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An American National Standard

Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods

American Welding Society

Key Words—Bare aluminum, filler metal, aluminum rods, aluminum electrodes, gas metal arc welding, gas tungsten arc welding, cast aluminum alloys, oxyfuel gas welding, plasma arc welding, classification, specification

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Approved by
American National Standards Institute
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Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods

Supersedes ANSI/AWS A5.10-92

Prepared by
AWS Committee on Filler Metals
and Allied Materials

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This specification prescribes requirements for the classification of bare, wrought and cast aluminum-alloy electrodes, and rods for use with the gas metal arc, gas tungsten arc, oxyfuel gas, and plasma arc welding processes. This specification makes use of both U.S. Customary Units and the International System of Units (SI). Since these are not equivalent, each system must be used independently of the other.

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

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Foreword

(This Foreword is not a part of AWS A5.10/A5.10M:1999, *Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods,* but is included for information purposes only.)

This document is the first of the A5.10 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, the *Metric Practice Guide for the Welding Industry* (ANSI/AWS A1.1), and International Standard ISO 864, *Solid Wires for Gas Shielded Metal Arc Welding of Mild Steel—Dimensions of Wires, Spools, Rims and Coils,* 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 provides for interchangeability of products in both the U.S. Customary and SI Units.

A5.10/A5.10M:1999 represents the seventh revision of the first bare aluminum filler metal specification issued in 1954 as a joint ASTM/AWS specification. After two revisions and publication as a joint specification, ASTM agreed to accept AWS as the sole society responsible for the development and publication of filler metal specifications.

In recent years, AWS filler metal specifications have been recognized by the American National Standards Institute. The evolution of this specification is shown below.

ASTM B285-54T AWS A5.10-54T	Tentative Specification for Aluminum and Aluminum Alloy Welding Rods and Bare Electrodes
ASTM B285-57T AWS A5.10-57T	Tentative Specification for Aluminum and Aluminum Alloy Welding Rods and Bare Electrodes
AWS A5.10-61T ASTM B285-61T	Tentative Specification for Aluminum and Aluminum Alloy Welding Rods and Bare Electrodes
AWS A5.10-69 ANSI W5.10-1973	Specification for Aluminum and Aluminum Alloy Welding Rods and Bare Electrodes
ANSI/AWS A5.10-80	Specification for Aluminum and Aluminum Alloy Bare Electrodes and Rods
ANSI/AWS A5.10-88	Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods
ANSI/AWS A5.10-92	Specification for Bare Aluminum and Aluminum Alloy Welding Electrodes and Rods

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

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

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Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods

1. Scope

This specification prescribes requirements for the classification of bare aluminum and aluminum-alloy welding electrodes and rods for use with the gas metal arc, gas tungsten arc, oxyfuel gas, and plasma arc welding processes.

Part A
General Requirements

2. Normative References

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

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

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

ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications.*

ASTM E 34, *Standard Methods for Chemical Analysis of Aluminum and Aluminum Alloys.*

ASTM B 108, *Standard Specification for Aluminum Alloy Permanent Mold Castings.*

ASTM E 142, *Standard Method for Controlling Quality of Radiographic Testing.*

ASTM B 209, *Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate.*

2.3 The following ISO standard[3] is referenced in the mandatory sections of this document:

ISO 864, *Arc Welding—Solid and Tubular Cored Wires which Deposit Carbon and Carbon Manganese Steel—Dimension of Wires, Spools, Rims, and Coils.*

3. Classification

3.1 The electrodes and rods covered by A5.10/A5.10M specification are classified using a system that is independent of U.S. Customary Units and the International System of Units (SI). Classification is according to the chemical composition of the filler metal as specified in Table 1 and their respective usability either as an electrode or rod as specified in Section 9, Weld Test Assemblies, and Table 2.

3.2 Any filler metal tested and classified as an electrode shall also be classified as a welding rod. Filler metal tested and classified only as a welding rod shall not be classified as an electrode.

3.3 The electrodes and rods classified under this specification are intended for gas metal arc, gas tungsten arc, oxyfuel gas, and plasma arc welding, but that is not to prohibit their use with any other process for which they are found suitable.

3.4 Filler metal containing more than 0.0008 percent by weight of beryllium shall not be classified as electrode and should not be used as an electrode (see A12.3).

1. ANSI/AWS standards may be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.
2. ASTM standards can be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.
3. ISO standards may be obtained from the American National Standards Institute (ANSI), 11 W. 42nd Street, 13th Floor, New York, NY 10036.

Table 1
Chemical Composition Requirements for Aluminum Electrodes and Rods

AWS Classification	UNS Number[c]	Weight Percent[a,b]											
											Other Elements		
		Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Each	Total	Al
ER1100	A91100	d	d	0.05–0.20	0.05	—	—	—	0.10	—	0.05[e]	0.15	99.00 min[f]
R1100	A91100	d	d	0.05–0.20	0.05	—	—	—	0.10	—	0.05[e]	0.15	99.00 min[f]
ER1188[g]	A91188	0.06	0.06	0.005	0.01	0.01	—	—	0.03	0.01	0.01[e]	—	99.88 min[f]
R1188[g]	A91188	0.06	0.06	0.005	0.01	0.01	—	—	0.03	0.01	0.01[e]	—	99.88 min[f]
ER2319[h]	A92319	0.20	0.30	5.8–6.8	0.20–0.40	0.02	—	—	0.10	0.10–0.20	0.05[e]	0.15	Remainder
R2319[h]	A92319	0.20	0.30	5.8–6.8	0.20–0.40	0.02	—	—	0.10	0.10–0.20	0.05[e]	0.15	Remainder
ER4009	A94009	4.5–5.5	0.20	1.0–1.5	0.10	0.45–0.6	—	—	0.10	0.20	0.05[e]	0.15	Remainder
R4009	A94009	4.5–5.5	0.20	1.0–1.5	0.10	0.45–0.6	—	—	0.10	0.20	0.05[e]	0.15	Remainder
ER4010	A94010	6.5–7.5	0.20	0.20	0.10	0.30–0.45	—	—	0.10	0.20	0.05[e]	0.15	Remainder
R4010	A94010	6.5–7.5	0.20	0.20	0.10	0.30–0.45	—	—	0.10	0.20	0.05[e]	0.15	Remainder
R4011[k]	A94011	6.5–7.5	0.20	0.20	0.10	0.45–0.7	—	—	0.10	0.04–0.20	0.05	0.15	Remainder
ER4043	A94043	4.5–6.0	0.8	0.30	0.05	0.05	—	—	0.10	0.20	0.05[e]	0.15	Remainder
R4043	A94043	4.5–6.0	0.8	0.30	0.05	0.05	—	—	0.10	0.20	0.05[e]	0.15	Remainder
ER4047	A94047	11.0–13.0	0.8	0.30	0.15	0.10	—	—	0.20	—	0.05[e]	0.15	Remainder
R4047	A94047	11.0–13.0	0.8	0.30	0.15	0.10	—	—	0.20	—	0.05[e]	0.15	Remainder
ER4145	A94145	9.3–10.7	0.8	3.3–4.7	0.15	0.15	0.15	—	0.20	—	0.05[e]	0.15	Remainder
R4145	A94145	9.3–10.7	0.8	3.3–4.7	0.15	0.15	0.15	—	0.20	—	0.05[e]	0.15	Remainder
ER4643	A94643	3.6–4.6	0.8	0.10	0.05	0.10–0.30	—	—	0.10	0.15	0.05[e]	0.15	Remainder
R4643	A94643	3.6–4.6	0.8	0.10	0.05	0.10–0.30	—	—	0.10	0.15	0.05[e]	0.15	Remainder
ER5183	A95183	0.40	0.40	0.10	0.50–1.0	4.3–5.2	0.05–0.25	—	0.25	0.15	0.05[e]	0.15	Remainder
R5183	A95183	0.40	0.40	0.10	0.50–1.0	4.3–5.2	0.05–0.25	—	0.25	0.15	0.05[e]	0.15	Remainder
ER5356	A95356	0.25	0.40	0.10	0.05–0.20	4.5–5.5	0.05–0.20	—	0.10	0.06–0.20	0.05[e]	0.15	Remainder
R5356	A95356	0.25	0.40	0.10	0.05–0.20	4.5–5.5	0.05–0.20	—	0.10	0.06–0.20	0.05[e]	0.15	Remainder
ER5554	A95554	0.25	0.40	0.10	0.50–1.0	2.4–3.0	0.05–0.20	—	0.25	0.05–0.20	0.05[e]	0.15	Remainder
R5554	A95554	0.25	0.40	0.10	0.50–1.0	2.4–3.0	0.05–0.20	—	0.25	0.05–0.20	0.05[e]	0.15	Remainder
ER5556	A95556	0.25	0.40	0.10	0.50–1.0	4.7–5.5	0.05–0.20	—	0.25	0.05–0.20	0.05[e]	0.15	Remainder
R5556	A95556	0.25	0.40	0.10	0.50–1.0	4.7–5.5	0.05–0.20	—	0.25	0.05–0.20	0.05[e]	0.15	Remainder

(continued)

Table 1 (Continued)

AWS Classification	UNS Number[c]	Weight Percent[a,b]											
											Other Elements		
		Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	Each	Total	Al
ER5654	A95654	i	i	0.05	0.01	3.1–3.9	0.15–0.35	—	0.20	0.05–0.15	0.05[e]	0.15	Remainder
R5654	A95654	i	i	0.05	0.01	3.1–3.9	0.15–0.35	—	0.20	0.05–0.15	0.05[e]	0.15	Remainder
R-206.0[j]	A02060	0.10	0.15	4.2–5.0	0.20–0.50	0.15–0.35	—	0.05	0.10	0.15–0.30	0.05	0.15	Remainder
R-C355.0	A33550	4.5–5.5	0.20	1.0–1.5	0.10	0.40–0.6	—	—	0.10	0.20	0.05	0.15	Remainder
R-A356.0	A13560	6.5–7.5	0.20	0.20	0.10	0.25–0.45	—	—	0.10	0.20	0.05	0.15	Remainder
R-357.0	A03570	6.5–7.5	0.15	0.05	0.03	0.45–0.6	—	—	0.05	0.20	0.05	0.15	Remainder
R-A357.0[k]	A13570	6.5–7.5	0.20	0.20	0.10	0.40–0.7	—	—	0.10	0.04–0.20	0.05	0.15	Remainder

Notes:

a. The filler 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 they do not exceed the limits specified for "Other Elements."
b. Single values are maximum, except where otherwise specified.
c. SAE/ASTM Unified Numbering System for Metals and Alloys.
d. Silicon plus iron shall not exceed 0.95 percent.
e. Beryllium shall not exceed 0.0008 percent.
f. The aluminum content for unalloyed aluminum is the difference between 100.00 percent and the sum of all other metallic elements present in the amounts of 0.010 percent or more each, expressed to the second decimal before determining the sum.
g. Vanadium content shall be 0.05 percent maximum. Gallium content shall be 0.03 percent maximum.
h. Vanadium content shall be 0.05–0.15 percent. Zirconium content shall be 0.10–0.25 percent.
i. Silicon plus iron shall not exceed 0.45 percent.
j. Tin content shall not exceed 0.05 percent.
k. Beryllium content shall be 0.04–0.07 percent.

