AWS A5.23/A5.23M:2021
An American National Standard

Specification for Low-Alloy *and High Manganese* Steel Electrodes and Fluxes for Submerged Arc Welding

American Welding Society®

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AWS A5.23/A5.23M:2021
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Specification for Low-Alloy *and High Manganese* Steel Electrodes and Fluxes for Submerged Arc Welding

6th Edition

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

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification provides requirements for the classification of solid and composite carbon steel, low-alloy steel, *and high manganese 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. Fluxes may be classified using a multiple-pass classification system or a two-run classification system, or both, under this specification. Multiple-pass classification is based on the mechanical properties and the deposit composition of weld metal produced with the flux and an electrode classified herein. Two-run classification is based upon mechanical properties only. 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.

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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 requested 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 informational purposes only.

This document is the fourth of the A5.23/A5.23M 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.

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.

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

(1) A new classification (Mn2) for an austenitic high manganese (nominal 19% Mn) weld deposit.

(2) New classifications (EB115 and B115) for an electrode and corresponding weld deposit with 10.5% Cr and 0.5% Mo modified with niobium and vanadium.

(3) New designators for low Mn + Ni B91 weld deposit.

(4) Requirements for reporting base and weld metal chemical composition for two-run classifications.

The welding terms used in this specification shall be interpreted in accordance with the definitions given in the latest edition of AWS A3.0M/A3.0, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*.

The current document is the sixth revision of the initial joint ASTM/AWS document issued in 1976. The evolution of the AWS A5.23 specification took place as follows:

ANSI/AWS A5.23-76	*Specification for Bare Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*
ANSI/AWS A5.23-80	*Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*
ANSI/AWS A5.23-90	*Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*
ANSI/AWS A5.23/A5.23M:1999	*Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*
AWS A5.23/A5.23M:2007	*Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*
AWS A5.23/A5.23M:2011	*Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*

Comments and suggestions for the 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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Table of Contents

Page No.

List of Tables

List of Figures

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Specification for Low-Alloy *and High Manganese* Steel Electrodes and Fluxes for Submerged Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of solid and composite carbon steel, low-alloy steel, *and high manganese* steel electrodes and flux-electrode combinations for submerged arc welding (SAW). This specification covers low-alloy *and high manganese* electrodes and low-alloy *and high manganese* multiple-pass flux-electrode classifications. This specification also addresses carbon steel, low-alloy steel, *and high manganese* steel two-run flux-electrode classifications. The multiple-pass classification of flux-electrode combinations for carbon steel SAW is not within the scope of this specification, but is covered in AWS A5.17/A5.17M.

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 A5.23 uses U.S. Customary Units. The specification A5.23M 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 specification A5.23 or A5.23M.

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 A11. Safety and health information is available from the following sources:

American Welding Society:

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

(2) AWS Safety and Health Fact Sheets

(3) Other safety and health information on the AWS website

Material or Equipment Manufacturers:

(1)Safety Data Sheets supplied by materials manufacturers

(2) Operating Manuals supplied by equipment manufacturers

Applicable Regulatory Agencies

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

2. Normative References

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

American Welding Society (AWS) documents:

AWS A1.1, *Metric Practice Guide for the Welding Industry*

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

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

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

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

AWS A5.17/A5.17M, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*

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

American National Standards Institute (ANSI) document:

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

ASTM International documents:

ASTM A36/A36M, *Specification for Carbon Structural Steel*

ASTM A131/A131M, *Specification for Structural Steel for Ships*

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

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

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

ASTM A335/A335M *Standard Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service*

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

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

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

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

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

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

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

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

ASTM A572/A572M, *Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel*

ASTM A588/A588M, *Specification for High-Strength Low-Alloy Structural Steel, up to 50 ksi [345 MPa] Minimum Yield Point with Atmospheric Corrosion Resistance*

ASTM A1106/A1106M, *Standard Specification for Pressure Vessel Plate, Alloy Steel, Austenitic High Manganese for Cryogenic Application*

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

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

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

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

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

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

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

International Organization for Standardization (ISO) document:

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

3. Classification

3.1 The SAW electrodes and fluxes covered by the A5.23 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, a two-run butt weld, or both; made with a combination of a particular flux and a particular classification of electrode, as specified in Tables 1 and 2.

(2) The condition of heat treatment in which the properties are obtained, as specified in 9.4 or 9.5, as applicable (and as shown in Figure 1 or Figure 2, as applicable).

(3) For multiple-pass classifications, the chemical composition of the weld metal obtained with the combination of a particular flux and a particular classification of electrode as specified in Table 3. Weld metal chemical composition is not specified for two-run classifications under this specification (see Figure 1 or Figure 2, as applicable).

(4) The chemical composition of either the electrode (for solid electrodes) as specified in Table 4, or the weld metal produced with a particular flux (for composite electrodes) as specified in Table 3.

3.1M The SAW electrodes and fluxes covered by the A5.23M 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, a two-run butt weld, or both; made with a combination of a particular flux and a particular classification of electrode, as specified in Tables 1M and 2.

(2) The condition of heat treatment in which the properties are obtained, as specified in 9.4 or 9.5, as applicable (and as shown in Figure 1M or Figure 2M, as applicable).

(3) For multiple-pass classifications, the chemical composition of the weld metal obtained with the combination of a particular flux and a particular classification of electrode as specified in Table 3. Weld metal chemical composition is not specified for two-run classifications under this specification (see Figure 1M or Figure 2M, as applicable).

(4) The chemical composition of either the electrode (for solid electrodes) as specified in Table 4, or the weld metal produced with a particular flux (for composite electrodes) as specified in Table 3.

3.2 Fluxes may be classified under any number of classifications; for weld metal in either or both the as-welded and postweld heat treated conditions, for weld metal deposited using different electrode classifications, for multiple-pass or two-run classifications, or any combination thereof. Flux-electrode combinations may be classified under A5.23 with U.S. Customary Units, under A5.23M using the International System of Units (SI), or both. Flux-electrode combinations classified under both A5.23 and A5.23M must meet all of the requirements for classification under each system. The classification systems are shown in Figures 1 and 1M for multiple-pass classifications and in Figures 2 and 2M for two-run classifications.

3.3 The electrodes and fluxes classified under this specification are intended for SAW, 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 AWS A5.01M/A5.01 and 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 the purpose of determining compliance with the requirements of this standard, the actual test values obtained shall be subjected to the rounding rules of ASTM E29 or Rule A in Clause B.3 of ISO 80000-1 (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 A5.23, to the nearest 10 MPa for tensile and yield strength for A5.23M 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 fulfil 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 5. 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 Table 6, Note d and Table 7, Note e.

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 3 is used to meet this requirement for the classification of composite electrodes. The welding parameters for the multiple-pass groove weld, as specified in Table 6, 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 4. Note g of Table 3 allows the sample for chemical analysis 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 in the groove weld in Figure 4. 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 multiple-pass classification of a flux-solid electrode combination or a flux-composite electrode combination. This is the groove weld in Figure 4 for mechanical properties and soundness of weld metal. A second test assembly, the weld pad in Figure 3, is required for chemical analysis of the weld metal. However, Note g of Table 3 allows the sample for chemical analysis 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 in the groove weld in Figure 4, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be the referee method.

One butt weld test assembly is required for each two-run classification of a flux-solid electrode combination or flux-composite electrode combination. This is the two-run weld test assembly in Figure 5 for mechanical properties and soundness of weld metal.

9.2 Preparation. Preparation of each weld test assembly shall be as prescribed in 9.3, 9.4, and 9.5. The base metal for the weld pad, the multiple-pass groove weld, and the two-run weld assemblies shall be as required in Table 8 and shall meet the requirements of the ASTM specification shown there or a chemically equivalent steel. Testing of the assemblies shall be as prescribed in Clauses 10 through 13.

9.3 Weld Pad. For composite electrodes or for any flux-electrode multiple-pass classification, a weld pad shall be prepared as specified in Figure 3, except when either alternative in 9.1.2 or 9.1.3 is selected. Base metal of any convenient size and of the type specified in Table 8, 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 is intended.

The welding parameters for the groove weld, as specified in Table 6, shall be used except that the preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 300°F [150°C]. The slag shall be removed after each pass. The pad may be quenched in water between passes 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 Multiple-Pass Classifications

9.4.1 For mechanical properties and soundness testing of a flux-electrode combination for multiple-pass classification, a test assembly shall be prepared and welded as specified in Figure 4 and Table 6 using base metal of the appropriate type specified in Table 8. Preheat and interpass temperatures shall be as specified in Table 9. 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 after welding 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 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 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.

9.4.1.1 When postweld heat treatment 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.

9.4.1.2 Any multiple-pass groove weld test assembly to be heat treated shall be heat treated at the time and temperature specified in Table 9 for the applicable weld metal designation. The welded test assembly shall be put into a suitable furnace at a temperature not greater than 600°F [315°C]. The temperature shall be raised at a rate of 150°F [85°C] to 500°F [280°C] per hour until the holding temperature specified in Table 9 is attained. This temperature shall be maintained for 1 hour (–0, +15 minutes), except as indicated in note e of Table 9.

9.4.1.3 The test assembly shall then be allowed to cool in the furnace at a rate not greater than 350°F [200°C] per hour. 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 Butt Weld for Two-Run Classifications

9.5.1 For mechanical properties and soundness testing of a flux-electrode combination for two-run classification, a test assembly shall be prepared and welded as specified in Figure 5 and Table 7 using base metal of the appropriate type specified in Table 8. The surfaces to be welded shall be clean and free of scale. Prior to welding, the assembly may be preset such 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 sufficiently flat after welding. Straightening of the test assembly is prohibited. Testing shall be as specified in Clauses 10 through 13, with the assembly in either the as-welded or postweld heat treated condition, according to the classification of the weld metal (see Figures 2 and 2M). 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.

9.5.1.1 When postweld heat treatment 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.

9.5.1.2 Any two-run butt weld test assembly to be heat treated shall be put into 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 30 minutes (–0, +7 minutes). The above postweld heat treat procedure also applies to FXTPXG-EXX flux-electrode classifications unless otherwise specified by the purchaser.

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

9.6 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. 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 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 and for the multiple-pass classification of flux-electrode combinations, the sample for analysis shall be taken from the weld pad in Figure 3, from the reduced section of the fractured tension test specimen in Figure 4, or from a corresponding location (or any location above it) in the weld metal in the butt weld in Figure 4. Weld metal from the butt weld used for two-run classification (Figure 5) may not be used for the purpose of classifying composite electrodes. In case of dispute, the weld pad in Figure 3 shall be used as the referee method.

The top surface of the pad described in 9.3 and shown in Figure 3 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 means that will not change the chemical composition. The sample shall be free of slag. The sample shall be taken at least 3/8 in [10 mm] from the nearest surface of the base metal. The sample from the reduced section of the fractured tension test specimen or from a corresponding location (or any location above it) in the groove weld in Figure 4 shall be prepared for analysis by any suitable means that will not change the chemical composition.

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 or ASTM E353, as appropriate for the metal type.

10.4 For composite electrodes and for the multiple-pass classification of flux-electrode combinations, the results of the weld metal analysis shall meet the requirements of Table 3 for the applicable weld metal designation. For solid electrodes, the results of the electrode analysis shall meet the requirements of Table 4 for the classification of electrode being tested.

10.5 *For two-run classifications, the chemical composition of the weld metal is not specified, but reporting of the chemical composition of the base and weld metal are required and shall include C, Mn, Si, S, P, Cu, Cr, Ni, Mo, V, Nb, Ti, and B. The base metal chemical composition may be obtained from the specific steel used for the certification test assembly or metal from the heat of steel used for the certification test assembly. A certified material test report from the base metal supplier traceable to the specific heat of steel used for the certification test assembly may be used. Weld metal chemical analysis shall be obtained from the weld deposit of the second pass.*

11. Radiographic Test

11.1 The groove weld for multiple-pass classifications described in 9.4 and shown in Figure 4 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] in order to facilitate backing and/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.

The butt weld for two-run classifications described in 9.5 and shown in Figure 5 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, both ends of the test joint may be trimmed off to remove run-on and run-off tabs, if any, and any excess weld joint material. The surfaces of both weld beads may 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] nominal below the original base metal surface in order to facilitate 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 6.

In evaluating the radiograph for the multiple-pass groove weld, 1 in [25 mm] of the weld on each end of the test assembly shall be disregarded. For the two-run butt weld, evaluation shall be made on a 10 in [250 mm] continuous length, as a minimum.

11.3.1 A rounded indication is an indication (on the radiograph) whose length is no more than three times its width. Rounded indications may be circular or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present. The 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 6 do not meet the requirements of this specification.

