Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding
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. Additional requirements are included for sizes, marking, manufacturing, and packaging. The form and usability of the flux are also included. A guide is appended to the specification as a source of information concerning the classification system employed and the intended use of submerged arc fluxes and electrodes.

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

All standards (codes, specifications, recommended practices, methods, classifications, and guides) of the American Welding Society (AWS) are voluntary consensus standards that have been developed in accordance with the rules of the American National Standards Institute (ANSI). When AWS American National Standards are either incorporated in, or made part of, documents that are included in federal or state laws and regulations, or the regulations of other governmental bodies, their provisions carry the full legal authority of the statute. In such cases, any changes in those AWS standards must be approved by the governmental body having statutory jurisdiction before they can become a part of those laws and regulations. In all cases, these standards carry the full legal authority of the contract or other document that invokes the AWS standards. Where this contractual relationship exists, changes in or deviations from requirements of an AWS standard must be by agreement between the contracting parties.

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Official interpretations of any of the technical requirements of this standard may only be obtained by sending a request, in writing, to the appropriate technical committee. Such requests should be addressed to the American Welding Society, Attention: Managing Director, Standards Development, 8669 NW 36 St, # 130, Miami, FL 33166 (see Annex B). With regard to technical inquiries made concerning AWS standards, oral opinions on AWS standards may be rendered. These opinions are offered solely as a convenience to users of this standard, and they do not constitute professional advice. Such opinions represent only the personal opinions of the particular individuals giving them. These individuals do not speak on behalf of AWS, nor do these oral opinions constitute official or unofficial opinions or interpretations of AWS. In addition, oral opinions are informal and should not be used as a substitute for an official interpretation.

This standard is subject to revision at any time by the AWS A5 Committee on Filler Metals and Allied Materials. It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn. Comments (recommendations, additions, or deletions) and any pertinent data that may be of use in improving this standard are required and should be addressed to AWS Headquarters. Such comments will receive careful consideration by the AWS A5 Committee on Filler Metals and Allied Materials and the author of the comments will be informed of the Committee’s response to the comments. Guests are invited to attend all meetings of the AWS A5 Committee on Filler Metals and Allied Materials to express their comments verbally. Procedures for appeal of an adverse decision concerning all such comments are provided in the Rules of Operation of the Technical Activities Committee. A copy of these Rules can be obtained from the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.
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Foreword

This foreword is not part of this standard but is included for information purposes only.

This document is the second of the A5.17/A5.17M specifications which makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other, without combining values in any way. In selecting rational metric units, AWS A1.1, Metric Practice 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 the U.S. Customary and SI Units.

The current document is the sixth revision of the initial joint ASTM/AWS document issued in 1965. There are no additions or deletions of alloys, classifications, or tests in this revision. It has been revised to bring it up to date with the current practices and rules of the AWS A5 Committee on Filler Metals. The document evolution took place as follows:

Document Evolution

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<td>ASTM A558-65T</td>
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<tr>
<td>AWS A5.17-69</td>
<td>Specification for Bare Carbon Mild Steel Electrodes and Fluxes for Submerged Arc Welding</td>
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Comments and suggestions for improvement of this standard are welcome. They should be sent to the Secretary, AWS A5 Committee on Filler Metals and Allied Materials, American Welding Society, 8669 NW 36 St # 130, Miami, FL 33166.
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Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of carbon steel electrodes (both solid and composite) and flux-electrode combinations for submerged arc welding. Two-run flux-electrode classification is not addressed in this specification, but is addressed in AWS A5.23/A5.23M.

1.2 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to weld metal properties. The specification with the designation A5.17 uses U.S. Customary Units. The specification A5.17M uses SI units. The latter are shown within brackets [], in appropriate columns in tables and figures and in paragraphs numbered with an “M” suffix. Standard dimensions based on either system may be used for the sizing of electrodes, packaging or both under A5.17 or A5.17M specifications.

1.3 Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein. Some safety and health information can be found in Annex A, Clauses A5 and A9. Safety and health information is available from the following sources:

American Welding Society:

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

Material or Equipment Manufacturers:

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

Applicable Regulatory Agencies

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

2. Normative References

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

2.1 American Welding Society (AWS) Documents:

(1) AWS A1.1, Metric Practice Guide for the Welding Industry
(2) AWS A4.3, Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding
(3) AWS A5.01M/A5.01, Welding Consumables—Procurement of Filler Metals and Fluxes
(4) AWS A5.02/A5.02M, Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes
(5) AWS B4.0, Standard Methods for Mechanical Testing of Welds
(6) AWS B4.0M, Standard Methods for Mechanical Testing of Welds

2.2 American National Standards Institute (ANSI) Document:
(1) ANSI Z49.1, Safety in Welding, Cutting, and Allied Processes.

2.3 ASTM International (ASTM) Documents:
(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 E29, Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications
(8) ASTM E1032, Standard Test Method for Radiographic Examination of Weldments
(9) ASTM E2033, Standard Practice for Computed Radiology (Photostimulable Luminescence Method)
(10) ASTM E2698, Standard Practice for Radiological Examination Using Digital Detector Arrays

2.4 International Organization for Standardization (ISO) Document:
(1) ISO 80000-1, Quantities and Units — Part 1 General

3. Classification

3.1 The submerged arc welding electrodes and fluxes covered by this 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 from a multiple pass groove weld made with a combination of a particular flux and a particular classification of electrode, as specified in Tables 6 and 7.
(2) The condition of heat treatment in which the properties are obtained, as specified in 9.4 and as shown in Figure 1.
(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 submerged arc welding electrodes and fluxes covered by this 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 from a multiple pass groove weld made with a combination of a particular flux and a particular classification of electrode, as specified in Tables 6M and 7.
(2) The condition of heat treatment in which the properties are obtained, as specified in 9.4 and as 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.
MANDATORY CLASSIFICATION DESIGNATORS*

The letter “F” indicates a submerged arc welding flux. 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.