Table 2
Required Tests

AWS Classification	Chemical Analysis	Radiographic Test* (Electrode)	Bead-on-Plate Test (Rod)
ER1100	X	X	—
R1100	X	—	X
ER1188	X	X	—
R1188	X	—	X
ER2319	X	X	—
R2319	X	—	X
ER4009	X	X	—
R4009	X	—	X
ER4010	X	X	—
R4010	X	—	X
R4011	X	—	X
ER4043	X	X	—
R4043	X	—	X
ER4047	X	X	—
R4047	X	—	X
ER4145	X	X	—
R4145	X	—	X
ER4643	X	X	—
R4643	X	—	X
ER5183	X	X	—
R5183	X	—	X
ER5356	X	X	—
R5356	X	—	X
ER5554	X	X	—
R5554	X	—	X
ER5556	X	X	—
R5556	X	—	X
ER5654	X	X	—
R5654	X	—	X
R-206.0	X	—	X
R-C355.0	X	—	X
R-A356.0	X	—	X
R-357.0	X	—	X
R-A357.0	X	—	X

*Filler metal meeting the radiographic requirement, when tested as an electrode, is not required to be tested as a rod, as specified in 9.2.

4. Acceptance

Acceptance[4] of the material shall be in accordance with the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines.*

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.[5]

6. Units of Measure and Rounding-Off Procedure

6.1 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining values in any way. The specification with the designation A5.10 uses the U.S. Customary Units. The specification A5.10M uses SI Units. The latter are shown in appropriate columns in tables and in figures, and within brackets [ ] when used in the text.

6.2 For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the "nearest unit" in the last right-hand place of figures used in expressing the limiting value in accordance with the rounding-off method given in ASTM E 29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications.*

Part B
Tests, Procedures, and Requirements

7. Summary of Tests

The tests required for each classification are specified in Table 2. The purpose of these tests is to determine the chemical composition of the filler metal, soundness of the weld metal produced by gas metal arc welding electrodes, and the deposition characteristics of welding rods. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Sections 9 through 12.

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 for retests may be taken from the original test sample or from one or two

4. See A3, Acceptance (in the Annex) for further information concerning acceptance, testing of the material shipped, and ANSI/AWS A5.01, *Filler Metal Procurement Guidelines.*

5. See A4, Certification (in the Annex) for further information concerning certification and the testing called for to meet this requirement.

new 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 test sample(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 Two weld test assemblies are required:

(1) The groove weld test assembly for the usability of electrodes and the soundness of the weld metal (see Figure 1).

(2) The bead-on-plate weld test assembly for the usability of rods (see 9.4).

9.2 Usability tests shall be made using electrodes and welding rods of each size. A filler metal that satisfactorily meets the requirements of the radiographic soundness test, when tested as an electrode, may also be classified as a welding rod without being subjected to the bead-on-plate test required for a welding rod. A filler metal that satisfactorily meets the bead-on-plate weld test requirements, when tested as a welding rod, shall also be tested as an electrode and meet the requirements of the radiographic soundness test in order to be classified as an electrode.

9.3 Groove Weld for Soundness and Usability of Electrodes

9.3.1 A test assembly shall be prepared and welded, as specified in Figure 1 and 9.3.2 through 9.3.4, using base metal of the appropriate type specified in Table 3. The welding position shall be as specified in Figure 1 for the different electrode sizes and classifications. Testing of the assembly shall be as specified in Section 11, Radiographic Test.

9.3.2 Welding of the test assembly shall be done using the gas metal arc welding process with techniques and procedures specified by the manufacturer as to the factors not covered herein.

9.3.3 Dimensions of the groove weld joint and the position of welding shall be as specified in Figure 1 for the electrode diameter being tested. The backing material shall be of the same type of base metal as the test plate base metal.

9.3.4 The test assembly shall be at a temperature of not less than 60°F [16°C] when commencing the initial or subsequent weld passes. Also, the initial or interpass temperatures shall not exceed 150°F [66°C].

9.4 Bead-on-Plate Weld Test for Usability of Welding Rods

9.4.1 The test assembly shall consist of a sheet or plate approximately 6 in. [150 mm] by 12 in. [300 mm] upon which a weld shall be made as specified in 9.4.2, using base metal of the appropriate type specified in Table 3. Examination of the assembly shall be as specified in Section 12, Bead-on-Plate Test.

9.4.2 Welding of the assembly shall be done in the flat position with the gas tungsten arc welding process employing alternating current and argon gas shielding. The test plate thickness and the welding current shall be compatible with the rod being tested.

9.4.3 The completed bead-on-plate welds shall be examined with the unaided eye (corrected to normal vision) and shall meet the requirements specified in Section 12, Bead-on-Plate Test.

9.4.4 A welding rod satisfactorily meeting the bead-on-plate test requirement using gas tungsten arc welding is also suitable for use with the oxyfuel gas and plasma arc welding processes.

10. Chemical Analysis

10.1 A sample of the filler metal, or the stock from which it is made, shall be prepared for chemical analysis.

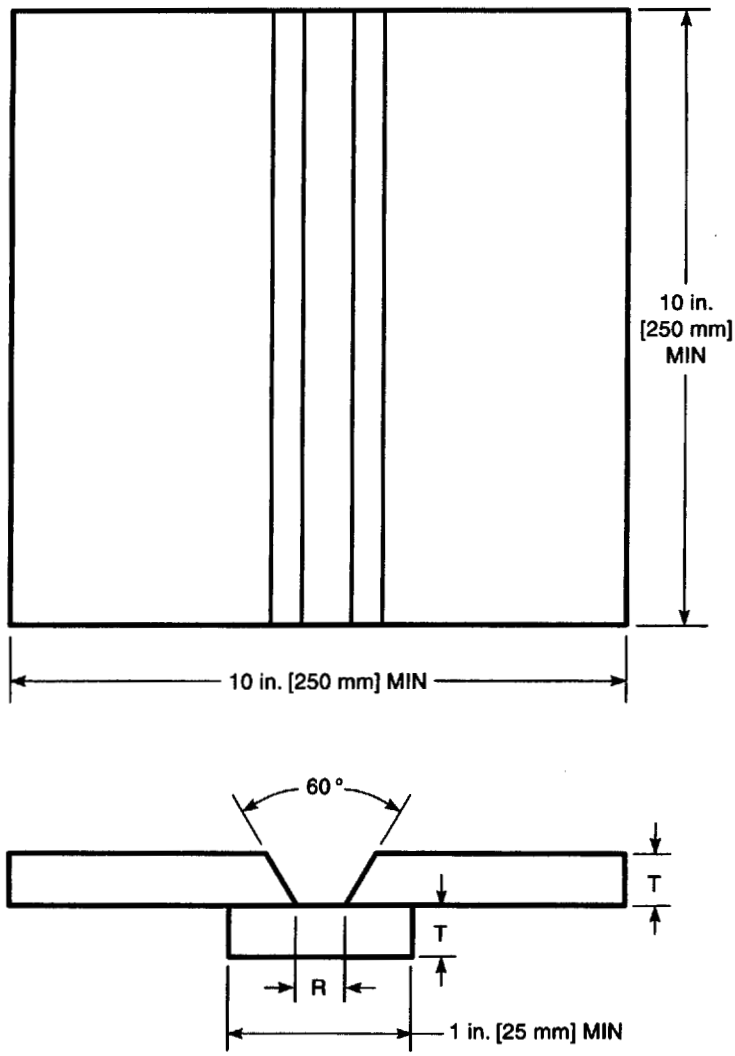
10.2 The sample shall be analyzed by accepted analytical methods.[6] The referee method shall be ASTM E 34, *Standard Methods for Chemical Analysis of Aluminum and Aluminum Alloys.*

10.3 The results of the analysis shall meet the requirements of Table 1 for the classification of electrode or rod under test.

11. Radiographic Test

11.1 The groove weld described in 9.3 and shown in Figure 1 shall be radiographed to evaluate the soundness of

6. See Section A10 (in the Annex) for further information concerning accepted analytical methods.



Electrode Diameter		Plate Thickness, T (Note C)		Nominal Root Opening, R		Welding Position
in.	mm	in.	mm	in.	mm	
0.030 0.035	0.8 0.9	3/16 or 1/4	5 or 6.5	1/4	6.5	Overhead
3/64	1.0 1.2	1/4 1/4	6.5 6.5	1/4 1/4	6.5 6.5	Overhead
1/16	1.6 2.0	3/8 3/8	10 10	3/8 3/8	10 10	Overhead
3/32	2.4 2.5	3/8 3/8	10 10	3/8 3/8	10 10	Flat
1/8	3.2	3/8	10	1/2	13	Flat

General Notes:

a. Assembly shall be welded employing the gas metal arc welding process.

b. Assembly may be machined or extruded as a single piece if the dimensions shown are maintained for the specific electrode size being tested.

c. A variation of ±5 percent in the specified plate thickness is acceptable.

