered electrodes for manual metal arc welding of nonalloy and fine grain steels — Classification.*
[b] ISO 3580, *Welding consumables — Covered electrodes for manual metal arc welding of creep-resisting steels — Classification.*
[c] ISO 18275, *Welding consumables — Covered electrodes for manual metal arc welding of high-strength steels — Classification.*

F, Table 1, of AWS A5.01M/A5.01 (ISO 14344 MOD). 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, and optional designators, if applicable, 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 the requirements of the specification. The only testing requirement implicit in this *certification* is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. *Certification* is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been made. The basis for the *certification* required by the specification is the classification test of *representative material* cited above, and the Manufacturer's Quality Assurance Program as defined in AWS A5.01M/A5.01 (ISO 14344 MOD).

A5. Ventilation During Welding

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 welding is done (with special regard to the height of the ceiling)

(2) Number of welders and welding operators working in that space

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

(4) The proximity of welders and welding operators to the fumes, as these fumes issue from the welding zone, and to the gases and dust 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, 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 clause on Ventilation in that document. *See also AWS F3.2*, Ventilation Guide for Weld Fume *for more detailed descriptions of ventilation options*.

A6. Welding Considerations

A6.1 Weld metal properties may vary widely, according to size of the electrode and amperage used, size of the weld beads, base metal thickness, joint geometry, preheat and interpass temperatures, surface condition, base metal composition, dilution, etc. Because of the profound effect of these variables, a test procedure was chosen for this specification that would represent good welding practice and minimize variation of the most potent of these variables.

A6.2 It should be recognized, however, that production practices may be different. The differences encountered may alter the properties of the weld metal. For instance, interpass temperatures may range from subfreezing to several hundred degrees. No single temperature or reasonable range of temperatures can be chosen for classification tests which will be representative of all of the conditions encountered in production work.

Properties of production welds may vary accordingly, depending on the particular welding conditions. Weld metal properties may not duplicate, or even closely approach, the values listed and prescribed for test welds. For example, ductility in single-pass welds in thick base metal made outdoors in cold weather without adequate preheating may drop to little more than half that required herein and normally obtained. This does not indicate that either the electrodes or the welds are below standard. It indicates only that the particular production conditions are more severe than the test conditions prescribed by this specification.

A6.3 Hydrogen is another factor to be considered in welding. Weld metals, other than those from low-hydrogen electrodes {E(X)XX15-X, E(X)XX16-X, E(X)XX18-X, E(X)XX18M(1), and E(X)XX45-P2} contain significant quantities of hydrogen for some period of time after they have been made. Most of this hydrogen gradually escapes. After two to four weeks at room temperature or in 24 hours to 48 hours at 200°F to 220°F [95°C to 105°C], most of it has escaped. As a result of this change in hydrogen content, ductility of the weld metal increases towards its inherent value, while yield, tensile, and impact strengths remain relatively unchanged.

This specification permits aging of the test specimens of cellulosic electrodes at 200°F to 220°F [95°C to 105°C] for 48 hours before subjecting them to tension testing. This is done to minimize discrepancies in testing. Aging treatments are sometimes used for low-hydrogen electrodes, especially when testing high-strength deposits. Note that aging may involve holding test specimens at room temperature for several days or holding at a higher temperature for a shorter period of time. Consequently, users are cautioned to employ adequate preheat and interpass temperatures to avoid the deleterious effects of hydrogen in production welds.

A6.4 When weldments are given a postweld heat treatment, the temperature and time at temperature are very important. The tensile and yield strengths are generally decreased as postweld heat treatment temperatures and time at temperature are increased.

A6.5 Welds made with electrodes of the same classification and the same welding procedure will have significantly different tensile and yield strengths in the as-welded and postweld heat-treated conditions. Even weld metal produced from the same classification and the same welding procedure but with different postweld heat-treatment holding temperatures or times at holding temperatures will have different strength levels. With low-alloy steel weld metals produced by the classifications in this specification, postweld heat treatment can produce tempering (softening) or secondary hardening of the weld metal. It is recommended that users conduct their own evaluation of the welding procedure to be used in production in order to verify that the weld metal properties obtained in actual production are those desired.

A6.6 Preheat and interpass minimum temperatures also have a significant effect on the strength levels attained with certain low-alloy steel weld metals. These weld metals are affected by rapid cooling rates which tend to produce more martensitic or bainitic microstructures. These microstructures will often exhibit higher yield and tensile strengths with a decrease in ductility. The cooling rate can be retarded by utilizing a higher preheat and interpass temperature. The preheat and interpass temperature ranges given in Table 7 of this specification are adequate for the preparation of the test assemblies. However, in actual production, users are encouraged to test their own procedures to verify that they have selected preheat and interpass temperatures which will produce desirable results in production.

A6.7 Heat input usually is measured as Joules per linear inch, J/in [kJ/mm]. However, in this specification the heat input is governed in the preparation of the test assembly by the bead sequence and the total weld layer count upon completion of the groove weld test assembly. Heat input will have a significant effect on the strength levels attained in many of the higher strength weld metals produced from the electrode classifications in this specification. For instance, weld metal produced with E11018M [E7618M] electrode at a 35 000 J/in [1.38 kJ/mm] heat input may exceed 110 ksi [760 MPa] yield strength in the as-welded condition and 95 ksi [655 MPa] yield strength after postweld heat treatment. On the other hand, if the heat input is raised to 55 000 J/in [2.17 kJ/mm], this same electrode will produce weld metal that does not exceed 110 ksi [760 MPa] as-welded yield strength and after postweld heat treatment may be below 95 ksi [655 MPa] yield strength. It is, therefore, recommended that, if the user is going to use either lower or higher heat inputs than normally used for classification testing of electrodes, the user should test the welding procedure to be used to determine that the strength levels expected will be attained in production. This is especially true if out-of-position welding is to be performed.