Indicates the minimum tensile strength (in increments of 10 000 psi) of weld metal deposited with the flux and a specific classification of electrode under the welding conditions specified in Figure 3 and Table 5. For example, when the designator is 7, the tensile requirement is 70 000 to 95 000 psi (see Table 6).

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 the temperature in °F at or above which the impact toughness of the weld metal referred to above meets or exceeds 20 ft·lbf (see Table 7).

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” will appear after the “E” as part of the electrode classification designation when the electrode is a composite electrode (refer to Table 2 for composite electrode classifications).

Optional supplemental diffusible hydrogen designator (see Table 8).

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

This designator is optional.

EXAMPLES

F7A2-EM12K is a complete designation for a flux-electrode classification. 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 toughness of at least 20 ft·lbf at –20°F when produced with an EM12K electrode under the conditions called for in this specification.

F6P6-EC1 is a complete designation for a flux-electrode classification when the trade name of the flux used for classification is indicated as well [see 16.7.1(3)]. It refers to a flux that will produce weld metal with that electrode which, in the postweld heat treated condition, will have a tensile strength of 60 000 to 80 000 psi and Charpy V-Notch impact toughness of at least 20 ft·lbf at –60°F under the conditions called for in this specification.

Figure 1—A5.17M Classification System for U.S. Customary Units
MANDATORY CLASSIFICATION DESIGNATORS

The letter “F” indicates a submerged arc welding flux. 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.

Indicates the minimum tensile strength [in increments of 10 megapascals (MPa)] of weld metal deposited with the flux and a specific classification of electrode under the welding conditions specified in Figure 3 and Table 5. For example, when the designator is 49, the tensile requirement is 490 MPa–660 MPa (see Table 6M).

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 the temperature in °C at or above which the impact toughness of the weld metal referred to above meets or exceeds 27 Joules (see Table 7).

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” will appear after the “E” as part of the electrode classification designation when the electrode is a composite electrode (refer to Table 2 for composite electrode classifications).

FXXXX – EXXX – HX

OPTIONAL SUPPLEMENTAL DESIGNATOR

Optional supplemental diffusible hydrogen designator (see Table 8).

EXAMPLES

F43A2-EM12K is a complete designation for a flux-electrode classification. It refers to a flux that will produce weld metal which, in the as-welded condition, will have a tensile strength of 430 MPa to 560 MPa and Charpy V-Notch impact toughness of at least 27 Joules at –20°C when produced with an EM12K electrode under the conditions called for in this specification.

F49P6-EC1 is a complete designation for a flux-electrode classification when the trade name of the flux used for classification is indicated as well [see 16.7.1(3)]. It refers to a flux that will produce weld metal with that electrode which, in the postweld heat treated condition, will have a tensile strength of 490 MPa to 660 MPa and Charpy V-Notch impact toughness of at least 27 Joules at –60°C under the conditions called for in this specification.

Figure 1M—A5.17M Classification System for the International System of Units (SI)
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<td>0.03–0.17</td>
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<tr>
<td>EM15K</td>
<td>K01515</td>
<td>0.10–0.20</td>
<td>0.80–1.25</td>
<td>0.10–0.35</td>
<td>0.030</td>
<td>0.030</td>
<td>0.35</td>
<td>—</td>
</tr>
<tr>
<td>High Manganese Electrodes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EH10K</td>
<td>K01210</td>
<td>0.07–0.15</td>
<td>1.30–1.70</td>
<td>0.05–0.25</td>
<td>0.025</td>
<td>0.025</td>
<td>0.35</td>
<td>—</td>
</tr>
<tr>
<td>EH11K</td>
<td>K11140</td>
<td>0.06–0.15</td>
<td>1.40–1.85</td>
<td>0.80–1.15</td>
<td>0.030</td>
<td>0.030</td>
<td>0.35</td>
<td>—</td>
</tr>
<tr>
<td>EH12K</td>
<td>K01213</td>
<td>0.06–0.15</td>
<td>1.50–2.00</td>
<td>0.20–0.65</td>
<td>0.025</td>
<td>0.025</td>
<td>0.35</td>
<td>—</td>
</tr>
<tr>
<td>EH14</td>
<td>K11585</td>
<td>0.10–0.20</td>
<td>1.70–2.20</td>
<td>0.10</td>
<td>0.030</td>
<td>0.030</td>
<td>0.35</td>
<td>—</td>
</tr>
</tbody>
</table>

\(^a\) The electrode shall be analyzed for the specific elements for which values are shown in this table. In addition, analysis is required to be reported for boron (B) if intentionally added, or if it is known to be present at levels greater than 0.0010%. 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%.  
\(^b\) Single values are maximum.  
\(^c\) ASTM DS-56 (SAE HS-1086), Metals & Alloys in the Unified Numbering System.  
\(^d\) The copper limit includes any copper coating that may be applied to the electrode.