Figure 1—Groove Weld Test Assembly for Radiographic Test

Table 3
Base Metal for Test Assemblies

Electrode and Rod (AWS Classification)	Base Metal[1] (Aluminum Association Designations)[2]
ER1100, R1100, ER1188, R1188	1060, 1100, 1350, or 3003
ER2319, R2319, ER4145, R4145	2014, 2219, or 3003
ER4009, R4009, ER4010, R4010 R4011, ER4043, R4043 ER4047, R4047, ER4643, R4643	3003 or 6061
ER5183, R5183, ER5356, R5356 ER5554, R5554, ER5556 R5556, ER5654, R5654	3004, 5052, 5083, 5086, 5154, 5454, or 5456
R-206.0	206.0, 2014, 2219, or 3003
R-C355.0	355.0, C355.0, or 3003
R-A356.0, R357.0, R-A357.0	356.0, A356.0, 357.0, A357.0, or 3003

Notes:
1. All wrought base alloys 1060, 1100, 2014, 2219, 3003, 3004, 5052, 5083, 5086, 5154, 5454, and 6061 are included in ASTM B209. Cast base alloys 355.0, C355.0, 356.0, A356.0, 357.0, and A357.0 are included in ASTM B108.
2. The Aluminum Association, Inc., 900 19th Street, N.W., Suite 300, Washington, DC 20006.

the weld metal and to determine the usability of the electrode. In preparation for radiography, the backing shall be removed and both surfaces of the weld shall be machined or ground smooth. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

11.2 The weld shall be radiographed in accordance with ASTM E 142, *Standard Method for Controlling Quality of Radiographic Testing*. The quality level of inspection shall be 2-2T.

11.3 The soundness of the weld metal and the usability of the electrode meet 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 2 for test assemblies welded in the overhead position for electrode sizes up to and including 1/16 in. [1.6 mm] and Figure 3 for test assemblies welded in the flat position for electrode sizes larger than 1/16 in. [1.6 mm]. In evaluating the radiograph, the center 6 in. [150 mm] of the test specimen shall be considered, and all extra weld shall be disregarded.

A rounded indication is an indication on the radiograph whose length is no more than three times its width. Rounded indications may be circular, elliptical, conical, or irregular in shape and they may have tails. The size of the rounded indication is the largest dimension of the indication including any tail that may be present. Indications whose largest dimension does not exceed 1/64 in. [0.4 mm] shall be disregarded. Test assemblies with indications larger than the large indications permitted in the radiographic standards do not meet the requirements of this specification.

11.4 An electrode that produces a groove weld which satisfactorily meets these radiographic requirements may also be classified as a welding rod under this specification without conducting the test specified in 9.4.

12. Bead-on-Plate Test

12.1 Welding rod tested in accordance with 9.4 shall produce weld metal that flows freely and uniformly without sputtering or other irregularities. The resultant weld metal shall be smooth and uniform with no visible evidence of cracks or porosity.

12.2 If a filler metal satisfactorily meets the weld bead-on-plate test requirements when tested as a welding rod, it also shall be tested as an electrode, if it is to be classified as an electrode.

Part C
Manufacture, Identification, and Packaging

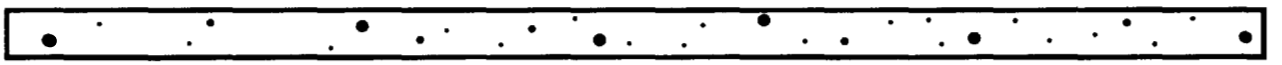
13. Method of Manufacture

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

14. Standard Sizes

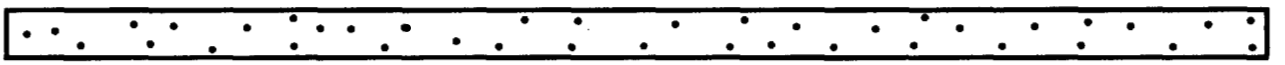
14.1 Standard sizes for round filler metal in the different package forms of straight lengths, coils without support, and spools are as shown in Table 4. Diameters of cast rods in straight lengths are approximate with no specified tolerance.

14.2 Typical sizes for flattened shapes of straight length welding rod are shown in Table 5. The cross-sectional area of such shapes shall be equivalent to that of corresponding round rods of the same nominal diameter as listed in Table 5.



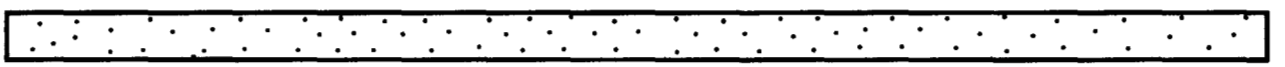
ASSORTED ROUNDED INDICATIONS

SIZE PERMITTED IS 0.050 in. [1.3 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD IS 29 WITH THE FOLLOWING RESTRICTIONS:
LARGE: UP TO 0.050 in. [1.3 mm]—6 PERMITTED
MEDIUM: UP TO 0.031 in. [0.8 mm]—5 PERMITTED
SMALL: UP TO 0.020 in. [0.5 mm]—18 PERMITTED



MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 0.030 in. [0.8 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD IS 39



SMALL ROUNDED INDICATIONS

SIZE PERMITTED IS 0.020 in. [0.5 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD IS 72

Notes:
1. In using these standards, the chart that is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Indications which do not exceed 1/64 in. [0.4 mm] diameter or length, or both, shall be disregarded.
3. Total area of porosity in a 6 in. [150 mm] length of weld is 0.0225 sq in. [14.52 sq mm] based on 1.5% T per in. [25 mm] where T is the base metal thickness.

RADIOGRAPHIC ACCEPTANCE STANDARD FOR 3/16 in. [5 mm] AND 1/4 in. [6.4 mm] THICK TEST ASSEMBLIES

Figure 2A—Radiographic Acceptance Standards for Test Assemblies—Overhead Welding Position

15. Finish and Uniformity

15.1 All filler metal shall have a smooth finish that is free from slivers, depressions, scratches, scale, seams, laps, and foreign matter that would adversely affect the welding characteristics, the operation of the welding equipment, or the properties of the weld metal.

15.2 Each continuous length of filler metal shall be from a single lot of material, and welds, when present, shall have been made so as not to interfere with the uniform, uninterrupted feeding of the filler metal on automatic and semiautomatic equipment.

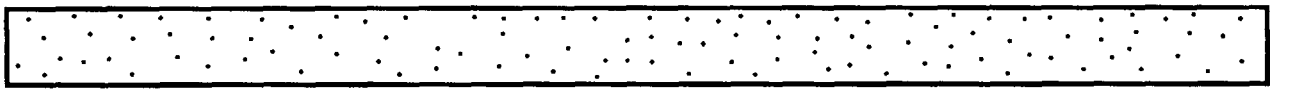
16. Standard Package Forms

16.1 Standard package forms are straight lengths, coils without support, and spools. Standard package dimensions and weights for each form are given in Table 6. Package forms, sizes, and weights other than these shall be as agreed between purchaser and supplier.

16.2 Dimensions of the standard spool sizes shall be as shown in Figures 4 and 5. Spools shall be designed and constructed to prevent distortion of themselves and of the filler metal during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal.

ASSORTED ROUNDED INDICATIONS

SIZE PERMITTED IS 0.075 in. [1.9 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD IS 26 WITH THE FOLLOWING RESTRICTIONS:
LARGE: UP TO 0.075 in. [1.9 mm]—4 PERMITTED
MEDIUM: UP TO 0.049 in. [1.3 mm]—5 PERMITTED
SMALL: UP TO 0.020 in. [0.5 mm]—17 PERMITTED



SMALL ROUNDED INDICATIONS

SIZE PERMITTED IS 0.020 in. [0.5 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD IS 108

Notes:
1. In using these standards, the chart that is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Indications which do not exceed 1/64 in. [0.4 mm] diameter or length, or both, shall be disregarded.
3. Total area of porosity in a 6 in. [150 mm] length of weld is 0.0337 sq in. [21.7 sq mm] based on 1.5 percent T per in. [25 mm] where T is the base metal thickness.

RADIOGRAPHIC ACCEPTANCE STANDARDS FOR 3/8 IN. [10 mm] THICK TEST ASSEMBLIES

These radiographic acceptance standards are identical to those previously incorporated in MIL-E-16053L (Amendment 2, 20 October 1980) and as Class 3 NAVSEA 0900-LP-003-9000. (See Annex A5.)

Figure 2B—Radiographic Acceptance Standards for Test Assemblies—Overhead Welding Position

17. Winding Requirements

17.1 Filler metal on spools and in coils without support shall be wound so that kinks, waves, sharp bends, overlapping, or wedging are not encountered, leaving the filler metal free to unwind without restriction. The outside end of the filler metal (the end with which welding is to begin) shall be identified so it can be located readily and shall be fastened to avoid unwinding.

17.2 The outermost layer of spooled electrode or spooled rod shall not be closer than 1/8 in. [3 mm] to the outside diameter of the flanges.

17.3 The cast and helix of filler metal on spools shall be such that the filler metal will feed in an uninterrupted manner in automatic and semiautomatic equipment.

18. Filler Metal Identification

18.1 The product information and the precautionary information required in Section 20, Marking of Packages, shall also appear on each coil and spool.

18.2 Coils without support shall have a tag containing this information securely attached to the filler metal at the inside end of the coil.

18.3 Spools shall have the information securely affixed in a prominent location on the outside of at least one flange of the spool.

19. Packaging

Filler metal shall be suitably packaged to ensure against damage during shipment and storage under normal conditions.