A6.8 Electrodes that meet all the requirements of any given classification may be expected to have similar characteristics (the "G" classifications notwithstanding). Certain minor differences continue to exist from one brand to another due to differences in preferences that exist regarding specific operating characteristics.

A6.9 Since electrodes within a given classification have similar operating characteristics and mechanical properties, the user can usually limit study of available electrodes to those within a single classification after determining which classification best suits the user's particular requirements.

A6.10 This specification does not establish values for all characteristics of the electrodes falling within a given classification, but it does establish values to measure those of major importance. In some instances, a particular characteristic is common to a number of classifications and testing for it is not necessary. In other instances, the characteristics are so intangible that no adequate tests are available. This specification does not necessarily provide all the

information needed to determine which classification would best fulfill a particular need. The information included in Annex A7 regarding typical applications for each classification supplements information given elsewhere in the specification and is intended to provide assistance in making electrode selections. However, it must be noted that it is the fabricator's responsibility to ensure that the electrode selected will satisfy all the performance requirements for the intended applications under the specific fabrication conditions in use.

A6.11 Some important tests for measuring major electrode characteristics are as follows:

A6.11.1 Radiographic Test. Nearly all the low-alloy steel electrodes covered by this specification are capable of producing welds that meet most radiographic soundness requirements. However, if incorrectly applied, unsound welds may be produced by any of the electrodes. For electrodes of some classifications, the radiographic requirements in Table 9 are not necessarily indicative of the average radiographic soundness to be expected in production use. Electrodes of the E(X)XX10-X, E(X)XX11-X, and E7020-X classifications can be expected to produce acceptable radiographic results. Under certain conditions, notably in welding long, continuous joints in relatively thick base metal, low-hydrogen electrodes of the E(X)XX15-X, E(X)XX16-X, E(X)XX18M(1), E(X)XX18-X, and E(X)XX45-P2 classifications will often produce even better results.

On the other hand, in joints open to the atmosphere on the root side, at the ends of joints, in joints with many stops and starts, and in welds on small diameter pipe or in small, thin, irregularly-shaped joints, the low-hydrogen electrodes tend to produce welds of poor radiographic soundness. E(X)XX13-X electrodes usually produce the best radiographic soundness in welding small, thin parts.

E7027-X [E4927-X] electrodes produce welds which may be either quite good or rather inferior in radiographic soundness. The tendency seems to be in the latter direction.

A6.11.2 Fillet Weld Test. This test is included as a means of demonstrating the usability of an electrode. This test is concerned with the appearance of the weld (i.e., weld face contour and smoothness, undercut, overlap, size, and resistance to cracking). It also provides an excellent and inexpensive method of determining the adequacy of fusion at the weld root (one of the important considerations for an electrode). Test results may be influenced by the level of welder skill.

A6.11.3 Toughness. Charpy V-notch impact requirements are included in the specification. All classifications of electrodes in the specification can produce weld metal of sufficient toughness for many applications. The inclusion of impact requirements for certain electrode classifications allows the specification to be used as a guide in selecting electrodes where low-temperature toughness is required. There can be considerable variation in the weld-metal toughness unless particular attention is given to the welding procedure and the preparation and testing of the specimens. The impact energy values are for Charpy V-notch specimens and should not be confused with values obtained with other toughness tests.

A6.12 Electrode Covering Moisture Content and Conditioning

A6.12.1 Hydrogen can have adverse effects on welds in some steels under certain conditions. One source of this hydrogen is moisture in the electrode coverings. For this reason, the proper storage, treatment, and handling of electrodes are necessary.

A6.12.2 Electrodes are manufactured to be within acceptable moisture limits, consistent with the type of covering and strength of the weld metal. They are then normally packaged in a container that has been designed to provide the degree of moisture protection considered necessary for the type of covering involved.

A6.12.3 If there is a possibility that the noncellulosic covered electrodes may have absorbed excessive moisture; they may be reconditioned by rebaking. Some electrodes require rebaking at a temperature as high as 800°F [425°C] for approximately 1 hour to 2 hours. The manner in which the electrodes have been produced and the relative humidity and temperature conditions under which the electrodes are stored determine the proper length of time and temperature used for conditioning. Some typical storage and drying conditions are included in Table A2.

A6.12.4 Cellulosic coverings for E(X)XX10-X and E(X)XX11-X classifications need moisture levels of approximately 3% to 7% for proper operation. Therefore, storage or conditioning above ambient temperature may dry these electrodes too much and adversely affect their operation (see Table A2).

A6.13 Core Wire. The core wire for all the electrodes in this specification is usually (but not always) a mild steel having a typical composition which may differ significantly from that of the weld metal produced by the covered electrode.

Table A2
Typical Storage and Drying Conditions for Covered Arc Welding Electrodes

AWS Classifications		Storage Conditions[a]		
A5.5	**A5.5M**	**Ambient Air**	**Holding Ovens**	**Drying Conditions[b]**
E(X)XX10-X E(X)XX11-X	EXX10-X EXX11-X	Ambient temperature	Not recommended	Not recommended
E(X)XX13-G E7020-X E7027-X	EXX13-G E4920-X E4927-X	60°F–100°F [15°C–40°C] 50% max. relative humidity	100°F–120°F [40°C–50°C]	250°F–300°F [125°C–150°C] 1 hour at temperature
E(X)XX15-X E(X)XX16-X E(X)XX18M(1) E(X)XX18-X E(X)XX45-P2	EXX15-X EXX16-X EXX18M(1) EXX18-X EXX45-P2	Not recommended[c]	250°F–300°F [125°C–150°C]	500°F–800°F [250°C–425°C] 1 hour at temperature

[a] After removal from manufacturer's packaging.
[b] Because of inherent differences in covering compositions the manufacturer should be consulted for the exact drying conditions.
[c] Some of these electrode classifications may be designated as meeting low moisture absorbing requirements. This designation does not imply that storage in ambient air is recommended.

