

Specification for Low-Alloy Steel Electrodes and Rods For Gas Shielded Arc Welding



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American National Standards Institute
September 13, 2022

Specification for

Low-Alloy Steel Electrodes and Rods

For Gas Shielded Arc Welding

5th Edition

Revises AWS A5.28/A5.28M:2020

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

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification prescribes the requirements for classification of solid low-alloy steel electrodes and rods, composite stranded low-alloy steel electrodes and rods, and composite metal cored low-alloy steel electrodes and rods for gas shielded welding processes including gas metal arc welding, gas tungsten arc welding, and plasma arc welding. Classification is based on chemical composition of the electrode for solid electrodes and rods, chemical composition of weld metal for composite stranded and composite metal cored electrodes and rods and the as-welded or postweld heat treated mechanical properties of the weld metal for each. Additional requirements are included for manufacture, sizes, lengths and packaging. Optional supplemental designators are also included for lower temperature toughness requirements, diffusible hydrogen limits, reduced Mn + Ni levels in Cr-Mo compositions, and shielding gas ranges. A guide is appended to the specification as a source of information concerning the classification system employed and the intended use of the electrodes and rods.

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



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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 It must be reviewed every five years, and if not revised, it must be either reaffirmed or withdrawn.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 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, provide for interchangeability of products in both the U.S. Customary and SI Units.

This current document is the fourth revision of the initial AWS document issued in 1979. The evolution took place as follows:

AWS A5.28-79 *Specification for Low Alloy Steel Filler Metals for Gas Shielded Metal Arc Welding*

AWS A5.28-96 *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*

AWS A5.28/A5.28M:2005, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*

AWS A5.28/A5.28M:2005 (R2015), *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*

AWS A5.28/A5.28M:2020, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*

Substantive changes included in this revision include:

- Optional supplemental designators to indicate ranges of shielding gases for which an electrode meets the requirements for classification, including any optional diffusible hydrogen (“HX”), low temperature toughness (“J”) or reduced Mn + Ni supplemental designators.
- The maximum manganese limit for the E80C-Ni1 classification has been raised to 1.75%.
- Added new classification ER90S-B115 [ER62S-B115]
- Added new classification E90C-K14 [E62C-K14]
- Added allowance for an electrode to be classified with both a “-G” chemical composition designator as well as with a defined chemical composition designator. This is being done at the request of the end user community to ease the transition from “-G” classification to a defined composition classification and to prevent burdensome requalification for long-entrenched products with “-G” classifications.

These substantive changes are shown in *italic font*.

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

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

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

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Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of low-alloy steel electrodes (solid, composite stranded and composite metal cored) for gas metal arc welding (GMAW) and low-alloy steel rods (solid, composite stranded and composite metal cored) for gas tungsten arc welding (GTAW) and plasma arc welding (PAW). With two exceptions (the 20% manganese types “Mn1” and “Mn2”), iron is the only element whose content exceeds 10.5% in undiluted weld metal deposited by these electrodes or rods, as applicable.

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 values in any way. In selecting rational metric units, AWS A1.1, *Metric Practice Guide for the Welding Industry* and ISO 544, *Welding Consumables-Technical Delivery Conditions for Welding Filler Materials and Fluxes-Type of Product, Dimensions, Tolerances and Markings*, are used where suitable. Tables and figures make use of both U.S. Customary and SI units, which, with the application of the specified tolerances, provide for interchangeability of products in both U.S. Customary and SI Units. The specification with the designation A5.28 uses U.S. Customary Units. The specification A5.28M uses SI Units. The latter are shown within brackets [] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for sizing of electrodes or packaging or both under the A5.28 or A5.28M specifications.

1.3 Safety and health issues and concerns are beyond the scope of this standard; some safety and health information is provided, but such issues are not fully addressed herein. Some safety and health information can be found in the nonmandatory annex, Clauses B5 and B10.

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 AWS website

Material or Equipment Manufacturers:

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

Applicable federal and state regulations.

