

AWS A5.5/A5.5M:2022
An American National Standard

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



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An American National Standard

Approved by the
American National Standards Institute
September 8, 2022

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

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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 this standard but is included for informational purposes only.

This document 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* is used where suitable.

Substantive changes in this document are shown in italic font and include:

(1) *A requirement is included to report the boron level of the deposit if intentionally added or known to be present at levels greater than 0.0010%.*

(2) *New filler metal classifications (E9016-B9A, E8016-B23A, E9016-B92A, E9015-B115, E9016-C1, E7016-C6, E8016-C7, E10016-NM3, E9016-NM4, E10016-NM5, E11016-NM6, E11016-NM7, E11018-NM8, E(X)XX45-G, E10016-Mn2 and E10018-Mn2 have been added.*

(3) *Computed Radiology (CR) and Digital Radiology (DR) have been added as options for radiographic inspection.*

(4) *Fillet weld requirements have been adapted to facilitate measurement with fillet weld gauges.*

(5) *Deleted Table A3 (Typical Amperage Ranges for Covered Arc welding electrodes). Manufacturer to be consulted for recommended parameters.*

(6) *Added allowance for an electrode to be classified with both a “-G” chemical composition designator as well as with a defined chemical composition designator. This is being done at the request of the end user community to ease the transition from “-G” classification to a defined composition classification and to prevent burdensome requalification for long-entrenched products with “-G” classifications.*

The current document is the 10th revision of the initial ASTM/AWS document issued in 1948. The evolution took place as follows:

ASTM A 316-48T AWS A5.5-48T	<i>Tentative Specifications for Low-Alloy Steel Arc-Welding Electrodes</i>
ASTM A 316-54T AWS A5.5-54T	<i>Tentative Specifications for High Tensile and Low-Alloy Steel Covered Arc-Welding Electrodes</i>
AWS A5.5-58T ASTM A 316-58T	<i>Tentative Specification for Low-Alloy Steel Covered Arc-Welding Electrodes</i>
AWS A5.5-64T ASTM A 316-64T	<i>Tentative Specification for Low-Alloy Steel Covered Arc-Welding Electrodes</i>
AWS A5.5-69 ANSI W3.5-1973	<i>Specification for Low-Alloy Steel Covered Arc-Welding Electrodes</i>
AWS A5.5-69 Add. 1-77	<i>1977 Addenda to Specification for Low-Alloy Steel Covered Arc-Welding Electrodes</i>
ANSI/AWS A5.5-81	<i>Specification for Low-Alloy Steel Covered Arc Welding Electrodes</i>
ANSI/AWS A5.5-96	<i>Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding</i>
AWS A5.5/A5.5M:2006	<i>Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding</i>
AWS A5.5/A5.5M:2014	<i>Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding</i>

The user's attention is called to the possibility that compliance with this standard may require use of an invention covered by patent rights. By publication of this standard, no position is taken with respect to the validity of any such claim(s) or of any patent rights in connection therewith. If a patent holder has filed a statement of willingness to grant a license under these rights on reasonable and nondiscriminatory terms and conditions to applicants desiring to obtain such a license, then details may be obtained from the standards developer.

Comments and suggestions for the improvement of this specification are welcome. They should be sent to the Secretary, Committee on Filler Metals and Allied Materials, American Welding Society, 8669 NW 36 St # 130, Miami, FL 33166.

All errata to a standard shall be published in the *Welding Journal* and posted on the AWS website.

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

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. The weld metal deposited by these electrodes are steel alloys in which no single alloying element exceeds 10.5 percent.

In addition to the low-alloy steel electrodes above, this specification also prescribes the requirements for the classification of austenitic, high manganese steel electrodes having weld metal with nominally 20% Mn.

1.2. 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. 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.

1.3. Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein. Some safety and health information can be found in Annex A, Clauses A5 and A10.

Safety and health information is available from the following sources:

American Welding Society:

- (1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*
- (2) AWS Safety and Health Fact Sheets
- (3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

- (1) Safety Data Sheets supplied by materials manufacturers
- (2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies.