A6.14 Coverings

A6.14.1 Electrodes of some classifications have substantial quantities of iron and other metal powders added to their coverings. (Use of the term "iron powder" herein is intended to include metal powders added to the coating for alloying of the weld metal. For example, quite large quantities of chromium and ferro-chromium powders can be added in such alloy designations as B7, B8, and *B91*.) The iron powder fuses with the core wire as the electrode melts, and is deposited as part of the weld metal, just as is the core wire and other metals in the covering. Relatively high currents can be used since a considerable portion of the electrical energy passing through the electrode is used to melt the thicker covering containing iron powder. The result is that more weld metal may be obtained from a single electrode with iron powder in its covering than from a single electrode of the same size without iron powder.

A6.14.2 Due to the thick covering and deep cup produced at the arcing end of the electrode, iron powder electrodes can be used very effectively with a "drag" technique. This technique consists of keeping the electrode covering in contact with the workpiece at all times, which makes for easy handling. However, a technique using a short arc length is preferable if the 3/32 in [2.5 mm] or 1/8 in [3.2 mm] electrodes are to be used in other than flat or horizontal fillet welding positions or for making groove welds.

A6.14.3 The E70XX-X [E49XX-X] electrodes were included in this specification to recognize the lowest strength levels obtained with low-alloy steel electrodes, as well as to recognize the industry demand for low-alloy electrodes with 70 ksi [490 MPa] minimum tensile strength. Unlike the E70XX [E49XX] classifications in AWS A5.1/A5.1M, these electrodes do contain deliberate alloy additions, and some are required to meet minimum tensile properties after postweld heat treatment.

A6.14.4 Low-hydrogen electrodes have mineral coverings, which are high in calcium carbonate and other ingredients that are low in moisture and organic materials and hence "low in hydrogen content." Low-hydrogen electrodes were developed for welding low-alloy, high-strength steels, some of which were high in carbon content. Electrodes with other than low-hydrogen coverings may produce "hydrogen induced cracking" in those steels. These underbead cracks occur in the base metal, usually just below the weld bead. Weld cracks also may occur. These cracks are caused by the hydrogen absorbed from the arc atmosphere. Although these cracks do not generally occur in carbon steels which have low carbon content, they may occur when welding higher carbon or low-alloy steels with other than low-hydrogen electrodes and without precautions, such as increased preheat temperatures and postweld heating. For more information on special tests for low-hydrogen electrodes, see Clauses 16 and 17 in the specification and A8.2 and A8.3 in this Annex.

Some extra-low-hydrogen (H4) electrode coatings may be prone to reduced operability and producing unacceptable porosity. The unacceptable condition is usually associated with varying or excessive arc length and is highly dependent on operator skill level.

A6.15 Amperage Ranges. Table A3 gives amperage ranges that are satisfactory for most electrode classifications. When welding in the vertical position with upward progression, currents near the lower limit of the range are generally used.

A7. Description and Intended Use of Electrodes

A7.1 Chemical Composition. The chemical composition of the weld metal produced is often the primary consideration for electrode selection. Together with appropriate heat treatments, each composition can achieve a wide range of corrosion resistance and mechanical properties at various service temperatures. It is usually desirable for weld metal to match the chemical composition and the mechanical properties of the base metal as closely as possible. In fact, many of the electrodes classified to this specification have been developed for specific base metal grades or classes. If an optimum match is not possible, engineering judgment together with weld testing may be required to select the most suitable electrodes.

Table 2 provides detailed weld metal chemical composition requirements for each electrode classification. Tables 3 and 4 list the mechanical properties of the weld metal when the electrode is used in the flat downhand position, and the weldment is subjected to the Postweld Heat-Treatment (PWHT) requirements in Tables 3 and 7. It should be noted that changes in welding position, welding variables, or heat treatment can be expected to affect the mechanical properties. However, except for the effects of dilution, the chemical composition can be expected to remain reasonably unchanged.

The suffixes, which are part of each alloy electrode classification, identify the chemical composition of the weld metal produced by the electrode. The following paragraphs highlight the differences between these electrodes and electrode groups and indicate typical applications.

A7.1.1 E70XX-A1 [E49XX-A1] (C-Mo Steel) Electrodes. These electrodes are similar to the E70XX [E49XX] carbon steel electrodes classified in AWS A5.1/A5.1M, except that 0.5% molybdenum has been added. This addition increases the strength of the weld metal, especially at elevated temperatures, and provides some increase in corrosion resistance; however, it may reduce the notch toughness of the weld metal. Typical applications include the welding of C-Mo steel base metals such as ASTM A204 plate and A335-P1 pipe.

A7.1.2 EXXXX-BX and EXXXX-BXL (Cr-Mo Steel) Electrodes. These low-hydrogen electrodes produce weld metal that *nominally* contains between 0.5% and *10%* chromium and *up to 1.25%* molybdenum. They are designed to produce weld metal for high-temperature service and for matching the properties of the typical Cr-Mo base metals, some of which are shown in Table 6.

For many of these Cr-Mo electrode classifications, low carbon EXXXX-BXL classifications have been established. While regular Cr-Mo electrodes produce weld metal with about 0.08% carbon, the "L-Grades" are limited to a maximum of 0.05% carbon. While the lower percent carbon in the weld metal will improve ductility and lower hardness, it will also reduce the high-temperature strength and creep resistance of the weld metal.

Since all Cr-Mo electrodes produce weld metal which will harden in still air, both preheat and PWHT are required for most applications.

No minimum notch toughness requirements have been established for any of the Cr-Mo electrode classifications. While it is possible to obtain Cr-Mo electrodes with minimum toughness values at ambient temperatures down to 32°F [0°C], specific values and testing must be agreed upon between the purchaser and supplier.