<table>
<thead>
<tr>
<th>Electrode Classification</th>
<th>UNS Number(^a^2)</th>
<th>C</th>
<th>Mn</th>
<th>Si</th>
<th>S</th>
<th>P</th>
<th>Cu(^d)</th>
<th>Ti</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC1</td>
<td>W06041</td>
<td>0.15</td>
<td>1.80</td>
<td>0.90</td>
<td>0.035</td>
<td>0.035</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>ECG</td>
<td>Not Specified</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) The weld metal shall be analyzed for the specific elements for which values are shown in this table. In addition, analysis is required to be reported for boron (B) if intentionally added, or if it is known to be present at levels greater than 0.0010%. 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%.  
\(^b\) 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 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 HS-1086/ASTM DS-56, Metals & Alloys in the Unified Numbering System.
3.2 Fluxes may be classified under any number of classifications: for weld metal in either or both the as-welded and post weld heat treated conditions, for weld metal deposited using different electrode classifications, or any combination thereof. Flux-electrode combinations may be classified under A5.17 with U.S. Customary Units, under 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 of the requirements for classification under each system. The classification systems are shown in Figures 1 and 1M.

3.3 The electrodes and fluxes classified under this specification are intended for submerged arc welding, but may be used 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 AWS A5.01M/A5.01, or the tests and requirements of this specification. See A3 (in Annex A) for further information concerning acceptance, testing of the material shipped, and AWS A5.01M/A5.01.

5. Certification

By affixing the AWS specification and classification designations to the packaging or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification. See A4 (in Annex A) for further information concerning certification and the testing called for to meet this requirement.

6. Rounding Procedure

For purpose of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding rules of ASTM E29 or Rule A in Clause B.3 of ISO 80000-1 (the results are the same). If the measured values are obtained by equipment calibrated in units other than those of the specified limit, the measured values shall be converted to the units of the specified limit before rounding. If an average value is to be compared to the specified limit, rounding shall be done only after calculating the average. An observed or calculated value shall be rounded to the nearest 1000 psi (1 ksi) for tensile and yield strength for A5.17, to the nearest 10 MPa for tensile and 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. The rounded results shall fulf the requirements for the classification under test.

7. Summary of Tests

7.1 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 solid electrode is made may also be used provided the electrode manufacturing process does not alter the chemical composition. For composite electrodes, chemical analysis of the weld metal produced with the composite electrode and a particular flux is required.

7.2 The tests required for each flux-electrode classification are specified in Table 3. The purpose of these tests is to determine the mechanical properties and soundness of the weld metal. The base metal for test assemblies, preparation of the test samples, the welding and testing procedures to be employed, and the results required are given in Clauses 9 through 14.

7.3 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 Table 5.
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 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.

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 pad shown in Figure 2 is used to meet this requirement for the classification of composite electrodes. The welding parameters for the groove weld, as specified in Table 5, shall be used. 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 3. 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 or from a corresponding location (or any location above it) in the weld metal of the groove weld in Figure 3. 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 3 for mechanical properties and soundness of weld metal.

9.2 Weld Test Assemblies. Preparation of each weld test assembly shall be as specified in 9.3 and 9.4. The base metal for the weld pad and groove weld assemblies shall be as specified in Table 4 and shall meet the requirements of the ASTM specification shown there or a chemically equivalent steel. Testing of these assemblies shall be as prescribed in Clauses 10 through 13.

<table>
<thead>
<tr>
<th>AWS Classification</th>
<th>Chemical Analysis</th>
<th>Radiographic Test</th>
<th>Tension Test</th>
<th>Impact Test</th>
<th>Diffusible Hydrogen Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Solid Electrodes</td>
<td>Required</td>
<td>Not Required</td>
<td>Not Required</td>
<td>Not Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>All Composite Electrodes</td>
<td>Not Required</td>
<td>Required</td>
<td>Not Required</td>
<td>Not Required</td>
<td>Not Required</td>
</tr>
<tr>
<td>All Flux—Solid or Composite Electrode Classifications</td>
<td>Not Required</td>
<td>Not Required</td>
<td>Required</td>
<td>Required</td>
<td>Required*a</td>
</tr>
</tbody>
</table>

*a When the “Z” impact designator (no impact requirement per Table 7) 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 Table 8 and Clause A8).
For composite electrodes only, a weld pad shall be prepared as specified in Figure 2, except when the 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 and free from scale. The pad shall be welded in the flat position, three beads 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 300°F [150°C]. The welding parameters for the groove weld, as specified in Table 5, shall be used. 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 Clause 10, Chemical Analysis.

**Figure 2—Weld Pad for Chemical Analysis of Weld Metal from Composite Electrodes**

**9.3 Weld Pad.** For composite electrodes only, a weld pad shall be prepared as specified in Figure 2, except when the 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 and free from scale. The pad shall be welded in the flat position, three beads 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 300°F [150°C]. The welding parameters for the groove weld, as specified in Table 5, shall be used. 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 Clause 10, Chemical Analysis.