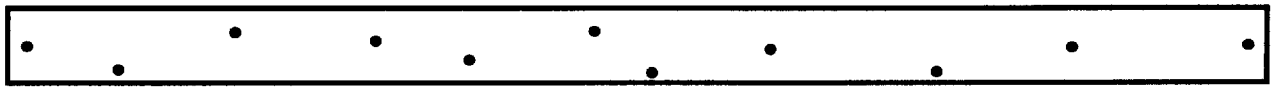
ASSORTED ROUNDED INDICATIONS

SIZE PERMITTED IS 0.075 in. [1.9 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD IS 17 WITH THE FOLLOWING RESTRICTIONS:

LARGE: UP TO 0.075 in. [1.9 mm]—3 PERMITTED
MEDIUM: UP TO 0.049 in. [1.3 mm]—3 PERMITTED
SMALL: UP TO 0.020 in. [0.5 mm]—11 PERMITTED

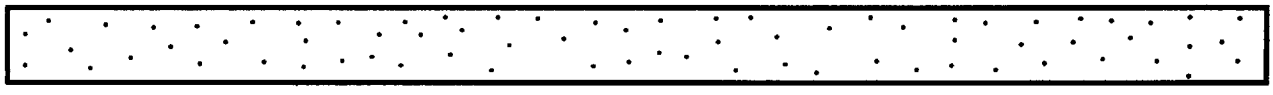
LARGE ROUNDED INDICATIONS

SIZE PERMITTED IS 0.075 in. [1.9 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD IS 5



MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 0.049 in. [1.3 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD IS 11



SMALL ROUNDED INDICATIONS

SIZE PERMITTED IS 0.020 in. [0.5 mm] MAXIMUM
NUMBER PERMITTED IN ANY 6 in. [150 mm] OF WELD IS 72

Notes:

1. In using these standards, the chart that is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Indications which do not exceed 1/64 in. [0.4 mm] diameter or length, or both, shall be disregarded.
3. Total area of porosity in a 6 in. [150 mm] length of weld is 0.0225 sq in. [14.52 sq mm] based upon 1.0% T per in. [25 mm] where T is the base metal thickness.

This radiographic acceptance standard is identical to that previously incorporated in MIL-E-16053L (Amendment 2, 20 October 1980) and as Class 1 NAVSEA 0900-LP-003-9000. (See Annex A5.)

Figure 3—Radiographic Acceptance Standard for Test Assemblies—Flat Position Welding

Table 4
Standard Sizes[a]

Standard Package Forms	Diameter in.[b]	Diameter mm	Tolerances in.	Tolerances mm
Straight Lengths and Coils without Support (Notes c, d)	1/16	(0.062)	1.6	+0.001, –0.002	+0.03, –0.05
		(0.079)	2.0		
	3/32	(0.094)	2.4[e]		
		(0.098)	2.5		
	1/8	(0.125)	3.2		
	5/32	(0.156)	4.0		
	3/16	(0.188)	4.8[e]		
		(0.197)	5.0		
	1/4	(0.250)	6.4[e]		
4-in. [100 mm] and 8-in. [200 mm] Spools	0.030		0.8	+0.001, –0.002	+0.03, –0.05
	0.035		0.9		
		(0.039)	1.0		
	3/64	(0.047)	1.2		
	1/16	(0.062)	1.6		
12-in. [300 mm] Spools	0.030		0.8	+0.001, –0.002	+0.03, –0.05
	0.035		0.9		
		(0.039)	1.0		
	3/64	(0.047)	1.2		
	1/16	(0.062)	1.6		
		(0.079)	2.0		
	3/32	(0.094)	2.4[e]		
		(0.098)	2.5		
	1/8	(0.125)	3.2		
13-1/2 [340 mm] Spools	1/16	(0.062)	1.6	+0.001, –0.002	+0.03, –0.05
		(0.079)	2.0		
	3/32	(0.094)	2.4[e]		
		(0.098)	2.5		
	1/8	(0.125)	3.2		

Notes:
a. Dimensions, tolerances, and package forms (for round filler metal) other than those shown shall be as agreed by purchaser and supplier.
b. Decimal inch are exact conversions with appropriate rounding.
c. There is no specified tolerance for cast rod in straight lengths.
d. Length of wrought rods shall be 36 in., +0, –1/2 in. [900 mm ± 2%]. Length of cast rods shall be 18 in., ± 1/2 in. [450 mm ± 2%].
e. Metric sizes not shown in ISO 864.

Table 5
Typical Sizes of Flattened Rods

Equivalent Round Diameter in.	Equivalent Round Diameter mm	Thickness in.	Thickness mm	Width in.	Width mm
1/16	1.6	0.047	1.2	0.072	1.8
	2.0[b]		1.5		2.1
3/32	2.4	0.070	1.8	0.105	2.7
	2.5[b]		1.9		2.6
1/8	3.2	0.095	2.4	0.142	3.6
5/32	4.0	0.115	2.9	0.175	4.4
3/16	4.8	0.140	3.6	0.210	5.0
	5.0[b]		3.8		5.2
1/4	6.4	0.187	4.8	0.280	7.1

Notes:
a. Standard length shall be 36 in., +0, –1/2 in. [900 mm ± 2%].
b. Metric sizes not normally available in the U.S.A.

20. Marking of Packages

20.1 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[7] and classification designation (year of issue may be excluded)
(2) Supplier's name and trade designation
(3) Size and net weight
(4) Lot, control, or heat number

20.2 The following precautionary information (as a minimum) shall be predominantly displayed in legible print on all packages of welding material, including individual unit packages enclosed within a larger package:

7. Products supplied in U.S. Customary Units shall be marked A5.10. If all dimensional and other requirements of A5.10M are met, the product may be marked A5.10/A5.10M.

WARNING:

Protect yourself and others. Read and understand this label.

FUMES and GASES can be hazardous to your health.

ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can KILL.

- Before use, read and understand the manufacturer's instructions, Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch live electrical parts.

See American National Standard, ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes,* published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; and OSHA *Safety and Health Standards*, available from the U.S. Government Printing Office, Washington, DC 20402.

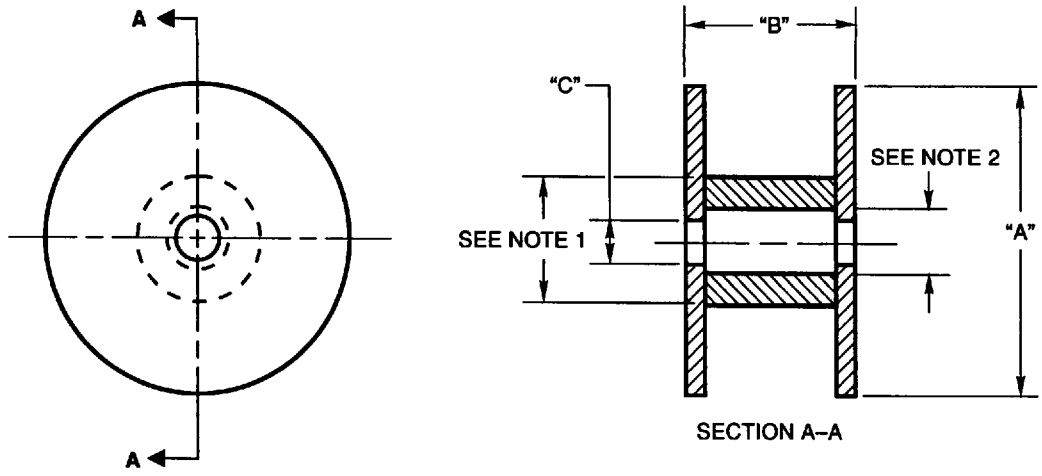
DO NOT REMOVE THIS INFORMATION

Table 6
Standard Packages, Dimensions, and Weights[a]

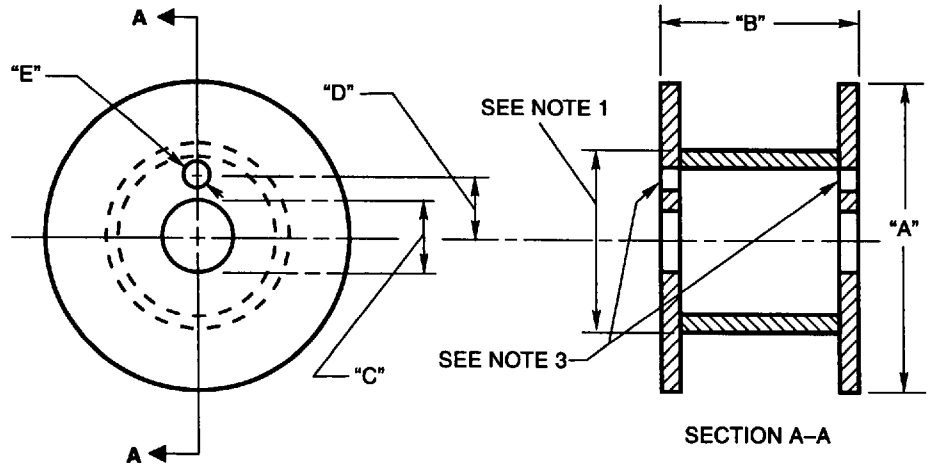
Package Form[b]			Nominal Net Weight	
			lb	kg
Straight Lengths			5	2.5
			10	5
			25	10
			50	25
Coils Without Support[c]			25	10
			50	25
Spools[d]	in.	mm		
	4	100	1	0.5
	8	200	5	2.5
	12	300	10–26	5–12
	13-1/2	340	30	15

Notes:

a. Filler metal diameters for all forms and lengths are given in Table 4.
b. No more than one classification or size shall be included in each package.
c. Dimensions of coils shall be as agreed between purchaser and supplier.
d. Dimensions of standard spools are shown in Figures 4 and 5.



