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An American National Standard

Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding

American Welding Society

Key Words— Carbon steel electrodes, submerged arc flux crushed slag, welding electrodes, filler metal specification, mild steel, solid electrode, composite electrode

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Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding

Supersedes ANSI/AWS A5.17-89

Prepared by
AWS Committee on Filler Metals

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This specification provides requirements for the classification of solid and composite carbon steel electrodes and fluxes for submerged arc welding. Electrode classification is based on chemical composition of the electrode for solid electrodes, and chemical composition of the weld metal for composite electrodes. Flux classification is based on the mechanical properties of weld metal produced with the flux and an electrode classified herein. Other requirements include sizes, marking, manufacturing and packaging. The form and usability of the flux are also included.

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.

American Welding Society
550 N.W. LeJeune Road, Miami, Florida 33126

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Foreword

(This Foreword is not a part of ANSI/AWS A5.17/A5.17M-97, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*, but is included for information purposes only).

This is the fifth revision of the document originally issued in 1965. That document was issued jointly by the American Welding Society and the American Society for Testing and Materials. The practice of issuing filler metal specifications as joint AWS/ASTM documents was discontinued shortly after the original version of this specification was issued. The 1969 revision, published by AWS, was accepted by the American National Standards Institute as an ANSI standard. Subsequent revisions have become ANSI/AWS standards.

This document is the first of the A5.17 specifications which is a combined specification providing for classification utilizing a system based upon U.S. Customary Units, or utilizing a system based upon 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, ANSI/AWS A1.1, *Metric Procedure Guide for the Welding Industry*, is 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. Paragraphs, Tables, and Figures which carry the suffix letter "U" are applicable only to those products classified to the system based upon U.S. Customary Units under the A5.17 specification. Those which carry the suffix letter "M" are applicable only to those products classified to the system based upon the International System of Units (SI), under the A5.17M specification.

Document Development

AWS A5.17-65T ASTM A558-65T	Tentative Specifications for Bare Mild Steel Electrodes and Fluxes for Submerged Arc Welding
AWS A5.17-69 ANSI W3.17-1973	Specification for Bare Mild Steel Electrodes and Fluxes for Submerged Arc Welding
ANSI/AWS A5.17-77	Specification for Bare Carbon Mild Steel Electrodes and Fluxes for Submerged Arc Welding
ANSI/AWS A5.17-80	Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding
ANSI/AWS A5.17-89	Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding

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

The welding terms used in this specification shall be interpreted in accordance with the definitions given in the latest edition of ANSI/AWS A3.0, *Standard Welding Terms and Definitions*.

Official interpretations of any of the technical requirements of this standard may be obtained by sending a request, in writing, to the Managing Director, Technical Services Division, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126. A formal reply will be issued after it has been reviewed by the appropriate personnel following established procedures.

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Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding

1. Scope

This specification prescribes requirements for the classification of carbon steel electrodes (both solid and composite) and fluxes for submerged arc welding.

This document is the first of the A5.17 specifications which is a combined specification providing for classification utilizing a system based upon U.S. Customary Units, or utilizing a system based upon 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, ANSI/AWS A1.1, *Metric Practice Guide for the Welding Industry*, is used where suitable. Tables and Figures make use of both U.S. Customary Units and SI Units which, with the application of the specified tolerances, provides for interchangeability of products in both U.S. Customary and SI Units.

(1) Paragraphs, tables and figures which carry the suffix letter "U" are applicable only to those products classified to the system based upon U.S. Customary Units under the A5.17 specification.

(2) Paragraphs, tables and figures which carry the suffix letter "M" are applicable only to those products classified to the system based upon the International System of Units (SI), under the A5.17M specification.

(3) Paragraphs, tables and figures which do not have either the suffix letter "U" or the suffix letter "M" are applicable to those products classified under either the U.S. Customary Units System or the International System of Units (SI).

Part A General Requirements

2. Normative References

2.1 The following ANSI/AWS standards[1] are referenced in the mandatory sections of this document:

(1) ANSI/AWS A1.1, *Metric Practice Guide for the Welding Industry.*

(2) ANSI/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) ANSI/AWS A5.01, *Filler Metal Procurement Guidelines.*

(4) ANSI/AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.*

(5) ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds.*

2.2 The following ASTM standards[2] are referenced in the mandatory sections of this document:

(1) ASTM A29/A29M, *Specification for Steel Bars, Carbon and Alloy, Hot-Wrought and Cold-Finished.*

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

(3) ASTM A285/A285M, *Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength.*

(4) ASTM A515/A515M, *Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service.*

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

(6) ASTM DS-56, SAE HS-1086, *Metals and Alloys in the Unified Numbering System.*

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

(8) ASTM E142, *Method for Controlling Quality of Radiographic Testing.*

1. AWS standards may be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

2. ASTM standards can be obtained from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

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

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

(1) ISO 864, *Arc Welding—Solid and Tubular Cored Wires which Deposit Carbon and Carbon-Manganese Steel—Dimensions of Wires, Spools, Rims and Coils.*

3. Classification

3.1U The welding electrodes and fluxes covered by the A5.17 specification utilize a classification system based upon U.S. Customary Units and are classified according to the following:

(1) The mechanical properties of the weld metal obtained with a combination of a particular flux and a particular classification of electrode, as specified in Tables 5U and 6U.

(2) The condition of heat treatment in which those properties are obtained, as specified in 9.4 (and shown in Figure 1U).

(3) The chemical composition of the electrode (for solid electrodes) as specified in Table 1, or the weld metal produced with a particular flux (for composite electrodes) as specified in Table 2.

3.1M The welding electrodes and fluxes covered by the A5.17M specification utilize a classification system based upon the International System of Units (SI) and are classified according to the following:

(1) The mechanical properties of the weld metal obtained with a combination of a particular flux and a particular classification of electrode, as specified in Tables 5M and 6M.

(2) The condition of heat treatment in which those properties are obtained, as specified in 9.4 (and shown in Figure 1M).

(3) The chemical composition of the electrode (for solid electrodes) as specified in Table 1, or the weld metal produced with a particular flux (for composite electrodes) as specified in Table 2.

3.2 Solid electrodes classified under one classification shall not be classified under any other classification in this specification, except that solid electrodes meeting the chemical composition requirements of both the EL8 and EL12 classifications (Table 1) may be given both classifications. Composite electrodes may be classified under more than one classification when used with different fluxes. Fluxes may be classified under any number of classifications, for weld metal in either or both the as-welded and postweld heat-treated conditions, using different electrode classifications. Flux-electrode combinations may be classified under A5.17 with U.S. Customary Units, A5.17M using the International System of Units (SI), or both. Flux-electrode combinations classified under both A5.17 and A5.17M must meet all requirements for classification under each system. The classification systems are shown in Figures 1U and 1M.

3.3 The electrodes and fluxes classified under this specification are intended for submerged arc welding, but that is not to prohibit their use with any other process for which they are found suitable.

4. Acceptance

Acceptance of the electrodes and fluxes shall be in accordance with the provisions of the latest edition of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines* (see Annex A3).

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 (see Annex A4).

6. Units of Measure and Rounding-Off Procedure

6.1 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way. The specification with the designation A5.17 uses U.S. Customary Units. The specification with the designation A5.17M uses SI Units. The latter are shown in appropriate columns in the Tables or Figures or are shown within brackets [ ] when used in the text. Figures in parentheses ( ), following the U.S. Customary Units, are calculated equivalent SI values for the specified dimensions. Figures in brackets [ ], following U.S. Customary Units used in the text, are rational SI Units.

6.2 For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi for tensile and yield strength for A5.17 [to the nearest 10 MPa for tensile and

3. ISO standards may be obtained from American National Standards Institute (ANSI), 11 West 42nd St., 13th Floor, New York, NY 10036-8002.

MANDATORY CLASSIFICATION DESIGNATORS[a]

Indicates a submerged arc welding flux.

Indicates that the welding flux being classified is made solely from crushed slag or is a blend of crushed slag with unused (virgin) flux. Omission of the "S" indicates that the flux being classified is virgin flux.

Indicates the minimum tensile strength (in increments of 10 000 psi) of weld metal deposited with the flux and some specific classification of electrode under the welding conditions specified in Figure 3. For example, when the designator is 7, the tensile requirement is 70 000 to 95 000 psi (see Table 5U).

Designates the condition of heat treatment in which the tests were conducted: "A" for as-welded and "P" for postweld heat treated. The time and temperature of the PWHT are specified in 9.4.

Indicates a temperature in °F at or above which the impact strength of the weld metal referred to above meets or exceeds 20 ft·lbf (See Table 6U).

Classification of the electrode used in producing the weld metal referred to above. The letter "E" in the first position indicates electrode. The letter "C," when present in the second position, indicates that the electrode is a composite electrode (refer to Table 2 for classifications). Omission of the "C" indicates that the electrode is a solid electrode (refer to Table 1 for classifications).

FSXXX- ECXXX- HX

OPTIONAL SUPPLEMENTAL DESIGNATORS[b]

Optional supplemental diffusible hydrogen designator (see Table 7).

Notes:
(a) The combination of these designators constitutes the flux-electrode classification.
(b) These designators are optional and do not constitute a part of the flux-electrode classification.

Examples

F7A6-EM12K is a complete designation for a flux-electrode combination. It refers to a flux that will produce weld metal which, in the as-welded condition, will have a tensile strength of 70 000 to 95 000 psi and Charpy V-notch impact strength of at least 20 ft·lbf at –60°F when produced with an EM12K electrode under the conditions called for in this specification. The absence of an "S" in the second position indicates that the flux being classified is a virgin flux.

F7P4-EC1 is a complete designation for a flux-composite electrode combination when the trade name of the electrode used in the classification is indicated as well [see 17.4.1(3)]. It refers to a virgin flux that will produce weld metal with that electrode which, in the postweld heat treated condition, will have a tensile strength of 70 000 to 95 000 psi and Charpy V-notch energy of at least 20 ft·lbf at –40°F under the conditions called for in this specification.