**9.4 Groove Weld for Mechanical Properties and Soundness.** For mechanical properties and soundness testing of a flux-electrode combination, a test assembly shall be prepared and welded as specified in Figure 3 and Table 5 using base metal of the appropriate type specified in Table 4. Preheat and interpass temperatures shall be as specified in Table 5.
Figure 3—Groove Weld Test Assembly

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Description</th>
<th>A5.17, in</th>
<th>A5.17M, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>Length (min.)</td>
<td>12</td>
<td>300</td>
</tr>
<tr>
<td>T</td>
<td>Thickness</td>
<td>1 ± 1/16</td>
<td>25 ± 1.5</td>
</tr>
<tr>
<td>W</td>
<td>Width (min.)</td>
<td>5</td>
<td>130</td>
</tr>
<tr>
<td>D</td>
<td>Specimen center</td>
<td>3/8 ± 1/32</td>
<td>9.5 ± 1.0</td>
</tr>
<tr>
<td>B</td>
<td>Backup width (min.)</td>
<td>2</td>
<td>50</td>
</tr>
<tr>
<td>R</td>
<td>Root opening</td>
<td>1/2 ± 1/16</td>
<td>13 ± 1.5</td>
</tr>
<tr>
<td>Z</td>
<td>Discard (min.)</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>θ</td>
<td>Groove angle—prior to optional preset</td>
<td>30° ± 5°</td>
<td>30° ± 5°</td>
</tr>
<tr>
<td>H</td>
<td>Approximate temperature measurement distance</td>
<td>1</td>
<td>25</td>
</tr>
<tr>
<td>V</td>
<td>Backing thickness (min.)</td>
<td>1/2</td>
<td>13</td>
</tr>
</tbody>
</table>
The surfaces to be welded shall be clean and free of scale. 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° of plane. A welded test assembly that is more than 5° out of plane shall be discarded. Straightening of the test assembly is prohibited.

Testing of this assembly shall be as specified in Clauses 11 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 1 and 1M). When 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.

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

9.4.2 For any test assembly that will be heat treated, the test assembly shall be put in a suitable furnace at a temperature not greater than 600°F [315°C]. The temperature shall be raised at the rate of 150°F [85°C] to 500°F [280°C] per hour until the postweld heat treatment temperature of 1150°F ± 25°F [620°C ± 15°C] is attained. This temperature shall be maintained for one hour (–0, +15 minutes).

The test assembly shall then be allowed to cool in the furnace at a rate not greater than 350°F [200°C] per hour. After the test assembly has reached 600°F [315°C] it may be removed from the furnace and allowed to cool in still air.

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, diffusible hydrogen test assemblies shall be prepared, welded, and tested as specified in Clause 14, Diffusible Hydrogen Test.
10. Chemical Analysis

10.1 For solid electrodes, a sample of the electrode or the rod stock from which it is made shall be prepared for chemical analysis. Solid electrodes, when analyzed for elements that are present in a coating (copper flashing, for example), shall be analyzed without removing the coating. Rod stock analyzed for elements not in the coating may be analyzed prior to reducing the rod to the finished electrode diameter and applying the coating.

10.2 For composite electrodes, the sample for analysis shall be taken from weld metal produced with the electrode and the flux with which it is classified. The sample shall be taken from the weld pad in Figure 2, from the reduced section of the fractured tension test specimen in Figure 3 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 in Figure 2 shall be used as 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 means that will not change the composition. The sample shall be free of slag.

The sample taken as provided by the alternatives to the weld pad in 9.1.2 shall be prepared for analysis by any suitable means that will not change the composition. The sample shall be taken at least 3/8 in [10 mm] from the nearest surface of the base metal.

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.

10.4 For solid electrodes, the results of the analysis shall meet the requirements of Table 1 for the classification of electrode being tested. For composite electrodes, the results of the analysis shall meet the requirements of Table 2 for the classification of electrode being tested.

11. Radiographic Test

11.1 The groove weld described in 9.4 and shown in Figure 3 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth and flush with the original surfaces of the base metal or with a uniform reinforcement not exceeding 3/32 in [2.5 mm]. It is permitted on both sides of the test assembly to remove base metal to a depth of 1/16 in [1.5 mm] less than the nominal base metal thickness, to facilitate backing or buildup removal. The thickness of the weld metal shall not be reduced by more than 1/16 in [1.5 mm] so that the thickness of the prepared radiographic test specimen equals at least the thickness of the base metal minus 1/16 in [1.5 mm].

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 one of the following. The quality level of inspection shall be 2-2T.

   (1) Film Radiology: ASTM E1032.

   (2) Computed Radiology (CR): ASTM E2033 and the requirements of ASTM E1032 except where CR differs from film. The term film, as used within ASTM E1032, applicable to performing radiography in accordance with ASTM E2033, refers to phosphor imaging plate.

   (3) Digital Radiology (DR): ASTM E2698 and the requirements of ASTM E1032 except where DR differs from film. The term film, as used within ASTM E1032, applicable to performing radiography in accordance with ASTM E2698, refers to digital detector array (DDA).

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

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

   (2) No slag inclusions longer than 5/16 in [8 mm], no groups of slag inclusions in line that have an aggregate length greater than the thickness of the weld in a length 12 times the thickness of the weld except when the distance between the successive inclusions exceeds six times the length of the longest inclusion in the group; and

   (3) No rounded indications in excess of those permitted by the radiographic standards in Figure 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. The indication may be of porosity or slag inclusions.

11.3.2 Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded. Test assemblies with any rounded indications larger than the large indications permitted in Figure 4 do not meet the requirements of this specification.
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.

Figure 4—Radiographic Standards for Rounded Indications
12. Tension Test

12.1 One all-weld metal tension test specimen, as specified in the Tension Test section of AWS B4.0 or B4.0M shall be machined from the groove weld described in 9.4 and shown in Figure 3. The all-weld-metal 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 AWS B4.0 or B4.0M. The results of the tension test shall meet the requirements specified in Table 6 [or Table 6M], as applicable.