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) Standards:

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 A5.01M/A5.01 (ISO 14344:2010 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 A5.18/A5.18M, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*

AWS A5.32M/A5.32 (ISO 14175: 2008 MOD), *Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*

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

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

American National Standards Institutes (ANSI) document:

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

ASTM International (ASTM) documents:

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

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

ASTM A285/A285M, *Standard 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, *Standard Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum*

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

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

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

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

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

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

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

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 Method 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 Test Method for Radiographic Examination Using Computed Radiography (Photostimulable Luminescence Method).*

ASTM E2698, *Standard Test Method for Radiographic Examination Using Digital Detector Arrays.*

International Organization for Standardization (ISO) documents:

ISO 544, *Welding Consumables—Technical Delivery Conditions for Welding Filler Materials and Fluxes—Type of Product, Dimensions, Tolerances and Markings*

ISO 15792-1-Amendment 1, *Test methods—Part 1: Test Methods for All-weld Metal Test Specimens in Steel, Nickel and Nickel Alloys*

ISO 80000-1:2009/COR 1:2011, *Quantities and Units—Part 1: General*

United States Department of Defense (DODSSP) publications:

MIL-S-16216, *Military Specification, Steel Plate, Alloy, Structural, High Yield Strength (HY-80 and HY-100)*

NAVSEA Technical Publication T9074-BD-GIB-010/0300, *Base Materials for Critical Applications: Requirements for Low Alloy Steel Plate, Forgings, Castings, Shapes, Bars, and Heads of HY-80/100/130 and HSLA-80/100, Appendix B (16216) Steel Plate, Alloy, Structural, High-Yield Strength (HY-80 and HY-100).*

American Petroleum Institute (API) document:

Spec 5L, *Specification for Line Pipe*

3. Classification

3.1 Solid Electrodes and Rods

3.1.1 The solid electrodes and rods covered by this A5.28 specification utilize a classification system based upon U.S. Customary Units as shown in Figure 1. They are classified according to the chemical composition of the electrode, as specified in Table 1, and the mechanical properties of the weld metal as specified in Tables 2 and 3 with the shielding gas specified in Table 2.

3.1.2 The solid electrodes and rods covered by this A5.28M specification utilize a classification system based upon the International System of Units (SI) as shown in Figure 1. They are classified according to the chemical composition of the electrode or rod as specified in Table 1, and the mechanical properties of the weld metal, as specified in Tables 2 and 3 with the shielding gas specified in Table 2.

3.1.3 Either one of the two GMAW weld assemblies in Figure 2, using shielding gas in Table 2, is required and sufficient to classify solid wires offered as an electrode or an electrode and rod. The GTAW groove weld in Figure 2 is required for solid wires offered as a rod only. The GTAW weld assembly may be requested in addition to the GMAW assembly as an option and as agreed upon between the purchaser and the supplier.

3.2 Composite Metal Cored and Composite Stranded Electrodes and Rods

3.2.1 The composite metal cored and composite stranded electrodes and rods covered by this A5.28 specification also utilize a classification system based upon U.S. Customary Units as shown in Figure 1. They are classified according to the chemical composition and mechanical properties of the weld metal as specified in Tables 2, 3, and 4 with the shielding gas specified in Table 2.

3.2.2 The composite metal cored and composite stranded electrodes and rods covered by this A5.28M specification also utilize a classification system based upon the International System of Units (SI) as shown in Figure 1. They are classified according to the chemical composition and mechanical properties of the weld metal as specified in Tables 2, 3, and 4 with the shielding gas specified in Table 2.

3.2.3 Either one of the two GMAW weld assemblies in Figure 2, using shielding gas in Table 2, is required for composite filler metals classified as an electrode. The GTAW groove weld in Figure 2 is required for composite filler metals classified as a rod. Either one of the two GMAW weld assemblies and the GTAW weld assembly in Figure 2 are required for composite filler metals classified as an electrode and rod.

3.3 Electrodes and rods classified under one classification shall not be classified under any other classification in this specification with the exception of the following:

(1) ER80S-D2 [ER55S-D2] may also be classified as ER90S-D2 [ER62S-D2] provided the product meets the requirements of both classifications.

(2) Electrodes and rods may be classified under A5.28 using U.S. Customary Units, or under A5.28M using the International System of Units (SI), or both. Electrodes and rods classified under either unit system must meet all requirements for classification under that unit system.

(3) Electrodes and rods may be classified with both a defined chemical composition designator and a “-G” composition designator.

3.4 The welding electrodes and rods classified under this specification are intended for GMAW, GTAW, and PAW, but that is not to prohibit their use with any other process (or any other shielding gas, or combination of shielding gases) for which they are found suitable. *See Clauses 14.4 and B8.4 for information on optional shielding gas range designators.*

4. Acceptance

Acceptance of the electrodes and rods shall be in accordance with the provisions of AWS A5.01M/A5.01. See Clause B3, Acceptance (in Annex B) 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 Clause B4, Certification (in Annex B) for further information concerning certification and the testing called for to meet this requirement.

6. Rounding Procedure

For purposes 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 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 1 000 psi for tensile and yield strength for A5.28 classifications and to the nearest 10 MPa for tensile and yield strength for A5.28M classifications and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities. The rounded results shall fulfill the requirements for the classification under test.