Figure 1U—A5.17 Classification System for U.S. Customary Units

MANDATORY CLASSIFICATION DESIGNATORS[a]

Indicates a submerged arc welding flux.

Indicates that the welding flux being classified is made solely from crushed slag or is a blend of crushed slag with unused (virgin) flux. Omission of the "S" indicates that the flux being classified is virgin flux.

Indicates the minimum tensile strength [in increments of 10 megapascals (MPa)] of weld metal deposited with the flux and some specific classification of electrode under the welding conditions specified in Figure 3. For example, when this designator is 43, the tensile requirement is 430 to 560 MPa (see Table 5M).

Designates the condition of heat treatment in which the tests were conducted: "A" for as-welded and "P" for postweld heat treated. The time and temperature of the PWHT are specified in 9.4.

Indicates a temperature in °C at or above which the impact strength of the weld metal referred to above meets or exceeds 27 J (See Table 6M).

Classification of the electrode used in producing the weld metal referred to above. The letter "E" in the first position indicates electrode. The letter "C," when present in the second position, indicates that the electrode is a composite electrode (refer to Table 2 for classifications). Omission of the "C" indicates that the electrode is a solid electrode (refer to Table 1 for classifications).

FSXXX- ECXXX- HX

OPTIONAL SUPPLEMENTAL DESIGNATORS[b]

Optional supplemental diffusible hydrogen designator (see Table 7).

Notes:

(a) The combination of these designators constitutes the flux-electrode classification.

(b) These designators are optional and do not constitute a part of the flux-electrode classification.

Examples

F43A2-EM12K is a complete designation for a flux-electrode combination. It refers to a flux that will produce weld metal which, in the as-welded condition, will have a tensile strength of 430 to 560 MPa and Charpy V-notch impact strength of at least 27 J at –20 °C when produced with an EM12K electrode under the conditions called for in this specification. The absence of an "S" in the second position indicates that the flux being classified is a virgin flux.

F48P6-EC1 is a complete designation for a flux-composite electrode combination when the trade name of the electrode used in the classification is indicated as well [see 17.4.1(3)]. It refers to a virgin flux that will produce weld metal with that electrode which, in the postweld heat treated condition, will have a tensile strength of 480 to 660 MPa and Charpy V-notch energy of at least 27 J at –60 °C under the conditions called for in this specification.

Figure 1M—A5.17M Classification System for the International System of Units (SI)

Table 1
Chemical Composition Requirements for Solid Electrodes

Electrode Classification	UNS Number[c]	wt. percent[a,b] C	Mn	Si	S	P	Cu[d]	Ti
Low-Manganese Electrodes								
EL8	K01008	0.10	0.25–0.60	0.07	0.030	0.030	0.35	—
EL8K	K01009	0.10	0.25–0.60	0.10–0.25	0.030	0.030	0.35	—
EL12	K01012	0.04–0.14	0.25–0.60	0.10	0.030	0.030	0.35	—
Medium-Manganese Electrodes								
EM11K	K01111	0.07–0.15	1.00–1.50	0.65–0.85	0.030	0.025	0.35	—
EM12	K01112	0.06–0.15	0.80–1.25	0.10	0.030	0.030	0.35	—
EM12K	K01113	0.05–0.15	0.80–1.25	0.10–0.35	0.030	0.030	0.35	—
EM13K	K01313	0.06–0.16	0.90–1.40	0.35–0.75	0.030	0.030	0.35	—
EM14K	K01314	0.06–0.19	0.90–1.40	0.35–0.75	0.025	0.025	0.35	0.03–0.17
EM15K	K01515	0.10–0.20	0.80–1.25	0.10–0.35	0.030	0.030	0.35	—
High-Manganese Electrodes								
EH10K	K01210	0.07–0.15	1.30–1.70	0.05–0.25	0.025	0.025	0.35	—
EH11K	K11140	0.06–0.15	1.40–1.85	0.80–1.15	0.030	0.030	0.35	—
EH12K	K01213	0.06–0.15	1.50–2.00	0.20–0.65	0.025	0.025	0.35	—
EH14	K11585	0.10–0.20	1.70–2.20	0.10	0.030	0.030	0.35	—
EG		Not Specified						

Notes:
a. The electrode shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated, in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed 0.50 percent.
b. Single values are maximum.
c. SAE/ASTM Unified Numbering System for Metals and Alloys.
d. The copper limit includes any copper coating that may be applied to the electrode.

Table 2
Chemical Composition Requirements for Composite Electrode Weld Metal

Electrode Classification	UNS Number[d]	wt. percent[a,b,c] C	Mn	Si	S	P	Cu
EC1	W06041	0.15	1.80	0.90	0.035	0.035	0.35
ECG		Not Specified					

Notes:
a. The weld metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated, in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed 0.50 percent.
b. Single values are maximum.
c. As a substitute for the weld pad in Figure 2, the sample for chemical analysis may be taken from the reduced section of the fractured tension test specimen (see 12.1) or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 3. In case of dispute, the weld pad shall be the referee method.
d. SAE/ASTM Unified Numbering System for Metals and Alloys.

yield strength for A5.17M] and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities in accordance with the rounding-off method given in ASTM E29, *Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications.*

Part B Tests, Procedures, and Requirements

7. Summary of Tests

The tests required for classification of solid electrodes, composite electrodes, and flux-electrode combinations are specified in Table 3.

7.1 Electrodes

7.1.1 Solid Electrodes. Chemical analysis of the electrode is the only test required for classification of a solid electrode under this specification. The chemical analysis of the rod stock from which the electrode is made may also be used, provided the electrode manufacturing process does not alter the chemical composition.

7.1.2 Composite Electrodes. Chemical analysis of weld metal produced with the composite electrode and a particular flux is the only test required for classification of a composite electrode under this specification.

7.2 Fluxes. The tests specified in Table 3 determine the mechanical properties and soundness of the weld metal obtained with a particular flux-electrode combination. The base metal for the test assemblies, the welding and testing procedures to be employed, and the results required are given in Sections 9 through 13.

7.3 Flux classification is based upon a 5/32 in. [4.0 mm] electrode size as standard. If this size electrode is not manufactured, the closest size shall be used for classification tests. See Note d of Figure 3B.

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Material, specimens, or samples for retest may be taken from the original test assembly or sample or from one or two new test assemblies or samples. 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 test specimen(s) or in conducting the test, the test shall be considered invalid, without regard to whether the test was actually completed or whether test results met, or failed to meet, the requirement. That test shall be repeated, following proper prescribed procedures. In this case, the requirement for doubling the number of test specimens does not apply.

Table 3
Tests Required for Classification

AWS Classification	Chemical Analysis		Radiographic Test	Tension Test	Impact Test	Diffusible Hydrogen Test
	Electrode	Weld Metal				
All Solid Electrodes	Required	Not Required	Not Required	Not Required	Not Required	Not Required
All Composite Electrodes	Not Required	Required	Not Required	Not Required	Not Required	Not Required
All Flux-Solid Electrode Combinations	Not Required	Not Required	Required	Required	Required[a]	b
All Flux-Composite Electrode Combinations	Not Required	Not Required	Required	Required	Required[a]	b

Notes:
a. When the "Z" impact designator (no impact requirement—Table 6U and 6M) is used, the Impact Test is not required.
b. Diffusible hydrogen test is required only when specified by the purchaser or when the manufacturer puts the diffusible hydrogen designator on the label (see also Section A3 and A6.4 in the Annex).

9. Weld Test Assemblies

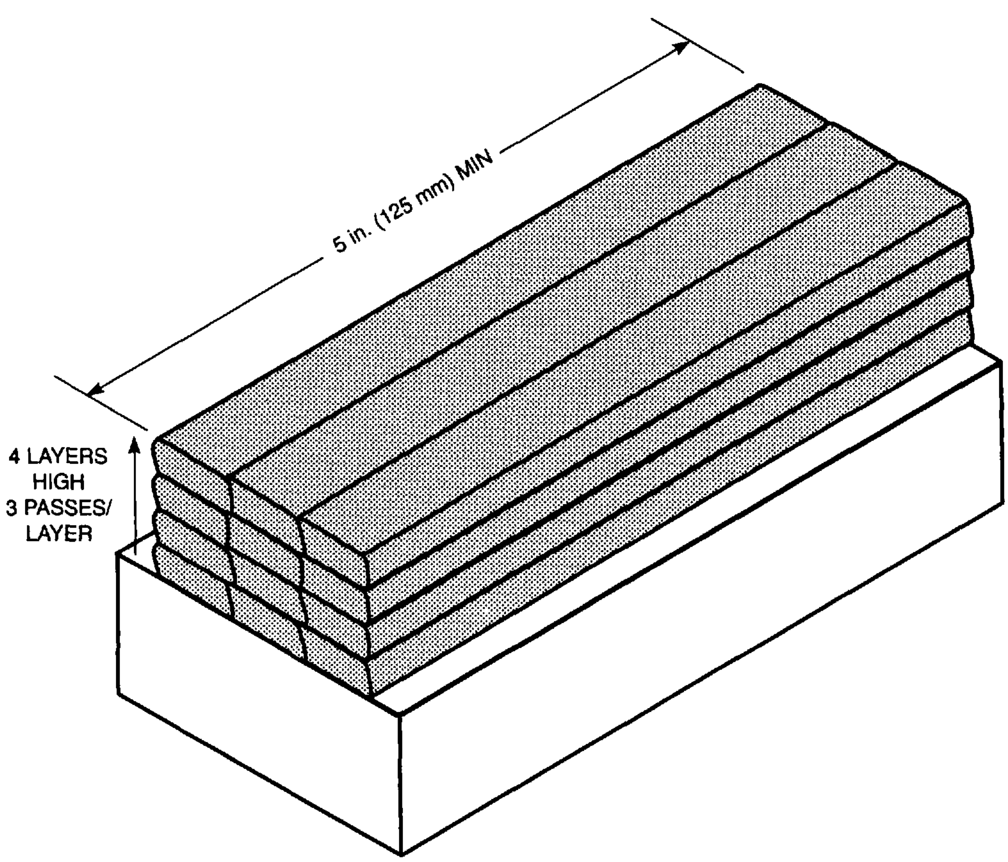
9.1 Requirements for Classification

9.1.1 Classification of Solid Electrodes. No weld test assembly is required for classification of solid electrodes.

9.1.2 Classification of Composite Electrodes. The chemical analysis of weld metal produced with the composite electrode and a particular flux is required for classification of a composite electrode under this specification. The weld test assembly, shown in Figure 2, is used to meet this requirement for the classification of composite electrodes. Figure 2 is the weld pad test assembly for chemical analysis of weld metal. As an alternative to the weld pad, the sample for chemical analysis of composite electrode weld metal may be taken from the groove weld in Figure 3A. Note c to Table 2 allows the sample for chemical analysis in the case of a composite electrode to be taken from the reduced section of the fractured tension test specimen of Figure 5 or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 3A. In case of dispute, the weld pad shall be the referee method.