12. Tension Test

12.1 For multiple-pass classifications, one all-weld metal tension test specimen, as specified in the Tension Test clause of AWS B4.0, shall be machined from the groove weld described in 9.4 and shown in Figure 4. The all-weld-metal tension specimen shall have a nominal diameter of 0.500 in [12.5 mm] and a nominal gage length to diameter ratio of 4:1.

12.1.1 For flux-electrode combinations classified in the postweld heat-treated condition, the weld metal shall be heat-treated as shown in Table 9 before final machining of the specimen (refer to 9.4.1).

12.1.2 For flux-electrode classifications to be tested in the as-welded condition, the weld test assembly or tension test specimen may be aged at temperatures up to 220°F [105°C] for up to 48 hours, then allowed to cool to room temperature. In case of dispute, aging the tension test specimen shall be the referee method. If the tension specimen or the test assembly is aged, that fact, together with the manner of aging, shall be recorded on the test certificate. Refer to A10.6 in Annex A for a discussion on the purpose of aging.

12.1.3 The specimen shall be tested in the manner described in the Tension Test clause of AWS B4.0.

12.1.4 The results of the tension test shall meet the requirements specified in Table 1 or Table 1M, as applicable.

12.2 For two-run classifications, one longitudinal tension test specimen, as specified in the Tension Test clause of AWS B4.0 shall be machined from the butt weld described in 9.5 and shown in Figure 5. The tensile specimen shall have a nominal diameter of 0.250 in [6.0 mm] and a nominal gage length to diameter ratio of 4:1. The reduced section of the longitudinal tensile specimen shall be located entirely within the weld zone.

12.2.1 For flux-electrode combinations classified in the postweld heat-treated condition, the weld metal shall be heat treated as described in 9.5.1 before final machining of the specimen.

12.2.2 For flux-electrode classifications to be tested in the as-welded condition, the weld test assembly or tension test specimen may be aged at temperatures up to 220°F [105°C] for up to 48 hours, then allowed to cool to room temperature. In case of dispute, aging the tension test specimen shall be the referee method. If the tension specimen or the test assembly is aged, that fact, together with the manner of aging, shall be recorded on the test certificate. Refer to A10.6 in Annex A for a discussion on the purpose of aging.

12.2.3 The specimen shall be tested in the manner described in the Tension Test clause of AWS B4.0.

12.2.4 The results of the tension test shall meet the requirements specified in Table 1 or Table 1M, as applicable.

13. Impact Test

13.1 Five full-size Charpy V-notch impact specimens, as specified in the Fracture Toughness Test clause of AWS B4.0, shall be machined from the test assembly shown in Figure 4 or Figure 5, as applicable, for those classifications for which impact testing is required in Table 5. 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 10X magnification. 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 clause of AWS B4.0. The test temperature shall be that specified in Table 2 for the classification under test.

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

13.4 For classifications with the "N" (nuclear) designation, three additional specimens shall be prepared. These specimens shall be tested at 60°F to 90°F [15°C to 32°C]. Two of the three values shall equal or exceed 75 ft·lbf [100 J], and the third value shall not be lower than 70 ft·lbf [95 J]. The average of the three shall equal or exceed 75 ft·lbf [100 J].

13.5 For classifications with an impact designator of "32" per A5.23 or an impact designator of "20" per A5.23M, the lateral expansion of the three Charpy specimens remaining after discarding the specimens with the highest and lowest absorbed energy levels shall be measured in accordance with ASTM E23. The average of these three specimens shall exhibit a lateral expansion of at least 0.015 in [0.38 mm], as specified in Table 2.

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 10, the appropriate diffusible hydrogen designator may be added to the end of the classification. *Austenitic weld metal, including that classified as Mn2, is not suitable for diffusible hydrogen determination.*

14.2 The welding procedure shown in Table 6 for the multiple-pass 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. If the actual test results for a flux-electrode combination meet the requirements for the lower or lowest hydrogen designator, as specified in Table 10, the flux-electrode combination also meets the requirements for all higher designators in Table 10 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 flux 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% 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.

16. Electrode Requirements

16.1 Standard Sizes. Standard sizes for electrodes 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

16.3.1 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. 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 and trade designation.

(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 electrodes, 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 SAW 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 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. For flux-composite electrode classifications the trade designation of the composite electrode shall be indicated. It is not required that all of the classifications published for the flux (with different 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. 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.

Table 1
A5.23 Tension Test Requirements

Flux-Electrode Classifications[a]		Tensile Strength (psi)	Minimum Yield Strength at 0.2% Offset (psi)	Minimum Elongation (%)
Multiple-Pass Classifications	F7XX-EXX-XX	70 000 to 95 000	58 000	22
	F8XX-EXX-XX	80 000 to 100 000	68 000	20
	F9XX-EXX-XX	90 000 to 110 000	78 000	17
	F10XX-EXX-XX	100 000 to 120 000	88 000	16
	F10XX-EXX-Mn2	*100 000 minimum*	*58 000*	22
	F11XX-EXX-XX	110 000 to 130 000	98 000	15[b]
	F12XX-EXX-XX	120 000 to 140 000	108 000	14[b]
	F13XX-EXX-XX	130 000 to 150 000	118 000	14[b]
Two-Run Classifications	F6TXX-EXX	60 000 minimum	50 000	22
	F7TXX-EXX	70 000 minimum	60 000	22
	F8TXX-EXX	80 000 minimum	70 000	20
	F9TXX-EXX	90 000 minimum	80 000	17
	F10TXX-EXX	100 000 minimum	90 000	16
	F11TXX-EXX	110 000 minimum	100 000	15
	F12TXX-EXX	120 000 minimum	110 000	14
	F13TXX-EXX	130 000 minimum	120 000	14

[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 used is a composite electrode. For two-run classifications, the letter "G" will appear after the impact designator (immediately before the hyphen) to indicate that the base steel used for classification is not one of the base steels prescribed in Table 8 but is a different steel, as agreed between purchaser and supplier. 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 weld metal. See Figure 1 or 2, as applicable, for a complete explanation of the classification designators.

[b] Elongation may be reduced by one percentage point for F11XX-EXX-XX, F11XX-ECXX-XX, F12XX-EXX-XX, F12XX-ECXX-XX, F13XX-EXX-XX, and F13XX-ECXX-XX weld metals in the upper 25% of their tensile strength range.

Table 1M
A5.23M Tension Test Requirements

Flux-Electrode Classifications[a]		Tensile Strength (MPa)	Minimum Yield Strength at 0.2% Offset (MPa)	Minimum Elongation (%)
Multiple-Pass Classifications	F49XX-EXX-XX	490 to 660	400	22
	F55XX-EXX-XX	550 to 700	470	20
	F62XX-EXX-XX	620 to 760	540	17
	F69XX-EXX-XX	690 to 830	610	16
	F69XX-EXX-Mn2	*690 minimum*	*400*	*22*
	F76XX-EXX-XX	760 to 900	680	15[b]
	F83XX-EXX-XX	830 to 970	740	14[b]
	F90XX-EXX-XX	900 to 1040	810	14[b]
Two-Run Classifications	F43TXX-EXX	430 minimum	350	22
	F49TXX-EXX	490 minimum	415	22
	F55TXX-EXX	550 minimum	490	20
	F62TXX-EXX	620 minimum	555	17
	F69TXX-EXX	690 minimum	625	16
	F76TXX-EXX	760 minimum	690	15
	F83TXX-EXX	830 minimum	760	14
	F90TXX-EXX	900 minimum	830	14

[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 used is a composite electrode. For two-run classifications, the letter "G" will appear after the impact designator (immediately before the hyphen) to indicate that the base steel used for classification is not one of the base steels prescribed in Table 8 but is a different steel, as agreed between purchaser and supplier. 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 weld metal. See Figure 1M or 2M, as applicable, for a complete explanation of the classification designators.

[b] Elongation may be reduced by one percentage point for F76-EXX-XX, F76-ECXX-XX, F83XX-EXX-XX, F83XX-ECXX-XX, F90XX-EXX-XX, and F90XX-ECXX-XX weld metals in the upper 25% of their tensile strength range.

Table 2
Impact Test Requirements

A5.23 Requirements			A5.23M Requirements		
A5.23 Impact Designator[a, c]	**Maximum Test Temperature**[b] **(°F)**	**Minimum Average Energy Level** ***or Lateral Expansion***[d]	**A5.23M Impact Designator**[a, c]	**Maximum Test Temperature**[b] **(°C)**	**Minimum Average Energy Level** ***or Lateral Expansion***[d]
0	0	20 ft·lbf	0	0	27 J
2	–20	20 ft·lbf	2	–20	27 J
4	–40	20 ft·lbf	3	–30	27 J
5	–50	20 ft·lbf	4	–40	27 J
6	–60	20 ft·lbf	5	–50	27 J
8	–80	20 ft·lbf	6	–60	27 J
10	–100	20 ft·lbf	7	–70	27 J
15	–150	20 ft·lbf	10	–100	27 J
32	*–320*	*0.015 in*	*20*	*–196*	*0.38 mm*
Z	No Impact Requirements		Z	No Impact Requirements	

[a] Based on the results of the impact tests of the weld metal, the manufacturer shall insert in the classification the appropriate designator from this table, as indicated in Figure 1, 1M, 2, or 2M, as applicable.
[b] Weld metal from a specific flux-electrode combination that meets the impact requirements at a given temperature also meets the requirements at all higher temperatures in this table. For example, weld metal meeting the A5.23 requirements for designator "5" also meets the requirements for designators 4, 2, 0, and Z. (Weld metal meeting the A5.23M requirements for designator "5" also meets the requirements for designators 4, 3, 2, 0, and Z.)
[c] When classifying flux-electrode combinations to A5.23 using U.S. Customary Units, the Impact Designator indicates the impact test temperature in °F. When classifying to A5.23M using the International System of Units (SI), the Impact Designator indicates the impact test temperature in °C. With the exception of the Impact Designator "4," a given Impact Designator will indicate different temperatures depending upon whether classification is according to A5.23 in U.S. Customary Units or according to A5.23M in the International System of Units (SI). For example, a "2" Impact Designator when classifying to A5.23 indicates a test temperature of –20°F. When classifying to A5.23M, the "2" Impact Designator indicates a test temperature of –20°C, which is –4°F.
[d] *Requirements for impact designator "32" [impact designator "20"] are lateral expansion values. See 13.5 for more details.*

Table 3
Chemical Composition Requirements for Weld Metal[a]

Weld Metal Designation[b, c]	UNS Number[d]	Weight Percent[e, f, g]									
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu	Other[h]
A1	W17041	0.12	1.00	0.80	0.030	0.030	—	—	0.40–0.65	0.35	—
A2	W17042	0.12	1.40	0.80	0.030	0.030	—	—	0.40–0.65	0.35	—
A3	W17043	0.15	2.10	0.80	0.030	0.030	—	—	0.40–0.65	0.35	—
A4	W17044	0.15	1.60	0.80	0.030	0.030	—	—	0.40–0.65	0.35	—
B1	W51040	0.12	1.60	0.80	0.030	0.030	0.40–0.65	—	0.40–0.65	0.35	—
B2[i]	W52040	0.05–0.15	1.20	0.80	0.030	0.030	1.00–1.50	—	0.40–0.65	0.35	—
B2H	W52240	0.10–0.25	1.20	0.80	0.020	0.020	1.00–1.50	—	0.40–0.65	0.35	V: 0.30
B3[i]	W53040	0.05–0.15	1.20	0.80	0.030	0.030	2.00–2.50	—	0.90–1.20	0.35	—
B4	W53340	0.12	1.20	0.80	0.030	0.030	1.75–2.25	—	0.40–0.65	0.35	—
B5	W51340	0.18	1.20	0.80	0.030	0.030	0.40–0.65	—	0.90–1.20	0.35	—
B6	W50240	0.12	1.20	0.80	0.030	0.030	4.50–6.00	—	0.40–0.65	0.35	—
B6H	W50140	0.10–0.25	1.20	0.80	0.030	0.030	4.50–6.00	—	0.40–0.65	0.35	—
B8	W50440	0.12	1.20	0.80	0.030	0.030	8.00–10.00	—	0.80–1.20	0.35	—
B23	K20857	0.04–0.12	1.00	0.80	0.015	0.020	1.9–2.9	0.50	0.30	0.25	W: 1.50–2.00 V: 0.15–0.30 Nb: 0.02–0.10 B: 0.006 Al: 0.04 N: 0.07
B24	K20885	0.04–0.12	1.00	0.80	0.015	0.020	1.9–2.9	0.30	0.80–1.20	0.25	V: 0.15–0.30 Nb: 0.02–0.10 Ti: 0.10 B: 0.006 Al: 0.04 N: 0.05
B91	W50442	0.08–0.13	1.20[j]	0.80	0.010	0.010	8.0–10.5	0.80[j]	0.85–1.20	0.25	Nb: 0.02–0.10 N: 0.02–0.07 V: 0.15–0.25 Al: 0.04