7. Summary of Tests

7.1 The tests required for each classification are specified in Table 5. The purpose of these tests is to determine the chemical composition of the electrode or rod or weld metal, and the mechanical properties and soundness of the weld

metal. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Clauses 9 through 13.

7.2 This document provides for optional supplemental tests and designations which are not required for classification but which are included to provide additional information which may be useful to the user. See Figure 1, Clause 14, and Annex A.

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Specimens for retest may be taken from the original test assembly or sample, or from one or two new test assemblies or samples. For chemical analysis, retest need be only for those specific elements that failed to meet their 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 specified or proper procedures were not followed in preparing the weld test assembly or test specimens, or in conducting the test, the test shall be considered invalid, without regard to whether the test was actually completed, or whether the test results met, or failed to meet, the requirement. That test shall be repeated, following proper specified procedures. In this case, the requirement for doubling the number of test specimens does not apply.

9. Weld Test Assemblies

9.1 At least one weld test assembly is required, and two may be required (depending on the electrode—solid as opposed to composite—and the manner in which the sample for chemical analysis is taken), as specified in Table 5. They are as follows:

- (1) Either one of the two GMAW groove weld assemblies in Figure 2 for mechanical properties and soundness of the weld metal for both solid and composite electrodes based on gas metal arc welding.
- (2) The GTAW groove weld in Figure 2 for mechanical properties and soundness based on gas tungsten arc welding of solid filler metals classified as rods only and all composite filler metals classified as rods.
- (3) The weld pad in Figure 3 for chemical analysis of the weld metal from composite stranded and composite metal cored filler metals.
- (4) The sample for chemical analysis of weld metal from composite electrodes or rods may be taken from the reduced section of the fractured all-weld-metal tension test specimen or from the corresponding location or from any location above it along the weld centerline in the groove weld used for mechanical properties and soundness in Figure 2, thereby avoiding the need to make a weld pad. In case of dispute, the sample from either groove weld in Figure 2 as just described, shall be the referee method.

9.2 Preparation of each weld test assembly shall be as specified in 9.3 and 9.4. The base metal for each assembly shall be as required in Table 6 and shall meet the requirements of the specification shown there, or a chemically equivalent specification. Testing of each assembly shall be as specified in 10.2, 10.3, and Clauses 11 through 13.

9.3 Groove Weld

9.3.1 For all classifications, a test assembly shall be prepared and welded as specified in Figure 2, using base metal of the appropriate type specified in Table 6, and the preheat and interpass temperature specified in Table 7. The electrode used for either GMAW test assembly shall be 0.045 in or 1/16 in [1.2 mm or 1.6 mm] diameter (or the diameter the manufacturer produces that is closest to one of these, if these diameters are not produced) and welded as specified in Table 8. The rod used for the GTAW test assembly shall be 3/32 in or 1/8 in [2.4 mm or 3.2 mm] diameter (or the diameter the manufacturer produces that is closest to one of these, if these diameters are not produced). The GTAW test assembly shall be prepared and welded, when required in Clauses 3.1.3 or 3.2.3, as specified in Figure 2 and Table 9.

Welding shall be performed in the flat position, and the assembly shall be restrained (or preset) during welding to prevent warpage in excess of 5°. A welded assembly that is warped more than 5° out of plane shall be discarded. Test assemblies

shall not be straightened. The test assembly shall be tack welded at or above room temperature and welding shall begin within the preheat and interpass temperature range specified in Table 7. Welding shall continue until the assembly has reached the interpass temperature specified in Table 7, measured by temperature indicating crayons or surface thermometers at the location shown in Figure 2.

For the remainder of the weld, the range between preheat and interpass temperature as specified in Table 7 shall be maintained. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be reheated to within the preheat and interpass temperature range specified in Table 7 before welding is resumed. When welding has been completed and the assembly has cooled, the assembly shall be prepared and tested as specified in Clauses 11, Radiographic Test; 12, Tension Test; and 13, Impact Test. Testing shall be performed in the as-welded or postweld heat-treated condition, as specified in Table 7.

9.3.2 When postweld heat treatment (PWHT) is required in Table 7, the heat treatment shall be applied to the test assembly before removal of the mechanical test specimens. This PWHT may be done either before or after the radiographic examination. If radiographic examination is conducted prior to PWHT, the weldment shall first be allowed to cool in still air to below 200 °F [93 °C].

9.3.2.1 The furnace shall be at a temperature not higher than 600 °F [320 °C] when the test assembly is placed in it. The heating rate, from that point to the holding temperature specified in Table 7, shall not exceed 400 °F per hour [220 °C per hour].