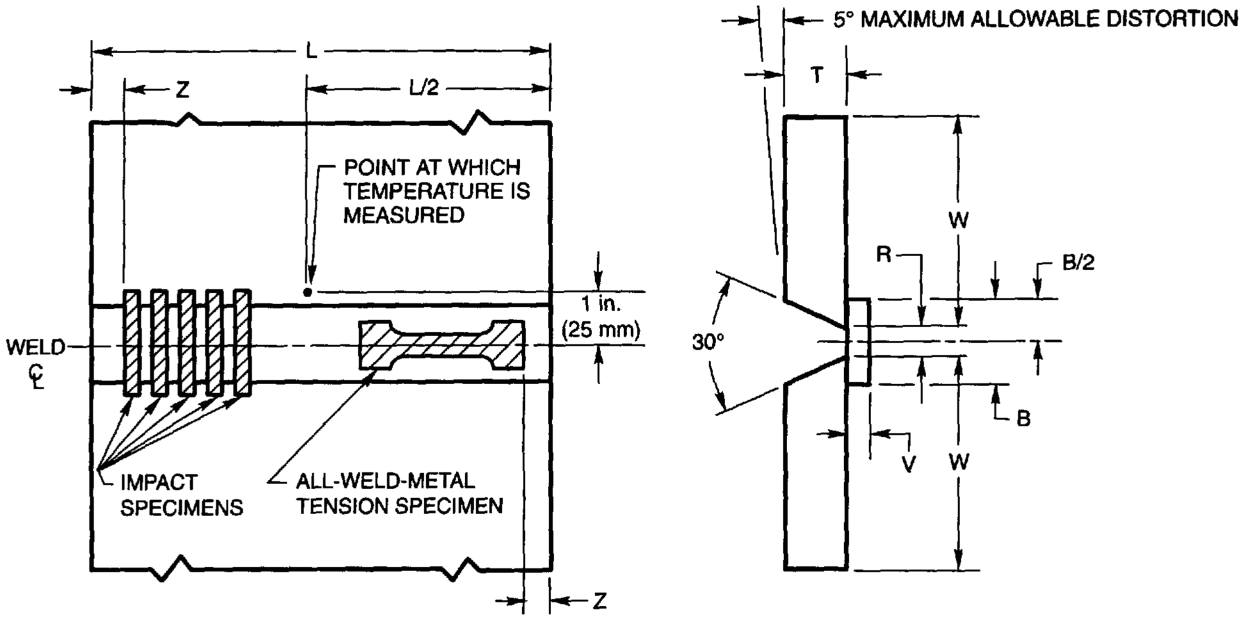
9.1.3 Classification of Flux-Electrode Combinations. One groove weld test assembly is required for each classification of a flux-solid electrode combination or a flux-composite electrode combination. This is the groove weld in Figure 3A for mechanical properties and soundness of weld metal.

9.2 Preparation. Preparation of each weld test assembly shall be as prescribed in 9.3 and 9.4. The base metal for the weld pad and groove weld assemblies shall be as required in Table 4 corresponding to the tests to be con-

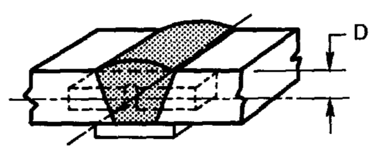


General Notes:
1. Width and thickness of the base-metal plate may be any dimensions suitable for the electrode diameter and current in use.
2. Weld beads shall be deposited without oscillation. The welding conditions shall be in accordance with the manufacturer's recommendations.
3. The first and last 2 in. [50 mm] of the weld length shall be discarded. The top surface shall be removed, and chemical analysis samples shall be taken from the underlying metal of the fourth layer of the weld pad.

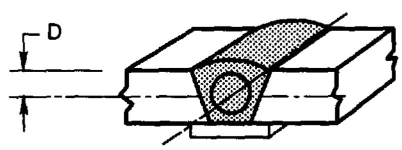
Figure 2—Weld Pad for Chemical Analysis of Weld Metal



(A) JOINT CONFIGURATION AND LOCATION OF TEST SPECIMENS



(B) LOCATION OF IMPACT TEST SPECIMENS



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

Letter	Dimensions	in.	mm
L	Length (min)	12	305
T	Thickness	1 ± 1/16	25 ± 1.5
W	Width (min)	5	127
V	Backup Thickness	1/2 ± 1/16	13 ± 1.5
D	Specimen Center	3/8 ± 1/32	9.5 ± 1.0
B	Backup Width (min)	2	50
R	Root Opening	1/2 ± 1/16	13 ± 1.5
Z	Discard (min)	1	25

Figure 3A—Groove Weld Test Assembly

Welding Conditions for Solid Electrodes[a,b,c]

Electrode Size[d]		Welding Current (Amperes)[f]	Arc Voltage (Volts)	Electrode Extension[g]		Travel Speed		Current Type[h]	Preheat Temperature[i]	Interpass Temperature[i]
in.	mm[e]			in.	mm	ipm (±1)	mm/sec. (±0.5)			
1/16	1.6	250 to 350	26 to 29	1/2 to 3/4	13 to 19	12	5.0			
5/64	2.0	300 to 400	26 to 29	1/2 to 3/4	13 to 19	13	5.5			
3/32	2.4	350 to 450	27 to 30	3/4 to 1-1/4	19 to 32	14	6.0			
—	2.5	350 to 450	27 to 30	3/4 to 1-1/4	19 to 32	14	6.0			
7/64	2.8	400 to 500	27 to 30	3/4 to 1-1/4	19 to 32	14	6.0			
—	3.0	400 to 500	27 to 30	1 to 1-1/2	25 to 38	15	6.5			
1/8	3.2	425 to 525	27 to 30	1 to 1-1/2	25 to 38	15	6.5	A.C. or D.C. either polarity	60–325°F [15–165°C]	275–325°F [135–165°C]
5/32	4.0	475 to 575	27 to 30	1 to 1-1/2	25 to 38	16	7.0			
3/16	4.8	525 to 625	27 to 30	1 to 1-1/2	25 to 38	17	7.0			
—	5.0	550 to 650	27 to 30	1 to 1-1/2	25 to 38	17	7.0			
7/32	5.6	575 to 675	28 to 31	1-1/4 to 1-3/4	32 to 44	18	7.5			
—	6.0	625 to 725	28 to 31	1-1/4 to 1-3/4	32 to 44	19	8.0			
1/4	6.4	700 to 800	28 to 32	1-1/2 to 2	38 to 50	20	8.5			

Notes:

a. Values specified in inches or ipm apply to A5.17. Values specified in mm or mm/sec apply to A5.17M.

b. These welding conditions are intended for machine or automatic welding with straight progression (no weaving). Welding shall be performed in the flat position. The first layer shall be produced in either 1 or 2 passes. All other layers shall be produced in 2 or 3 passes per layer except the last, which shall be produced in 3 or 4 passes. The completed weld shall be at least flush with the surface of the test plate.

c. Welding conditions for composite electrodes shall be as agreed between purchaser and supplier.

d. Classification is based on the properties of weld metal with 5/32 in. [4.0 mm] electrodes or the closest size manufactured, if 5/32 in. [4.0 mm] is not manufactured. The conditions given above for sizes other than 5/32 in. [4.0 mm] are to be used when classification is based on those sizes, or when they are required for lot acceptance testing under A5.01, *Filler Metal Procurement Guidelines* (unless other conditions are specified by the purchaser).

e. 4.8 mm, 5.6 mm, and 6.4 mm are not included as standard sizes in ISO 864:1988.

f. Lower currents may be used for the first layer.

g. The electrode extension is the contact tube-to-work distance. When an electrode manufacturer recommends a contact tube-to-work distance outside the range shown, that recommendation shall be followed ±1/4 in. [6.5 mm].

h. In case of dispute, DCEP (direct current-electrode positive) shall be used as the referee current.

i. The first bead shall be produced with the assembly at any temperature between 60 and 325°F [15 to 165°C]. Welding shall continue, bead by bead, until a temperature within the interpass temperature range has been attained. Thereafter, production of subsequent beads may begin only when the assembly is within the interpass temperature range. The point of temperature measurement shall be at the mid-length of the test assembly, approximately 1 in. [25 mm] from the weld centerline.

Figure 3B—Groove Weld Test Welding Parameters

Table 4
Base Metals for Test Assemblies

Test Assembly	Type	ASTM Specification[a]	UNS Number[b]
Weld Pad for Chemical Analysis	Carbon Steel	A29 Grade 1015	G10150
		A29 Grade 1020	G10200
		A36	K02600
		A285 Grade A	K01700
		A285 Grade B	K02200
		A285 Grade C	K02801
		A285 Grade D	K02702
		A515 Grade 70	K03101
		A516 Grade 70	K02700
Groove Weld of Figure 3	Carbon Steel	A36	K02600
		A285 Grade A	K01700
		A285 Grade B	K02200
		A285 Grade C	K02801
		A285 Grade D	K02702
		A515 Grade 70	K03101
		A516 Grade 70	K02700

Notes:
a. Chemically equivalent steel may be used. In case of dispute, ASTM A36 shall be used as the referee steel.
b. As classified in ASTM DS-56, SAE HS-1 Metals and Alloys in the Unified Numbering System.

ducted and shall meet the requirements of the appropriate ASTM specification shown in Table 4, or an equivalent specification. Testing of the assemblies shall be as prescribed in Sections 10 through 13.