Work performed in accordance with this standard may involve the use of materials that have been deemed hazardous and may involve operations or equipment that may cause injury or death. This standard does not purport to address all safety and health risks that may be encountered. The user of this standard should establish an appropriate safety program to address such risks as well as to meet applicable regulatory requirements. ANSI Z49.1 should be considered when developing the safety program.

2. Normative References

The documents listed below are referenced within this publication and are mandatory to the extent specified herein. For undated references, the latest edition of the referenced standard shall apply. For dated references, subsequent amendments to or revisions of any of these publications do not apply.

American Welding Society (AWS) documents:

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

AWS A4.3 ADD1, Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding

AWS A4.4M, Standard Procedure for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coatings

AWS A4.5M/A4.5, Standard Methods for Classification Testing of Positional Capacity and Root Penetration of Welding Consumables in a Fillet Weld

AWS A5.01M/A5.01, Welding and Brazing Consumables — Procurement of Filler Metals and Fluxes

AWS A5.02/A5.02M, Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes

AWS B4.0, Standard Methods for Mechanical Testing of Welds

American National Standards Institute (ANSI) documents:

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

ASTM International (ASTM) documents:

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

ASTM A36/A36M, Standard Specification for Carbon Structural Steel

ASTM A203/A203M, Standard Specification for Pressure Vessel Plates, Alloy Steel, Nickel

ASTM A204/A204M, Standard Specification for Pressure Vessel Plates, Alloy Steel, Molybdenum

ASTM A242/A242M, Standard Specification for High-Strength Low-Alloy Structural Steel

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

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

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

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

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

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

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

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

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

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

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

ASTM A709/A709M, Standard Specification for Carbon Structural Steel for Bridges

ASTM A1106, Standard Specification for Pressure Vessel Plate, Alloy Steel, Austenitic High Manganese for Cryogenic Application

ASTM E23, Standard Test Methods for Notched Bar Impact Testing of Metallic Materials

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

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

ASTM E353, Standard Test Methods for Chemical Analysis of Stainless, Heat-Resisting, Maraging, and Other Similar Chromium-Nickel-Iron Alloys

ASTM E1032, Standard Test Method for Radiographic Examination of Weldments

ASTM E2033, Standard Practice for Radiographic Examination Using Computed Radiography (Photostimulable Luminescence Method)

ASTM E2698, Standard Practice for Radiographic Examination Using Digital Detector Arrays

International Organization for Standardization (ISO) documents:

ISO 80000-1, *Quantities and units—Part 1: General*.

United States Department of Defense (DODSSP) publications:

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*

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*

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

American Petroleum Institute (API) standard:

Specification 5L, *Line Pipe*

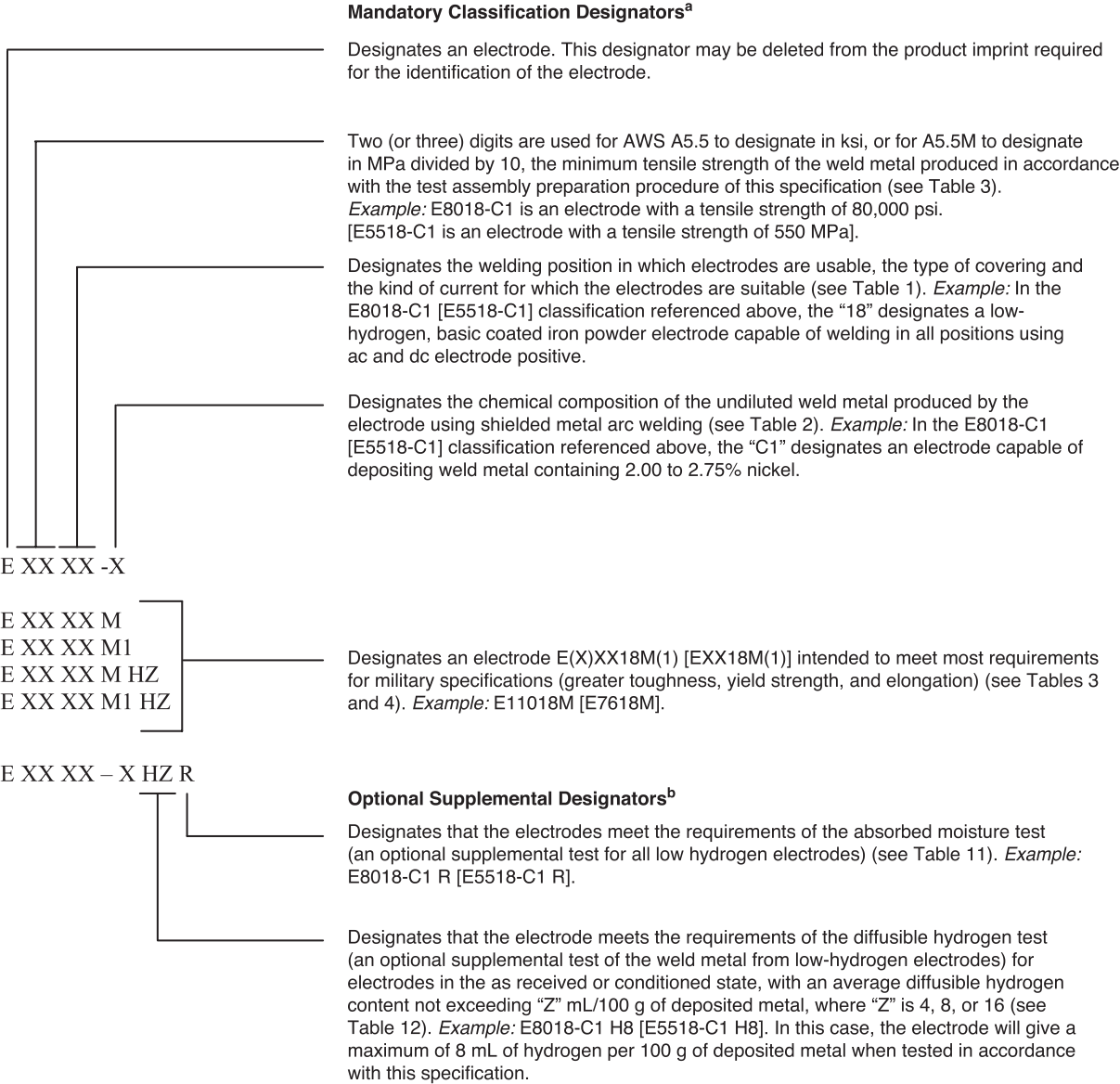
3. Classification

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 Electrodes classified under one classification shall not be classified under any other classification in this specification, *except that an electrode may be classified with both a defined chemical composition designator and a “-G” composition designator*. Also, an electrode may be classified under both A5.5 and A5.5M specifications.

3.3 Electrodes may be classified under A5.5 using U.S. Customary Units or under A5.5M using the International System of Units (SI), or they may be classified under both systems. Electrodes classified under either classification system must meet all requirements for classification under that system. The classification system is shown in Figure 1.



^a The combination of these designators constitutes the electrode classification.
^b These designators are optional and do not constitute a part of the electrode classification.