13. Impact Test

13.1 Five full-size Charpy V-Notch impact specimens, as specified in the Fracture Toughness Test section of AWS B4.0 or B4.0M shall be machined from the test assembly shown in Figure 3 for those classifications for which impact testing is required in Table 3. The Charpy V-Notch specimens shall have the notched surface and the struck surface parallel within 0.002 in [0.05 mm]. The other two surfaces of the specimen shall be square with the notched or struck surfaces within 10 minutes of a degree. The notch shall be smoothly machined and shall be square with the longitudinal edge of the specimen within one degree. The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at a minimum 50X magnification on either a shadowgraph or metallograph. The correct location of the notch shall be verified by etching before or after machining.

13.2 The five specimens shall be tested in accordance with the Fracture Toughness test section of AWS B4.0 or B4.0M. The test temperature shall be that specified in Table 7 for the classification under test.
In evaluating the test results, the lowest and the highest values obtained shall be disregarded. Two of the remaining three values shall equal or exceed the specified 20 ft·lbf [27 J] energy level. One of the three may be lower, but not lower than 15 ft·lbf [20 J] and the average of the three shall be not less than the required 20 ft·lbf [27 J] energy level.

### 14. Diffusible Hydrogen Test

14.1 Each flux-electrode combination to be identified by an optional supplemental diffusible hydrogen designator shall be tested according to one of the methods given in AWS A4.3. Based upon the average value of test results which satisfy the requirements of Table 8, the appropriate diffusible hydrogen designator may be added to the end of the flux-electrode classification.

14.2 The welding procedure shown in Table 5 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 flux, electrode, 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 certificate. The manufacturer of the flux, electrode, or both, should be consulted for their recommendation regarding the time and temperature for restoring their products to the as-manufactured condition.

14.3 For purposes of certifying compliance with diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of ten (10) grains of moisture/lb [1.43 g/kg] of dry air at the time of welding. The actual atmospheric conditions shall be reported along with the average diffusible hydrogen value for the test according to AWS A4.3.

14.4 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification provided the actual test results satisfy the diffusible hydrogen requirements for the applicable designator. Likewise, if the actual test results for a flux meet the requirements for the lower, or lowest hydrogen designator, as specified in Table 8, the flux and electrode combination also meets the requirements for all higher designators in Table 8 without need to retest.
15. Method of Manufacture

15.1 Electrodes and Fluxes. 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.

15.2 Crushed Slag. 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 the original brand of unused (virgin) flux may be classified as welding fluxes under this specification. When classifying a blend of crushed slag with virgin flux, the ratio of the blend mixture shall not vary from nominal by more than 10% by weight of the minor component. For example, a nominal blend of 40% crushed slag with 60% virgin flux shall contain at least 36%, but no more than 44% crushed slag. The classification of more than one blend ratio of crushed slag with the original brand of unused (virgin) flux is permitted under this specification. In each case, however, the nominal blend ratio shall be noted on the packaging or on the corresponding lot certificate, as applicable. See A6.1.4 in Annex A.

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 further defined as a closed-loop crushed slag. Closed-loop crushed slag and blends of closed-loop crushed slag with the original brand of unused (virgin) flux are classified under this specification using the same requirements specified for crushed slags and blends of crushed slag with virgin flux. See A6.1.4 in Annex A.

16. Electrode Requirements

16.1 Standard Sizes. Standard sizes for electrode in the different package forms (coils with support, coils without support, spools and drums) are as specified in AWS A5.02/A5.02M.

16.2 Finish and Uniformity

16.2.1 Finish and uniformity shall be as specified in AWS A5.02/A5.02M.

16.2.2 A suitable protective coating may be applied to any filler metal in this specification, however the coating composition must be included when analyzing and reporting the composition of the electrode.

16.3 Standard Package Forms. Standard package forms are coils with support, coils without support, spools and drums. Standard package dimensions for each form shall be as specified in AWS A5.02/A5.02M. Package forms and sizes other than these shall be as agreed between purchaser and supplier.

16.4 Winding Requirements

16.4.1 Winding requirements shall be as specified in AWS A5.02/A5.02M.

16.4.2 The cast and helix of the electrode shall be as specified in AWS A5.02/A5.02M.
16.5 Electrode Identification

16.5.1 Filler Metal Identification. Product information and the precautionary information shall be as specified in AWS A5.02/A5.02M. Coils without support shall have a tag containing this information securely attached to the filler metal at the inside end of the coil.

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 product information specified in AWS A5.02/A5.02M and the following (as a minimum) shall be legibly marked so as to be visible from the outside of each unit package.

(1) AWS specification and classification along with the applicable optional and supplemental designators. The year of issuance may be excluded. It is not required that all classifications published for the electrode (with various fluxes, with and without PWHT, etc.) be included on the packaging.

(2) Supplier’s name, trade designation, and country of manufacture.

(3) In the case of a composite electrode, the trade designation of the flux (or fluxes) with which it is classified.

(4) Size and net weight.

(5) Lot, control or heat number.

16.7.2 The appropriate precautionary information as given in ANSI Z49.1 (as a minimum), or its equivalent shall be prominently displayed in legible print on all packages of electrode, including individual unit packages enclosed within a larger package. Typical examples of “warning labels” and precautionary information are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.

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 addressed, 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 along with the applicable optional, supplemental designators. The year of issuance may be excluded. It is not required that all classifications published for the flux (with various electrodes, with and without PWHT, etc.) be included on the packaging.
(2) Supplier’s name, trade designation, and country of manufacture. In the case of crushed slags (or blends of crushed slag with virgin flux), the crusher (or crusher/blender), not the original producer, shall be considered the supplier. Crushed slag or a blend of crushed slag with virgin flux shall have a unique trade designation that clearly differentiates it from the original virgin flux used in its manufacture. For blends of crushed slag with virgin flux, the nominal blend composition shall be noted on the packaging or on the corresponding certificate of test, as applicable. See also A6.1.4 in Annex A.