A7.1.2.1 E70XX-B2L [E49XX-B2L] and E80XX-B3L [E55XX-B3L] Electrodes. In AWS A5.5–81, and previous revisions, electrodes classified as E70XX-B2L [E49XX-B2L] were classified as E80XX-B2L [E55XX-B2L]. Likewise, electrodes herein classified as E80XX-B3L [E55XX-B3L] were classified as E90XX-B3L [E62XX-B3L]. The composition ranges in AWS A5.5–96, or the present edition, have not been changed from A5.5–81 for the corresponding classifications. The strength designations and room-temperature strength requirements after postweld heat treatment have been reduced to reflect the fact that commercial products have been producing marginal tensile strength results in classification tests over many years. The base metals with which these classifications are generally used have lower strength requirements than were reflected by the former electrode classifications. Therefore, unless the higher strength

Table A3
Typical Amperage Ranges for Covered Arc Welding Electrodes

Electrode Diameter		E(X)XX10-X, E(X)XX11-X	E(X)XX13-G	E7020-X [E4920-X]	E7027-X [E4927-X]	E(X)XX15-X, E(X)XX16-X	E(X)XX18M(1), E(X)XX18-X	E(X)XX45-P2
in	mm							
3/32	2.5	40 to 80	45 to 90	—	—	65 to 110	70 to 100	80 to 110
1/8	3.2	75 to 125	80 to 130	100 to 150	125 to 185	100 to 150	115 to 155	125 to 160
5/32	4.0	110 to 170	105 to 180	130 to 190	160 to 240	140 to 200	135 to 185	170 to 215
—	4.5	—	—	—	—	—	—	180 to 240
3/16	5.0	140 to 215	150 to 230	175 to 250	210 to 300	180 to 255	200 to 275	—
7/32	—	170 to 250	—	225 to 310	250 to 350	240 to 320	260 to 340	—
1/4	6.0	210 to 320	—	275 to 375	300 to 420	300 to 390	315 to 400	—
5/16	8.0	—	—	—	375 to 475	—	—	—

indicated by the former classifications of these electrodes is specifically necessary for a particular welding procedure, the E70XX-B2L [E49XX-B2L] classifications in this standard should be considered as identical to the corresponding E80XX-B2L [E55XX-B2L] classifications of A5.5–81. Likewise, the E80XX-B3L [E55XX-B3L] classifications in this standard should be considered as identical to the E90XX-B3L [E62XX-B3L] classifications of A5.5–81.

A7.1.2.2 E8015-B6 [E5515-B6] and E8015-B6L [E5515-B6L] Electrodes. The E8015-B6 [E5515-B6] and E8015-B6L [E5515-B6L] electrodes were formerly classified as E502–15 in AWS A5.4–92, *Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*. The E8016-B6 [E5516-B6] and E8016-B6L [E5516-B6L] were formerly classified as E502–16 in A5.4–92. The E8018-B6 [E5518-B6] and E8018-B6L [E5518-B6L] were not formerly classified, but were produced to the E502 composition ranges in A5.4–92 but with the EXX18 covering of this specification. Similarly, the E80XX-B7(L) [E55XX-B7(L)] classifications were formerly classified as E7Cr-XX in A5.4–92; and the E80XX-B8(L) [E55XX-B8(L)] classifications were formerly classified as E505-XX in A5.4–92.

A7.1.2.3 ***E90XX-B23 [E62XX-B23] Electrodes.*** *E90XX-B23 [E62XX-B23] is a 2.5% Cr–1.5% W–0.2% Mo–0.20% V–0.04% Nb, low-hydrogen electrode designed to provide improved creep strength, toughness, fatigue life, and oxidation and corrosion resistance at elevated temperatures. In addition to the classification requirements in this specification, impact toughness or high temperature creep strength properties may be determined. Additional testing requirements must be agreed upon between the purchaser and supplier depending upon the application.*

A7.1.2.4 ***E90XX-B24 [E62XX-B24] Electrodes.*** *E90XX-B24 [E62XX-B24] is a 2.5% Cr–1.0% Mo–0.20% V–0.10% Ti–0.04% Nb, low-hydrogen electrode designed to provide improved creep strength, toughness, fatigue life, and oxidation and corrosion resistance at elevated temperatures. In addition to the classification requirements in this specification, impact toughness or high temperature creep strength properties may be determined. Additional testing requirements must be agreed upon between the purchaser and supplier depending upon the application.*

A7.1.2.5 E90XX-*B91* [E62XX-*B91*] (*formerly E90XX-B9 [E62XX-B9]*) Electrodes. This electrode, *formerly classified as E90XX-B9 [E62XX-B9],* is a 9% Cr–1% Mo, low-hydrogen electrode modified with niobium (columbium) and vanadium, designed to provide improved creep strength, toughness, fatigue life, and oxidation and corrosion resistance at elevated temperatures. Due to the higher elevated temperature properties of this alloy, components that are now fabricated from stainless and ferritic steels may be fabricated from a single alloy, eliminating problems associated with dissimilar welds.

In addition to the classification requirements in this specification, impact toughness or high-temperature creep strength properties may be determined. Due to the influence of various levels of carbon and niobium (columbium), testing must be agreed upon between the purchaser and supplier.

Thermal treatment of this alloy is critical and must be closely controlled. The temperature at which the microstructure has complete transformation to martensite (M_f) is relatively low. For applications requiring optimal ductility and creep resistance, consideration should be given to allowing the weldment to cool sufficiently to maximize transformation to martensite.

The maximum allowable temperature for postweld heat treatment is also critical in that the lower transformation temperature (Ac_1) is also comparably low. To aid in allowing for an adequate postweld heat treatment, the restriction on Mn +Ni has been imposed (see Table 2, note g). The combination of Mn and Ni tends to lower the Ac_1 temperature to the point where the PWHT temperature approaches the Ac_1, possibly causing partial transformation of the microstructure. By restricting the Mn + Ni, the PWHT temperature will be sufficiently below the Ac_1 to avoid this partial transformation.