(Continued)

Table 3 (Continued)
Chemical Composition Requirements for Weld Metal[a]

Weld Metal Designation[b, c]	UNS Number[d]	Weight Percent[e, f, g]									
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu	Other[h]
B91(1.2)	*W50442*	*0.08–0.13*	*1.20*[j]	*0.80*	*0.010*	*0.010*	*8.0–10.5*	*0.80*[j]	*0.85–1.20*	*0.25*	*Nb: 0.02–0.10 N: 0.02–0.07 V: 0.15–0.25 Al: 0.04*
B91(1.0)	*W50442*	*0.08–0.13*	*1.20*[j]	*0.80*	*0.010*	*0.010*	*8.0–10.5*	*0.80*[j]	*0.85–1.20*	*0.25*	*Nb: 0.02–0.10 N: 0.02–0.07 V: 0.15–0.25 Al: 0.04*
B115	—	*0.06–0.13*	*1.00*	*0.15–0.50*	*0.010*	*0.015*	*9.5–12.0*	*0.45*	*0.40–0.65*	*0.20*	*V: 0.10–0.30 Nb: 0.02–0.10 N: 0.02–0.06 Al: 0.04*
F1	W21150	0.12	0.70–1.50	0.80	0.030	0.030	0.15	0.90–1.70	0.55	0.35	—
F2	W20240	0.17	1.25–2.25	0.80	0.030	0.030	—	0.40–0.80	0.40–0.65	0.35	—
F3	W21140	0.17	1.25–2.25	0.80	0.030	0.030	—	0.70–1.10	0.40–0.65	0.35	—
F4	W20440	0.17	1.60	0.80	0.035	0.030	0.60	0.40–0.80	0.25	0.35	Ti + V + Zr: 0.03
F5	W22540	0.17	1.20–1.80	0.80	0.020	0.020	0.65	2.00–2.80	0.30–0.80	0.50	—
F6	W22640	0.14	0.80–1.85	0.80	0.020	0.030	0.65	1.50–2.25	0.60	0.40	—
M1	W21240	0.10	0.60–1.60	0.80	0.030	0.030	0.15	1.25–2.00	0.35	0.30	Ti + V + Zr: 0.03
M2	W21340	0.10	0.90–1.80	0.80	0.020	0.020	0.35	1.40–2.10	0.25–0.65	0.30	Ti + V + Zr: 0.03
M3	W22240	0.10	0.90–1.80	0.80	0.020	0.020	0.65	1.80–2.60	0.20–0.70	0.30	Ti + V + Zr: 0.03
M4	W22440	0.10	1.30–2.25	0.80	0.020	0.020	0.80	2.00–2.80	0.30–0.80	0.30	Ti + V + Zr: 0.03
M5	W21345	0.12	1.60–2.50	0.50	0.015	0.015	0.40	1.40–2.10	0.20–0.50	0.30	Ti: 0.03 V: 0.02 Zr: 0.02
M6	W21346	0.12	1.60–2.50	0.50	0.015	0.015	0.40	1.40–2.10	0.70–1.00	0.30	Ti: 0.03 V: 0.02 Zr: 0.02
Mn2	—	*0.25–0.50*	*16.0–24.0*	*1.5*	*0.015*	*0.025*	*1.5–3.5*	*2.0*	*1.5*	*0.50*	—
Ni1	W21040	0.12	1.60[k]	0.80	0.025	0.030	0.15	0.75–1.10	0.35	0.35	Ti + V + Zr: 0.05

(Continued)

Table 3 (Continued)
Chemical Composition Requirements for Weld Metal[a]

Weld Metal Designation[b, c]	UNS Number[d]	Weight Percent[e, f, g]									
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu	Other[h]
Ni2	W22040	0.12	1.60[k]	0.80	0.025	0.030	—	2.00–2.90	—	0.35	—
Ni3	W23040	0.12	1.60[k]	0.80	0.025	0.030	0.15	2.80–3.80	—	0.35	—
Ni4	W21250	0.14	1.60	0.80	0.025	0.030	—	1.40–2.10	0.10–0.35	0.35	—
Ni5	W21042	0.12	1.60[k]	0.80	0.025	0.030	—	0.70–1.10	0.10–0.35	0.35	—
Ni6	W21042	0.14	1.60[k]	0.80	0.025	0.030	—	0.70–1.10	0.10–0.35	0.35	—
W	W20140	0.12	0.50–1.60	0.80	0.030	0.035	0.45–0.70	0.40–0.80	—	0.30–0.75	—
G		As agreed between supplier and purchaser									

[a] These requirements are applicable to both flux-solid electrode and flux-composite electrode combinations.
[b] The weld metal designation for composite electrodes is obtained by placing an "EC" before the appropriate electrode designation.
[c] The letter "N," when added as a suffix is an optional supplemental designator indicating that the limits on the phosphorous, vanadium, and copper are as follows: P = 0.012% max., V = 0.05% max., and Cu = 0.08% max. Additional requirements are given in 13.4. See A2.1 in Annex A for a discussion of the intended use of "N" designator electrodes.
[d] Refer to ASTM DS-56/SAE HS-1086, *Metals & Alloys in the Unified Numbering System.*
[e] 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%.
[f] Single values are maximum.
[g] As a substitute for the weld pad in Figure 3, the sample for chemical analysis may be taken from the reduced section of the fractured tension test specimen (see 10.2) or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 4. In case of dispute, the weld pad shall be the referee method.
[h] Analysis for B is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.0010%.
[i] The letter "R" when added as a suffix is an optional supplemental designator indicating that the limits on sulfur, phosphorous, copper, arsenic, tin, and antimony are as follows: S = 0.010% max., P = 0.010% max., Cu = 0.15% max., As = 0.005% max., Sn = 0.005% max., and Sb = 0.005% max. These reduced residual limits are necessary to meet the "X" factor requirements for step cooling applications.
[j] *The designation B91 requires Mn + Ni 1.40% maximum. The designation B91(1.2) requires Mn + Ni 1.20% maximum. The designation B91(1.0) requires Mn + Ni 1.00% maximum. A composition meeting the B91(1.0) requirements will also meet the requirements of B91(1.2) and B91. A composition meeting the B91(1.2) will also meet the requirements of B91. See A7.2.3.1 in Annex A.*
[k] Manganese in the Ni1, Ni2, Ni3, Ni5, and Ni6 designated weld metals may be 1.80% maximum when the carbon is restricted to 0.10% maximum.

Table 4
Chemical Composition Requirements for Solid Electrodes

Electrode AWS Classification[c]	UNS Number[d]	Weight Percent[a, b]										
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu[e]	V	Other[f]
EL8[g]	K01008	0.10	0.25–0.60	0.07	0.030	0.030	—	—	—	0.35	—	—
EL8K[g]	K01009	0.10	0.25–0.60	0.10–0.25	0.030	0.030	—	—	—	0.35	—	—
EL12[g]	K01012	0.04–0.14	0.25–0.60	0.10	0.030	0.030	—	—	—	0.35	—	—
EM11K[g]	K01111	0.07–0.15	1.00–1.50	0.65–0.85	0.030	0.025	—	—	—	0.35	—	—
EM12[g]	K01112	0.06–0.15	0.80–1.25	0.10	0.030	0.030	—	—	—	0.35	—	—
EM12K[g]	K01113	0.05–0.15	0.80–1.25	0.10–0.35	0.030	0.030	—	—	—	0.35	—	—
EM13K[g]	K01313	0.06–0.16	0.90–1.40	0.35–0.75	0.030	0.030	—	—	—	0.35	—	—
EM14K[g]	K01314	0.06–0.19	0.90–1.40	0.35–0.75	0.025	0.025	—	—	—	0.35	—	Ti: 0.03–0.17
EM15K[g]	K01515	0.10–0.20	0.80–1.25	0.10–0.35	0.030	0.030	—	—	—	0.35	—	—
EH10K[g]	K01210	0.07–0.15	1.30–1.70	0.05–0.25	0.025	0.025	—	—	—	0.35	—	—
EH11K[g]	K11140	0.06–0.15	1.40–1.85	0.80–1.15	0.030	0.030	—	—	—	0.35	—	—
EH12K[g]	K01213	0.06–0.15	1.50–2.00	0.20–0.65	0.025	0.025	—	—	—	0.35	—	—
EH14[g]	K11585	0.10–0.20	1.70–2.20	0.10	0.030	0.030	—	—	—	0.35	—	—
EA1	K11222	0.05–0.15	0.65–1.00	0.20	0.025	0.025	—	—	0.45–0.65	0.35	—	—
EA1TiB	K11020	0.05–0.15	0.65–1.00	0.35	0.025	0.025	—	—	0.45–0.65	0.35	—	Ti: 0.05–0.30 B: 0.005–0.030
EA2TiB	K11126	0.05–0.17	0.95–1.35	0.35	0.025	0.025	—	—	0.45–0.65	0.35	—	Ti: 0.05–0.30 B: 0.005–0.030
EA2	K11223	0.05–0.17	0.95–1.35	0.20	0.025	0.025	—	—	0.45–0.65	0.35	—	—
EA3	K11423	0.05–0.17	1.65–2.20	0.20	0.025	0.025	—	—	0.45–0.65	0.35	—	—
EA3K	K21451	0.05–0.15	1.60–2.10	0.50–0.80	0.025	0.025	—	—	0.40–0.60	0.35	—	—
EA4	K11424	0.05–0.15	1.20–1.70	0.20	0.025	0.025	—	—	0.45–0.65	0.35	—	—
EB1	K11043	0.10	0.40–0.80	0.05–0.30	0.025	0.025	0.40–0.75	—	0.45–0.65	0.35	—	—

(Continued)

Table 4 (Continued)
Chemical Composition Requirements for Solid Electrodes

Electrode AWS Classification[c]	UNS Number[d]	Weight Percent[a, b]										
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu[e]	V	Other[f]
EB2[h]	K11172	0.07–0.15	0.45–1.00	0.05–0.30	0.025	0.025	1.00–1.75	—	0.45–0.65	0.35	—	—
EB2H	K23016	0.28–0.33	0.45–0.65	0.55–0.75	0.015	0.015	1.00–1.50	—	0.40–0.65	0.30	0.20–0.30	—
EB3[h]	K31115	0.05–0.15	0.40–0.80	0.05–0.30	0.025	0.025	2.25–3.00	—	0.90–1.10	0.35	—	—
EB5	K12187	0.15–0.23	0.40–0.70	0.40–0.60	0.025	0.025	0.45–0.65	—	0.90–1.20	0.30	—	—
EB6	S50280	0.10	0.35–0.70	0.05–0.50	0.025	0.025	4.50–6.50	—	0.45–0.70	0.35	—	—
EB6H	S50180	0.25–0.40	0.75–1.00	0.25–0.50	0.025	0.025	4.80–6.00	—	0.45–0.65	0.35	—	—
EB8	S50480	0.10	0.30–0.65	0.05–0.50	0.025	0.025	8.00–10.50	—	0.80–1.20	0.35	—	—
EB23	K20857	0.05–0.12	1.10	0.50	0.015	0.015	1.9–3.0	0.50	0.50	0.10	0.15–0.30	W: 1.50–2.00 Nb: 0.02–0.10 B: 0.006 Al: 0.04 N: 0.05
EB24	K20885	0.04–0.12	1.00	0.50	0.015	0.020	1.9–3.0	0.30	0.80–1.20	0.10	0.15–0.30	Nb: 0.02–0.10 Ti: 0.10 B: 0.006 Al: 0.04 N: 0.07
EB91	S50482	0.07–0.13	1.25[i]	0.50	0.010	0.010	8.50–10.50	1.00[i]	0.85–1.15	0.10	0.15–0.25	Nb: 0.02–0.10 N: 0.03–0.07 Al: 0.04
EB115	—	*0.06–0.13*	*0.55*	*0.15–0.50*	*0.010*	*0.015*	*9.5–12.0*	*0.45*	*0.40–0.65*	*0.20*	*0.10–0.30*	*Nb: 0.02–0.10* *N: 0.02–0.06* *Al: 0.04*
EF1	K11160	0.07–0.15	0.90–1.70	0.15–0.35	0.025	0.025	—	0.95–1.60	0.25–0.55	0.35	—	—
EF2	K21450	0.10–0.18	1.70–2.40	0.20	0.025	0.025	—	0.40–0.80	0.40–0.65	0.35	—	—
EF3	K21485	0.10–0.18	1.50–2.40	0.30	0.025	0.025	—	0.70–1.10	0.40–0.65	0.35	—	—
EF4	K12048	0.16–0.23	0.60–0.90	0.15–0.35	0.030	0.025	0.40–0.60	0.40–0.80	0.15–0.30	0.35	—	—
EF5	K41370	0.10–0.17	1.70–2.20	0.20	0.015	0.010	0.25–0.50	2.30–2.80	0.45–0.65	0.50	—	—
EF6	K21135	0.07–0.15	1.45–1.90	0.10–0.30	0.015	0.015	0.20–0.55	1.75–2.25	0.40–0.65	0.35	—	—
EM2[j]	K10882	0.10	1.25–1.80	0.20–0.60	0.015	0.010	0.30	1.40–2.10	0.25–0.55	0.25	0.05	Ti: 0.10 Zr: 0.10 Al: 0.10