9.3 Weld Pad. For composite electrodes only, a weld pad shall be prepared as specified in Figure 2, except when either alternative in 9.1.2 is selected. Base metal of any convenient size, and of the type specified in Table 4, shall be used as the base metal 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, three passes per layer, four layers high, using the flux for which classification of the composite electrode is intended. The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 325°F [165°C]. The slag shall be removed after each pass. The pad may be quenched in water between passes but shall be dry before the start of each pass. Testing of this assembly shall be as specified in Section 10, Chemical Analysis.

9.4 Groove Weld for Mechanical Properties and Soundness. For classification of a flux- electrode combination, a test assembly shall be prepared and welded as specified in Figure 3A using base metal of the appropriate type specified in Table 4. Prior to welding, the assembly may be preset so that the welded joint will be 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 welded test assembly that is more than 5 degrees out of plane shall be discarded. Straightening of the test assembly is prohibited. Testing shall be as specified in Sections 10 through 13, with the assembly in either the as-welded or the postweld heat-treated condition, according to the classification of the weld metal (See Figures 1U and 1M).

When the tests are to be conducted in each condition (as-welded and postweld heat treated), two such assemblies, or one single assembly of sufficient length to provide the specimens required for both conditions, shall be prepared. In the latter case, the single assembly shall be cut transverse to the weld into two pieces; one of the pieces shall be tested in the as-welded condition, and the other piece shall be heat treated prior to testing.

Any test assembly to be heat treated shall be heat treated at 1150 ± 25°F [620 ± 15°C] for one hour (−0, +15 minutes). The furnace shall be at a temperature not higher than 600°F [315°C] when the test assembly is placed in it. The heating rate, from that point to the 1150 ± 25°F [620 ± 15°C] holding temperature, shall not exceed 400°F per hour [220°C per hour]. When the holding time has been completed, the assembly shall be allowed to cool in the furnace to a temperature below 600°F [315°C] at a rate not exceeding 350°F per hour [195°C per hour]. The assembly may be removed from the furnace at any temperature below 600°F [315°C] and allowed to cool in still air, to room temperature.

9.5 Diffusible Hydrogen. In those cases in which an optional supplemental diffusible hydrogen designator is to be added to the flux-electrode classification designation, four diffusible hydrogen test assemblies shall be prepared, welded, and tested as specified in Section 14, Diffusible Hydrogen Test.

10. Chemical Analysis

10.1 For solid electrodes, a sample of the electrode shall be prepared for chemical analysis. The rod stock from which the electrode is made may also be used for chemical analysis, provided the electrode manufacturing process does not alter the chemical composition. Solid electrodes, when analyzed for elements that are present in a coating (copper flashing, for example), shall be analyzed without removing the coating. When the electrode is analyzed for elements other than those in the coating, the coating shall be removed if its presence affects the results of the analysis for other elements. Rod stock may be analyzed prior to coating for those elements not added in the coating. In this case, the analysis of the elements in the electrode coating must be made on the finished electrode.

10.2 Composite electrodes shall be analyzed in the form of weld metal. The sample for analysis shall be taken from weld metal obtained with the electrode and the flux with which it is classified. The sample shall come from the weld pad in Figure 2, from the reduced section of the fractured tension test specimen (see 12.1), or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 3A. In case of dispute, the weld pad shall be the referee method.

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 of the fourth layer of the weld pad by any appropriate mechanical means. The sample shall be free of slag.

The alternatives to the weld pad outlined above and in 9.1.2 shall be prepared for analysis by any appropriate mechanical means.

10.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be the procedure in the latest edition of ASTM E350, *Testing Methods for Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron.*

10.4 The results of the analysis shall meet the requirements of Table 1 or 2, as applicable, for the classification of electrode under test.

11. Radiographic Test

11.1 The groove weld described in 9.4 and shown in Figure 3A 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. 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 E142, *Method for Controlling Quality of Radiographic Testing*. 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 the following:

(1) No cracks, no incomplete fusion, and no incomplete penetration

(2) No slag inclusions longer than 5/16 in. [8 mm] or no groups of slag inclusions in line that have an aggregate length greater than 1 in. [25 mm] in a 12 in. [300 mm] length except when the distance between the successive inclusions exceeds 6 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 4

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

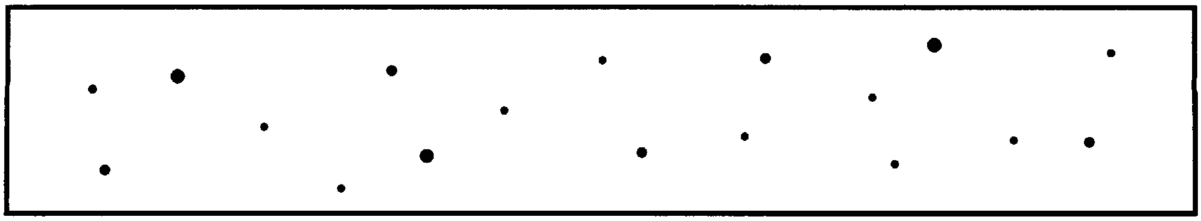
11.3.1 A rounded indication is an indication (on the radiograph) whose length is no more than 3 times its width. Rounded indications may be circular, or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present.

11.3.2 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 standard round tensile specimen, as specified in the Tension Tests section of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*, shall be machined from the groove weld described in 9.4 and shown in Figure 3A. The tensile specimen shall have a nominal diameter of 0.500 in. [12.5 mm] and a nominal gage length-to-diameter ratio of 4:1.

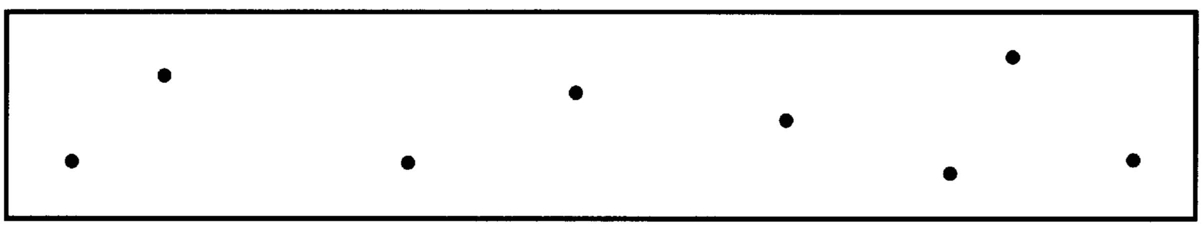
12.2 The specimen shall be tested in the manner described in the tension test section of the latest edition of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds.*



(A) ASSORTED ROUNDED INDICATIONS

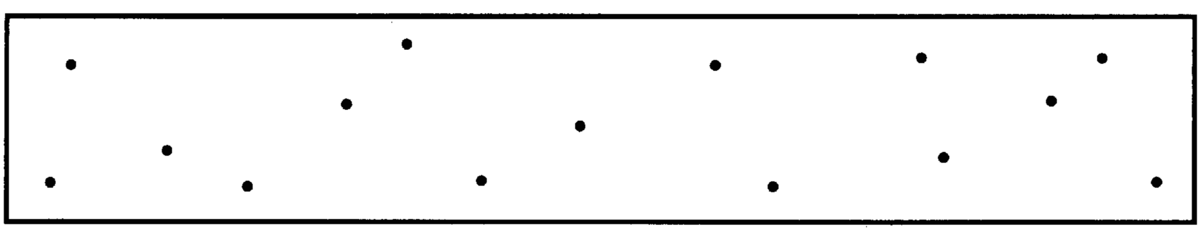
SIZE PERMITTED IS 1/64 in. [0.4 mm] TO 1/16 in. [1.6 mm]
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD = 18,
WITH THE FOLLOWING RESTRICTIONS:

LARGE:	3/64 in. [1.2 mm] TO 1/16 in. [1.6 mm] =	3 PERMITTED.
MEDIUM:	1/32 in. [0.8 mm] TO 3/64 in. [1.2 mm] =	5 PERMITTED.
SMALL:	1/64 in. [0.4 mm] TO 1/32 in. [0.8 mm] =	10 PERMITTED.



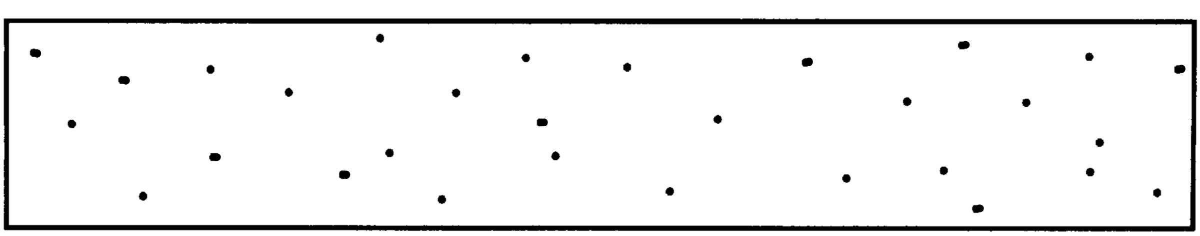
(B) LARGE ROUNDED INDICATIONS

SIZE PERMITTED IS 3/64 in. [1.2 mm] TO 1/16 in. [1.6 mm]
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD = 8.



(C) MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 1/32 in. [0.8 mm] TO 3/64 in. [1.2 mm]
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD = 15.



(D) SMALL ROUNDED INDICATIONS

SIZE PERMITTED IS 1/64 in. [0.4 mm] TO 1/32 in. [0.8 mm]
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD = 30.

Notes:
1. The chart which is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used for determination of conformance with this specification. Rounded indications smaller than 1/64 in. [0.4 mm] shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.
2. These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those usually encountered in general fabrication. They are equivalent to the Grade 1 standards of ANSI/AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding.*

Figure 4—Radiographic Standards for Rounded Indication

12.3 The results of the tension test shall meet the requirements specified in Table 5U or Table 5M, as applicable.

13. Impact Test

13.1 For those classifications for which impact testing is specified in Table 3, five Charpy V-notch impact specimens, as specified in the Fracture Toughness Testing of Welds section of ANSI/AWS B4.0, shall be machined from the test assembly shown in Figure 3A.