A7.1.2.6 E90XX-B92 [E62XX-B92] Electrodes*. E90XX-B92 [E62XX-B92] is a 9% Cr–2% W–0.5% Mo–0.20% V–0.05% Nb, low-hydrogen electrode designed to provide improved creep strength, toughness, fatigue life, and oxidation and corrosion resistance at elevated temperatures. Due to the higher elevated temperature properties of this alloy, components that are now fabricated from stainless and ferritic steels may be fabricated from a single alloy, eliminating problems associated with dissimilar welds.*

In addition to the classification requirements in this specification, impact toughness or high-temperature creep strength properties may be determined. Due to the influence of various levels of carbon and niobium, testing must be agreed upon between the purchaser and supplier.

Thermal treatment of this alloy is critical and must be closely controlled. The temperature at which the microstructure has complete transformation to martensite (M_f) is relatively low. For applications requiring optimum ductility and creep resistance, consideration should be given to allowing the weldment to cool to at least 200°F [93°C] before PWHT to maximize transformation to martensite.

The maximum allowable temperature for PWHT is also critical in that the lower transformation temperature (Ac_1) is also comparably low. To ensure proper PWHT results, a restriction on Mn + Ni has been imposed (see Table 2, Note g). The combination of Mn and Ni tends to lower the Ac_1 temperature to the point where the PWHT temperature approaches the Ac_1, possibly causing partial transformation of the microstructure. By restricting the Mn + Ni, the PWHT temperature will be sufficiently below the Ac_1 to avoid this partial transformation.

***A7.1.2.7 X-Factor**. A major application of the Cr-Mo steels is in the fabrication of pressure vessels for the petrochemical and power generation industries. Where these materials are subjected to elevated temperatures for extended periods of time, temper embrittlement usually occurs. Temper embrittlement is the migration of certain elements within the material matrix to the grain boundaries over time, resulting in a loss of impact toughness. In 1970, Bruscato [12] developed a formula using only the critical elements affecting temper embrittlement, as follows:*

X-Factor = (10 P + 5 Sb + 4 Sn + As)/100

with analytical results for the elements in ppm. The industry X-Factor requirement is less than 15. An X-Factor less than 15, combined with low Mn and Si levels, is recommended in industry to minimize temper embrittlement effects .[12]

A7.1.3 EXXXX-CX and EXXXX-CXL (Ni Steel) Electrodes. These low-hydrogen electrodes have been designed to produce weld metal with increased strength without being air-hardenable or with increased notch toughness at temperatures as low as –175°F [–115°C]. They have been specified with nickel contents which fall into five nominal levels of 1% Ni, 1.5% Ni, 2.5% Ni, 3.5% Ni, and 6.5% Ni in steel.

With carbon levels of up to 0.12%, strength increases and permits these Ni steel electrodes to be classified as E80XX-CX [E55XX-CX]. However, with lower levels of carbon, low-temperature toughness improves to match the base-metal properties of nickel steels, such as ASTM A203 Grade E, and ASTM A352 LC3 and LC4 classifications. Thus, the intended application and the needed mechanical properties determine whether or not "L-Grades" should be selected.

Many low-alloy steels require postweld heat treatment to stress relieve the weld or temper the weld metal and heat affected zone to achieve increased ductility. It is often acceptable to exceed the PWHT holding temperatures shown in Table 7. However, for many applications, nickel steel weld metal can be used without postweld heat treatment. If PWHT is to be specified for a nickel steel weldment, the holding temperature should not exceed the maximum temperature given in Table 7 for the classification considered since nickel steels can be embrittled at higher temperatures.

A7.1.4 EXXXX-NMX (Ni-Mo Steel) Electrodes

A7.1.4.1 E8018-NM1 [E5518-NM1] Electrodes. This low-hydrogen electrode, which contains about 1% nickel and 0.5% molybdenum, is similar to the Mn-Mo steel electrodes discussed in A7.1.5. However, this electrode can often be welded without PWHT, but the resulting strength and notch toughness are lower than the values obtained with Mn-Mo electrodes. Some typical applications include the welding of high-strength low-alloy or microalloyed structural steels.

***A7.1.4.2 E9018-NM2 [E6218-NM2] Electrodes.** This electrode is intended to meet strength requirements after extended postweld heat treatment as required in the construction of nuclear power plants and in the fabrication of components (*e.g.*, steam generators and pressurizers) used in nuclear power plants. In production environments, the length of postweld heat treatments can be as long as 48 hours. Increased carbon aids in achieving desired response to heat treatment. In addition to the requirements listed in this specification, these applications also often require drop weight testing to determine nil ductility temperature as well as measurement of mils of lateral expansion on broken Charpy V-notch specimens.*

A7.1.5 E(X)XX1X-DX [EXX1X-DX] (Mn-Mo Steel) Electrodes. These low-hydrogen electrodes produce weld metal that contains about 1.5% manganese and between 0.33% and 0.67% molybdenum. This weld metal provides higher strength and better notch toughness than the C–0.5% Mo and 1% Ni–0.5% Mo steel weld metal discussed in A7.1.1 and A7.1.4, respectively. However, the weld metal from these Mn-Mo steel electrodes is quite air-hardenable and usually requires preheat and PWHT. The individual electrodes classified under this electrode group have been designed to match the mechanical properties and corrosion resistance of the high-strength, low-alloy pressure vessel steels, such as ASTM A302 Grade B.

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[12] *Bruscato, R,. Welding Journal Research Supplement, Vol 49, pp. 148-s–156-s, 1970.*

A7.1.6 E(X)XXXX-G (General Low-Alloy Steel) Electrodes. These electrodes are described in A2.3. These electrode classifications may be either modifications of other discrete classifications or totally new classifications. Purchaser and user should determine from the supplier what the description and intended use of the electrode is.