(Continued)

Table 4 (Continued)
Chemical Composition Requirements for Solid Electrodes

Electrode AWS Classification[c]	UNS Number[d]	Weight Percent[a, b]										
		C	Mn	Si	S	P	Cr	Ni	Mo	Cu[e]	V	Other[f]
EM3[j]	K21015	0.10	1.40–1.80	0.20–0.60	0.015	0.010	0.55	1.90–2.60	0.25–0.65	0.25	0.04	Ti: 0.10 Zr: 0.10 Al: 0.10
EM4[j]	K21030	0.10	1.40–1.80	0.20–0.60	0.015	0.010	0.60	2.00–2.80	0.30–0.65	0.25	0.03	Ti: 0.10 Zr: 0.10 Al: 0.10
ENi1	K11040	0.12	0.75–1.25	0.05–0.30	0.020	0.020	0.15	0.75–1.25	0.30	0.35	—	—
ENi1K	K11058	0.12	0.80–1.40	0.40–0.80	0.020	0.020	—	0.75–1.25	—	0.35	—	—
ENi2	K21010	0.12	0.75–1.25	0.05–0.30	0.020	0.020	—	2.10–2.90	—	0.35	—	—
ENi3	K31310	0.13	0.60–1.20	0.05–0.30	0.020	0.020	0.15	3.10–3.80	—	0.35	—	—
ENi4	K11485	0.12–0.19	0.60–1.00	0.10–0.30	0.020	0.015	—	1.60–2.10	0.10–0.30	0.35	—	—
ENi5	K11240	0.12	1.20–1.60	0.05–0.30	0.020	0.020	—	0.75–1.25	0.10–0.30	0.35	—	—
ENi6	K11240	0.07–0.15	1.20–1.60	0.05–0.30	0.020	0.020	—	0.75–1.25	0.10–0.30	0.35	—	—
EW	K11245	0.12	0.35–0.65	0.20–0.35	0.030	0.025	0.50–0.80	0.40–0.80	—	0.30–0.80	—	—
EG	Not Specified											

[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%.
[b] Single values are maximum.
[c] The letter "N," when added as a suffix to the electrode classification, is an optional supplemental designator indicating that the limits on phosphorous, vanadium, and copper are as follows: P = 0.012% max., V = 0.05% max., Cu = 0.08% max. See A2.1 in the Annex for a discussion of the intended use of "N" designator electrodes.
[d] Refer to ASTM DS-56/SAE HS-1086, *Metals & Alloys in the Unified Numbering System*.
[e] The copper limit includes any copper coating that may be applied to the electrode.
[f] Analysis for B is required to be reported if intentionally added, or if it is known to be present at levels greater than 0.0010%.
[g] This electrode is also classified under AWS A5.17/A5.17M. It is included in this specification because it can be used with an alloy flux to deposit some of the weld metals designated in Table 3. In addition, this carbon steel electrode can be used for the two-run classification of flux-electrode combinations according to the provisions of this specification.
[h] The letter "R" when added as a suffix is an optional supplemental designator indicating that the limits on sulfur, phosphorous, copper, arsenic, tin and antimony are as follows: S = 0.010% max., P = 0.010% max., Cu = 0.15% max., As =0.005% max., Sn = 0.005% max., and Sb = 0.005% max. These reduced residual limits are necessary to meet "X" factor requirements for step cooling applications.
[i] See A7.2.3.1 in Annex A for a discussion of the B91 alloy and recommendation regarding the Mn + Ni level achieved in the weld deposit. *See also Note j of Table 3 for limits on the Mn + Ni content of the B91 weld deposit.*
[j] The composition ranges of classifications with the "EM" prefix are intended to conform to the ranges of similar electrodes in the military specifications.

Table 5
Tests Required for Classification

AWS Classification	Chemical Analysis: Base Metal	Chemical Analysis: Electrode	Chemical Analysis: Weld Metal	Radiographic Test	Tension Test	Impact Test	Diffusible Hydrogen Test
All Solid Electrodes	Not Required	Required	Not Required	Not Required	Not Required	Not Required	Not Required
All Composite Electrodes	Not Required	Not Required	Required	Not Required	Not Required	Not Required	Not Required
All Flux—Solid or Composite Electrode Multiple-Pass Classifications	Not Required	Not Required	Required	Required	Required	Required[a]	(Note b)
All Flux—Solid or Composite Electrode Two-Run Classifications	Required	Not Required	Required	Required	Required	Required[a]	(Note b)

[a] When the "Z" impact designator (no impact requirement—Table 2) 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 Clause A10 in Annex A).

Table 6
Welding Parameters for Multiple-Pass Groove Weld Test Assembly

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

Electrode Size[d]		Welding Current (amperes)[e]	Arc Voltage (volts)	Electrode Extension[f]		Travel Speed		Current Type[g]	Preheat and Interpass Temperature
in	mm			in	mm	in/min (±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	AC or DC either polarity	Refer to Table 9 for the Preheat and Interpass Temperatures Applicable to the Weld Metal Being Classified
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		
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		

[a] Values specified in inches or in/min apply to A5.23. Values specified in mm or mm/sec apply to A5.23M.
[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 2, 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 AWS A5.01M/A5.01 (unless otherwise specified by the purchaser).
[e] Lower currents may be used for the first layer.
[f] 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].
[g] In case of dispute, DCEP (direct current electrode positive) shall be used as the referee current.

Table 7
Welding Parameters for Two-Run Weld Test Assembly[a, b]

Electrode Diameter				
in	mm	Procedure Type[c]	Preheat/Interbead Temperature	Heat Input[d] (each pass)
5/32[e]	4.0[e]	DCEP (single electrode) or AC (single electrode) or DCEP lead, AC trail (tandem) or AC lead, AC trail (tandem)	212°F [115°C] Maximum	55 kJ/in–80 kJ/in [2.2 kJ/mm–3.1 kJ/mm]

[a] The test assembly shall be welded in the flat position in two runs, one from each side. The welding procedures shall be in conformance with the requirements of this table and shall be consistent with accepted welding practice. The procedure used shall ensure adequate tie-in of the weld beads made from each side. The requirements listed above apply to both solid electrodes and composite electrodes.

[b] These welding conditions are intended for machine or automatic welding with straight progression (no weaving).

[c] Single electrode procedures with either DCEP (direct current, electrode positive) or AC (alternating current) or two-electrode tandem procedures (DCEP/AC or AC/AC) may be used for classification purposes. The procedure type used shall be the same for both weld passes. In case of dispute, DCEP shall be used as the referee current.

[d] The calculation to be used for heat input is:

$$(1)\ \text{Heat Input (kJ/in)} = \frac{\text{volts} \times \text{amps} \times 60}{\text{travel speed (in/min)} \times 1000} \quad \text{or} \quad \frac{\text{volts} \times \text{amps} \times 60 \times \text{arc time (min)}}{\text{weld length (in)} \times 1000}$$

$$(2)\ \text{Heat Input (kJ/mm)} = \frac{\text{volts} \times \text{amps} \times 60}{\text{travel speed (mm/min)} \times 1000} \quad \text{or} \quad \frac{\text{volts} \times \text{amps} \times 60 \times \text{arc time (min)}}{\text{weld length (mm)} \times 1000}$$

For two wire tandem procedures the heat input is the arithmetic sum of the heat inputs calculated for each electrode.

[e] Classification is based upon the properties of the weld made with 5/32 in [4.0 mm] electrodes or the closest size manufactured, if 5/32 in [4.0 mm] is not manufactured. An alternate electrode diameter may also be required, in some cases, for lot acceptance testing under AWS A5.01M/A5.01, unless other conditions are specified by the purchaser. The heat input requirements specified above for 5/32 in [4.0 mm] shall be used when using alternate diameters of electrode.

Table 8
Base Metals for Test Assemblies

Classification Type	Weld Metal Designation	Base Metal	
		ASTM Standard[a, b]	UNS Number[c]
Multiple-Pass Classifications	A1, A2, A3, and A4	A204 Grade A	K11820
	B2, B2H, and B5	A387 Grade 11	K11789
	B3 and B4	A387 Grade 22	K21590
	B6 and B6H	A387 Grade 5	S50200
	B8	A387 Grade 9	S50400
	B23	See Note a	See Note a
	B24	See Note a	See Note a
	B91	A387 Grade 91	S50460
	B115	*A335 Grade P115 or A182 Grade F115 or A387 Grade 91*	*K91060, S50460*
	F1, F2, F3, and F4	A537 Class 1 or 2, or A533 (any type or grade in this specification)	K12437, K12521, K12539, K12529, K12554
	F5 and F6	A514 or A517 (any type or grade in this specification	K11511, K11576, K11625, K11630, K11646, K11683, K11856, K21604, or K21650
	M1, M2, M3, M4, M5, and M6	A514 or A517 (any type or grade in this specification), or A543 Type B or C	K11511, K11576, K11625, K11630, K11646, K11683, K11856, K21604, K21650, or K42339
	Mn2	*A1106*	*K92594*
	Ni1	A516 Grade 60, 65, or 70, A537 Class 1 or 2	K02100, K02403, K02700, or K12437
	Ni2	A537 Class 1 or 2, or A203 Grade A or B	K12437, K21703, or K22103
	Ni3	A203 Grade D or E	K31718 or K32018
	Ni4, Ni5, and Ni6	A537 Class 1 or 2, or A203 Grade A or B	K12437, K21703, K22103
	W	A572 or A588 (any type or grade in this specification)	K02303, K02304, K02305, K02306, K11430, K12040, K12043, or K11538
	G	(Note d)	—
Two-Run Classifications[e]	Not Applicable	A131 Grade AH36	K11852
		A516 Grade 70	K02700

[a] For multiple-pass flux-electrode classifications, ASTM A36, A285 Grade C, A515 Grade 70, or A516 Grade 70 may be used for any weld metal classification in this specification. In that case, the groove faces and the contacting face of the backing shall be buttered as shown in Figure 4, using a flux-electrode combination of the same weld metal composition as that specified for the combination being tested, or using an electrode of the specified composition classified in another AWS low-alloy steel filler metal specification. Alternately, for the indicated weld metal classification, the corresponding base metals may be used for weld test assemblies without buttering. In case of dispute, buttered A 36 shall be the referee material.

[b] Chemically equivalent steels in other U.S. customary grades or in any metric grades, whose properties are expressed in SI Units, may also be used.

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

[d] For the "G" classification (multiple-pass flux-electrode classifications only), ASTM A36, A285 Grade C, A515 Grade 70, or A 516 Grade 70 may be used; however, the groove weld faces and the contacting face of the backing shall be buttered as shown in Figure 4, using either the flux-electrode combination being classified or using a matching composition in another AWS low-alloy filler metal specification. Alternatively, base metal for which the flux-electrode combination is recommended by the manufacturer can be used for this test.

[e] Base metal different from that prescribed in this table may be used for two-run classification purposes, as agreed between supplier and purchaser. This substitution of base metal is indicated by the addition of a "G" to the classification as indicated in Figures 2 and 2M.

Table 9
Preheat, Interpass, and Postweld Heat Treatment Temperatures for Multiple-Pass Classifications[a, b]

Weld Metal Designation	Preheat and Interpass Temperature[c]		Postweld Heat Treatment Temperature[d]	
	°F	°C	°F	°C
A1, A2, A3, A4, B1, B5, Ni1, Ni2, Ni3, Ni4, Ni5, Ni6, F1, F2, F3	300 ± 25	150 ± 15	1150 ± 25	620 ± 15
B2, B2H	300 ± 25	150 ± 15	1275 ± 25	690 ± 15
B3, B4	400 ± 25	205 ± 15	1275 ± 25	690 ± 15
B6, B6H, B8	400 ± 100	205 ± 50	1375 ± 25	745 ± 15
B91, *B115*	500 ± 100	260 ± 50	1400 ± 25[e]	760 ± 15[e]
B23, B24	425 ± 50	210 ± 20	1365 ± 25[e]	740 ± 15[e]
F4[f], F5[f], F6[f]	300 ± 25	150 ± 15	1050 ± 25	565 ± 15
M1[f], M2[f], M3[f], M4[f], M5[f], M6[f], W[f]	300 ± 25	150 ± 15	1125 ± 25	605 ± 15
Mn2[f, g]	*50 to 350*	*10 to 175*	*None*	*None*
G	Not Specified			

[a] These temperatures are specified for fluxes and electrodes tested and classified under this specification and are not necessarily for production use. The specific requirements for production welding shall be determined by the user. They may or may not differ from those called for here (see A8 in Annex A).