(3) Net Weight.
(4) Lot, control, or heat number.
(5) Particle size, if more than one particle size of flux of that trade designation is produced.

17.4.2 The appropriate precautionary information as given in ANSI Z49.1 (as a minimum), or its equivalent shall be prominently displayed in legible print on all packages of flux, including individual unit packages enclosed within a larger package. Typical examples of “warning labels” and precautionary information are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.
Annex A (Informative)


This annex is not a part of this standard and 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. Appropriate base metal specifications are referred to whenever that can be done and when it would be helpful. Such references are intended only as examples rather than complete listings of the materials for which each flux or electrode 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 1 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 a higher silicon content in the electrode. 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

A2.2.1 This specification includes electrodes classified as “EG” (or “ECG”). The “G” indicates that the electrode 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 electrodes that differ in one respect or another (chemical composition, for example) from all other classifications (meaning that the composition of the electrode, in the case of the example, does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful electrode, one that otherwise would have to wait for a revision of the specification, to be classified immediately under the existing specification. This means that two electrodes, each bearing the same “G” classification, may be quite different (chemical composition, for example).
A2.2.2 The point of difference (although not necessarily the amount) between an electrode of a “G” classification and an electrode of a similar classification, with or without the “G,” 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:

(1) *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.

(2) *Not Required* is used in those areas of the specification that refer to the tests that must be conducted in order to classify a welding flux or electrode. It indicates that that 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 flux or electrode 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. The purchaser will have to establish with the supplier what the testing procedure and the acceptance requirements are to be, for that test. The purchaser may want to incorporate that information via AWS A5.01M/A5.01 in the purchase order.

A2.2.3 Request for Filler Metal Classification. When a filler metal cannot be classified other than with a “G” classification, the manufacturer may request that a classification be established. The manufacturer shall do this using the following procedure.

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

(a) A declaration that the new classification will be offered for sale commercially.

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

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

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

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

(f) A request for a new classification without the above information will be considered incomplete. The secretary will return the request to the requester for further information.

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

(a) [Name of the requester] has filed a patent application [patent application number] for alloy [classification number]. [Name of the requester] does not hold and does not currently intend holding any essential patent claims.

(b1) [Name of the requester] has filed a patent application [patent application number] for alloy [classification number]. [Name of the requester] will make a license available to such essential patent claims to applicants desiring to utilize the license for the purpose of implementing the standard. The license will be under reasonable terms and conditions that are demonstrably free of any unfair discrimination.
(b2) [Name of the requester] has filed a patent application [patent application number] for alloy [classification number]. [Name of the requester] will make a license available to such essential patent claims to applicants desiring to utilize the license for the purpose of implementing the standard. The license will be without compensation and under reasonable terms and conditions that are demonstrably free of any unfair discrimination.

(c) [Name of the requester] indicates that the patent holder (or third party authorized to make above assurances on its behalf) will include in any documents transferring ownership of patents subject to the assurance, provisions sufficient to ensure that the commitments in the assurance are binding on the transferee, and that the transferee will similarly include appropriate provisions in the event of future transfers with the goal of binding each successor-in-interest.

(d) [Name of the requester] indicates that it is intended to be binding on successors-in-interest regardless of whether such provisions are included in the relevant transfer documents.

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

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

The published standard shall include a note as follows:

“NOTE: The user’s attention is called to the possibility that compliance with this standard may require use of an invention covered by patent rights.

By publication of this standard, no position is taken with respect to the validity of any such claim(s) or of any patent rights in connection therewith. If a patent holder has filed a statement of willingness to grant a license under these rights on reasonable and nondiscriminatory terms and conditions to applicants desiring to obtain such a license, then details may be obtained from the standards developer.”

(3) The request should be sent to the secretary of the Committee on Filler Metals and Allied Materials at AWS Headquarters.

(4) Upon receipt of the request, the secretary will:

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

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

(c) Send a copy of the request to the Chair of the Committee on Filler Metals and Allied Materials and the Chair of the particular Subcommittee involved.

(d) File the original request.

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

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

(6) The secretary shall include a copy of the log of all requests pending and those completed during the preceding year with the agenda for each of the Committee on Filler Metals and Allied Materials meetings. Any other publication of requests that have been completed will be at the discretion of the American Welding Society, as appropriate.

A2.3 Classification of Fluxes

A2.3.1 Fluxes are classified on the basis of the mechanical properties of the weld metal they produce with a certain classification of electrode under the test conditions called for in this specification. Refer to Tables 6, 6M, and 7, as applicable.
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 the various fluxes of the same classification often differ in one respect or another.

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

A2.4 An international system for designating welding filler metals developed by the International Institute of Welding (IIW) has been adopted in many ISO specifications. Table A.1 shows those used in ISO 14171, *Welding consumables — Wire electrodes and wire-flux combinations for submerged arc welding of non-alloy and fine grain steels — Classification*, with comparable classifications in this specification.

### A3. Acceptance

Acceptance of all fluxes and electrodes classified under this specification is in accordance with AWS A5.01M/A5.01, as the specification states. Any testing a purchaser requires of the supplier for fluxes or electrodes shipped in accordance with this specification needs to be clearly stated in the purchase order according to the provisions of AWS A5.01M/A5.01. In the absence of any such statement in the purchase order, the supplier may ship the fluxes or electrodes with whatever testing the supplier normally conducts on flux or electrode of that classification, as specified in Schedule F, Table 1, of AWS A5.01M/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.