Figure 1—Order of Electrode Mandatory and Optional Supplemental Designators

Table 1
Electrode Classification

AWS Classification ^a		Type of Covering	Welding Positions for Classification ^b	Type of Current ^c
A5.5	A5.5M			
E7010-X	E4910-X	High cellulose sodium	F, V, OH, H	dcep
E7011-X	E4911-X	High cellulose potassium	F, V, OH, H	ac, 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, dcep
E7018-X ^{d,e}	E4918-X ^{d,e}	Low hydrogen potassium, iron powder ^f	F, V, OH, H	ac, dcep
E7020-X	E4920-X	High iron oxide	H-fillets	ac, dcen
			F	ac, dcep, dcen
E7027-X	E4927-X	High iron oxide, iron powder ^f	H-fillet	ac, dcen
			F	ac, dcep, 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, dcep
E8013-G	E5513-G	High titania potassium	F, V, OH, H	ac, dcep, 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, dcep
E8018-X ^{d,e}	E5518-X ^{d,e}	Low hydrogen potassium, iron powder ^f	F, V, OH, H	ac, dcep
E8045-X ^{d,e}	E5545-X ^{d,e}	Low hydrogen sodium	F, OH, H, V-down	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, dcep
E9013-G	E6213-G	High titania potassium	F, V, OH, H	ac, dcep, 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, dcep
E9018-X ^{d,e}	E6218-X ^{d,e}	Low hydrogen potassium, iron powder ^f	F, V, OH, H	ac, dcep
E9018M ^{d,e}	E6218M ^{d,e}	Iron powder, low hydrogen ^f	F, V, OH, H	dcep
E9045-X ^{d,e}	E6245-X ^{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, dcep
E10013-G	E6913-G	High titania potassium	F, V, OH, H	ac, dcep, 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, dcep
E10018-X ^{d,e}	E6918-X ^{d,e}	Low hydrogen potassium, iron powder ^f	F, V, OH, H	ac, dcep
E10018M ^{d,e}	E6918M ^{d,e}	Iron powder, low hydrogen ^f	F, V, OH, H	dcep
E10045-X ^{d,e}	E6945-X ^{d,e}	Low hydrogen sodium	F, OH, H, V-down	dcep

(Continued)

Table 1 (Continued)
Electrode Classification

AWS Classification ^a		Type of Covering	Welding Positions for Classification ^b	Type of Current ^c
A5.5	A5.5M			
E11010-G	E7610-G	High cellulose sodium	F, V, OH, H	dcep
E11011-G	E7611-G	High cellulose potassium	F, V, OH, H	ac, dcep
E11013-G	E7613-G	High titania potassium	F, V, OH, H	ac, dcep, dcen
E11015-G ^{d,e}	E7615-G ^{d,e}	Low hydrogen sodium	F, V, OH, H	dcep
E11016-X ^{d,e}	E7616-X ^{d,e}	Low hydrogen potassium	F, V, OH, H	ac, dcep
E11018-X ^{d,e}	E7618-X ^{d,e}	Low hydrogen potassium, iron powder ^f	F, V, OH, H	ac, 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, dcep
E12013-G	E8313-G	High titania potassium	F, V, OH, H	ac, dcep, dcen
E12015-G ^{d,e}	E8315-G ^{d,e}	Low hydrogen sodium	F, V, OH, H	dcep
E12016-G ^{d,e}	E8316-G ^{d,e}	Low hydrogen potassium	F, V, OH, H	ac, dcep
E12018-G ^{e,e}	E8318-G ^{d,e}	Low hydrogen potassium, iron powder ^f	F, V, OH, H	ac, 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” in the composition designator position (see Figure 1) as used in this table and elsewhere in this specification stands for any allowable value of the designator *not otherwise individually listed*.

b. The abbreviations F, H, H-fillets, V, V-down, and OH 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)

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)

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-X which meet the 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-X 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).

Table 2
Chemical Composition Requirements for Undiluted Weld Metal

		Weight Percent ^{a,b}										
AWS Classifications ^c		UNS Number ^d	C	Mn	Si	P	S	Ni	Cr	Mo	Other Required Elements ^{e,f}	
A5.5	A5.5M										Element	Amount
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	E6216-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	—	—

(Continued)

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

AWS Classifications ^c		Weight Percent ^{a,b}									Other Required Elements ^{e,f}	
		UNS Number ^d	C	Mn	Si	P	S	Ni	Cr	Mo	Element	Amount
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	—	—
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	W50416	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	—	—

(Continued)