The Charpy V-notch specimens shall have the notched surface and the surface to be struck parallel within 0.002 in. [0.05 mm]. The other two surfaces shall be square with the notched or struck surface 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 minimum 50 times magnification on either a shadowgraph or a 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 impact test section of ANSI/AWS B4.0. The test temperature shall be as specified in Table 6U or Table 6M, as applicable, for the classification under test.

13.3U 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 energy level. One of the three may be lower, but not lower than 15 ft·lbf, and the average of the three shall not be less than the required 20 ft·lbf energy level.

13.3M 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 27 J energy level. One of the three may be lower, but not lower than 20 J, and the average of the three shall not be less than the required 27 J energy level.

14. Diffusible Hydrogen Test

14.1 For each flux-electrode combination to be identified by a diffusible hydrogen designator, that combination shall be tested in the as-manufactured condition according to one of the methods given in ANSI/AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*. The welding procedure shown in Figure 3B for the Groove Weld Test assembly shall be used for the diffusible hydrogen test. The travel speed, however, may be increased up to a maximum of 28 in./min [12 mm/s]. This adjustment in travel speed is permitted in order to establish a weld bead width that is appropriate for the specimen. The electrode, flux, or both, may be baked to restore the moisture content before testing to the as-manufactured condition. When this is done, the baking time and temperature shall be noted on the test report. The manufacturer of the electrode, flux, or both, should be consulted for their recommendation regarding the time and temperature for restoring their products to the as-manufactured condi-

Table 5U
A5.17 Tension Test Requirements

Flux-Electrode Classification[a]	Tensile Strength psi	Yield Strength[b] psi	Elongation[b] %
F6XX-EXXX	60 000–80 000	48 000	22
F7XX-EXXX	70 000–95 000	58 000	22

Notes:
a. The letter "S" will appear after the "F" as part of the classification designation when the flux being classified is a crushed slag or a blend of crushed slag with unused (virgin) flux. The letter "C" will appear after the "E" as part of the classification designation when the electrode being classified is a composite electrode. The letter "X" used in various places in this table stands for, respectively, the condition of heat treatment, the toughness of the weld metal, and the classification of the electrode. See Figure 1U for a complete explanation of the classification designators.
b. Minimum requirements. Yield strength at 0.2 percent offset and elongation in 2 in. gage length.

Table 5M
A5.17M Tension Test Requirements

Flux-Electrode Classification[a]	Tensile Strength MPa	Yield Strength[b] MPa	Elongation[b] %
F43XX-EXXX	430–560	330	22
F48XX-EXXX	480–660	400	22

Notes:
a. The letter "S" will appear after the "F" as part of the classification designation when the flux being classified is a crushed slag or a blend of crushed slag with unused (virgin) flux. The letter "C" will appear after the "E" as part of the classification designation when the electrode being classified is a composite electrode. The letter "X" used in various places in this table stands for, respectively, the condition of heat treatment, the toughness of the weld metal, and the classification of the electrode. See Figure 1M for a complete explanation of the classification designators.
b. Minimum requirements. Yield strength at 0.2 percent offset and elongation in 51 mm gage length.

Table 6U
A5.17 Impact Test Requirements[a,b]

Digit	Maximum Test Temperature °F	Minimum Average Energy Level
0	0	20 ft·lbf
2	–20	
4	–40	
5	–50	
6	–60	
8	–80	
Z	No impact requirements	

Notes:
a. Based on the results of the impact tests of the weld metal, the manufacturer shall insert in the classification the appropriate digit from the table above (Table 6U), as indicated in Figure 1U.
b. Weld metal from a specific flux-electrode combination that meets impact requirements at a given temperature also meets the requirements at all higher temperatures in this table (i.e., weld metal meeting the requirements for digit 5 also meets the requirements for digits 4, 2, 0, and Z).

Table 6M
A5.17M Impact Test Requirements[a,b]

Digit	Maximum Test Temperature °C	Minimum Average Energy Level
0	0	27 Joules
2	–20	
3	–30	
4	–40	
5	–50	
6	–60	
Z	No impact requirements	

Notes:
a. Based on the results of the impact tests of the weld metal, the manufacturer shall insert in the classification the appropriate digit from the table above (Table 6M), as indicated in Figure 1M.
b. Weld metal from a specific flux-electrode combination that meets impact requirements at a given temperature also meets the requirements at all higher temperatures in this table (i.e., weld metal meeting the requirements for digit 5 also meets the requirements for digits 4, 3, 2, 0, and Z).

tion. The diffusible hydrogen designator may be added to the classification designation according to the average test values as compared to the requirements of Table 7.

14.2 For purposes of certifying compliance with diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of 10 grains of moisture per pound [1.5 grams of moisture per kg] of dry air at the time of welding. The actual atmospheric conditions shall be reported along with the average diffusible hydrogen value for the test according to ANSI/AWS A4.3.

14.3 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 that the actual test results satisfy the diffusible hydrogen requirements for a given designator, as specified in Table 7.

Part C
Manufacture, Identification, and Packaging

15. Method of Manufacture

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

Crushed Slags. Slag formed during the welding process that is subsequently crushed for use as a welding flux is defined as *crushed slag*. Crushed slag and blends of crushed slag with unused (virgin) flux may be classified as a welding flux under this specification. The letter "S" shall be used as a mandatory classification designator as shown in Figures 1U and 1M when the flux being classified is a crushed slag or is a blend of crushed slag with virgin flux. (See A6.1.5 in the Annex.)

16. Electrode Requirements

16.1 Standard Sizes. Standard sizes for electrodes in the different package forms (coils with support, coils without support, and drums) are shown in Table 8U or Table 8M, as applicable.

16.2 Finish and Uniformity

16.2.1 The electrode shall have a smooth finish which is free from slivers, depressions, scratches, scale, seams and laps (exclusive of the longitudinal joint in composite electrodes), and foreign matter that would adversely affect the welding characteristics, the operation of the welding equipment, or the properties of the weld metal.

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

Table 7
Diffusible Hydrogen Requirements[a]

AWS Flux-Electrode Combination Classification	Optional Supplemental Diffusible Hydrogen Designator[b]	Average Diffusible Hydrogen, Maximum[c] (mL/100g Deposited Metal)
All	H16	16.0
All	H8	8.0
All	H4	4.0
All	H2	2.0

Notes:
a. Diffusible hydrogen test is required only when specified by the purchaser or when the manufacturer puts the diffusible hydrogen designator on the label (see also Section A3 and A6.4 in the Annex).
b. This designator is added to the end of the complete flux-electrode classification (see Figures 1U and 1M).
c. Flux-electrode combinations meeting requirements for an H2 designator also meet the requirements for H4, H8, and H16. Flux-electrode combinations meeting requirements for an H4 designator also meet the requirements for H8 and H16. Flux-electrode combinations meeting the requirements for an H8 designator also meet the requirements for H16.

Table 8U
A5.17 Standard Electrode Sizes and Tolerances[a]

Diameter (in.)	Tolerance (± in.) Solid (E)	Tolerance (± in.) Composite (EC)
1/16 or 0.062	0.002	0.003
5/64 or 0.078	0.002	0.003
3/32 or 0.094	0.002	0.003
7/64 or 0.109	0.003	0.004
1/8 or 0.125	0.003	0.004
5/32 or 0.156	0.004	0.005
3/16 or 0.188	0.004	0.005
7/32 or 0.219	0.004	0.005
1/4 or 0.250	0.004	0.005

Note:
a. Other sizes and tolerances may be supplied as agreed between purchaser and supplier.

Table 8M
A5.17M Standard Electrode Sizes and Tolerances[a]

Diameter (mm)	Tolerance (mm) Solid (E)	Tolerance (mm) Composite (EC)
1.6, 2, 2.4, 2.5, 2.8	±0.04	+0.04, −0.05
3, 3.2, 4, 4.8, 5, 5.6, 6, 6.4	±0.06	+0.06, −0.08

Note:
a. Other sizes and tolerances may be supplied as agreed between purchaser and supplier.

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

16.2.4 A suitable protective coating, such as copper, may be applied to any electrode covered in this specification.

16.3 Standard Package Forms

16.3.1 Standard package forms are coils with support, coils without support, and drums. Standard package dimensions and weights for each form are given in Table 9. Package forms, sizes and weights other than these shall be as agreed between purchaser and supplier.

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

16.3.3 Drums shall be designed and constructed to prevent distortion of the electrode during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the electrode.

16.4 Winding Requirements

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

Table 9
Standard Dimensions and Weights[a,b]

	Electrode Size[c]		Net Weight of Coil[d]		Inside Diameter of Liner		Width of Coil, Max.		Outside Diameter of Coil, Max	
	in.	mm	lb	kg	in.	mm	in.	mm	in.	mm
Coils with Support	1/16–1/4		25 50 60 65		12 ± 1/8		2-1/2 or 4-5/8		17-1/2 or 17	
		1.6–6.4		12 15 20 25 30		300 +15, –0		e		e
	3/32–1/4		100 150 200		e		5		31-1/2	
		2.4–6.4		45 70 90 100		610 ± 10		130		800
Coils without Support	1/16–1/4	1.6–6.4	As agreed between purchaser and supplier							
Drums	1/16–1/4	1.6–6.4	As agreed between purchaser and supplier							

Notes:
a. Values specified in "in." or "lb" apply to A5.17. Values specified in "mm" or "kg" apply to A5.17M.
b. Other dimensions and weights may be supplied as agreed between purchaser and supplier.
c. The range is inclusive.
d. Net weights shall not vary more than ± 10 percent.
e. This dimension shall be as agreed between the purchaser and supplier.

16.4.2 The cast and helix of the electrode in coils and drums shall be such that the electrode will feed in an uninterrupted manner in automatic and semiautomatic equipment.