DIMENSIONS OF STANDARD 4 in. [100 mm] SPOOL

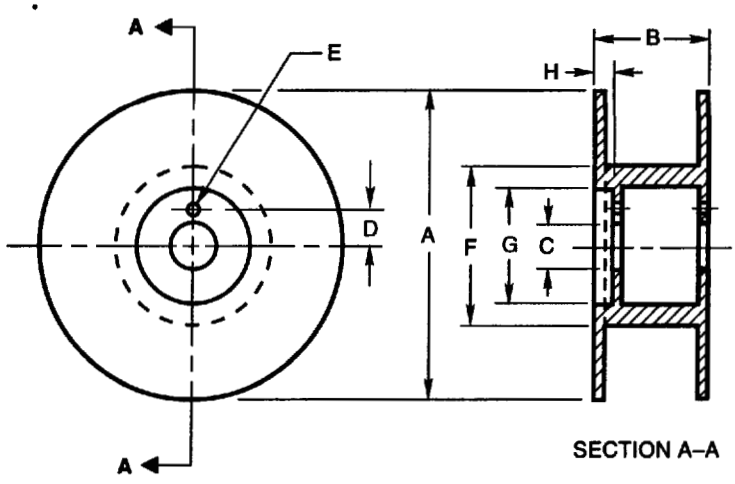


DIMENSIONS OF STANDARD 8 AND 12 in. [200 AND 300 mm] SPOOLS

		4 in. [100 mm]		8 in. [200 mm]		12 in. [300 mm]	
		in.	mm.	in.	mm	in.	mm
A	Diameter, max. (Note 4)	4.0	102	8.0	203	12	305
B	Width Tolerance	1.75 ±0.03	46 +0, –2	2.16 ±0.03	56 +0, –3	4.0 ±0.06	103 +0, –3
C	Diameter Tolerance	0.63 +0.01, –0	16 +1, –0	2.03 +0.06, –0	50.5 +2.5, –0	2.03 +0.06, –0	50.5 +2.5, –0
D	Distance between axes Tolerance	— —	— —	1.75 ±0.02	44.5 ±0.5	1.75 ± 0.02	44.5 ±0.5
E	Diameter (Note 3) Tolerance	— —	— —	0.44 +0, –0.06	10 +1, –0	0.44 +0, –0.06	10 +1, –0

Notes:
1. Outside diameter of barrel shall be such as to permit feeding of the filler metals.
2. Inside diameter of the barrel shall be such that swelling of the barrel or misalignment of the barrel and flanges will not result in the inside diameter of the barrel being less than the inside diameter of the flanges.
3. Holes are provided on each flange, but they need not be aligned. No driving holes required for 4 in. [100 mm] spools.
4. Metric dimensions and tolerances conform to ISO 864 except that "A" specifies ± tolerances on the nominal diameter, rather than a plus tolerance only, which is shown here as a maximum.

Figure 4—Dimensions of 4, 8, and 12 in. [100, 200, and 300 mm] Diameter Spools



		in.	mm
A	Diameter Tolerance	13.50 –0.063, +0	342 ±1
B	Width Tolerance	5.125 ±0.063	130 ±1.6
C	Diameter Tolerance	2.03 –0, +0.06	50.5 +2.5, –0
D	Distance between axes Tolerance	1.75 ±0.02	44.5 ±0.5
E	Diameter Tolerance	0.44 +0, –0.06	10 +1, –0
F	Diameter Tolerance	7.0 ± 0.031	177.5 ±1
G	Diameter Tolerance	5.0 ±0.031	127 ±0.8
H	Recess Tolerance	1.125 +0.125, –0	31 ±2

Note:
a. Holes are provided on each flange, but they need not be aligned.

Figure 5—Dimensions of Standard 13-1/2 in. [340 mm] Diameter Spool

Annex A

Guide to AWS Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods

(This Annex is not a part of AWS A5.10/A5.10M:1999, *Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods*, but is included for information purposes only.)

A1. Introduction

This guide is designed to correlate the filler metal classifications with their intended applications so the specification can be used more effectively. Reference to appropriate base metal alloys is made whenever that can be done and when it would be helpful. Such references are intended as examples rather than complete listings of the materials for which each filler metal is suitable.

A2. Classification System

A2.1 Both welding electrodes and rods are classified upon the basis of the chemical composition of the aluminum filler metal and a usability test. The AWS classifications used in this specification are based as follows:

A2.2 The Aluminum Association alloy designation nomenclature is used for the numerical portion to identify the alloy and thus its registered chemical composition.

A2.3 A letter prefix designates usability of the filler metal. The letter system for identifying the filler metal classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The prefix "E" indicates the filler metal is suitable for use as an electrode and the prefix "R" indicates suitability as welding rod. Since some of these filler metals are used as electrodes in gas metal arc welding, and as welding rods in oxyfuel gas, gas tungsten arc, and plasma arc welding, both letters, "ER," are used to indicate suitability as an electrode or a rod. In all cases, a product which meets the test requirements for an electrode in this specification, that meets the test requirements for a welding rod, must also pass the test for an electrode before being classified as an electrode.

A2.4 An international system for designating welding filler metals is under development by the International Institute of Welding (IIW) for use in future specifications to be issued by the International Standards Organization (ISO). Table A1 shows the proposed designations for aluminum filler metals. In that system, the initial "S" designates a solid wire or rod, the letter "A" the alloy system, followed by a four-digit number. For aluminum alloys, the four-digit number is the same as that commonly recognized worldwide, except for the cast rods, which adopt the first four digits of the UNS number (see Table A1).

A2.5 Minor changes in procedures used in the manufacture of aluminum filler metals can affect their surface quality and significantly affect the resultant weld soundness. Usability testing of the electrode is desirable on a periodic basis to assure that the product classified in this specification continues to meet the soundness requirement.

The supplier should perform the usability tests of this specification on an annual basis, as a minimum, to assure that the specified soundness and operating characteristics criteria are maintained. ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*, should be used by a purchaser for definition of lot and frequency of testing references when purchasing aluminum filler metals.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*, as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this

Table A1
Designation Reference Guide

AWS Composition Designation[a]	UNS Number	Proposed ISO Designation[b]	Usability Test Designation	AWS Classification Number[c]	ISO Number + Usability Designation[d]
1100	A91100	SA1100	ER	ER1100	ER SA1100
			R	R1100	R SA1100
1188	A91188	SA1188	ER	ER1188	ER SA1188
			R	R1188	R SA1188
2319	A92319	SA2319	ER	ER2319	ER SA2319
			R	R2319	R SA2319
4009	A94009	SA4009	ER	ER4009	ER SA4009
			R	R4009	R SA4009
4010	A94010	SA4010	ER	ER4010	ER SA4010
			R	R4010	R SA4010
4011	A94011	SA4011	R	R4011	R SA4011
4043	A94043	SA4043	ER	ER4043	ER SA4043
			R	R4043	R SA4043
4047	A94047	SA4047	ER	ER4047	ER SA4047
			R	R4047	R SA4047
4145	A94145	SA4145	ER	ER4145	ER SA4145
			R	R4145	R SA4145
4643	A94643	SA4643	ER	ER4643	ER SA4643
			R	R4643	R SA4643
5183	A95183	SA5183	ER	ER5183	ER SA5183
			R	R5183	R SA5183
5356	A95356	SA5356	ER	ER5356	ER SA5356
			R	R5356	R SA5356
5554	A95554	SA5554	ER	ER5554	ER SA5554
			R	R5554	R SA5554
5556	A95556	SA5556	ER	ER5556	ER SA5556
			R	R5556	R SA5556
5654	A95654	SA5654	ER	ER5654	ER SA5654
			R	R5654	R SA5654
206.0	A02060	SA0206	R	R206.0	R SA0206
C355.0	A33550	SA3355	R	R-C355.0	R SA3355
A356.0	A13560	SA1356	R	R-A356.0	R SA1356
357.0	A03570	SA0357	R	R357.0	R SA0357
A357.0	A13570	SA1357	R	R-A357.0	R SA1357

Notes:

a. AWS chemical composition designation number is the same as the Aluminum Association designation number.

b. The proposed ISO designation number contains the last four digits of the UNS number for wrought alloys (IIW doc. XII-1232-91). For cast alloys the first four digits of the UNS number are herein proposed for ISO designations.

c. The AWS classification number is a combination of AWS chemical composition designation plus AWS usability test designation.

d. The AWS usability test designation is applied as a prefix to the ISO designation.

specification, shall be clearly stated in the purchase order, according to the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing the supplier normally conducts on material of that classification, as specified in Schedule F, Table 1, of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*. Testing in accordance with any other Schedule in that Table must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

The act of placing the AWS specification and classification designations on the packaging enclosing the product or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of 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 the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been made. The basis for the certification required by the specification is the classification test of representative material cited above and the "Manufacturer's Quality Assurance Program" in ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.

A5. Application of Military and Federal Specifications

At the time of cancellation (June 7, 1982) of Military Specification MIL-E-16053L, Amendment 2 (October 20, 1980), *Electrodes, Welding, Bare, Aluminum Alloys*, the technical requirements were identical to those of AWS A5.10-80. They both covered the same aluminum alloys, compositions, welding tests, and radiographic standards. The MIL-E-16053L cancellation notice canceled the Qualified Products List QPL-16053 as well as the specification and stated, "Future acquisition of replacement electrodes should be made under ANSI/AWS A5.10-80, *Aluminum and Aluminum Alloy Bare Welding Rods and Electrodes*."

Federal Specification QQ-R-566B, *Rods and Electrodes, Welding, Aluminum, and Aluminum Alloys*, was technically the same as AWS A5.10 when it was issued July 5, 1973, and was in the process of being updated at the time the MIL-E-16053L cancellation. On November 29, 1982, Federal Specification QQ-R-566B was also canceled with the recommendation, "The ANSI/AWS Standard A5.10, latest issue in effect, concerning Aluminum Alloy Bare Welding Rods and Electrodes should be used." Straight length, coiled, and spooled rod for oxyfuel gas and gas tungsten arc welding were included in QQ-R-566B, as well as the spooled electrode for gas metal arc welding. Thus the total coverage was the same as ANSI/AWS A5.10.

AWS A5.10/A5.10M is a classification document, which defines tests and acceptance criteria to determine that the product meets the requirements for classification. These tests need to be repeated only if a significant change is made in the manufacturing process. These tests become a part of the specific procurement only when used in combination with ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*, which identifies lot classifications, level of testing and the frequency of tests.