[b] The preheat, interpass, and postweld heat treatment temperatures, as applicable, for multiple-pass flux-electrode classifications are listed for specific weld metal compositions as shown above (see 9.4). For two-run classifications the preheat and interpass temperatures are specified in Table 7 and the postweld heat treatment requirements are given in 9.5.

[c] The preheat and interpass temperatures listed here shall be used for the test assemblies regardless of whether the flux-electrode combination is classified in the as-welded or postweld heat treated condition. They are required for purposes of uniformity and may or may not be indicative of those that might be satisfactory for fabrication of any particular weldment. The fabricator shall determine what is required for the application (see also A8 in Annex A).

[d] Unless noted otherwise, weld metal specimens for flux-electrode combinations classified in the postweld heat treated condition shall be heat treated for one hour at the temperature shown for that classification (see 9.4).

[e] PWHT at specified temperature for two hours –0, +15 minutes.

[f] These classifications are normally used in the as-welded condition.

[g] *Because the Mn2 classification weld metal is austenitic, the mechanical properties are not highly sensitive to cooling rate. Therefore, narrow ranges of preheat and interpass temperatures are not necessary.*

Table 10
Diffusible Hydrogen Requirements[a]

AWS A5.23/A5.23M Flux-Electrode Classifications[b]	Optional Supplemental Diffusible Hydrogen Designator[c]	Average Diffusible Hydrogen, Maximum[d] (ml/100 g Deposited Metal)
All	H16	16
	H8	8
	H4	4
	H2	2

[a] The 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 Clause A10 in Annex A).

[b] *A hydrogen designator shall not be used with "Mn2" weld metal designation. See 14.1.*

[c] This designator is added to the end of the flux-electrode classification (see Figure 1, 1M, 2, or 2M, as applicable).

[d] Flux-electrode combinations meeting the 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 requirement for an H8 and H16. Flux-electrode combinations meeting the requirements for an H8 designator also meet the requirements for H16.

Mandatory Classification Designators[a]

The letter "F" indicates a submerged arc 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 some classification of electrode under the welding conditions specified in Figure 4 and Table 6. Two digits are used for weld metal of 100 000 psi tensile strength and higher. For example, when this designator is 11, the tensile requirement is 110 000 psi to 130 000 psi (see Table 1).

Designates the condition of heat treatment in which the tests were conducted: "A" is for as-welded and "P" for postweld heat treated. The time and temperature for PWHT are specified in Table 9.

One or two digits indicate the temperature in °F at or above which the impact strength of the weld metal referred to above meets or exceeds 20 ft·lbf (or 0.015 inch lateral expansion in the case of the "32" designator) as shown in Table 2.

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 when the electrode is a composite electrode. Refer to Table 4 for solid electrode classifications and Table 3 for composite electrode classifications.

Indicates the chemical composition of the weld metal obtained with the flux and the electrode. Two or more letters and/or digits are used (see Table 3).

FXXX – EXXX – XXXHX

Optional, Supplemental Designators[b]

Optional supplemental diffusible hydrogen designator (see Table 10).

Optional supplemental designator for special limits on residuals. See notes to Tables 3 and 4 for descriptions of these designators.

[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.

EXAMPLE

F9P0-EB3-B3 is a complete designation for a flux-electrode combination. It refers to a flux that will produce weld metal which, in the postweld heat treated condition, will have a tensile strength of 90 000 psi to 110 000 psi and Charpy V-notch impact strength of at least 20 ft·lbf at 0°F when produced with an EB3 electrode under the conditions called for in this specification. The composition of the weld metal will meet the requirements for a B3 designation as specified in Table 3.

Figure 1—A5.23 Multiple-Pass Classification System for U.S. Customary Units

Mandatory Classification Designators[a]

The letter "F" indicates a submerged arc 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 some classification of electrode under the welding conditions specified in Figure 4 and Table 6. For example, when this designator is 55, the tensile requirement is 550 MPa to 700 MPa (see Table 1M).

Designates the condition of heat treatment in which the tests were conducted: "A" is for as-welded and "P" for postweld heat treated. The time and temperature for PWHT are specified in Table 9.

One or two digits indicate the temperature in °C at or above which the impact strength of the weld metal referred to above meets or exceeds 27 J (or 0.38 mm lateral expansion in the case of the "20" designator) as shown in Table 2.

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 when the electrode is a composite electrode. Refer to Table 4 for solid electrode classifications and Table 3 for composite electrode classifications.

Indicates the chemical composition of the weld metal obtained with the flux and the electrode. Two or more letters and/or digits are used (see Table 3).

FXXXX – EXXX – XXXHX

Optional, Supplemental Designators[b]

Optional supplemental diffusible hydrogen designator (see Table 10).

Optional supplemental designator for special limits on residuals. See notes to Tables 3 and 4 for descriptions of these designators.

[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.

EXAMPLE

F62P2-EB3-B3 is a complete designation for a flux-electrode combination. It refers to a flux that will produce weld metal which, in the postweld heat treated condition, will have a tensile strength of 620 MPa to 760 MPa and Charpy V-notch impact strength of at least 27 J at –20°C when produced with an EB3 electrode under the conditions called for in this specification. The composition of the weld metal will meet the requirements for a B3 designation as specified in Table 3.

Figure 1M—A5.23M Multiple-Pass Classification System for the International System of Units (SI)

Mandatory Classification Designators[a]

The letter "F" indicates a submerged arc 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 5 and Table 7. One or two digits may be used depending on the strength level, as indicated in Table 1. The "T" at the end of the designator identifies the classification as a two-run classification. For example, when this designator is "7T," the two-run classification tensile requirement is 70 000 psi minimum. When this designator is "10T," the tensile requirement is 100 000 psi minimum.

Designates the condition of heat treatment in which the tests were conducted: "A" for as-welded and "P" for postweld heat treated. The PWHT procedure is specified in 9.5.

One or two digits indicate the temperature in °F at or above which the impact strength of the weld metal referred to above meets or exceeds 20 ft·lbf (or 0.015 inch lateral expansion in the case of the "32" designator) as shown in Table 2.

The letter "G," when it appears in this position, indicates that the base steel used for classification is not one of the base steels prescribed in Table 8 but is a different steel as agreed between purchaser and supplier.

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 when the electrode is a composite electrode. Refer to Table 4 for solid electrode classifications and Table 3 for composite electrode classifications.

FXTXXG – EXX – HX

Optional Supplemental Designator[b]

Optional supplemental diffusible hydrogen designator (see Table 10).

[a] The combination of these designators constitutes the flux-electrode classification.
[b] This designator is optional.

EXAMPLES

F7TA4-EM12K is a complete designation for a flux-electrode two-run classification. It refers to a flux that, when used with an EM12K electrode to weld the base plate prescribed in Table 8 in accordance with the two-run welding conditions called for in this specification, will produce weld metal in the as-welded condition having a minimum tensile strength of 70 000 psi and Charpy V-notch impact strength of at least 20 ft·lbf at –40°F.

F10TP2G-EA3 is a complete designation for a flux-electrode two-run classification. It refers to a flux that, when used with an EA3 electrode in accordance with the two-run welding conditions called for in this specification, will produce weld metal in the postweld heat treated condition having a minimum tensile strength of 100 000 psi and Charpy V-notch impact strength of at least 20 ft·lbf at –20°F. The "G" in the classification indicates that the base steel used is not as prescribed in Table 8 but is some other steel as agreed between purchaser and supplier.

Figure 2—A5.23 Two-Run Classification System for U.S. Customary Units

Mandatory Classification Designators[a]

The letter "F" indicates a submerged arc 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 MPa) of weld metal deposited with the flux and a specific classification of electrode under the welding conditions specified in Figure 5 and Table 7. The "T" at the end of the designator identifies the classification as a two-run classification. For example, when this designator is "62T," the two-run classification tensile requirement is 620 megapascals (MPa) minimum (see Table 1M).

Designates the condition of heat treatment in which the tests were conducted: "A" for as-welded and "P" for postweld heat treated. The PWHT procedure is specified in 9.5.

One or two digits indicate the temperature in °C at or above which the impact strength of the weld metal referred to above meets or exceeds 27 J (or 0.38 mm lateral expansion in the case of the "20" designator) as shown in Table 2.

The letter "G," when it appears in this position, indicates that the base steel used for classification is not one of the base steels prescribed in Table 8 but is a different steel as agreed between purchaser and supplier.

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 when the electrode is a composite electrode. Refer to Table 4 for solid electrode classifications and Table 3 for composite electrode classifications.

FXXTXXG – EXX – HX

Optional Supplemental Designator[b]

Optional supplemental diffusible hydrogen designator (see Table 10).

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

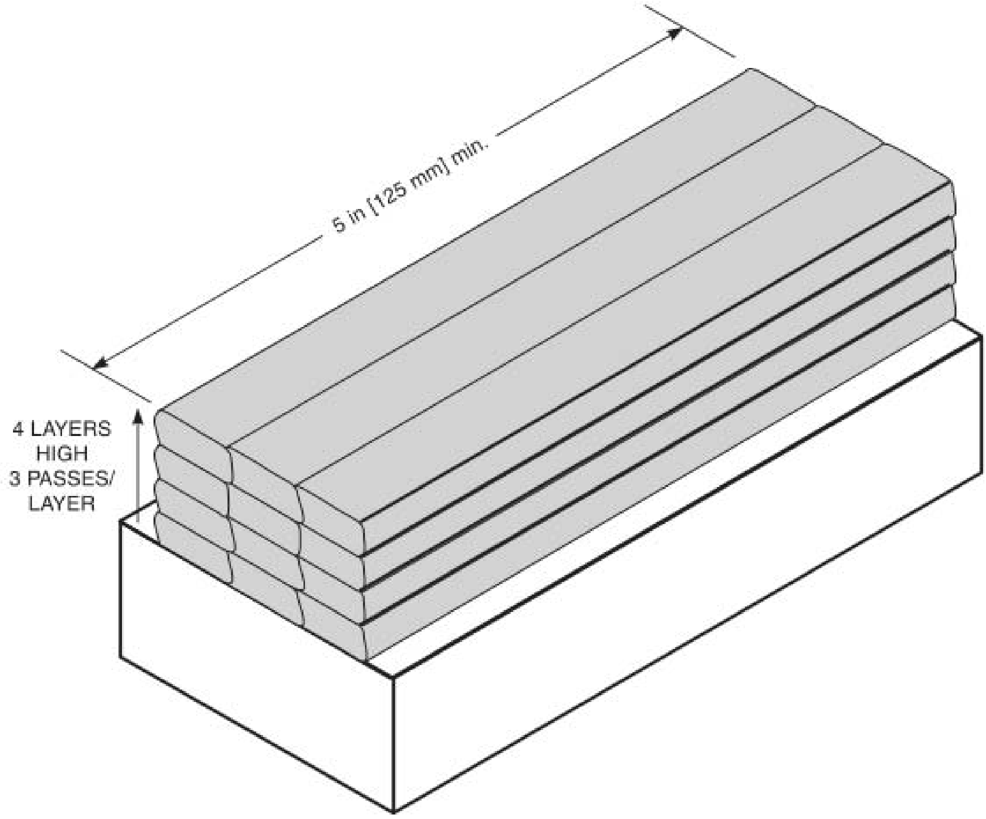
[b] This designator is optional.

EXAMPLES

F55TA3-EM12K is a complete designation for a flux-electrode two-run classification. It refers to a flux that, when used with an EM12K electrode to weld the base plate prescribed in Table 8 in accordance with the two-run welding conditions called for in this specification, will produce weld metal in the as-welded condition having a minimum tensile strength of 550 MPa and Charpy V-notch impact strength of at least 27 J at –30°C.