16.5 Electrode Identification

16.5.1 The product information and the precautionary information required in 16.7 for marking each package shall appear also on each coil and drum.

16.5.2 Coils without support shall be identified by a tag containing this information securely attached to the inside end of the coil.

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

16.5.4 Drums shall have the information securely affixed in a prominent location on the side of the drum.

16.6 Packaging. Electrodes shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

16.7 Marking of Packages

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

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

(2) Supplier's name and trade designation

(3) In the case of a composite electrode, the trade designation of the flux (or fluxes) with which its weld metal composition meets the requirements of Table 2

(4) Size and net weight

(5) Lot, control or heat number.

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

WARNING:

PROTECT yourself and others. Read and understand this information.

FUMES and GASES can be hazardous to your health.

ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can KILL.

- Before use, read, and understand the manufacturer's instructions, Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch live electrical parts.
- See American National Standard ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; and OSHA Safety and Health Standards, *29 CFR 1910*, available from the U.S. Government Printing Office, Washington, DC 20402.

DO NOT REMOVE THIS INFORMATION

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17. Flux Requirements

17.1 Form and Particle Size. Flux shall be granular in form and shall be capable of flowing freely through the flux feeding tubes, valves, and nozzles of standard submerged arc welding equipment. Particle size is not specified here, but, when it is addressed, it shall be a matter of agreement between the purchaser and the supplier.

17.2 Usability. The flux shall permit the production of uniform, well-shaped beads that merge smoothly with each other and the base metal. Undercut, if any, shall not be so deep or so widespread that a subsequent bead will not remove it.

17.3 Packaging

17.3.1 Flux shall be suitably packaged to ensure against damage during shipment.

17.3.2 Flux, in its original unopened container, shall withstand storage under normal conditions for at least six months without damage to its welding characteristics or the properties of the weld. Heating of the flux to assure dryness may be necessary when the very best properties (of which the materials are capable) are required. For specific recommendations, consult the manufacturer.

17.4 Marking of Packages

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

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

(2) Supplier's name and trade designation (In the case of crushed slags, the crusher, not the original producer, shall be considered the supplier. See also Annex A6.1.5.)

(3) The trade designation of each composite electrode with which the flux manufacturer has classified the flux, if applicable

(4) Net weight

(5) Lot, control, or heat number

(6) Particle size, if more than one particle size of flux of that trade designation is produced

17.4.2 All packages of flux shall be marked as required in 16.7.2 for the electrodes.

Annex

Guide to AWS Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding

(This Annex is not a part of ANSI/AWS A5.17/A5.17M-97, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*, but is included for information purposes only).

A1. Introduction

The purpose of this guide is to correlate the electrode and flux classifications with their intended applications so the specification can be used effectively. Reference to appropriate base metal specifications is made whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the base metals for which each electrode and flux combination is suitable.

A2. Classification System

A2.1 Classification of Electrodes. The system for identifying the electrode classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The letter "E" (or "EC" for composite electrodes) at the beginning of each classification designation stands for electrode. The remainder of the designation indicates the chemical composition of the electrode or, in the case of composite electrodes, the chemical composition of the weld metal obtained with a particular flux. See Figure 1U or Figure 1M, as applicable.

The letter "L" indicates that the solid electrode is comparatively low in manganese content. The letter "M" indicates a medium manganese content, while the letter "H" indicates a comparatively high manganese content. The one or two digits following the manganese designator indicate the nominal carbon content of the electrode. The letter "K," which appears in some designations, indicates that the electrode is made from a heat of silicon-killed steel. Solid electrodes are classified only on the basis of their chemical composition, as specified in Table 1 of this specification.

A composite electrode is indicated by the letter "C" after the "E" and a numerical suffix. The composition of a composite electrode may include metallic elements in the core material that are also present as oxides, fluorides, etc., of those same elements. Therefore, the chemical analysis of a composite electrode may not be directly comparable to an analysis made on a solid electrode. For this reason, the composition of composite electrodes is not used for classification purposes under this specification, and the user is referred to weld metal composition (Table 2) with a particular flux, rather than to electrode composition.

A2.2 'G' Classification and the Use of 'Not Specified' and 'Not Required'

A2.2.1 This specification includes filler metals classified as "EG" or "ECG." 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 without awaiting revision. 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).

A2.2.2 The point of difference (although not necessarily the amount of the 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 normally is required to be conducted to classify a filler metal. It indicates that the test is not required because the requirements (results) 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 a 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 also 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 ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*, in the purchase order.

A2.2.3 Request for Filler Metal Classification

(1) When a filler metal cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that filler metal. The manufacturer may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the Committee on Filler Metals recommends that the manufacturer still request that a classification be established for that filler metal, as long as the filler metal is of commercial significance.

(2) A request to establish a new filler metal classification must be submitted in writing, and it needs to provide sufficient detail to permit the Committee on Filler Metals or the Subcommittee to determine whether a new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. The request needs to state the variables and their limits, for such a classification or modification. The request should contain some indication of the time by which completion of the new classification or modification is needed.

(3) The request should be sent to the Secretary of the Committee on Filler Metals 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 the particular Subcommittee involved.

(d) File the original request.

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

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

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

A2.3 Classification of Fluxes. Fluxes are classified on the basis of the mechanical properties of the weld metal they produce, with some certain classification of electrode, under the specific test conditions called for in Part B of this specification.

A2.3.1U As examples of A5.17 U.S. Customary Unit classifications, consider the following:

F7A2-EH14
FS6A0-EM13K
F7P6-EM12K
F7P4-EC1

The prefix "F" designates an unused (virgin) flux. The prefix "FS" designates a flux that is made solely from crushed slag or is a blend of crushed slag with virgin flux. This is followed by a single digit representing the minimum tensile strength required of the weld metal in 10 000 psi increments.

When the letter "A" follows the strength designator, it indicates that the weld metal was tested (and is classified) in the as-welded condition. When the letter "P" follows the strength designator, it indicates that the weld metal was tested (and is classified) after postweld heat treatment called for in the specification. The digit that follows the "A" or "P" will be a number or the letter "Z." This digit refers to the impact strength of the weld metal. Specifically, it designates, on the Fahrenheit scale, a temperature at (and above) which the weld metal meets, or exceeds, the required 20 ft lbf Charpy V-notch impact strength (except for the letter "Z," which indicates that no impact requirement is specified—see Table 6U).[4] These mechanical property designations are followed by the designation of the electrode used in classifying the flux (see Tables 1 and 2). The suffix (EH14, EM12K, EC1, etc.) included after the hyphen refers to the electrode classification with which the flux will deposit weld metal that meets the specified mechanical properties when tested as called for in the specification.

A2.3.1M As examples of A5.17M International System of Units (SI) classifications, consider the following:

F43A3-EM13K
FS43A0-EM11K
F48P5-EH12K

The prefix "F" designates a virgin flux. The prefix "FS" designates a flux that is made solely from crushed slag or is a blend of crushed slag with virgin flux. This is followed by two digits representing the minimum tensile strength required of the weld metal in 10 MPa increments.

When the letter "A" or "P" follows the strength designators, it indicates, as it does in the A5.17 classification system, the weld metal was tested (and is classified) in either the as-welded (A) or postweld heat-treated (P) condition. The digit that follows the "A" or "P" will be a number or the letter "Z." This digit refers to the impact strength of the weld metal.

Specifically, it designates, on the Celsius scale, a temperature at (and above) which the weld metal meets, or exceeds, the required 27 J Charpy V-notch impact strength (except for the letter "Z," which indicates that no impact requirement is specified—see Table 6M). These mechanical property designations are followed by the designation of the electrode used in classifying the flux (see Tables 1 and 2). The suffix (EM13K, EH12K, etc.) included after the hyphen refers to the electrode classification with which the flux will deposit weld metal that meets the specific mechanical properties when tested as called for in the specification.

A2.3.2 It should be noted that flux of any specific trade designation may have many classifications. The number is limited only by the number of different electrode classifications and the condition of heat treatment (as-welded and postweld heat treated) with which the flux can meet the classification requirements. The flux marking lists at least one, and may list all, classifications to which the flux conforms. It should also be noted that the specific usability (or operating) characteristics of various fluxes of the same classification may differ in one respect or another.

A2.3.3 Solid electrodes having the same classification are interchangeable when used with a specific flux; composite electrodes may not be.

A2.4 International Designation System. An international system for designating welding filler metals is under development by the International Institute of Welding (IIW) for use in future specifications to be issued by the International Standards Organization (ISO). Table A1 shows the proposed designations for steel filler metals. In that system, the initial "S" designates a solid wire or rod followed by a four-digit number. Composite wires are designated with an initial "T."

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with the latest edition of ANSI/AWS A5.01, as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, in accordance with ANSI/AWS A5.01.

Table A1
Comparison of Electrode Designations

AWS Classification	Proposed ISO No.*
EL8	S1100
EL8K	S1110
EL12	S1000
EM11K	S2030
EM12	S2000
EM12K	S2010
EM13K	S2020
EM14K	S2021
EM15K	S2210
EH10K	S3000
EH11K	S3030
EH12K	S3010
EH14	S4000

*Based on IIW Doc. XII-1232-91.

4. Note that except for digit "4" the same designator for impact strength in Tables 6U and 6M signify different temperatures. For example, "6" in Table 6U signifies a maximum test temperature of –60°F, whereas the same designator in Table 6M signifies a maximum test temperature of –60°C, equivalent to –76°F.

In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing is normally conducted on material of that classification, as specified in Schedule F, Table 1, of ANSI/AWS A5.01. Testing in accordance with any other Schedule in that Table must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

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

The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation.

"Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been made. The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance System" in ANSI/AWS A5.01.

A5. Ventilation During Welding

A5.1 The following are five major factors which govern the quantity of fumes to which welders and welding operators can be exposed during welding:

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

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

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

(4) The proximity of the welders or welding operators to the fumes as they issue from the welding zone, and to the gases and dusts in the space in which the welders or welding operators are working

(5) The ventilation provided to the space in which the welding is done

A5.2 American National Standard ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is particularly drawn to the section dealing with ventilation.