To order the specific tests previously required by MIL-E-16053L and QQ-R-566B specifications, the following Lot Classification and Level of Testing defined in ANSI/AWS A5.01 document apply:

Lot Definition	ANSI/AWS A5.01 Lot Classification
A lot consists of bare solid electrodes or rods, not exceeding 100 000 lb [45 000 kg] of one classification, size, form and temper identified by controlled chemical composition	Class S2

Tests	Level of Testing Schedule
a. Conformance to chemical composition limits	Sch. H, I, or J
b. Welding tests upon the lot shipped	Sch. I or J
c. Visual Examination, diameters and finish	A5.10 Requirement
d. Filler wire tension test	Identify as part of Sch. K

The minimum tensile requirement for the test shall be as agreed upon between the supplier and purchaser.

Purchase Order Information

In addition to stating the AWS classification, AWS Specification (A5.10), diameter, form, and quantity, the purchase order should state that the material is to conform to ANSI/AWS A5.01, Lot Class S2, Schedule K. Schedule K must be stated to be, "Schedule J plus tension tests of the filler wire for each lot of 2000 lb [900 kg] supplied." When referencing level of testing Schedules I or J, certification of performance to the chemical composition limits and acceptable welding test results will be supplied. Quantitative results of the tension test can be requested on the purchase order.

A6. Ventilation During Welding

A6.1 Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators are exposed during welding:

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

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

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

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

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

A6.2 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 sections of that document covering Ventilation and Confined Spaces.

A7. Welding Considerations

The electrodes and rods described in this specification are primarily for use with the inert gas arc welding processes. However, they may be used with other welding processes such as electron beam or oxyfuel gas welding.

A7.1 The gas metal arc process permits the successful welding of aluminum alloys that are crack-sensitive when welded by oxyfuel gas or other manual welding processes. The reasons for this might be described briefly as follows:

Distortion is reduced to a minimum because the increase in temperature of the parts being welded is confined to a narrow zone. Because the aluminum alloys have high thermal conductivity, the reduction of distortion is greater than would be the case with ferrous base metals. Cracking of welds in the aluminum alloys is reduced if the cooling rate is high.

The gas metal arc process permits the welding of alloys that have a wide melting range, which heretofore have been difficult to weld without cracking.

A7.2 The high melting and solidification rate of the weld metal from the gas metal arc process can result in entrapped gas in the welds. Control of this factor should be understood to obtain good results. Gas in the welds can be caused by contaminating influences, such as grease, hydrocarbon cleaning agents, or moisture on the electrode or on the base metal. Moist air leaking into the inert gas lines may also cause this condition. Improper adjustment of electrode speed, welding current, or other machine variables may have a similar effect. The introduction of gas in the weld metal from any of these causes can result in porosity, because the solidification rate is high and the gas may not have time to escape before the molten metal solidifies.

A7.3 Welds can be made in all positions with the gas metal arc process. Edge preparation similar to that used for gas tungsten arc welding is satisfactory. Either argon or helium, or mixtures of these gases may be used as shielding. Semiautomatic welding, in which the welding gun is moved by a welder, is difficult to control on metal thicknesses below 0.08 in. [2 mm] with constant amperage. The use of a pulsed power supply permits the welding of base metal as thin as 0.03 in. [0.8 mm]. No upper limit on metal thickness has been established. Welds in plate up to 8 in. [200 mm] in thickness have been made. Automatic gas metal arc welding is suitable for all thicknesses welded, and particularly for 1/8 in. [3.2 mm] or less in thickness.

A7.4 Gas metal arc welding is done with direct current (electrode positive). Almost all drooping volt-ampere characteristic DC motor-generator sets and DC rectifier welding machines used for shielded metal arc welding with covered electrodes are suitable sources of power.

Constant-voltage power supplies are also suitable. An electrode feeding mechanism, in which electrode speed can be adjusted between 50 and 500 in./min. [21 and 210 mm/s] is needed. Electrode feeders possessing "touch-start" or "slow run-in" features, or both, are necessary when using a drooping volt-amperage characteristic power supply, and are desirable with constant-voltage power sources.

Radiused top and bottom electrode feed rolls are preferred in both manual and mechanized equipment. Stabilization of the arc with high-frequency current is not required.

A7.5 Gas tungsten arc welds can be made in all positions. Welding travel speed is reduced compared to GMA welding, however, this is beneficial in several aspects. The process is more maneuverable for manually welding small tubes or piping than GMAW; entrapment of gases is minimized to permit production of sound welds; short repair welds can be made more easily; and the reduced concentration of heat input allows welding aluminum base metal thicknesses as thin as 0.02 in. [0.5 mm] or less. Corner and edge joints in sheet gauges can be made more satisfactorily than with GMAW due to the better control of the filler metal additions.

A7.6 Gas tungsten arc welds are most commonly made with alternating-current power and argon (AWS A5.32/A5.32M Class SG-A) gas shielding. Helium (AWS A5.32/A5.32M Class SG-He) additions to the extent of 25 to 50 percent of the mixture with argon are used to increase the rate of initial melting and the amount of melting in thick base metal. Pure tungsten (AWS A5.12/A5.12M Class EWP or zirconia-tungsten (AWS A5.12/A5.12M Class EWZr-1) electrodes are preferred for AC-GTAW. The positive electrode polarity of the AC power provides an arc cleaning action to remove the surface oxide; however, thick aluminum oxides caused by weathering, thermal treatments, or anodic treatments need to be reduced by chemical or mechanical means prior to welding to obtain uniform results and proper fusion. As stated in A7.2, sources of hydrogen, such as moisture on the base or filler metals or in the gas shielding and residual hydrocarbons on the base or filler metals, must be removed to avoid porosity in the welds.

A7.7 Direct current power can also be used to GTA weld aluminum. DCEP power can be used to weld sheet gauges; however, a 1/4 in. [6.40 mm] diameter tungsten electrode is required to carry the 125 amperes needed to weld 1/8 in. [3.2 mm] thickness, so this polarity is seldom used. DCEN power is used with helium (AWS A5.32/A5.32M Class SG-He) gas shielding and a thoria-tungsten electrode for welding aluminum-base alloys. This negative electrode polarity provides a deep, narrow melting pattern, which is advantageous for repair of thick weldments or castings and for increased welding speeds in all thicknesses. Higher as-welded strength is obtained with DCEN-GTA welds in the heat treatable aluminum alloys due to the reduced heat input compared to AC-GTAW.

Since no arc cleaning action occurs in the DCEN arc, special attention must be given to minimizing the oxide thickness immediately before welding, such as mechanical scraping or arc cleaning all base metal surfaces within the fusion zone.

A8. Description and Intended Use of Aluminum Electrodes and Rods

A8.1 The selection of the proper classification of filler metal depends primarily on the aluminum alloy used in the parts to be welded; and secondly on the welding process, the geometry of the joints, the resistance to corrosion required in service, and on the finish or appearance desired on the welded part. For example, welded vessels for holding hydrogen peroxide require special aluminum alloys, quite frequently a high-purity alloy, in order to have good resistance to corrosion or to prevent contamination of the product contained. In this case, the proper choice of filler metal is an alloy that has at least as high a purity as the base metal. Another example is the foundry welding of castings, where an alloy meeting the composition limits of the castings is, in most cases, the best choice; for example, as in the repair and fabrication of cast alloys including 206.0, C355.0, A356.0, 357.0, and A357.0.

A8.2 Experience has shown that certain classifications of filler metal are suitable for welding specific base metals and combinations of base metals. These are listed in Table A2. If it is desired to weld other combinations than those listed, they should be evaluated as to suitability for the purpose intended. The alloy combinations listed will be suitable for most environments; some are preferable from one or more standpoints. In the absence of specific information, consultation with the material supplier is recommended. Additional information may be found in the aluminum chapter of *Welding Handbook*, Volume 3, Eighth Edition.

A8.3 Filler metal in the form of straight lengths and coils without support is used as welding rod with a number of welding processes. These include oxyfuel gas welding, plasma arc welding, and gas tungsten arc welding. The filler metal is usually fed by hand, although mechanized welding in these processes may involve either manual feeding of the welding rod or use of a feeding mechanism.

A8.4 Spooled filler metal is used most commonly as electrode for the gas metal arc welding process. It also is used as filler rod when mechanized feeding systems are employed for gas tungsten arc, plasma-arc welding and other processes. Finite lengths of filler metal can be removed from the spools for use as a high-quality, hand-fed filler rod with manual gas tungsten arc, plasma-arc or oxyfuel gas welding processes.

A8.5 The cleanliness and minimal surface oxidation of the filler metal are important with all welding processes. Oil, or other organic materials, as well as a heavy oxide film on the rod, will interfere with coalescence of the weld and also are sources of porosity. Because of this, it is necessary to clean the welding rod and electrode before packaging.