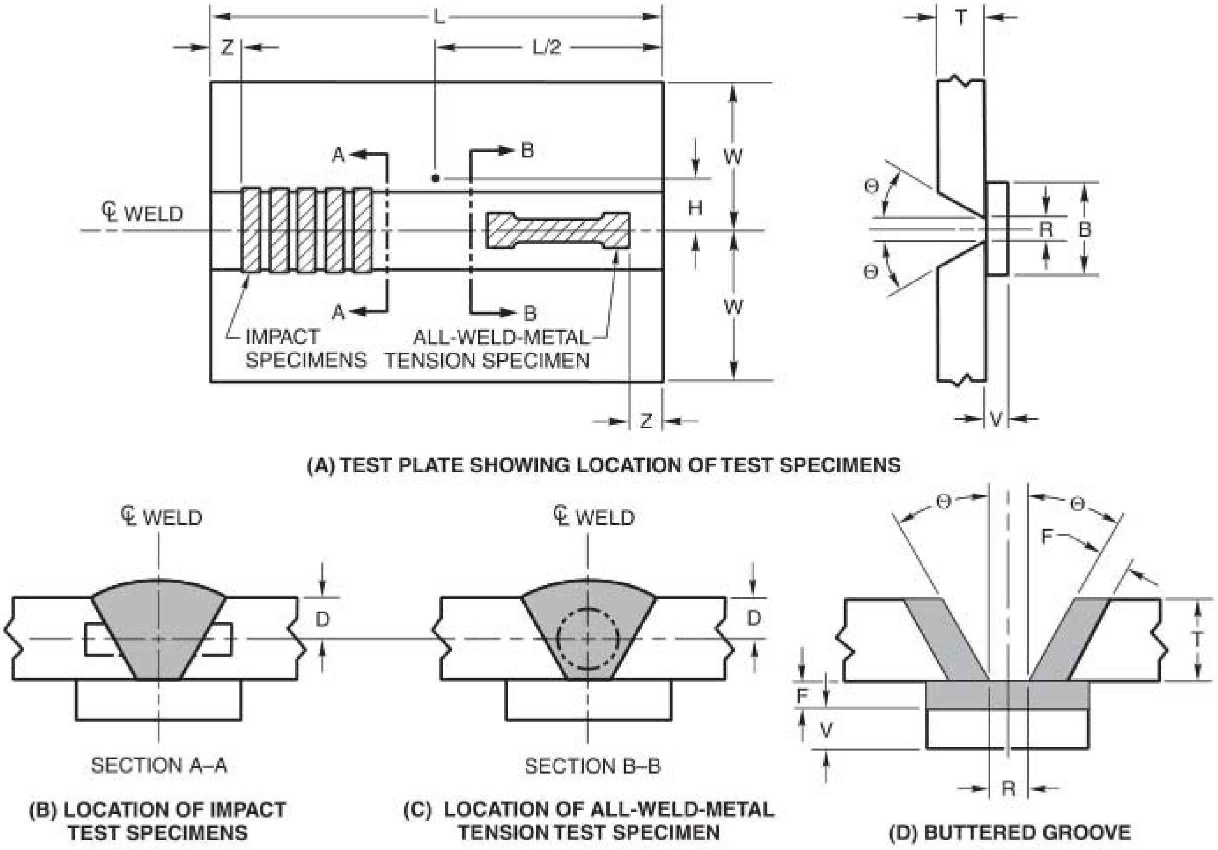
F62TP4G-EA1 is a complete designation for a flux-electrode two-run classification. It refers to a flux that, when used with an EA1 electrode in accordance with the two-run welding conditions called for in this specification, will produce weld metal in the postweld heat treated condition having a minimum tensile strength of 620 MPa and Charpy V-notch impact strength of at least 27 J at –40°C. The "G" in the classification indicates that the base steel used is not as prescribed in Table 8 but is some other steel as agreed between purchaser and supplier.

Figure 2M—A5.23M Two-Run Classification System for International System of Units (SI)



Notes:
1. Width, thickness, and length of the base metal plate may be any dimensions suitable for the electrode diameter and welding procedure. The base plate shall be of the type specified in Table 8 for the applicable weld metal designation.
2. Weld beads shall be deposited without oscillation. The welding conditions shall be in accordance with the welding parameters specified in Table 6 for the multiple-pass groove weld.
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 shall be taken from the underlying metal of the fourth layer of the weld pad.

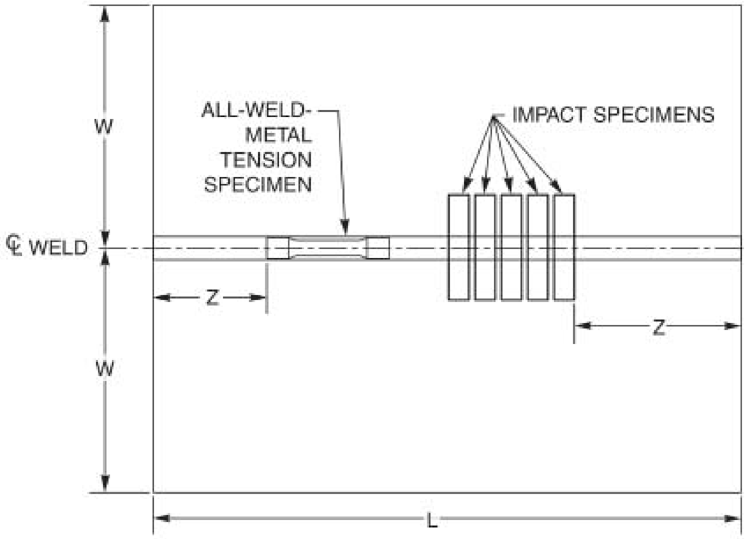
Figure 3—Weld Pad for Chemical Analysis of Weld Metal



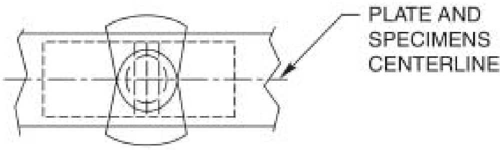
Dimension	Description	A5.23 (in)	A5.23M (mm)
L	Length, min.	12	300
T	Thickness	1 ± 1/16	25 ± 1.5
W	Width, min.	5	125
V	Backing Strip Thickness: When No Butter Layer is Applied, min. Including Butter Layer when Applied, min.	 1/2 1/2	 12 12
D	Top Surface to Specimen Center	3/8 ± 1/32	10 ± 1.0
B	Backing Strip Width, min.	2	50
R	Root Opening	1/2 ± 1/16	12± 1.5
Z	Discard, min.	1	25
Θ	Bevel Angle	15° ± 2°	
H	Approximate Point of Temperature Measurement	1	25
F	Butter layer thickness, min.	1/8	3

Note: See Table 8 Note a for details of buttered alternative base metal usage.

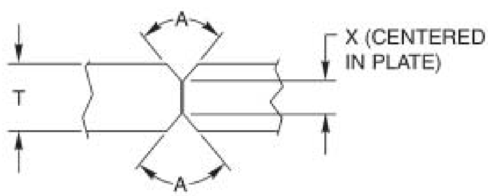
Figure 4—Multiple-Pass Groove Weld Test Assembly



(A) LOCATION OF TEST SPECIMENS



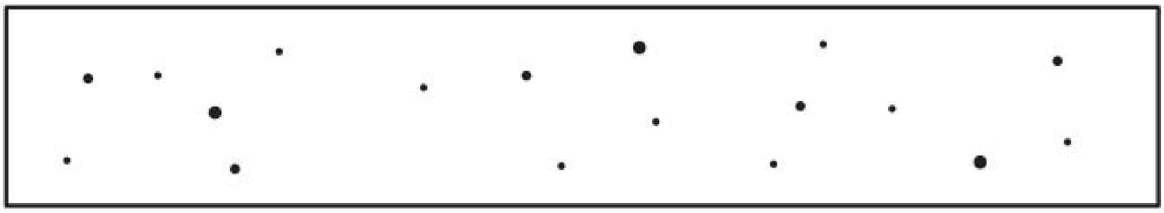
(B) LOCATION OF IMPACT AND TENSION TEST SPECIMENS



(C) JOINT CONFIGURATION

Dimension	Description	A5.23 (in)	A5.23M (mm)
A	Included angle (max.)	90°	
L	Length (min.)	12	300
T	Thickness	1/2 ± 1/16	12 ± 1.5
W	Width (min.)	5	125
X	Land (min.)	3/16	5
Z	Discard (min.)	1	25

Figure 5—Two-Run Weld Test Assembly

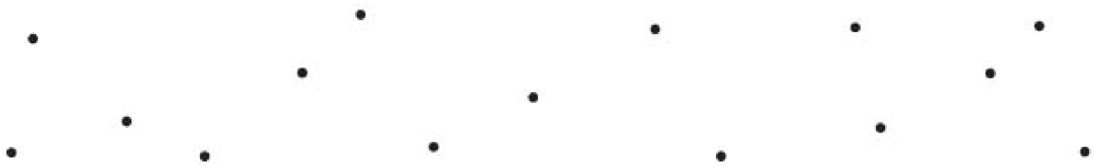


(A) ASSORTED ROUNDED INDICATIONS

MAXIMUM SIZE PERMITTED: 1/16 in [1.6 mm] max
NUMBER OF INDICATIONS PERMITTED IN ANY 6 in [150 mm] OF WELD: 18 max,
WITH THE FOLLOWING RESTRICTIONS IN THE NUMBER OF INDICATIONS OF EACH SIZE:
LARGE INDICATIONS (3/64 in to 1/16 in [1.2 mm to 1.6 mm]): 3 max.
MEDIUM INDICATIONS (1/32 in to 3/64 in [0.8 mm to 1.2 mm]): 5 max.
SMALL INDICATIONS (1/64 in to 1/32 in [0.4 mm to 0.8 mm]): 10 max.

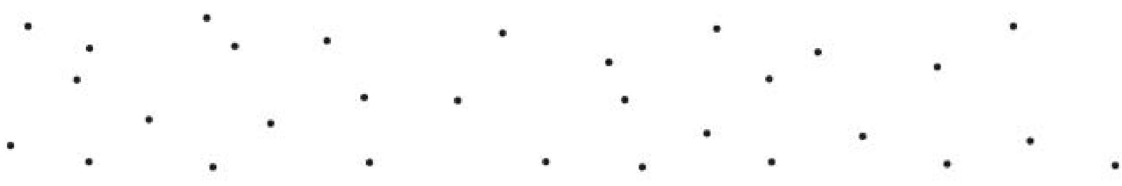
(B) LARGE ROUNDED INDICATIONS

SIZE PERMITTED: 3/64 in to 1/16 in [1.2 mm to 1.6 mm]
NUMBER OF INDICATIONS PERMITTED IN ANY 6 in [150 mm] OF WELD: 8 max.



(C) MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED: 1/32 in to 3/64 in [0.8 mm to 1.2 mm]
NUMBER OF INDICATIONS PERMITTED IN ANY 6 in [150 mm] OF WELD: 15 max.



(D) SMALL ROUNDED INDICATIONS

SIZE PERMITTED: 1/64 in to 1/32 in [0.4 mm to 0.8 mm]
NUMBER OF INDICATIONS PERMITTED IN ANY 6 in [150 mm] OF WELD: 30 max.

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 6—Radiographic Standards for Rounded Indications

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Annex A (Informative)

Guide to AWS Specification for Low-Alloy *and High Manganese* Steel Electrodes and Fluxes for Submerged Arc Welding

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, 1M, 2, or 2M, as applicable.

For solid carbon steel electrodes, the letter "L" after the "E" indicates that the solid electrode is comparatively low in manganese content. The letter "M" after the "E" indicates medium manganese content, while the letter "H" after the "E" indicates comparatively high manganese content. The one or two digits following the manganese designator indicate the nominal carbon content of the electrode. Note that the above indicators of manganese and carbon content are not applicable to solid low-alloy steel electrodes. For solid low-alloy steel electrodes, one or two letters after the "E" are used to indicate the general alloy type. Subsequent digits identify the specific classification. The letter "K," which appears in some designations, indicates a higher silicon content in the electrode. Solid carbon and low-alloy steel electrodes are classified only on the basis of their chemical composition, as specified in Table 4 of this specification.

A composite electrode is indicated by the letter "C" after the "E" and a numeric or alphanumeric 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 3) with a particular flux, rather than to electrode composition.

As examples, consider the following electrode designations: EL12, EM12K, EB3, EM3, and ECB3. As in other specifications, the prefix "E" designates an electrode. The EL12 and EM12K are solid carbon steel electrodes and the EB3 and EM3 are solid low-alloy steel electrodes. Their compositions are given in Table 4. The ECB3, however, is a composite electrode as indicated by the "C" after the "E." Composite electrodes are classified by the composition of the weld metal produced with a specific flux as shown in Table 3. An ECB3 electrode, therefore, is a composite electrode which, when used with a particular flux, will produce weld metal meeting the requirements for a B3 deposit as shown in Table 3.