9.3.2.2 The test assembly shall be maintained at the temperature specified in Table 7 for the specified time (–0, +15 minutes).

9.3.2.3 When the specified holding time has been completed, the assembly shall be allowed to cool in the furnace to a temperature below 600 °F [320 °C] at a rate not exceeding 350 °F per hour [190 °C per hour]. The assembly may be removed from the furnace at any temperature below 600 °F [320 °C] and allowed to cool in still air to room temperature. Testing of the assembly shall be as specified in Clauses 11 through 13.

9.4 Weld Pad. A weld pad shall be prepared using composite stranded and composite metal cored electrodes and rods as shown in Figure 3, except when, as permitted in 9.1, the sample for analysis is taken from the groove weld (Figure 2) or the fractured all-weld-metal tension test specimen. Base metal of any convenient size which will satisfy the minimum requirements of Figure 3, and of a type specified in Table 6, shall be used as the base for the weld pad. See Table 6, notes a and c, for the use of an alternate base metal. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple layers to obtain undiluted weld metal (4 layers minimum). The filler metal size shall be 0.045 in or 1/16 in [1.2 mm or 1.6 mm] for electrodes, or 3/32 in or 1/8 in [2.4 mm or 3.2 mm] for rods, or the size that the manufacturer produces that is closest to one of these, if these sizes are not produced. The preheat temperature shall not be less than 60 °F [15 °C] and the interpass temperature shall not exceed that specified in Table 7. Any slag shall be removed after each pass. The pad may be quenched in water between passes (temperature of the water not specified). The dimensions of the completed pad shall be as shown in Figure 3. Testing of this assembly shall be as specified in 10.2 and 10.3. The results shall meet the requirements of Table 4.

10. Chemical Analysis

10.1 A sample of the solid electrode or rod stock from which it is made shall be prepared for chemical analysis. Solid filler metal, when analyzed for elements that are present in a coating (copper flashing, for example), shall be analyzed without removing the coating. When the filler metal 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 the other elements.

10.2 Composite stranded or metal cored electrodes or rods shall be analyzed in the form of weld metal, not filler metal. The sample for analysis shall be taken from weld metal obtained with the electrode or rod and the shielding gas as specified in Table 2. The sample may be taken from the weld pad prepared in accordance with 9.4, from an area of the groove weld as specified in 9.1, or from the reduced section of the fractured tension test specimen. In case of dispute, the area of the groove weld described in 9.1 including the tensile specimen shall be the referee method.

The top surface of the pad described in 9.4 and shown in Figure 3 shall be removed and discarded. A sample for analysis shall be obtained from the underlying metal, no closer than 3/8 in [9.5 mm] to the surface of the base metal in Figure 3, by any appropriate means that will not affect the composition. The sample shall be free of slag. When the sample is taken

from the groove weld or the reduced section of the fractured tension test specimen, that material shall be prepared for analysis by any suitable means that will not affect the composition.

10.3 The sample obtained as specified in 10.1 or 10.2 shall be analyzed by accepted analytical methods. *The referee method shall be ASTM E350, with the exception of the Mn1 and Mn2 classifications. For the Mn1 and Mn2 classifications, the referee method shall be ASTM E353.*

10.4 The results of the analysis shall meet the requirements of Table 1 for solid electrodes or rods or Table 4 for composite electrodes or rods for the classification of electrode or rod under test.

11. Radiographic Test

11.1 The groove weld described in 9.3.1 and shown in Figure 2 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. It is permitted on both sides of the test assembly to remove base metal to a depth of 1/16 in [1.5 mm] nominal below the original base metal surface in order to facilitate backing and/or buildup removal. Thickness of the weld metal shall not be reduced by more than 1/16 in [1.5 mm] less than the nominal base metal thickness. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

11.2 The weld shall be radiographed in accordance with 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 no cracks, no incomplete fusion, and no rounded indications in excess of those permitted by the radiographic standards in Figure 4. In evaluating the radiograph, 1 in [25 mm] of the weld on each end of the test assembly shall be disregarded.

A rounded indication is an indication (on the radiograph) whose length is no more than 3 times its width. Rounded indications may be circular, elliptical, conical, 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. Indications whose largest dimension does not exceed 1/64 in [0.4 mm] shall be disregarded. Test assemblies with indications larger than the largest indications permitted in the radiographic standards (Figure 4) do not meet the requirements of this specification.