Table A2
Guide to the Choice of Filler Metal for General Purpose Welding

Base Metal	201.0 206.0 224.0	319.0, 333.0, 354.0, 355.0, C355.0	356.0, A356.0 357.0, A357.0 413.0, 443.0, A444.0	511.0, 512.0, 513.0, 514.0, 535.0	7004, 7005, 7039, 710.0, 712.0	6009 6010 6070	6005, 6061, 6063, 6101, 6151, 6201, 6351, 6951	5456	5454
1060, 1070, 1080, 1350	ER4145	ER4145	ER4043[a,b]	ER5356[c,d]	ER5356[c,d]	ER4043[a,b]	ER4043[b]	ER5356[d]	ER4043[b,d]
1100, 3003, Alc 3003	ER4145	ER4145	ER4043[a,b]	ER5356[c,d]	ER5356[c,d]	ER4043[a,b]	ER4043[b]	ER5356[d]	ER4043[b,d]
2014, 2036	ER4145[e]	ER4145[e]	ER4145	—	—	ER4145	ER4145	—	—
2219	ER2319[a]	ER4145[e]	ER4145[b,c]	ER4043	ER4043	ER4043[a,b]	ER4043[a,b]	—	ER4043[b]
3004, Alc 3004	—	ER4043[b]	ER4043[b]	ER5356[f]	ER5356[f]	ER4043[b]	ER4043[b,f]	ER5356[d]	ER5356[f]
5005, 5050	—	ER4043[b]	ER4043[b]	ER5356[f]	ER5356[f]	ER4043[b]	ER4043[b,f]	ER5356[d]	ER5356[f]
5052, 5652[i]	—	ER4043[b]	ER4043[f]	ER5356[f]	ER5356[f]	ER4043[b]	ER5356[c,f]	ER5356[f]	ER5356[f]
5083	—	—	ER5356[c,d]	ER5356[d]	ER5183[d]	—	ER5356[d]	ER5183[d]	ER5356[d]
5086	—	—	ER5356[c,d]	ER5356[d]	ER5356[d]	—	ER5356[d]	ER5356[d]	ER5356[d]
5154, 5254[i]	—	—	ER4043[f]	ER5356[f]	ER5356[f]	—	ER5356[f]	ER5356[f]	ER5356[f]
5454	—	ER4043[b]	ER4043[f]	ER5356[f]	ER5356[f]	ER4043[b]	ER5356[c,f]	ER5356[f]	ER5554[c,f]
5456	—	—	ER5356[c,d]	ER5356[d]	ER5556[d]	—	ER5356[d]	ER5556[d]	
6005, 6061, 6063 6101, 6151, 6201 6351, 6951	ER4145	ER4145[b,c]	ER4043[b, f, g]	ER5356[f]	ER5356[c,f]	ER4043[a,b,g]	ER4043[b,f,g]		
6009, 6010, 6070	ER4145	ER4145([b,c]	ER4043[a,b,g]	ER4043	ER4043	ER4043[a,b,g]			
7004, 7005, 7039 710.0, 712.0	—	ER4043[b]	ER4043[b,f]	ER5356[f]	ER5356[d]				
511.0, 512.0, 513.0 514.0, 535.0	—	—	ER4043[f]	ER5356[f]					
356.0, A356.0, 357.0 A357.0, 413.0 443.0, A444.0	ER4145	ER4145[b,c]	ER4043[b,h]						
319.0, 333.0 354.0, 355.0 C355.0	ER4145[c]	ER4145[b,c,h]							
201.0, 206.0, 224.0	ER2319[a,h]								

(continued)

Table A2 (Continued)

Base Metal	5154 5254[i]	5086	5083	5052 5652[i]	5005 5050	3004 Alc. 3004	2219	2014 2036	1100 3003 Alc. 3003	1060 1070 1080 1350
1060, 1070, 1080, 1350	ER5356[c,d]	ER5356[d]	ER5356[d]	ER4043[b,d]	ER1100[b,c]	ER4043[b,d]	ER4145[b,c]	ER4145	ER1100 [b,c]	ER1188[b,c,h,j]
1100, 3003, Alc 3003	ER5356[c,d]	ER5356[d]	ER5356[d]	ER4043[b,d]	ER1100[b,c]	ER4043[b,d]	ER4145[b,c]	ER4145	ER1100 [b,c]	
2014, 2036	—	—	—	—	ER4145	ER4145	ER4145[e]	ER4145[e]		
2219	ER4043	—	—	ER4043[b]	ER4043[a,b]	ER4043[a,b]	ER2319[a]			
3004, Alc 3004	ER5356[f]	ER5356[d]	ER5356[d]	ER5356[c,f]	ER5356[c,f]	ER5356[c,f]				
5005, 5050	ER5356[f]	ER5356[d]	ER5356[d]	ER5356[c,d]	ER5356[c,f]					
5052, 5652[i]	ER5356[f]	ER5356[d]	ER5356[d]	ER5654[c,f,i]						
5083	ER5356[d]	ER5356[d]	ER5183[d]							
5086	ER5356[d]	ER5356[d]								
5154, 5254[i]	ER5356[f,i]									

General Notes:

1. Service conditions such as immersion in fresh or salt water, exposure to specific chemicals, or a sustained high temperature (over 150°F [66°C]) may limit the choice of filler metals, Filler metals ER5183, ER5356, ER5556 are not recommended for sustained elevated temperature service.
2. Recommendations in this table apply to gas shielded arc welding processes. For oxyfuel gas welding, only ER1188, ER1100, ER4043, ER4047, and ER4145 filler metals are ordinarily used.
3. Where no filler metal is listed, the base metal combination is not recommended for welding.

Notes:

a. ER4145 may be used for some applications.
b. ER4047 may be used for some applications.
c. ER4043 may be used for some applications.
d. ER5183, ER5356, or ER5556 may be used.
e. ER2319 may be used for some applications. It can supply high strength when the weldment is postweld solution heat treated and aged.
f. ER5183, ER5356, ER5554, ER5556, and ER5654 may be used. In some cases, they provide: (1) improved color match after anodizing treatment, (2) highest weld ductility, and (3) higher weld strength. ER5554 is suitable for sustained elevated temperature service.
g. ER4643 will provide higher strength in 1/2 in. [12 mm] and thicker groove welds in 6XXX base alloys when postweld solution heat treated and aged.
h. Filler metal with the same analysis as the base metal is sometimes used. The following wrought filler metals possess the same chemical composition limits as cast filler alloys: ER4009 and R4009 as R-C355.0; ER4010 and R4010 as R-A356.0; and R4011 as R-A357.0.
i. Base metal alloys 5254 and 5652 are used for hydrogen peroxide service. ER5654 filler metal is used for welding both alloys for service temperatures below 150°F [66°C].
j. ER1100 may be used for some applications.

A8.6 Proper storage of welding rods and electrodes is essential to avoid contamination which may affect their performance. Packages of filler metal should not be left outdoors or in unheated buildings because the greater variations in temperature and humidity increase the possibility of condensation to create hydrated surface oxides. Experience has demonstrated that undesirable storage conditions may adversely affect filler metal performance. Investigation of the effect of storage time on electrode performance indicates that packaged electrodes, stored under good conditions (dry places in heated buildings), are satisfactory after extended storage.

A8.7 Contamination of filler metal from handling or storage may occur. In most cases, the contaminating influences will dictate the cleaning method. The practice of giving the welding rod, if it has been exposed to the shop atmosphere for long periods of time, a rub with stainless steel wool just before welding is quite widely followed.

A9. Special Tests

This specification classifies those aluminum and aluminum alloy filler metals used most extensively at the time of issuance of the specification. It is recognized that supplementary tests may be necessary to determine the suitability of these welding electrodes and rods for applications involving properties not considered in this specification. In such cases, additional tests to determine such specific properties as corrosion resistance, mechanical properties at high and low temperature, wear resistance, and suitability for welding combinations of dissimilar metals may need to be conducted.

A10. Chemical Analysis

The most widely used method for chemical analysis is ASTM E 227, *Optical Emission Spectrometric Analysis of Aluminum and Aluminum Alloy by the Point-to-Plane Technique,* but other established analytical methods are acceptable. The ASTM E 227 method analyzes a bulk sample and all elements simultaneously. The ASTM E 34 standard method prescribes individual test methods for which each element is tested. The ASTM E 34 tests methods are used as a referee method if a dispute arises concerning a specific element analysis.

A11. Discontinued and Replaced Alloys

Compositions of aluminum alloy welding electrodes and rods have been discontinued and/or replaced as new editions of A5.10 have been issued (see Table A3).

Table A3
Discontinued Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods

Discontinued		Replacement	
AWS Classification	A5.10 Issue	AWS Classification	A5.10 Issue
ER1060	1961	—	—
ER1260	1980	ER1188	1988
ER2014	1961	—	—
ER3004	1961	—	—
ER5039	1980	—	—
ER5052	1967	—	—
ER5154	1969	ER5654	1969
ER5254	1969	ER5654	1969
ER5652	1969	ER5654	1969
R242.0	1988	—	—
R295.0	1988	—	—
R355.0	1988	R-C355.0	1988
		ER4009 & R4009	1992
R356.0	1988	R-A356.0	1988
		ER4010 & R4010	1992
R-990A	1957	ER1100	1992
E-990A	1957	ER1100	1992
R-996A	1957	ER1060	1957
E-996A	1957	ER1060	1957
R-C4A	1980	R295.0	1980
R-CN42A	1980	R242.0	1980
R-C541A	1957	ER2014	1957
E-C541A	1957	ER2014	1957
R-G1A	1961	—	—
E-G1A	1961	—	—
R-GM50A	1957	ER5356	1957
E-GM50A	1957	ER5356	1957
R-GR20A	1957	ER5052	1957
E-GR20A	1957	ER5052	1957
R-GR40A	1957	ER5154	1957
E-GR40A	1957	ER5154	1957
R-MG11A	1957	ER3004	1957
E-MG11A	1957	ER3004	1957
R-SG70A	1980	R356.0	1980

A12. General Safety Considerations

A12.1 Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide pro-

tection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

When welding overhead or in confined spaces, ear plugs to prevent weld spatter from entering the ear canal should be worn. Goggles or equivalent should also be worn to protect eyes. Clothing should be kept free of grease and oil. Combustible materials should not be carried in pockets. If any combustible substance has been spilled on clothing, a change to clean, fire-resistant clothing should be made before working with open arcs or flame. Aprons, cape-sleeves, leggings, and shoulder covers with bibs designed for welding service should be used.

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

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

(1) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(2) *Code of Federal Regulations*, Title 29 Labor, Chapter XVII, Part 1910, OSHA General Industry Standards, available from the U.S. Government Printing Office, Washington, DC 20402.

(3) ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, American National Standards Institute, 11 W. 42nd Street, 13th Floor, New York, NY 10036.

(4) ANSI Z41, *American National Standard for Personal Protection—Protective Footwear,* American National Standards Institute, 11 W. 42nd Street, 13th Floor, New York, NY 10036.

A12.2 Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recommended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

The spool of electrode should be insulated from the welding equipment by an insulated spindle. All electrical equipment and the workpieces should be grounded. The workpiece lead is not a ground lead. It is used only to complete the welding circuit. A separate connection is required to ground the workpiece. The workpiece should not be mistaken for a ground connection.