The letter "N" when added as a suffix is an optional supplemental designator indicating that the electrode is intended for certain very special welds in nuclear applications. These welds are found in the core belt region of the reactor vessel. This region is subject to intense neutron radiation, and it is necessary, therefore, that the phosphorus, vanadium, and copper contents of this weld metal be limited in order to resist neutron radiation-induced embrittlement. It is also necessary that the weld metal have a high upper-shelf energy level in order to withstand some embrittlement, yet remain serviceable over the years. These electrodes are not required elsewhere; however, they could be used anywhere that weld metal with an exceptionally high upper-shelf energy level is required.

A2.2 "G" Classification

A2.2.1 This specification includes electrode 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, then, that two electrodes, each bearing the same "G" classification, may be quite different in some certain respects (chemical composition, for example).

A2.2.2 For the two-run classification a "G" is used in the classification designation when, as agreed between supplier and purchaser, a difference in base material from that specified is used for qualification. See the second example in Figures 2 and 2M.

A2.2.3 The point of difference between filler metal of a "G" classification and filler metal of a similar classification without the "G" (or even with it, for that matter) may be further clarified from the use of the words "not required" and "not specified" in the specification. The use of these words is as follows:

Not Required is used in those areas of the specification that specify the tests that must be conducted in order to classify a welding material. It indicates that that test is not required because the results for the particular test are not a requirement for that particular classification. When a test is "not required," 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 the product. The purchaser will have to establish with that supplier just what the testing procedure and the acceptance requirements are to be for that test. The purchaser may want to incorporate that information (via AWS A5.01M/A5.01) in the purchase order.

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. If the required results from a specific test are listed as "not specified" but the test in question is shown as "required" then the test results must be reported.

A2.2.4 Request for Filler Metal Classification. When a flux or electrode 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) The request should be sent to the secretary of the Committee on Filler Metals and Allied Materials at AWS Headquarters.

A2.3 Classification of Fluxes. Fluxes are classified on the basis of the mechanical properties of the weld metal they produce with a certain classification of electrode, under the specific test conditions called for in this specification. Multiple-pass flux-electrode classifications also have requirements for weld metal composition. Refer to Figure 1, 1M, 2, or 2M, as applicable.

A2.3.1 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, the condition of heat treatment (as-welded and postweld heat treated), and whether multiple-pass and two-run welding 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 may differ in one respect or another.

A2.3.2 Solid electrodes having the same classification are usually interchangeable when used with a specific flux. Composite electrodes may not be.

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.

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 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.

A.6 Description and Intended Use

A6.1 Types of Flux. SAW 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 composition 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 multiple-pass 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 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 increases the strength and hardness of the weld metal in multiple-pass welds but may lower the impact properties. For this reason, the voltage may need to be more tightly controlled for multiple-pass 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 multiple-pass welding.

A6.1.3 Alloy Fluxes. Alloy fluxes are those which can be used with a carbon steel electrode to make alloy weld metal. Some alloy for the weld metal is 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 as a welding flux 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 SAW 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 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 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. 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 3 is welded with the flux-electrode combination being tested. The welding parameters shall be as specified in Table 6 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:

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

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

A7. Description and Intended Use of Electrodes

A7.1 Choice of Electrodes. In choosing an electrode classification for SAW, the most important considerations are the mechanical properties expected of the weld metal, the requirements for weld metal composition, whether the weld is to be single-pass or multiple-pass, the cleanliness and composition of the steel to be welded, and the type of flux to be used. It is important to note that the mechanical properties obtained on a one-run or two-run weld are often quite different than those obtained on a multiple-pass weld made with the same flux and electrode. For that reason, a two-run flux-electrode classification option is included in this specification to provide for an alternate classification system based upon welding conditions that more closely reflect limited pass applications. The AWS A5.23/A5.23M specification (instead of the AWS A5.17/A5.17M specification) was selected for the inclusion of a two-run classification system because for these types of applications it is common commercial practice to use a low-alloy electrode for the welding of carbon steel to enhance the weld metal mechanical properties. For example, an EA1 molybdenum-bearing electrode is routinely used in pipemills to improve the strength level and impact properties of the two-run welds made to manufacture pipe. In addition, the strength level requirements for two-run welds such as used for the manufacture of pipe can be significantly higher than those shown in A5.17/A5.17M and are more consistent with the strength levels included in A5.23/A5.23M.

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 4) 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 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.

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, 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.

A7.2 Chemical Composition. For the welding of low-alloy steel, the chemical composition of the weld metal produced is often the primary consideration for electrode selection. Together with appropriate heat treatments, each composition can achieve a wide range of corrosion resistance and mechanical properties at various service temperatures. It is usually desirable for weld metal to match the chemical composition and the mechanical properties of the base metal as closely as possible. In fact, many of the electrodes classified to this specification have been developed for specific base metal grades or classes. If an optimum match is not possible, engineering judgment together with weld testing may be required to select the most suitable electrodes. Table 3 provides detailed weld metal chemical composition requirements. Tables 1, 1M, and 2 list the mechanical properties of the weld metal in the as-welded condition or in the postweld heat-treated condition when the weldment is subjected to the PWHT requirements in Table 9. It should be noted that changes in welding variables or heat treatment can be expected to affect the mechanical properties. However, except for the effects of dilution, the chemical composition can be expected to remain reasonably unchanged when using a neutral flux.

The electrode classification identifies the chemical composition of the electrode. The following paragraphs highlight the differences between these electrodes and electrode groups and indicate typical applications.

A7.2.1 EL8, EL8K, EL12, EM11K, EM12, EM12K, EM13K, EM14K, EM15K, EH10K, EH11K, EH12K, and EH14 (Carbon Steel) Electrodes. These electrodes are carbon steel electrodes which vary from one another in their carbon, manganese, and silicon contents. An electrode from this group is selected for use with a particular flux to provide the best combination of these elements to meet application requirements. These requirements can include (but are not limited to) resistance to cracking and porosity, welding characteristics, welding speed, bead appearance, and weld metal mechanical properties. The EM14K electrodes also contain small additions of titanium, although they are considered carbon steel electrodes. The titanium functions to improve strength and toughness under certain conditions of high heat input welding or PWHT. The manufacturer should be consulted for specific recommendations.

A7.2.2 EA1, EA2, EA3, EA3K, and EA4 (C-Mo Steel) Electrodes. These electrodes are similar to the medium manganese and high manganese carbon steel electrodes shown above except that 0.5% molybdenum is added. This addition increases the strength of the weld metal, especially at elevated temperatures, and provides some increase in corrosion resistance. Typical applications include the welding of C-Mo steel base metals such as ASTM A204 plate and ASTM A335-P1 pipe. Electrodes of this type are particularly useful in developing impact strength on single-pass welds such as are used in the manufacture of line pipe.

A7.2.3 EB1, EB2, EB2H, EB3, EB5, EB6, EB6H, EB8, EB23, EB24, EB91, and *EB115* (Cr-Mo Steel) Electrodes. These electrodes produce weld metal that contains between 0.5% and *12%* chromium and between 0.5% and 1% molybdenum. They are designed to produce weld metal for high temperature service.

The letter "R" when added as a suffix to the EB2 or EB3 electrode classification or to the B2 or B3 weld metal designation is an optional supplemental designator indicating that the electrode will meet the reduced residual limits necessary to meet "X" factor requirements for step cooling applications.

Since all Cr-Mo weld deposits will air harden in still air, both preheat and postweld heat treatment are required for most applications.

A7.2.3.1 EB91 (previously EB9) is a 9% Cr-1% Mo electrode modified with niobium and vanadium designed to provide improved creep strength, and oxidation and corrosion resistance at elevated temperatures. Due to the higher elevated temperature properties of this alloy, components that are now fabricated from stainless and ferritic steels may be fabricated from a single alloy, eliminating problems associated with dissimilar welds.

In addition to the classification requirements of this specification, impact toughness and high temperature creep strength properties should be determined. Due to the influence of various levels of carbon and niobium (columbium), specific values and testing must be agreed to by the purchaser and supplier.

Thermal treatment of the B91 alloy is critical and must be closely controlled. The temperature at which the microstructure has complete transformation into martensite (M_f) is relatively low; therefore, upon completion of welding and before postweld heat treatment, it is recommended that the weldment be allowed to cool below 200°F [93°C] to maximize transformation to martensite. The maximum allowable temperature for PWHT is also critical in that the lower transformation temperature (Ac_1) is also comparably low. *To aid in allowing for an adequate postweld heat treatment, the restriction of Mn + Ni has been imposed (see Table 3, Note j).* The combination of Mn and Ni tends to lower the Ac_1 temperature to the point where the PWHT temperature approaches the Ac_1, possibly causing partial transformation of the microstructure. By restricting the Mn + Ni, the PWHT temperature will be sufficiently below the Ac_1 to avoid this partial transformation. See Table 3 for B91 designations with lower Mn + Ni levels.

A7.2.3.2 *EB115 is a 10.5% Cr-0.5% Mo electrode modified with niobium and vanadium to provide improved creep strength, oxidation, and corrosion resistance at elevated temperatures. This filler metal is similar to the EB91 type but has a higher Cr content to enhance the oxidation resistance, and a higher vanadium to niobium ratio to ensure long-term rupture strength in the time-dependent regime*

A7.2.4 EF4, EF5, and EF6 (Cr-Ni-Mo Steel) Electrodes. These electrodes use a combination of Cr, Ni, and Mo to develop the strength levels and notch toughness required for a number of high-strength, low-alloy or microalloyed structural steels.

A7.2.5 EM2, EM3, and EM4 (High-Strength, Low-Alloy Steel) Electrodes. These electrodes may contain a combination of Cr, Ni, Mo, Ti, Zr, and Al. They are intended to produce high-strength deposits meeting 100 000 psi [690 MPa], 110 000 psi [760 MPa], or 120 000 psi [830 MPa] minimum tensile requirements to weld steels such as HY80 and HY100. They are most typically used for weldments not subject to PWHT.

A7.2.6 ECMn2. *Weld metal of this composition has been designed for joining austenitic steels of similar composition used for containing liquid natural gas and other cryogenic liquids. Weld metal of this composition is also used for welding nickel steels such as 3-1/2% and 9% nickel steels.*

A7.2.7 ENi1, ENi1K, ENi2, and ENi3 (Ni Steel) Electrodes. These electrodes have been designed to produce weld metal with increased strength without being hardenable or with increased notch toughness at temperatures as low as –100°F (–73°C) or lower. They have been specified with nickel contents which fall into three nominal levels of 1% Ni, 2.5% Ni, and 3.5% Ni. With carbon levels of up to 0.12%, strength increases and weld deposits can meet 80 000 psi [550 MPa] minimum tensile strength requirements. However, with lower levels of carbon, low temperature toughness improves to match the base metal properties of nickel steels such as ASTM A203 Gr. E, ASTM A352 LC3 and LC4 classifications.

Many low-alloy steels require PWHT to stress relieve the weld or temper the weld metal and heat-affected zone (HAZ) to achieve increased ductility. It is often acceptable to exceed the PWHT holding temperatures shown in Table 9. However, for many applications, nickel steel weld metal can be used without PWHT. If PWHT is to be specified for a nickel steel weldment, the holding temperature should not exceed the maximum temperature given in Table 9 for the classification considered since nickel steels can be embrittled at higher temperatures.

A7.2.8 ENi4, ENi5, ENi6, EF1, EF2, and EF3 (Ni-Mo Steel) Electrodes. These electrodes contain between 0.5% and 2% nickel and between 0.25% and 0.5% molybdenum. They are typically used for multiple-pass welding of high-strength, low-alloy, or microalloyed structural steels where a combination of strength and good notch toughness is required.

A7.2.9 EW (Weathering Steel) Electrode. This electrode has been designed to produce weld metal that matches the corrosion resistance and the coloring of the ASTM weathering-type structural steels. These special properties are achieved by the addition of about 0.5% copper to the weld metal. To meet strength, ductility, and notch toughness in the weld metal, some chromium and nickel additions are also made. This electrode is used to weld the typical weathering steel, such as ASTM A242 and ASTM A588.

A7.2.10 EG (General Low-Alloy Steel) Electrodes. These electrodes are described in A2.2. These electrode classifications may be either modifications of other discrete classifications or totally new classifications. Purchaser and user should obtain from the supplier the description and intended use for any EG electrode.