A6. Welding Considerations

A6.1 Types of Flux. Submerged arc welding fluxes are granular, fusible mineral compounds of various proportions and quantities, manufactured by any of several different methods. In addition, some fluxes may contain intimately mixed metallic ingredients to deoxidize the weld pool. Any flux is likely to produce weld metal of somewhat different composition from that of the electrode used with it due to chemical reactions in the arc and sometimes to the presence of metallic ingredients in the flux. A change in arc voltage during welding will change the quantity of flux interacting with a given quantity of electrode and may, therefore, change the composition of the weld metal. This latter change provides a means of describing fluxes as "neutral," "active," or "alloy."

A6.1.1 Neutral Fluxes. Neutral fluxes are those which will not produce any significant change in the weld metal chemical analysis as a result of a large change in the arc voltage, and thus, the arc length.

The primary use for neutral fluxes is in multipass welding, especially when the base metal exceeds 1 in. [25 mm] in thickness.

Note the following considerations concerning neutral fluxes:

(1) Since neutral fluxes contain little or no deoxidizers, they must rely on the electrode to provide deoxidation. Single-pass welds with insufficient deoxidation on heavily oxidized base metal may be prone to porosity, centerline cracking, or both.

(2) While neutral fluxes do maintain the chemical composition of the weld metal even when the voltage is changed, it is not always true that the chemical composition of the weld metal is the same as the chemical composition of the electrode used. Some neutral fluxes decompose in the heat of the arc and release oxygen, resulting in a lower carbon value in the weld metal than the carbon content of the electrode itself. Some neutral fluxes contain manganese silicate which can decompose in the heat of the arc to add some manganese and silicon to the weld metal even though no metallic manganese or silicon was added to these particular fluxes. These changes in the chemical composition of the weld metal are fairly consistent, even when there are large changes in voltage.

(3) Even when a neutral flux is used to maintain the weld metal chemical composition through a range of welding voltages, weld properties such as strength level

and impact properties can change because of changes in other welding parameters such as depth of fusion, heat input, and number of passes.

A6.1.2 Active Fluxes. Active fluxes are those which contain small amounts of manganese, silicon, or both. These deoxidizers are added to the flux to provide improved resistance to porosity and weld cracking caused by contaminants on or in the base metal.

The primary use for active fluxes is to make single-pass welds, especially on oxidized base metal. Note the following considerations concerning active fluxes:

(1) Since active fluxes do contain some deoxidizers, the manganese, silicon, or both, in the weld metal will vary with changes in arc voltage. An increase in manganese or silicon increases the strength and hardness of the weld metal in multipass welds but may lower the impact properties. For this reason, the voltage may need to be more tightly controlled for multipass welding with active fluxes than when using neutral fluxes.

(2) Some fluxes are more active than others. This means they offer more resistance to porosity due to base-metal surface oxides in single-pass welds than a flux which is less active, but may pose more problems in multipass welding.

A6.1.3 Alloy Fluxes. Alloy fluxes are those which can be used with a carbon steel electrode to make alloy weld metal. The alloys for the weld metal are added as ingredients in the flux.

The primary use for alloy fluxes is to weld low-alloy steels and for hardfacing. As such, they are outside of the scope of this specification. See the latest edition of ANSI/AWS A5.23/A5.23M, *Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*, for a more complete discussion of alloy fluxes.

A6.1.4 Wall Neutrality Number. The Wall Neutrality Number (N) is a convenient relative measure of flux neutrality. The Wall Neutrality Number addresses fluxes and electrodes for welding carbon steel with regard to the weld metal manganese and silicon content. It does not address alloy fluxes. For a flux-electrode combination to be considered neutral, it should have a N of 35 or less. The lower the number, the more neutral is the flux.

Determination of the Wall Neutrality Number can be done in accordance with the following:

(1) A weld pad of the type shown in Figure 2 is welded with the flux-electrode combination being tested. The welding parameters shall be as specified in Figure 3B for the weld test plate for the diameter electrode being used.

(2) A second weld pad is welded using the same parameters, except that the arc voltage is increased by 8 volts.

(3) The top surface of each of the weld pads is ground or machined smooth to clean metal. Samples sufficient for analysis are removed by machining. Weld metal is analyzed only from the top (fourth) layer of the weld pad. The samples are analyzed separately for silicon and manganese.

(4) The Wall Neutrality Number depends on the change in silicon, regardless of whether it increases or decreases, and on the change in manganese, regardless of whether it increases or decreases. The Wall Neutrality Number is the absolute value (ignoring positive or negative signs) and is calculated as follows:

$$N = 100\,(|\Delta\%\mathrm{Si}| + |\Delta\%\mathrm{Mn}|)$$

where $\Delta\%$ Si is the difference in silicon content of the two pads, and $\Delta\%$ Mn is the corresponding difference in manganese content.

A6.1.5 Crushed Slags. Slag formed during the welding process that is subsequently crushed for use as a welding flux is defined as *crushed slag*. This is different from a recycled flux which was never fused into a slag and can often be collected from a clean surface and reused without crushing. Crushed slag and blends of crushed slag with unused (virgin) flux may be classified as a welding flux under this specification, but shall not be considered to be the same as virgin flux.

Although it is possible to crush and reuse submerged arc slag as a welding flux, the crushed slag, regardless of any addition of virgin flux to it, is a new and chemically different flux. This is because the slag formed during submerged arc welding does not have the same chemical composition or welding characteristics as the virgin flux. Its composition is affected by the composition of the original flux, chemical reactions which occur due to the welding arc, the base metal and electrode compositions, and the welding parameters.

Blends of crushed slag with the original brand of virgin flux from which it was generated cannot be assumed to conform to the classification of either component, even when both the crushed slag and virgin flux conform to the same classification (except for the "S" designator). It shall be the responsibility of the crusher or fabricator partner, who performs the blending, to verify that any intended blend of crushed slag with the original brand of virgin flux is in full conformance with the classification requirements of this specification.

As with any flux product, the manufacturer (crusher) shall follow a detailed processing procedure with controlled input material, preparation, crushing, and blending, which will ensure that a standard quality of output welding flux product is attained that meets the requirement for the classification designator.

A6.1.6 Closed-Loop, Crushed Slags. Slag generated by a fabricator from a specific brand of flux under controlled welding conditions and crushed for subsequent reuse by the same fabricator is defined as *closed-loop, crushed slag*.

Closed-loop, crushed slags, or blends of closed-loop, crushed slag with the original brand of virgin flux ensure better control of input material by virtue of the inherent partnering of the fabricator with the crusher. In some instances, these partners may be one and the same. If blending of slag with virgin flux is done, changes in the original brand of virgin flux or in the blending ratio can affect the quality of the final product.

A6.2 Choice of Electrodes. In choosing an electrode classification for submerged arc welding of carbon steel, the most important considerations are the manganese and silicon contents in the electrode, the effect of the flux on recovery of manganese and silicon in the weld metal, whether the weld is to be single pass or multipass, and the mechanical properties expected of the weld metal.

A certain minimum weld-metal manganese content is necessary to avoid centerline cracking. This minimum depends upon restraint of the joint and upon the weld-metal composition. In the event that centerline cracking is encountered, especially with a low-manganese electrode (see Table 1) and neutral flux, a change to a higher manganese electrode, a change to a more active flux, or both, may eliminate the problem.

Certain fluxes, generally considered to be neutral, tend to remove carbon and manganese to a limited extent and to replace these elements with silicon. With such fluxes, a silicon-killed electrode is often not necessary though it may be used. Other fluxes add no silicon and may therefore require the use of a silicon-killed electrode for proper wetting and freedom from porosity. The flux manufacturer should be consulted for electrode recommendations suitable for a given flux.

In welding single-pass fillet welds, especially on scaly base metal, it is important that the flux, electrode, or both, provide sufficient deoxidation to avoid unacceptable porosity. Silicon is a more powerful deoxidizer than manganese. In such applications, use of a silicon-killed electrode or of an active flux, or both, may be essential. Again, manufacturer's recommendations should be consulted.

The EM14K electrodes are alloyed with small amounts of titanium, although they are considered as carbon steel electrodes. The titanium functions to improve strength and notch toughness under certain conditions of high-heat input welding or PWHT. The manufacturer's recommendations should be consulted.

Electrodes of the EH12K classification are high Mn electrodes with the Mn and Si balanced to enhance impact properties on applications that require high deposition rates or multiple arc procedures, or both, in both the as-welded and postweld heat-treated conditions.

Composite electrodes are generally designed for a specific flux. The flux identification is required (see 16.7.1) to be marked on the electrode package. Before using a composite electrode with a flux not indicated on the electrode package markings, the electrode producer should be contacted for recommendations. A composite electrode might be chosen for higher melting rate and lower depth of fusion at a given current level than would be obtained under the same conditions with a solid electrode.

A6.3 Mechanical Properties of Submerged Arc Welds. Tables 5U and 6U (for the U.S. Customary Units classification system) and Tables 5M and 6M (for the International System of Units classification system) of this specification list the mechanical properties required of weld metal from flux-electrode classifications (the electrodes are classified in Tables 1 and 2). The mechanical properties are determined from specimens prepared according to the procedure called for in the specification. That procedure minimizes dilution from the base metal and thereby more accurately reflects the properties of the undiluted weld metal from each flux-electrode combination.

In use, the electrodes and fluxes are handled separately, and either of them may be changed without changing the other. For this reason, a classification system with standardized test methods is necessary to relate the electrodes and fluxes to the properties of their weld metal. Chemical reactions between the molten portion of the electrode and the flux, and dilution by the base metal all affect the composition of the weld metal.

Submerged arc welds are not always made with the multipass procedure required in the specification. They frequently are made in a single pass, at least within certain limits on the thickness of the base metal. When a high level of notch toughness is required, multipass welds may be necessary.

The specific mechanical properties of a weld are a function of its chemical composition, cooling rate, and postweld heat treatment. High-amperage, single-pass welds have greater depth of fusion and hence, greater dilution by the base metal than lower current, multipass welds. Moreover, large, single-pass welds solidify and cool more slowly than the smaller weld beads of a multipass weld. Furthermore, the succeeding passes of a multipass weld subject the weld metal of previous passes to a variety of temperature and cooling cycles that alter the metallurgical structure of different portions of those beads. For this reason, the properties of a single-pass weld may be somewhat different from those of a multipass weld made with the same electrode and flux.