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

		Weight Percent ^{a,b}									Other Required Elements ^{e,f}	
AWS Classifications ^c		UNS Number ^d	C	Mn	Si	P	S	Ni	Cr	Mo	Element	Amount
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	W50506	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	—	—
<i>E9016-B9A</i>	<i>E6216-B9A</i>	—	<i>0.04–0.12</i>	<i>1.00–2.00</i>	<i>0.60</i>	<i>0.025</i>	<i>0.025</i>	<i>0.50–1.00</i>	<i>8.0–10.5</i>	<i>0.85–1.20</i>	<i>V</i>	<i>0.15–0.50</i>
											<i>Nb</i>	<i>0.02–0.15</i>
											W	1.50–2.00
											V	0.15–0.30
E9015-B23	E6215-B23										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
											<i>W</i>	<i>1.30–2.00</i>
											<i>V</i>	<i>0.15–0.30</i>
											<i>Nb</i>	<i>0.01–0.10</i>
<i>E8016-B23A</i>	<i>E5516-B23A</i>	—	<i>0.03–0.12</i>	<i>1.00</i>	<i>0.60</i>	<i>0.015</i>	<i>0.015</i>	<i>0.50</i>	<i>1.9–2.9</i>	<i>0.30</i>	<i>B</i>	<i>0.006</i>
											<i>Al</i>	<i>0.04</i>
											<i>Cu</i>	<i>0.25</i>
											<i>N</i>	<i>0.05</i>
E9015-B24	E6215-B24										V	0.15–0.30
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	Nb	0.02–0.10
E9018-B24	E6218-B24										Ti	0.10
											B	0.006
											Al	0.04
											Cu	0.25
											N	0.07

(Continued)

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

AWS Classifications ^c		UNS Number ^d	Weight Percent ^{a,b}								Other Required Elements ^{e,f}	
			C	Mn	Si	P	S	Ni	Cr	Mo	Element	Amount
A5.5	A5.5M	W50425	0.08–0.13	1.20	0.30	0.01	0.01	0.80	8.0–10.5	0.85–1.20	V	0.15–0.30
											Cu	0.25
											Al	0.04
											Nb	0.02–0.10
											N	0.02–0.07
E9015-B91 ^{g,h} E9016-B91 ^{g,h} E9018-B91 ^{g,h}	E6215-B91 ^{g,h} E6216-B91 ^{g,h} E6218-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	W	1.50–2.00
											V	0.15–0.30
											Nb	0.02–0.08
											B	0.006
											Al	0.04
											Cu	0.25
											N	0.03–0.08
											W	1.50–2.00
											V	0.10–0.40
											Co	1.00–2.00
											Nb	0.01–0.08
E9015-B92 ^g E9016-B92 ^g E9018-B92 ^g	E6215-B92 ^g E6216-B92 ^g E6218-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
											Al	0.04
											Cu	0.25
											N	0.03–0.08
											W	1.50–2.00
											V	0.10–0.40
											Co	1.00–2.00
											Nb	0.01–0.08
											B	0.006
											Al	0.04
E9016-B92A E9018-B92A	E6216-B92A E6218-B92A	—	0.06–0.15	1.20	0.60	0.020	0.015	1.00	8.0–10.5	0.10–0.70	Cu	0.25
											N	0.03–0.08
											V	0.10–0.30
											Nb	0.02–0.10
											Al	0.04
											Cu	0.20
											N	0.02–0.07
											W	1.50–2.00
											V	0.10–0.40
											Co	1.00–2.00
E9015-B115 E9016-B115 E9018-B115	E6215-B115 E6216-B115 E6218-B115	—	0.08–0.13	0.80	0.50	0.01	0.01	0.50	9.5–12.0	0.40–0.65	Nb	0.02–0.10
											Al	0.04
											Cu	0.20
											N	0.02–0.07
											W	1.50–2.00
											V	0.10–0.40
											Co	1.00–2.00
											Nb	0.01–0.08
											B	0.006
											Al	0.04
											Cu	0.25

(Continued)