<table>
<thead>
<tr>
<th>AWS A5.17/A5.17M Classification</th>
<th>ISO Designations</th>
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<tbody>
<tr>
<td></td>
<td>14171A</td>
</tr>
<tr>
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<td>EH12K</td>
<td></td>
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<tr>
<td>EH14</td>
<td>S4</td>
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</tbody>
</table>

*The electrodes listed on the same line are similar, but not identical.*
A4. Certification

The act of placing the AWS specification and classification designations and optional supplemental designators, if applicable, on the packaging enclosing the product, or the classification on the product itself constitutes the supplier’s (manufacturer’s) certification that the product meets all of the requirements of the specification. The only testing requirement implicit in this certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped and that material met the requirements of the specification. Representative material, in this case, is material from any production run of that classification using the same formulation. Certification is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the certification required by the specification is the classification test of representative material cited above, and the Manufacturer’s Quality Assurance Program in AWS A5.01M/A5.01.

A5. Ventilation During Welding

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

1. Dimensions of the space in which the welding is done (with special regard to the height of the ceiling).
2. Number of welding operators working in that space.
3. Rate of evolution of fumes, gases, or dust, according to the materials and processes used.
4. The proximity of the welding operators to the fumes, as these fumes issue from the welding zone, and to the gases and dusts in the space in which they are working.
5. The ventilation provided to the space in which the welding is done.

A5.2 American National Standard ANSI Z49.1, Safety in Welding, Cutting, and Allied Processes (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the Clause on Ventilation in that document. See also AWS F3.2, Ventilation Guide for Weld Fume, for more detailed descriptions of ventilation options.

A6. Description and Intended Use of Fluxes and Electrodes

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. 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 the 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 amount of flux melted. The primary use for neutral fluxes is in multipass welding, especially when the base metal exceeds 1 in [25mm] 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 maintain the chemical composition of the weld metal even when the voltage is changed, the chemical composition of the weld metal may not be the same as that of the electrode. 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 and add 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 metal 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 will increase 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 welds 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. As with active fluxes, where the recovery of manganese and silicon is affected significantly by arc voltage, so with alloy fluxes, the recovery of alloy elements from the flux is affected significantly by the arc voltage. With alloy fluxes, the manufacturer’s recommendations should be closely followed if desired weld metal compositions are to be obtained. The use of crushed slags generated from alloy flux is not recommended.

A6.1.4 Crushed Slags. Slag formed during the welding process that is subsequently crushed for use as a welding flux is defined as a 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 slags 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 a 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, to ensure that a standard flux product meeting the requirements of the classification is attained.

Slag generated by a fabricator from a specific brand of flux under controlled welding conditions, segregated at all points during collection and processing from other sources of slag or contaminants, crushed by the fabricator or another crushing organization, possibly blended with a specific virgin flux and returned to the same fabricator for use as a welding flux 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 ensures 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. When blending crushed slag with virgin flux, changes in the original virgin flux trade designation or in the blending ratio can affect the quality of the final product.

**A6.2 Wall Neutrality Number.** The Wall Neutrality Number (N) is a convenient measure of relative 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 an N value of 35 or lower. The lower the number, the more neutral 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 Table 5 for the groove weld test assembly for the diameter of 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:

\[
N = 100 \left( |\Delta\%Si| + |\Delta\%Mn| \right)
\]

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

**A6.3 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 of 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 multiple pass, 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.

When welding single-pass fillet welds, especially on base metal with mill scale, 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, the manufacturer’s recommendations should be consulted.

The EM14K electrodes are alloyed with small additions of titanium, although they are considered as carbon steel electrodes. The titanium functions to improve strength and 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 manganese electrodes with the Mn and Si balanced to enhance mechanical properties on applications that require high deposition rates or multiple arc procedures, or both, in both the as-welded and PWHT 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 listed on the electrode package, the electrode producer should be contacted for recommendations. A composite electrode might be chosen for a 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.

**A6.4 Mechanical Properties of Submerged Arc Welds.** Tables 6, 6M, and 7 list the mechanical properties required for flux-electrode classifications (the electrodes are classified in Tables 1 and 2 of this specification). The mechanical properties are determined from specimens prepared according to the procedures called for in this specification. The multiple pass procedure minimizes dilution from the base metal and thereby more accurately reflects the properties of the undiluted weld metal from each flux-electrode classification.

While electrodes are generally interchangeable, fluxes are not. For this reason, a classification system with standardized test methods is necessary to relate the fluxes and electrodes to the properties of their weld metal. Chemical reactions between the molten portion of the flux and electrode and dilution by the base metal all affect the composition of the weld metal.

The mechanical properties of a weld are a function of its chemical composition, cooling rate, and PWHT. High amperage, single-pass welds have a greater depth of fusion and hence, greater dilution by the base metal than lower current, multi-pass welds. Large, single-pass welds solidify and cool more slowly than the smaller weld beads of a multipass weld, and succeeding passes of a multi-pass 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 these reasons, the properties of a single-pass weld may be different than those of a multi-pass weld made with the same electrode and flux.