The weld metal properties in this specification are determined either in the as-welded condition or after a postweld heat treatment (one hour at 1150°F [620°C]), or both. Most of the weld metals are suitable for service in either condition, but the specification cannot cover all of the conditions that such weld metals may encounter in fabrication and service. For this reason, the classifications in this specification require that the weld metals be produced and tested under certain specific conditions.

Procedures employed in practice may require voltage, amperage, type of current, and travel speeds that are considerably different from those required in this specification. In addition, differences encountered in electrode size, electrode composition, electrode extension, joint configuration, preheat temperature, interpass temperature, and postweld heat treatment can have a significant effect on the properties of the joint. Within a given electrode classification, the electrode composition can vary sufficiently to produce variations in the mechanical properties of the weld deposit in both the as-welded and postweld heat-treated conditions.

Postweld heat-treatment times in excess of the 1 hour used for classification purposes in this specification (conventionally, 20 to 30 hours for very thick sections) may have a major influence on the strength and toughness of the weld metal. Both can be substantially reduced. The user needs to be aware of this and of the fact that the mechanical properties of carbon steel weld metal produced with other procedures may differ from the properties required by Tables 5U and 6U or Tables 5M and 6M of this specification, as applicable.

A6.4 Diffusible Hydrogen. The submerged arc welding process can be used to provide low-hydrogen weld deposits when care is taken to maintain the flux and electrode in a dry condition. In submerged arc welding with carbon steel electrodes and fluxes classified in this specification, weld metal or heat-affected zone cracking associated with diffusible hydrogen tends to become more of a problem with increasing weld-metal strength, increasing heat-affected zone hardness, increasing diffusible hydrogen content, decreasing preheat and interpass temperature, and decreasing time at or above the interpass temperature during and after welding. The detection of hydrogen cracking may be delayed for several hours after cooling due to the time required for the crack to grow to a size which can be detected by routine inspection methods. It may appear as transverse weld cracks, longitudinal centerline cracks (especially in root beads), and toe or underbead cracks in the heat-affected zone.

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 a particular flux-electrode combination. Accordingly, the use of optional supplemental designators for diffusible hydrogen is introduced to indicate the maximum average value obtained under a clearly defined test condition in ANSI/AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*.

The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values from those indicated by the designator. The use of a reference atmospheric condition during welding is necessitated because the arc always is imperfectly shielded. Moisture from the air, distinct from that in the electrode or flux, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. This effect can be minimized by maintaining a suitable depth of flux cover (normally 1 to 1-1/2 in. [25 to 38 mm]) in front of the electrode during welding.

Nevertheless, some air will mix with the flux cover and add its moisture to the other sources of diffusible hydrogen.

It is possible for this extra diffusible hydrogen to significantly affect the outcome of a diffusible hydrogen test. For this reason, it is appropriate to specify a reference atmospheric condition. The reference atmospheric condition of 10 grains of moisture per lb [1.5 grams of moisture per kilogram] of dry air is equivalent to 10 percent relative humidity at 68°F [20°C].

A7. General Safety Considerations

A7.1 Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

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

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

The following sources are for more detailed information on personal protection:

(1) American National Standards Institute. ANSI/ASC Z41.1, *Safety-Toe Footwear.* New York, N.Y.: American National Standards Institute.[5]

(2) ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes.* Miami, Fla.: American Welding Society.

(3) ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection.* New York, N.Y.: American National Standards Institute.

(4) Occupational Safety and Health Administration. *Code of Federal Regulations,* Title 29 Labor, Chapter XVII, Part 1910. Washington, D.C.: U.S. Government Printing Office.[6]

A7.2 Electrical Hazards. Electric shock can kill; however, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

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

The correct cable size should be used, since sustained overloading will cause cable failure and result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce dangerous arcs and sparks. Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity.

To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber-soled shoes, or stand on a dry board or insulated platform. Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits.Worn, damaged, or bare cables should not be used. Open-circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating current machines are being used, the open-circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

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

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

A7.3 Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles that originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Management personnel and welders alike should be aware of the effects of these fumes and gases. The amount and composition of these fumes and gases depend upon the composition of the filler metal and base metal, welding process, current level, arc length, and other factors.

The possible effects of overexposure range from irritation of eyes, skin, and respiratory system to more severe complications. Effects may occur immediately or at some later time. Fumes can cause symptoms such as

5. ANSI documents are available from the American National Standards Institute, 11 West 42 Street, 13th Floor, New York, NY 10036.

6. OSHA documents are available from U.S. Government Printing Office, Washington, DC 20402.

nausea, headaches, dizziness, and metal fume fever. The possibility of more serious health effects exists when especially toxic materials are involved. In confined spaces, the shielding gases and fumes might displace breathing air and cause asphyxiation. One's head should always be kept out of the fumes. Sufficient ventilation, exhaust at the arc, or both, should be used to keep fumes and gases from the breathing zone and the general area.

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

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

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

(2) The recommended threshold limit values for fumes and gases may be found in *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*, published by the American Conference of Governmental Industrial Hygienists (ACGIH), 1330 Kemper Meadow Drive, Cincinnati, OH 45240-1634.

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

(4) Manufacturer's Material Safety Data Sheet for the product.

A7.4 Radiation. Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. One should become acquainted with the effects of this radiant energy.

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

A7.4.1 Ionizing Radiation. Ionizing radiation is produced by the electron beam welding process. It is ordinarily controlled within acceptance limits by use of suitable shielding enclosing the welding area.

A7.4.2 Nonionizing Radiation. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base-metal composition, fluxes, and any coating or plating on the base metal. Some processes, such as resistance welding and cold pressure welding, ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc welding when used properly), laser welding and torch welding, cutting, brazing, or soldering can produce quantities of nonionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by nonionizing radiant energy from welding include the following measures:

(1) One should not look at welding arcs except through welding filter plates which meet the requirements of ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, published by American National Standards Institute. It should be noted that transparent welding curtains are not intended as welding filter plates, but rather, are intended to protect passersby from incidental exposure.

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

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

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

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

A7.4.3 Ionizing radiation information sources include the following:

(1) AWS F2.1-78, *Recommended Safe Practices for Electron Beam Welding and Cutting*, available from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(2) Manufacturer's product information literature.

A7.4.4 The following include nonionizing radiation information sources:

(1) American National Standards Institute. ANSI/ASC Z136.1, *Safe Use of Lasers*, New York, N.Y.: American National Standards Institute.

(2) —. ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*. New York, N.Y.: American National Standards Institute.

(3) —. ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*. (published by AWS) Miami, Fla.: American Welding Society.

(4) Hinrichs, J. F. Project Committee on Radiation—Summary Report. *Welding Journal,* January 1978.

(5) Moss, C. E. "Optical Radiation Transmission Levels through Transparent Welding Curtains." *Welding Journal,* March 1979.

(6) Moss, C. E., and Murray, W. E. "Optical Radiation Levels Produced in Gas Welding, Torch Brazing, and Oxygen Cutting." *Welding Journal,* September 1979.

(7) Marshall, W. J., Sliney, D. H., *et al.* "Optical Radiation Levels Produced by Air-Carbon Arc Cutting Processes," *Welding Journal,* March 1980.

(8) National Technical Information Service. Nonionizing radiation protection special study no. 42-0053-77, *Evaluation of the Potential Hazards from Actinic Ultraviolet Radiation Generated by Electric Welding and Cutting Arcs.* Springfield, Va.: National Technical Information Service. ADA-033768.

(9) —.Nonionizing radiation protection special study No. 42-0312-77, *Evaluation of the Potential Retina Hazards from Optical Radiation Generated by Electrical Welding and Cutting Arcs.* Springfield, Va.: National Technical Information Service, ADA-043023.

AWS Filler Metal Specifications by Material and Welding Process

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

AWS Filler Metal Specifications and Related Documents

AWS Designation	Title
FMC	Filler Metal Comparison Charts
UGFM	Users Guide for Filler Metals
A4.2	Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Austenitic-Ferritic Stainless Steel Weld Metal
A4.3	Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding
A5.01	Filler Metal Procurement Guidelines
A5.1	Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding
A5.2	Specification for Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding
A5.3	Specification for Aluminum and Aluminum Alloy Electrodes for Shielded Metal Arc Welding
A5.4	Specification for Stainless Steel Welding Electrodes for Shielded Metal Arc Welding
A5.5	Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding
A5.6	Specification for Covered Copper and Copper Alloy Arc Welding Electrodes
A5.7	Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes
A5.8	Specification for Filler Metals for Brazing and Braze Welding
A5.9	Specification for Bare Stainless Steel Welding Electrodes and Rods
A5.10	Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods
A5.11	Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding
A5.12	Specification for Tungsten and Tungsten Alloy Electrodes for Arc Welding and Cutting
A5.13	Specification for Solid Surfacing Welding Rods and Electrodes
A5.14	Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods
A5.15	Specification for Welding Electrodes and Rods for Cast Iron
A5.16	Specification for Titanium and Titanium Alloy Welding Electrodes and Rods
A5.17	Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding
A5.18	Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding
A5.19	Specification for Magnesium Alloy Welding Electrodes and Rods
A5.20	Specification for Carbon Steel Electrodes for Flux Cored Arc Welding
A5.21	Specification for Composite Surfacing Welding Rods and Electrodes
A5.22	Specification for Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding
A5.23	Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
A5.24	Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods
A5.25	Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag
A5.26	Specification for Carbon and Low-Alloy Steel Electrodes for Electrogas Welding
A5.28	Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding
A5.29	Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding
A5.30	Specification for Consumable Inserts
A5.31	Specification for Fluxes for Brazing and Braze Welding
A5.32	Specification for Welding Shielding Gases

For ordering information, contact the AWS Order Department, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126. Telephones: (800) 334-9353, (305) 443-9353, ext. 280; FAX (305) 443-7559.