12. Tension Test

12.1 One all-weld-metal round tension test specimen, as specified in the Tension Tests Clause of AWS B4.0, shall be machined from the weld test assembly described in 9.3.1, and shown in Figure 2, as required in Table 5. The tensile specimen, when machined from the GMAW weld test assembly shown in Figure 2, shall have a nominal diameter of 0.500 in [12.5 mm] and a nominal gage length-to-diameter ratio of 4:1. The tensile specimen, when machined from the GTAW weld test assembly shown in Figure 2, shall have a nominal diameter of 0.350 in [9 mm] and a nominal gage length-to-diameter ratio of 4:1. Other dimensions of the tension test specimen shall be as specified in the Tension Tests Clause of AWS B4.0.

12.1.1 After machining, but before testing, the specimen may be aged at 200 °F to 220 °F [95 °C to 105 °C] for up to 48 hours, then allowed to cool to room temperature. Refer to B8.3 for a discussion on the purpose of aging.

12.1.2 The specimen shall be tested in the manner described in the Tension Tests Clause of AWS B4.0.

12.1.3 The results of the all-weld-metal tension test shall meet the requirements specified in Table 2. Test reports shall indicate if the specimen was tested in the aged condition.

13. Impact Test

13.1 For those classifications for which impact testing is required in Table 3 and Table 5, five Charpy V-notch impact test specimens, as specified in the Fracture Toughness Tests Clause of AWS B4.0, shall be machined from the test assembly shown in Figure 2.

The Charpy V-Notch specimens shall have the notched surface and the surface to be struck parallel within 0.002 in [0.05 mm]. The other two surfaces shall be square with the notched or struck surface within ± 10 minutes of a degree. The notch shall be smoothly cut and be square with the longitudinal edge of the specimen within one degree. Test specimens shall not contain metal that has been affected thermally as a result of cutting or preparation.

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 10 times magnification on either a shadowgraph or metallograph. The correct location of the notch shall be verified by etching before or after machining.

13.2 The five specimens shall be tested in accordance with the Fracture Toughness Tests Clause of AWS B4.0. The test temperature shall be that specified in Table 3 or lower for the classification under test. The actual test temperature shall be shown on test reports.

13.3 In evaluating the test results, the lowest and the highest absorbed energy values obtained shall be disregarded.

13.3.1 For classifications requiring 20 ft•lbf [27 J] minimum absorbed energy level, at least two of the remaining three values shall equal, or exceed, the specified 20 ft•lbf [27 J] absorbed 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.

13.3.2 For classifications requiring 50 ft•lbf [68 J] absorbed energy level, at least two of the remaining three values shall equal, or exceed, the specified 50 ft•lbf [68 J] energy level. One of the three may be lower, but not lower than 40 ft•lbf [54 J], and the average of the three shall be not less than the required 50 ft•lbf [68 J] energy level.

13.3.3 For classifications requiring lateral expansion testing, 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. All three of these specimens shall exhibit a lateral expansion of at least 0.015 in [0.38 mm]. However, if the average of these three specimens is at least 0.015 in [0.38 mm] and one of the three specimens is lower than 0.015 in [0.38 mm], an additional set of three specimens shall be tested. If all three of the additional set of specimens exhibit a lateral expansion of at least 0.015 in [0.38 mm], these results may be reported and used to determine conformity with the classification. The additional set of three specimens may be taken from the original test assembly or from a new test assembly that was welded and postweld heat treated (if required) to the requirements of this standard.

14. Optional, Supplemental Tests and Requirements

Provisions are made in this specification for additional tests. These tests are optional and are not required for electrode classification. The optional, supplemental designators which indicate conformance to the supplemental test requirements do not constitute a part of the electrode classification.

14.1 Diffusible Hydrogen Test. An optional, supplemental designator (H2, H4, H8 or H16) is used to indicate the diffusible hydrogen content of the deposited weld metal. Refer to Clause A1 in Annex A.

14.2 Supplemental Designators to Indicate Conformance to Reduced Levels of Mn + Ni in B91 and B92 Type Electrodes and Deposits. Some applications of the B91 and B92 alloy types may require lower levels of Mn + Ni than the 1.40% maximum specified in Table 1 or Table 4. Supplemental designators (1.0) and (1.2) are provided to indicate that the solid electrode (rod) composition or the weld deposit, as applicable, meets 1.00% or 1.20% maximum Mn + Ni, respectively. Conformance with the supplemental designator (1.0) satisfies the requirements of the supplemental designator (1.2) as well as the B91 or B92 classification requirements. Conformance with the supplemental designator (1.2) satisfies the requirements of the B91 or B92 classification. All other requirements of the B91 or B92 classifications