The weld metal properties in this specification are determined in either the as-welded condition or after a PWHT, or both. For multiple pass classifications tested in the postweld heat treated condition (“P” designtor, see Figure 1 or 1M, as applicable) the PWHT procedure is one hour at 1150°F [620°C] as prescribed in 9.4. Most of the weld metals are suitable for service in either condition, but the specification cannot cover all of the conditions that such weld metal may encounter in fabrication or service. Hence, the classifications in this specification require that the weld metals be produced and tested under 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 PWHT can have a significant effect on the properties of the weld. Within a particular 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 PWHT conditions. PWHT times in excess of the one hour used for classification purposes in this specification may have a major influence on the strength and toughness of the weld metal. The strength can be substantially reduced and the toughness increased or reduced. The user should aware of this and should understand that the mechanical properties of carbon steel weld metal produced with other procedures than those required in this specification may differ from the properties required by Tables 6, 6M, and 7 of this specification.

**A7. Special Tests**

It is recognized that supplementary tests may be required for certain applications. In such cases, tests to determine specific properties such as corrosion resistance, scaling resistance or strength at elevated or cryogenic temperatures may be required. AWS A5.01M/A5.01 contains provisions for ordering such tests. This clause is included for the guidance of those who choose to specify such special tests. These tests may be conducted as agreed upon between the purchaser and supplier.

**A8. Diffusible Hydrogen Test**

**A8.1** Hydrogen-induced cracking of weld metal or the heat-affected zone is not generally a problem with carbon steels containing 0.3% or less carbon, nor with lower-strength alloy steels. However, the fluxes and electrodes classified in this specification are sometimes used to join higher carbon steels or low-alloy, high-strength steels where hydrogen-induced cracking may be a serious problem.
A8.2 Submerged arc welding is generally considered to be a low-hydrogen welding process. As the weld metal or heat-affected zone strength or hardness increases, the concentration of diffusible hydrogen that will cause cracking under given conditions of restraint and heat input becomes lower. This cracking (or its detection) is usually delayed some hours after cooling. It may appear as transverse weld cracks, longitudinal cracks (especially in the root beads), and toe or under-bead cracks in the heat-affected zone.

A8.3 Since the available diffusible hydrogen level strongly influences the tendency towards hydrogen-induced cracking, it may be desirable to measure the diffusible hydrogen content resulting from welding with a particular flux-electrode combination. This specification has, therefore, included the use of optional designators for diffusible hydrogen to indicate the maximum average value obtained under a clearly defined test condition in AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*.

A8.4 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values from those indicated by the designator.

A8.5 Fluxes and composite electrodes can be contaminated by the condensation of moisture from the atmosphere and in some cases can absorb significant moisture if stored in a humid environment in damaged or open packages, especially if unprotected for long periods of time. In extreme cases of high humidity, even overnight exposure of unprotected flux or composite electrode can lead to a significant increase of diffusible hydrogen. In the event the flux or composite electrode has been exposed, the manufacturer should be consulted regarding probable damage to its low hydrogen characteristics and possible reconditioning of the flux or composite electrode. Solid electrodes can also be contaminated under the same conditions. In this case, the moisture contamination is on the surface and can be seen as surface rust.

A8.6 Flux/electrode combinations for some classifications may not be available in the H16, H8, H4, or H2 diffusible hydrogen levels. The manufacturer of a given flux or composite electrode should be consulted for availability of products meeting these limits.

A9. General Safety Considerations

A9.1 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in Annex Clause A5. Safety and health information is available from other sources, including, but not limited to Safety and Health Fact Sheets listed in A9.3, ANSI Z49.1 *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations. ANSI Z49.1 is published by the American Welding Society.

A9.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A9.3 AWS Safety and Health Fact Sheets Index (SHF)

<table>
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<th>No.</th>
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<tbody>
<tr>
<td>1</td>
<td>Fumes and Gases</td>
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<tr>
<td>2</td>
<td>Radiation</td>
</tr>
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Annex B (Informative)

Requesting an Official Interpretation on an AWS Standard

This annex is not part of this standard but is included for informational purposes only.

B1. Introduction

The following procedures are here to assist standard users in submitting successful requests for official interpretations to AWS standards. Requests from the general public submitted to AWS staff or committee members that do not follow these rules may be returned to the sender unanswered. AWS reserves the right to decline answering specific requests; if AWS declines a request, AWS will provide the reason to the individual why the request was declined.

B2. Limitations

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

B3. General Procedure for all Requests

B3.1 Submission. All requests shall be sent to the Managing Director, AWS Standards Development. For efficient handling, it is preferred that all requests should be submitted electronically through standards@aws.org. Alternatively, requests may be mailed to:

Managing Director
Standards Development
American Welding Society
8669 NW 36 St, # 130
Miami, FL 33166

B3.2 Contact Information. All inquiries shall contain the name, address, email, phone number, and employer of the inquirer.

B3.3 Scope. Each inquiry shall address one single provision of the standard unless the issue in question involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the request along with the edition of the standard (e.g., D1.1/D1.1M:2012) that contains the provision(s) the inquirer is addressing.

B3.4 Question(s). All requests shall be stated in the form of a question that can be answered ‘yes’ or ‘no’. The request shall be concise, yet complete enough to enable the committee to understand the point of the issue in question. When the point is not clearly defined, the request will be returned for clarification. Sketches should be used whenever appropriate, and all paragraphs, figures, and tables (or annexes) that bear on the issue in question shall be cited.

B3.5 Proposed Answer(s). The inquirer shall provide proposed answer(s) to their own question(s).
B3.6 Background. Additional information on the topic may be provided but is not necessary. The question(s) and proposed answer(s) above shall stand on their own without the need for additional background information.

B4. AWS Policy on Interpretations

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

B5. AWS Response to Requests

Upon approval by the committee, the interpretation is an official interpretation of the Society, and AWS shall transmit the response to the inquirer, publish it in the Welding Journal, and post it on the AWS website.

B6. Telephone Inquiries

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