A7.1.7 E(X)XX18M(1) (Military-Similar) Electrodes. These low-hydrogen electrodes were originally designed for military applications such as welding HY80 and HY100 type steels. To achieve desired weld metal properties and soundness, these electrodes have small alloy additions (especially some Ni) and require careful control of moisture in the electrode covering. It is important that moisture levels in the coating be maintained during electrode manufacture, packaging, transport, and site storage.

These electrodes are usually employed without subsequent postweld heat treatment. However, hydrogen-release treatments at lower temperatures, typically less than 500°F [260°C], are often applied. In the as-welded condition, the weld-metal mechanical properties include ultimate tensile strength minima ranging from 90 ksi to 120 ksi [620 MPa to 830 MPa] and good notch toughness at temperatures ranging from 0°F to –60°F [–20°C to –50°C]. With these properties, the E(X)XX18M(1) type electrodes are suitable for joining many high-strength, low-alloy or microalloyed steels to themselves or to lower strength steels, including carbon steels.

A7.1.8 EXX10-P1 (Pipeline) Electrodes. These electrodes have been designed primarily for welding typical high-strength pipe butt joints in the vertical welding position with downward or upward progression. With their cellulosic coverings, they produce deep penetrating, spray-type welding arcs and thin, easily removable slag. This combination is best suited for achieving full penetration and radiographic quality for the downhill welding of butt joints when the axis of the pipe is in the horizontal position.

While weld metals produced from these electrodes do not have any minimum chemical composition requirements, the supplier must provide sufficient alloying elements to meet the increased mechanical property requirements. Special emphasis must be placed upon the minimum yield strength values, since most transmission pipeline materials and systems are designed to yield strength limits. Typical application for E7010-P1 [E4910-P1], E8010-P1 [E5510-P1], and E9010-P1 [E6210-P1] electrodes is the welding of API–5L-X52, API–5L-X65, and API–5L-X70 piping assemblies, respectively.

A7.1.9 EXX18-P2 Pipe Welding Electrodes: These electrodes have been designed primarily for the welding of the hot, fill, and cap passes in high strength pipe butt joints in the vertical position, in upward progression. Some electrodes of these classifications may also be used on fillet welds with downward progression. The low-hydrogen nature of the coating of these electrodes makes them especially suited for joining crack-sensitive high strength pipe. Typical application for electrodes of these classifications is the welding of API 5L pipe steels up to and including Grade X80, along with many other high strength, medium and high carbon, and low-alloy steels. Electrodes of these classifications are normally not recommended for the root pass (stringer bead) on open gaps.

A7.1.10 E(X)XX45-P2 Pipe Welding Electrodes. These electrodes have specifically been designed for the welding of hot, fill, and cap passes in high strength pipe butt joints using vertical downward progression. This classification is not recommended for welding with vertical upward progression. While specifically designed for butt welds, electrodes of these classifications can often be used on fillet welds with downward progression, such as repair welding when attaching pipe sleeves. The low-hydrogen nature of the coating of these electrodes makes them especially suited for downhill welding of butt joints on crack sensitive high strength pipe when the axis of the pipe is horizontal. Typical application for electrodes of these classifications is the welding of API 5L pipe steels using the appropriate strength level electrode, along with many other high strength, medium and high carbon, and low-alloy steels. Electrodes of these classifications are normally not recommended for root pass (stringer bead) on open gaps.

A7.1.11 EXX18-WX (Weathering Steel) Electrodes. These low-hydrogen electrodes have been designed to produce weld metal that matches the corrosion resistance and the coloring of the ASTM weathering-type structural steels. These special properties are achieved by the addition of about 0.5% copper to the weld metal. To meet strength, ductility, and notch toughness in the weld metal, some chromium and nickel additions are also made. These electrodes are used to weld the typical weathering steels, such as ASTM A242 and ASTM A588.

A8. Special Tests

It is recognized that supplementary tests may be necessary for certain applications. In such cases, tests to determine specific properties such as hardness, corrosion resistance, mechanical properties at elevated or cryogenic temperatures, wear resistance, and suitability for welding different carbon and low-alloy steels may be required. AWS A5.01M/A5.01 (ISO

14344 MOD) contains provisions for ordering such tests. This clause is included for the guidance of those who desire to specify such special tests. Those tests may be conducted as agreed upon between the purchaser and supplier.

A8.1 Diffusible Hydrogen Test.

A8.1.1 Hydrogen-induced cracking of weld metal or the heat affected zone generally is not a problem with carbon steels containing 0.3% or less carbon, or with lower-strength alloy steels. However, the electrodes classified in this specification are sometimes used to join higher carbon steels or low-alloy, high-strength steels where hydrogen-induced cracking may be a serious problem.

A8.1.2 Since the available diffusible hydrogen level strongly influences the tendency towards hydrogen-induced cracking, it may be desirable to measure the diffusible hydrogen content resulting from welding with a particular electrode. This specification has, therefore, included the use of optional designators for diffusible hydrogen to indicate the maximum average value obtained under a clearly defined test condition in AWS A4.3.

A8.1.3 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values than those indicated by the designator.

A8.1.4 The use of a reference atmospheric condition during welding is necessitated because the arc is subject to atmospheric contamination due to imperfect shielding. Moisture from the air, distinct from that in the electrode, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. This effect can be minimized by maintaining as short an arc length as possible consistent with a steady arc. Experience has shown that the effect of arc length is minor at the H16 level, but can be very significant at the H4 level. An electrode meeting the H4 requirements under the reference atmospheric conditions may not do so under conditions of high humidity at the time of welding, especially if a long arc length is maintained.

A8.1.5 Low-hydrogen electrodes can absorb significant moisture if stored in a humid environment in damaged or open packages, or especially if unprotected for long periods of time. In the worst cases of high humidity, even exposure of unprotected electrodes for as little as 2 hours can lead to a significant increase of diffusible hydrogen. In the event the electrodes have been exposed, the manufacturer should be consulted regarding probable damage to low-hydrogen characteristics and possible reconditioning of the electrodes.