A8. Mechanical Properties of Submerged Arc Welds

Tables 1, 1M, and 2 (as applicable) of this specification list the mechanical properties required of weld metal for both multiple-pass and two-run flux-electrode classifications. The mechanical properties are determined from specimens prepared according to the procedures called for in this specification. The multiple-pass procedure (for multiple-pass flux-electrode classifications) minimizes dilution from the base metal and provides a finer grain structure due to the reheating of the deposited metal by subsequent weld passes. Therefore, this classification procedure more accurately reflects the properties of the undiluted weld metal from each flux-electrode classification. The two-run procedure (for two-run flux-electrode classifications) more accurately reflects the properties of as-deposited weld metal made with a particular flux and electrode under conditions of high base plate dilution. For this reason the composition of the base material is highly influential on the composition and mechanical properties of two-run weld deposits.

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, multiple-pass welds. Large, single-pass welds solidify and cool more slowly than the smaller weld beads of a multiple-pass weld, and succeeding passes of a multiple-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 from those of a multiple-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 postweld heat treatment, or both. For multiple-pass classifications tested in the postweld heat treated condition ("P" designator, see Figure 1 or 1M, as applicable) the PWHT procedure is as indicated in Table 9 and 9.4. For two-run classifications tested in the postweld heat treated condition ("P" designator, see Figure 2 or 2M, as applicable) the PWHT procedure is as indicated in 9.5. 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 certain specific conditions.

Procedures employed in practice may require voltage, amperage, type of current, number of welding arcs, 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 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 postweld heat treated conditions.

For multiple-pass welds, postweld heat treatment times in excess of the time used for multiple-pass classification purposes in this specification may have a major influence on the strength and toughness of the weld metal. The user should be aware of this and understand that the mechanical properties of weld metal produced with other procedures than those required in this specification may differ from the properties required by Tables 1, 1M, and 2 of this specification, as applicable.

A9. 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.

A10. Diffusible Hydrogen Test

A10.1 The SAW process is generally considered to be a low-hydrogen welding process. As the weld metal or HAZ 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 underbead cracks in the HAZ.

A10.2 Since the available diffusible hydrogen level strongly influences the tendency towards hydrogen-induced cracking, it may be desirable to measure the diffusible hydrogen content resulting from welding with a particular 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*.

A10.3 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values from those indicated by the designator.

A10.4 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.

A10.5 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.

A10.6 Aging of Tensile Specimens. Weld metals may contain significant quantities of hydrogen for some time after they have been made. Most of this hydrogen gradually escapes over time. This may take several weeks at room temperature or several hours at elevated temperatures. As a result of this eventual change in hydrogen level, ductility of the weld metal increases toward its inherent value, while yield, tensile, and impact strengths remain relatively unchanged. The A5.23 and A5.23M specifications permit the aging of the test specimens or weld test assembly at elevated temperatures not exceeding 220°F [105°C] for up to 48 hours before cooling them to room temperature and subjecting them to testing. The purpose of this treatment is to facilitate removal of hydrogen from the test specimen in order to minimize wide variations in test results.

Aging treatments are sometimes used for low hydrogen electrode deposits, especially when testing high strength deposits. Note that aging may involve holding test specimens or weld test assemblies at room temperature for several days or holding at a somewhat higher temperature for a shorter period of time. Consequently, users are cautioned to employ adequate preheat and interpass temperatures to avoid the deleterious effects of hydrogen in production welds. It should be kept in mind that aging test assemblies may not remove as much diffusible hydrogen as aging the individual specimens. The purchaser may, by mutual agreement with the supplier, have the thermal aging of specimens prohibited for all mechanical testing done to schedule I or J of AWS A5.01M/A5.01.

A11. General Safety Considerations

A11.1 Safety issues and concerns are addressed in this standard, although health issues and concerns are beyond the scope of this standard. 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, ANSI Z49.1, and applicable federal and state regulations.

A11.2 Safety and Health Fact Sheets. The Safety and Health Fact Sheets 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.

Table A.1
Comparison of Solid Electrode Designations[a]

AWS A5.23/A5.23M Classification	ISO 14171[b] Designation		ISO 24598[c] Designation		ISO 26304[d] Designation	
	ISO 14171-A	ISO 14171-B	ISO 24598-A	ISO 24598-B	ISO 26304-A	ISO 26304-B
EL8[e]	S1	(SU11)	—	—	—	—
EL8K[e]	S1Si1	SU08	—	—	—	—
EL12[e]	S1	(SU11)	—	—	—	—
EM11K[e]	—	SU111	—	—	—	—
EM12[e]	S2	(SU22)	—	—	—	—
EM12K[e]	S2Si	SU21	—	—	—	—
EM13K[e]	S2Si2	SU25	—	—	—	—
EM14K[e]	—	SU24	—	—	—	—
EM15K[e]	S2Si	(SU21)	—	—	—	—
EH10K[e]	S3Si	SU10	—	—	—	—
EH11K[e]	—	SU31	—	—	—	—
EH12K[e]	S4Si	(SU42)	—	—	—	—
EH14[e]	—	(SU41)	—	—	—	—
EA1	—	SU1M3	(SMo)	SU1M3	—	—
EA1TiB	—	SUM3TiB	—	—	—	—
EA2	S2Mo	(SU2M3)	SMo	SU3M3	—	—
EA2TiB	—	SU2M3TiB	—	—	—	—
EA3	S4Mo	SU4M3	—	SU4M3	—	—
EA3K	—	SU4M31	—	SU4M31	—	—
EA4	S3Mo	SU3M3	SMnMo	—	—	—
EB1	—	—	—	SUCM	—	—
EB2	—	—	SCrMo1	SU1CM	—	—
EB2H	—	—	—	SU1CMVH	—	—
EB3	—	—	SCrMo2	SU2C1M	—	—
EB5	—	—	—	SUC1MH	—	—
EB6	—	—	SCrMo5	SU5CM	—	—
EB6H	—	—	—	SU5CMH	—	—
EB8	—	—	SCrMo9	SU9C1M	—	—
EB23	—	—	—	—	—	—
EB24	—	—	—	—	—	—
EB91	—	—	—	SU9C1MV	—	—

(Continued)

Table A.1 (Continued)
Comparison of Solid Electrode Designations[a]

AWS A5.23/A5.23M Classification	ISO 14171[b] Designation		ISO 24598[c] Designation		ISO 26304[d] Designation	
	ISO 14171-A	ISO 14171-B	ISO 24598-A	ISO 24598-B	ISO 26304-A	ISO 26304-B
EF1	—	—	—	—	S2Ni1Mo	SUN2M2
EF2	—	—	—	—	—	SUN1M3
EF3	—	—	—	—	—	SUN2M33
EF4	—	—	—	—	—	SUN1C1M1
EF5	—	—	—	—	—	SUN5CM3
EF6	—	—	—	—	—	SUN4C1M3
EM2	—	—	—	—	—	SUN3M2
EM3	—	—	—	—	—	SUN4M2
EM4	—	—	—	—	—	SUN5M3
ENi1	S2Ni1	SUN2	—	—	—	—
ENi1K	—	SUN21	—	—	—	—
ENi2	—	SUN5	—	—	—	—
ENi3	S2Ni3	SUN7	—	—	—	—
ENi4	—	SUN4M1	—	—	—	SUN4M1
ENi5	—	SUN2M1	—	—	—	SUN2M1
ENi6	—	—	—	—	—	—
EW	—	SUNCC1	—	—	—	—

[a] The requirements for the equivalent classifications shown are not necessarily identical in every respect.
[b] ISO 14171, *Welding Consumables — Wire Electrodes and Wire-Flux Combinations for Submerged Arc Welding of Non-Alloy and Fine Grain Steels — Classification*, is a cohabitation document providing for classification utilizing a system based upon the yield strength and the average impact energy for all-weld metal of 47 J (ISO 14171-A), or utilizing a system based upon the tensile strength and the average impact energy for all-weld metal of 27 J (ISO 14171-B).
[c] ISO 24598 *Welding Consumables — Solid Wire Electrodes, Tubular Cored Electrodes and Electrode-Flux Combinations for Submerged Arc Welding of Creep-Resisting Steels — Classification*, is a cohabitation document. The classification according to system A is mainly based on EN 12070. The classification according to system B is mainly based upon standards used around the Pacific Rim.
[d] ISO 26304, *Welding Consumables — Solid Wire Electrodes, Tubular Cored Electrodes and Electrode/Flux Combinations for Submerged Arc Welding of High Strength Steels — Classification*, is a cohabitation document. The classification according to system A is mainly based on EN 14295. The classification according to system B is mainly based upon standards used around the Pacific Rim.
[e] These solid wire electrode classifications also appear in AWS A5.17/A5.17M.

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., D1.1:2006) 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.

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, A5.35	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, A5.35	A5.9, A5.22	A5.22	A5.9, A5.22, A5.39	A5.9, A5.22, A5.39	A5.9	A5.8, A5.31
Cast Iron	A5.15	A5.15	A5.15	A5.15				A5.8, A5.31
Nickel Alloys		A5.11, A5.35	A5.14, A5.34	A5.34	A5.14, A5.34, A5.39	A5.14, A5.34, A5.39		A5.8, A5.31
Aluminum Alloys		A5.3	A5.10					A5.8, A5.31
Copper Alloys		A5.6	A5.7					A5.8, A5.31
Titanium Alloys			A5.16					A5.8, A5.31
Zirconium Alloys			A5.24					A5.8, A5.31
Magnesium Alloys			A5.19					A5.8, A5.31
Tungsten Electrodes			A5.12					
Brazing Alloys and Fluxes								A5.8, A5.31
Surfacing Alloys	A5.21	A5.13	A5.21	A5.21	A5.21			
Consumable Inserts			A5.30					
Shielding Gases			A5.32	A5.32			A5.32	

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AWS Filler Metal Specifications and Related Documents

Designation	Title
A4.2M (ISO 8249 MOD)	*Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*
A4.3	*Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*
A4.4M	*Standard Procedures for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings*
A4.5M/A4.5 (ISO 15792-3 MOD)	*Standard Methods for Classification Testing of Positional Capacity and Root Penetration of Welding Consumables in a Fillet Weld*
A5.01M/A5.01 (ISO 14344 MOD)	*Welding and Brazing Consumables—Procurement of Filler Metals and Fluxes*
A5.02/A5.02M	*Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*
A5.1/A5.1M	*Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*
A5.2/A5.2M	*Specification for Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding*
A5.3/A5.3M	*Specification for Aluminum and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding*
A5.4/A5.4M	*Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*
A5.5/A5.5M	*Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*
A5.6/A5.6M	*Specification for Copper and Copper-Alloy Electrodes for Shielded Metal Arc Welding*
A5.7/A5.7M	*Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes*
A5.8M/A5.8	*Specification for Filler Metals for Brazing and Braze Welding*
A5.9/A5.9M (ISO 14343 MOD)	*Welding Consumables—Wire Electrodes, Strip Electrodes, Wires, and Rods for Arc Welding of Stainless and Heat Resisting Steels—Classification*
A5.10/A5.10M (ISO 18273 MOD)	*Welding Consumables—Wire Electrodes, Wires, and Rods for Welding of Aluminum and Aluminum-Alloys—Classification*
A5.11/A5.11M	*Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding*
A5.12M/A5.12 (ISO 6848 MOD)	*Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting*
A5.13/A5.13M	*Specification for Surfacing Electrodes for Shielded Metal Arc Welding*
A5.14/A5.14M	*Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods*
A5.15	*Specification for Welding Electrodes and Rods for Cast Iron*
A5.16/A5.16M (ISO 24034 MOD)	*Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods*
A5.17/A5.17M	*Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*
A5.18/A5.18M	*Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*
A5.19	*Specification for Magnesium-Alloy Welding Electrodes and Rods*
A5.20/A5.20M	*Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*
A5.21/A5.21M	*Specification for Bare Electrodes and Rods for Surfacing*
A5.22/A5.22M	*Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods*
A5.23/A5.23M	*Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*
A5.24/A5.24M	*Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods*
A5.25/A5.25M	*Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding*
A5.26/A5.26M	*Specification for Carbon and Low-Alloy Steel Electrodes for Electrogas Welding*
A5.28/A5.28M	*Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*
A5.29/A5.29M	*Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*
A5.30/A5.30M	*Specification for Consumable Inserts*
A5.31M/A5.31	*Specification for Fluxes for Brazing and Braze Welding*
A5.32M/A5.32 (ISO 14175 MOD)	*Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*
A5.34/A5.34M	*Specification for Nickel-Alloy Flux Cored and Metal Cored Welding Electrodes*
A5.35/A5.35M-AMD1	*Specification for Covered Electrodes for Underwater Wet Shielded Metal Arc Welding*
A5.39/A5.39M	*Specification for Flux and Electrode Combinations for Submerged Arc and Electroslag Joining and Surfacing of Stainless Steel and Nickel Alloys*

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