The correct cable size should be used, since sustained overloading will cause cable failure and result in possible electrical shock or fire hazard. All electrical connections should be tight, clean, and dry. Poor connections can overheat and even melt. Further, they can produce hazardous arcs and sparks. Water, grease, or dirt should not be allowed to accumulate on plugs, sockets, or electrical units. Moisture can conduct electricity. To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber-soled shoes, or stand on a dry board or insulated platform.

Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used. Open-circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating-current machines are being used, the open-circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

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

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

A12.3 Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles which originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced

by the effects of process radiation on the surrounding environment. Management, personnel and welders alike should be aware of the effects of these fumes and gases. The amount and composition of these fumes and gases depend upon the composition of the filler metal and base metal, welding process, flux, current level, arc length, and other factors. Fluxes, used for oxyfuel gas welding of aluminum alloys, are composed primarily of chlorides plus small fluoride additions.

The possible effects of overexposure range from irritation of eyes, skin, and respiratory system to more severe complications. Effects may occur immediately or at some later time. Fumes can cause symptoms such as nausea, headaches, dizziness, and metal fume fever. The possibility of more serious health effects exists when especially toxic materials are involved. In confined spaces, the shielding gases and fumes might displace breathing air and cause asphyxiation. One's head should always be kept out of the fumes. Sufficient ventilation, exhaust at the arc or flame, or both, should be used to keep fumes and gases from your breathing zone and the general area.

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

Forced ventilation or exhaust of the welding atmosphere is most desirable when gas metal arc welding with the ER5XXX series aluminum electrodes. The ER5XXX electrodes can create high concentrations of metallic particulates as evidenced by the smoky fumes when GMA welding with these electrodes.

All bare aluminum electrodes possess a compositional control of 0.0008 percent maximum beryllium content. This provides a check by the manufacturer that the filler metal is essentially free of this element and thus avoids the presence of concentrations of this highly toxic metallic particulate during the filler metal transfer across the arc. Since the spooled electrodes are all fabricated as drawn, wrought aluminum wire, the same beryllium control has been applied to all wrought filler metals covered by this ANSI/AWS A5.10 specification where beryllium is not stated as a range (as in R4011). Thus, all wrought aluminum rods except R4011 also possess a 0.0008 percent Be maximum limit.

When melting the filler metal in the weld pool, as in gas tungsten arc welding, instead of spraying the filler metal across an arc gap, the metallic particulates have been quite low when welding the aluminum alloys. Regardless of this fact however, when welding with R4011 or R-A357.0, which possess beryllium as a deliberately added element, the user should sample the atmosphere under the actual welding conditions to assure that a satisfactory environment exists.

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

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

(2) The recommended threshold limit values for these fumes and gases may be found in *Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment*, published by the American Conference of Governmental Industrial Hygienists (ACGIH), 1330 Kemper Meadow Drive, Suite 600, Cincinnati, OH 45240-1634.

(3) The results of an AWS-funded study are available in a report entitled, *Fumes and Gases in the Welding Environment*, available from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

A12.4 Radiation. Welding, cutting, and allied operations may produce radiant energy (radiation) harmful to health. One should become acquainted with the effects of this radiant energy.

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

A12.4.1 Ionizing Radiation. Ionizing radiation is produced by the electron beam welding process. It is ordinarily controlled within acceptance limits by use of suitable shielding enclosing the welding area.

A12.4.2 Nonionizing Radiation. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base metal composition, fluxes, and any coating or plating on the base metal. Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc when used properly), laser welding and torch welding, cutting, brazing, or soldering can produce quantities of nonionizing radiation such that precautionary measures are necessary.

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

(1) One should not look at welding arcs except through welding filter plates which meet the requirements of ANSI/ASC Z87.1, *Practice for Occupational and Education Eye and Face Protection*, published by American National Standards Institute, 11 W. 42nd Street,

13th Floor, New York, NY 10036. It should be noted that transparent welding curtains are not intended as welding filter plates, but rather are intended to protect passersby from incidental exposure.

(2) Exposed skin should be protected with adequate gloves and clothing as specified in ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes,* published by American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

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

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

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

A12.4.3 Ionizing radiation information sources include:

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

(2) Manufacturer's product information literature.

A12.4.4 Nonionizing radiation information sources include:

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

(2) Nonionizing Radiation Protection Special Study No. 42-0053-77, *Evaluation of the Potential Hazards from Actinic Ultraviolet Radiation Generated by Electric Welding and Cutting Arcs*, available from the National Technical Information Service, Springfield, VA 22161, ADA-033768.

(3) Nonionizing Radiation Protection Special Study No. 42-0312-77, *Evaluation of the Potential Retina Hazards from Optical Radiation Generated by Electrical Welding and Cutting Arcs*, available from the National Technical Information Service, Springfield, VA 22161, ADA-043023.

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

(5) "Optical Radiation Levels Produced by Air-Carbon Arc Cutting Processes," *Welding Journal*, March 1980.

(6) ANSI Z136.1, *Safe Use of Lasers,* published by American National Standards Institute, 11 W. 42nd Street, 13th Floor, New York, NY 10036.

(7) ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

(8) ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*, published by American National Standards Institute, 11 W. 42nd Street, 13th Floor, New York, NY 10036.

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

Annex B

Guidelines for Preparation of Technical Inquiries for AWS Technical Committees

(This Annex is not a part of AWS A5.10/A5.10M:1999, *Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods*, but is included for information purposes only.)

B1. Introduction

The AWS Board of Directors has adopted a policy whereby all official interpretations of AWS standards will be handled in a formal manner. Under that policy, all interpretations are made by the committee that is responsible for the standard. Official communication concerning an interpretation is through the AWS staff member who works with that committee. The policy requires that all requests for an interpretation be submitted in writing. Such requests will be handled as expeditiously as possible but due to the complexity of the work and the procedures that must be followed, some interpretations may require considerable time.

B2. Procedure

All inquiries must be directed to: Managing Director, Technical Services, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

All inquiries must contain the name, address, and affiliation of the inquirer, and they must provide enough information for the committee to fully understand the point of concern in the inquiry. Where that point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and should also be in the format used here.

B2.1 Scope. Each inquiry must address one single provision of the Standard, unless the point of the inquiry involves two or more interrelated provisions. That provision must be identified in the Scope of the inquiry, along with the edition of the standard that contains the provisions or that the Inquirer is addressing.

B2.2 Purpose of the Inquiry. The purpose of the inquiry must be stated in this portion of the inquiry. The purpose can be either to obtain an interpretation of a Standard requirement, or to request the revision of a particular provision in the Standard.

B2.3 Content of the Inquiry. The inquiry should be concise, yet complete, to enable the committee to quickly and fully understand the point of the inquiry. Sketches should be used when appropriate and all paragraphs, figures, and tables (or the Annex), which bear on the inquiry must be cited. If the point of the inquiry is to obtain a revision of the Standard, the inquiry must provide technical justification for that revision.

B2.4 Proposed Reply. The inquirer should, as a proposed reply, state an interpretation of the provision that is the point of the inquiry, or the wording for a proposed revision, if that is what inquirer seeks.

B3. Interpretation of Provisions of the Standard

Interpretations of provisions of the Standard are made by the relevant AWS Technical Committee. The secretary of the committee refers all inquiries to the chairman of the particular subcommittee that has jurisdiction over the portion of the Standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire committee for review and approval. Upon approval by the committee, the interpretation will be an

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official interpretation of the Society, and the secretary will transmit the response to the inquirer and to the *Welding Journal* for publication.

B4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal*.

B5. 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 Board of Directors' Policy 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. The Headquarters Staff cannot provide consulting services. The staff can, however, refer a caller to any of those consultants whose names are on file at AWS Headquarters.

B6. The AWS Technical Committee

The activities of AWS Technical Committees in regard to interpretations, are limited strictly to the Interpretation of provisions of Standards prepared by the Committee or to consideration of revisions to existing provisions on the basis of new data or technology. Neither the committee nor the Staff is in a position to offer interpretive or consulting services on: (1) specific engineering problems, or (2) requirements of Standards applied to fabrications outside the scope of the document or 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.

AWS Filler Metal Specifications by Material and Welding Process

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

AWS Filler Metal Specifications and Related Documents

AWS Designation	Title
FMC	Filler Metal Comparison Charts
UGFM	User's Guide to Filler Metals
A4.2M/A4.2	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
A5.01	Filler Metal Procurement Guidelines
A5.1	Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding
A5.2	Specification for Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding
A5.3/A5.3M	Specification for Aluminum and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding
A5.4	Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding
A5.5	Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding
A5.6	Specification for Covered Copper and Copper Alloy Arc Welding Electrodes
A5.7	Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes
A5.8	Specification for Filler Metals for Brazing and Braze Welding
A5.9	Specification for Bare Stainless Steel Welding Electrodes and Rods
A5.10/A5.10M	Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods
A5.11/A5.11M	Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding
A5.12/A5.12M	Specification for Tungsten and Tungsten-Alloy Electrodes for Arc Welding and Cutting
A5.13	Specification for Solid Surfacing Welding Rods and Electrodes
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	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	Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding
A5.19	Specification for Magnesium Alloy Welding Electrodes and Rods
A5.20	Specification for Carbon Steel Electrodes for Flux Cored Arc Welding
A5.21	Specification for Composite Surfacing Welding Rods and Electrodes
A5.22	Specification for Stainless Steel Electrodes for Flux Cored Arc Welding and Stainless Steel Flux Cored Rods for Gas Tungsten Arc Welding
A5.23/A5.23M	Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding
A5.24	Specification for Zirconium and Zirconium Alloy Welding Electrodes and Rods
A5.25/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	Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding
A5.29	Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding
A5.30	Specification for Consumable Inserts
A5.31	Specification for Fluxes for Brazing and Braze Welding
A5.32/A5.32M	Specification for Welding Shielding Gases

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

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