A8.1.6 Not all classifications may be available in H16, H8, and H4 diffusible hydrogen levels. The manufacturer of a given electrode should be consulted for availability of products meeting these limits.

A8.2 Aging of Tensile and Bend Specimens. Weld metals may contain significant quantities of hydrogen for some time after they have been made. Most of this hydrogen gradually escapes over time. This may take several weeks at room temperature or several hours at elevated temperatures. As a result of this eventual change in hydrogen level, ductility of the weld metal increases towards its inherent value, while yield, tensile, and impact strength remain relatively unchanged. This specification permits the aging of tension and bend test specimens at elevated temperatures up to 220 °F [105 °C] for up to 48 h before subjecting them to tension or bend testing. The purpose of this treatment is to facilitate removal of hydrogen from the test specimen in order to minimize discrepancies in testing. Aging treatments are sometimes used for low-hydrogen electrode deposits, especially when testing high-strength deposits. Note that aging may involve holding test specimens at room temperature for several days or holding at a higher temperature for a shorter period of time. Consequently, users are cautioned to employ adequate preheat and interpass temperatures to avoid the deleterious effects of hydrogen in production welds.

A8.3 Absorbed Moisture Test. The development of low-hydrogen electrode coverings that resist moisture absorption during exposure to humid air is a recent improvement in covered electrode technology. Not all commercial low-hydrogen electrodes possess this characteristic. To assess this characteristic, the absorbed moisture test described in Clause 16 was devised. The exposure conditions selected for the test are arbitrary. Other conditions may yield quite different results.

A task group of the AWS A5A Subcommittee evaluated this test and concluded that it can successfully differentiate moisture resistant electrodes from those which are not. The task group also observed considerable variability of covering moisture results after exposure of electrodes in cooperative testing among several laboratories. The precision of the test is such that, with moisture resistant electrodes from a single lot, the participating laboratories could observe exposed covering moisture values ranging, for example, from 0.15% or less to 0.35% or more. The task group concluded that the variability was due to both variations in the exposure conditions and the variability inherent in the application of the moisture test procedure. Therefore, it is not realistic to set a limit for covering moisture of exposed moisture resistant electrodes lower than 0.4% at this time.

A9. 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 A4, along with the year in which they were last included in the specification.

Table A4
Discontinued Electrode Classifications[a]

AWS Classification	Last A5.5 (ASTM A316[b]) Publication Date	AWS Classification	Last A5.5 (ASTM A316[b]) Publication Date
E7010[c]	1954	E10026	1948
E7011[c]	1954	E10030	1948
E7013	1948	E12015[c]	1954
E7015[d]	1954	E12016[c]	1954
E7016[d]	1954	E7015-C1	1954
E7020[c]	1954	E7016-C1	1954
E7025	1948	E7015-C2	1954
E7026	1948	E7016-C2	1954
E7030	1948	E9010-B3	1954
E8010[c]	1954	E9011-B3	1954
E8011[c]	1954	E9013-B3	1954
E8013[c]	1954	E8010-B1	1958
E8015[c]	1954	E8011-B1	1958
E8016[c]	1954	E8013-B1	1958
E8020	1948	E8015-B1	1958
E8025	1948	E8010-B2	1958
E8026	1948	E8011-B2	1958
E8030	1948	E8013-B2	1958
E9010[c]	1954	E8015-B4	1958
E9011[c]	1954	E8016-B4	1958
E9013[c]	1954	E8018-B4	1958
E9015[c]	1954	E8015-C1	1958
E9016[c]	1954	E8015-C2	1958
E9020	1948	E8015-C3	1958
E9025	1948	E9016-D1	1958
E9026	1948	E7018-W[e]	1981
E9030	1948	E8015-B2L[f]	1981
E10010[c]	1954	E8018-B2L[f]	1981
E10011[c]	1954	E8018-NM[g]	1981
E10013[c]	1954	E8018-W[e]	1981
E10015[c]	1954	E9015-B3L[f]	1981
E10016[c]	1954	E9018-B3L[f]	1981
E10020	1948	*E90XX-B9 [E62XX-B9][h]*	*2006*
E10025	1948		

[a] See Clause A10, Discontinued Classifications (in Annex A), for information on discontinued classifications and how they may be used.
[b] ASTM A316 *was withdrawn without replacement in 1969.*
[c] The higher tensile strength electrode classifications without chemistry requirements for classifications were discontinued in 1958 and replaced with the "G" classifications in order to permit a single classification system with chemistry requirements.
[d] Both E7015 and E7016 classifications were transferred to AWS A5.1–58T and continue to be included in the current revision of that specification.
[e] Both E7018-W and E8018-W classification designations have been changed to E7018-W1 and E8018-W2 in order to permit the suffix designator to differentiate between the two chemical compositions of undiluted weld metal.
[f] These Cr-Mo electrode classifications were modified by using a lower strength designator. This reflects a more realistic minimum tensile strength for low-carbon chromium molybdenum steel weld metal. This change may or may not show a corresponding reduction in creep strength of the weld metal depending on how the chemical composition of the weld metal is controlled.
[g] The E8018-NM classification has been changed to E8018-NM1 to allow for other possible Ni-Mo steel electrode classifications in future revisions.
[h] *The E90XX-B9 [E62XX-B9] classification has been changed to E90XX-B91[E62XX-B91] to better conform to industry standards and practices.*

A10. General Safety Considerations

A10.1 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 A10.3, ANSI Z49.1, [13] and applicable federal and state regulations.

A10.2 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.