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

		Weight Percent ^{a,b}									Other Required Elements ^{e,f}	
AWS Classifications ^c		UNS Number ^d	C	Mn	Si	P	S	Ni	Cr	Mo	Element	Amount
A5.5	A5.5M											
Nickel Steel Electrodes												
E8016-C1	E5516-C1	W22016	0.12	1.25	0.60	0.03	0.03	2.00–2.75	—	—	—	—
<i>E9016-C1</i>	<i>E6216-C1</i>	—	<i>0.12</i>	<i>0.60–1.20</i>	<i>0.80</i>	<i>0.03</i>	<i>0.03</i>	<i>2.00–2.75</i>	—	<i>0.30</i>	—	—
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	—	—	—	—

(Continued)

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

AWS Classifications ^c		UNS Number ^d	Weight Percent ^{a,b}								Other Required Elements ^{e,f}	
A5.5	A5.5M		C	Mn	Si	P	S	Ni	Cr	Mo	Element	Amount
											V	0.05
E7016-C6	E4916-C6	—	0.12	0.60–1.60	0.25–0.90	0.03	0.03	0.30–1.00	—	0.35	Ti	0.005–0.035
											B	0.0005–0.0045
E8016-C7	E5516-C7	—	0.10	1.00–1.60	0.60	0.03	0.03	1.10–2.00	—	—	Ti	0.005–0.035
											B	0.0005–0.0045
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	0.02
											Cu	0.10
											Al	0.05
E9018-NM2	E5518-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	0.05
											Cu	0.10
											Al	0.05
E10016-NM3	E6916-NM3	—	0.12	1.20–1.70	0.80	0.03	0.03	1.20–1.70	0.10–0.30	0.10–0.30	—	—
E9016-NM4	E6216-NM4	—	0.12	0.70–1.50	0.80	0.03	0.03	0.30–1.00	—	0.10–0.40	—	—
E10016-NM5	E6916-NM5	—	0.12	0.80–1.40	0.80	0.03	0.03	3.00–3.80	0.10–0.40	0.30–0.60	—	—
E11016-NM6	E7616-NM6	—	0.12	1.20–1.80	0.80	0.03	0.03	1.50–2.10	0.10–0.40	0.25–0.55	—	—
E11016-NM7	E7616-NM7	—	0.12	1.40–2.00	0.80	0.03	0.03	2.10–2.80	—	0.50–0.80	—	—
E11018-NM8	E7618-NM8	—	0.12	1.20–1.90	0.20–0.75	0.03	0.03	2.50–3.30	—	0.40–1.00	—	—
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	—	—

(Continued)

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

Weight Percent ^{a,b}												
AWS Classifications ^c		UNS Number ^d	C	Mn	Si	P	S	Ni	Cr	Mo	Other Required Elements ^{e,f}	
A5.5	A5.5M										Element	Amount
E8016-D3	E5516-D3	W18016	0.12	1.00–1.80	0.60	0.03	0.03	0.90	—	0.40–0.65	—	—
<i>E9016-D3</i>	<i>E6216-D3</i>	—	<i>0.12</i>	<i>1.00–1.80</i>	<i>0.60</i>	<i>0.03</i>	<i>0.03</i>	<i>0.90</i>	—	<i>0.40–0.65</i>	—	—
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	—	—
High Manganese Electrodes												
<i>E10016-Mn2</i>	<i>E6916-Mn2</i>	—	<i>0.25–0.50</i>	<i>16.0–24.0</i>	<i>1.0</i>	<i>0.020</i>	<i>0.015</i>	<i>3.0</i>	<i>1.5–3.5</i>	<i>1.5</i>	<i>Cu</i>	<i>0.5</i>
<i>E10018-Mn2</i>	<i>E6918-Mn2</i>	—	<i>0.25–0.50</i>	<i>16.0–24.0</i>	<i>1.0</i>	<i>0.020</i>	<i>0.015</i>	<i>3.0</i>	<i>1.5–3.5</i>	<i>1.5</i>	<i>Cu</i>	<i>0.5</i>
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
E(X)XX45-G ⁱ	EXX45-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
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

(Continued)