A10.3 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	*Electrical Hazards*
6	*Fire and Explosion Prevention*
7	*Burn Protection*
8	*Mechanical Hazards*
9	*Tripping and Falling*
10	*Falling Objects*
11	*Confined Spaces*
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 and 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*
31	*Eye and Face Protection for Welding and Cutting Operations*
33	*Personal Protective Equipment (PPE) for Welding and Cutting*
34	*Coated Steels: Welding and Cutting Safety Concerns*
35	*Welding Safety in Education and Schools*
36	*Ventilation for Welding and Cutting*
37	*Selecting Gloves for Welding and Cutting*
38	*Respiratory Protection Basics for Welding Operations*
40	*Asbestos Hazards Encountered in the Welding and Cutting Environment*
41	*Combustible Dust Hazards in the Welding and Cutting Environment*

[13] ANSI Z49.1 is published by the American Welding Society, 8669 NW 36th St, # 130, Miami, FL 33166.
[14] AWS standards are published by the American Welding Society, 8669 NW 36th St, # 130, Miami, FL 33166.

Annex B (*Informative*)
Guidelines for Preparation of Technical Inquiries for AWS Technical Committees

This annex is not part of AWS A5.5/A5.5M: 2014, *Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*, but is included for informational purposes only.

B1. Introduction

The AWS Board of Directors has adopted a policy whereby all official interpretations of AWS standards will be handled in a formal manner. Under that policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is 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 must be directed to:

Managing Director
Technical Services Division
American Welding Society
8669 NW 36th St, # 130
Miami, FL 33166.

All inquiries must contain the name, address, and affiliation of the inquirer, and they must provide enough information for the committee to fully understand the point of concern in the inquiry. Where that point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and should also be in the format used here.

B2.1 Scope. Each inquiry must address one single provision of the Standard, unless the point of the inquiry involves two or more interrelated provisions. That provision must be identified in the Scope of the inquiry, along with the edition of the standard that contains the provisions or that the inquirer is addressing.

B2.2 Purpose of the Inquiry. The purpose of the inquiry must be stated in this portion of the inquiry. The purpose can be either to obtain an interpretation of a Standard 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 quickly and fully understand the point of the inquiry. Sketches should be used when appropriate, and all paragraphs, figures, and tables (or the Annex) that bear on the inquiry must be cited. If the point of the inquiry is to obtain a revision of the Standard, the inquiry must 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 the wording for a proposed revision, if that is what the inquirer seeks.

B3. Interpretation of Provisions of the Standard

Interpretations of provisions of the Standard are made by the relevant AWS Technical Committee. The secretary of the committee refers all inquiries to the chairman 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 will be an official interpretation of the Society, and the secretary will transmit 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*.

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 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. The Headquarters Staff cannot provide consulting services. The staff can, however, 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 in regard to interpretations are limited strictly to the interpretation of provisions of Standards prepared by the Committee or to consideration of revisions to existing provisions on the basis of new data or technology. Neither the Committee nor the Staff is in a position to offer interpretive or consulting services on: (1) specific engineering problems, or (2) requirements of Standards applied to fabrications outside the scope of the document or 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, A5.36	A5.20, A5.36	A5.17	A5.25	A5.26	A5.8, A5.31
Low-Alloy Steel	A5.2	A5.5	A5.28, A5.36	A5.29, A5.36	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	A5.34	A5.14	A5.14		A5.8, A5.31
Aluminum Alloys		A5.3	A5.10					A5.8, A5.31
Copper Alloys		A5.6	A5.7					A5.8, A5.31
Titanium Alloys			A5.16					A5.8, A5.31
Zirconium Alloys			A5.24					A5.8, A5.31
Magnesium Alloys			A5.19					A5.8, A5.31
Tungsten Electrodes			A5.12					
Brazing Alloys and Fluxes								A5.8, A5.31
Surfacing Alloys	A5.21	A5.13	A5.21	A5.21	A5.21			
Consumable Inserts			A5.30					
Shielding Gases			A5.32	A5.32			A5.32	

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AWS Filler Metal Specifications and Related Documents

Designation	Title
FMC	*Filler Metal Comparison Charts*
IFS	*International Index of Welding Filler Metal Classifications*
UGFM	*User's Guide to Filler Metals*
A4.2M (ISO 8249 MOD)	*Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of 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*
A4.5M/A4.5 (ISO 15792–3 MOD)	*Standard Methods for Classification Testing of Positional Capacity and Root Penetration of Welding Consumables in a Fillet Weld*
A5.01M/A5.01 (ISO 14344 MOD)	*Welding Consumables — Procurement of Filler Metals and Fluxes*
A5.02/A5.02M	*Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*
A5.1/A5.1M	*Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*
A5.2/A5.2M	*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/A5.6M	*Specification for Copper and Copper-Alloy Electrodes for Shielded Metal Arc Welding*
A5.7/A5.7M	*Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes*
A5.8M/A5.8	*Specification for Filler Metals for Brazing and Braze Welding*
A5.9/A5.9M	*Specification for Bare Stainless Steel Welding Electrodes and Rods*
A5.10/A5.10M (ISO 18273 MOD)	*Welding Consumables — Wire Electrodes, Wires and Rods for Welding of Aluminum and Aluminum-Alloys — Classification*
A5.11/A5.11M	*Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding*
A5.12M/A5.12 (ISO 6848 MOD)	*Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting*
A5.13/A5.13M	*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 *(ISO 24034 MOD)*	*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/A5.21M	*Specification for Bare Electrodes and Rods for Surfacing*
A5.22/A5.22M	*Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods*
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/A5.30M	*Specification for Consumable Inserts*
A5.31M/A5.31	*Specification for Fluxes for Brazing and Braze Welding*
A5.32M/A5.32 (ISO 14175 MOD)	*Welding Consumables — Gases and Gas Mixtures for Fusion Welding and Allied Processes*
A5.34/A5.34M	*Specification for Nickel-Alloy Electrodes for Flux Cored Arc Welding*
A5.36/A5.36M	*Specification for Carbon and Low-Alloy Steel Flux Cored Electrodes for Flux Cored Arc Welding and Metal Cored Electrodes for Gas Metal Arc Welding*