

ANSI/AWS A5.19-92 (R2006)
An American National Standard

Specification for Magnesium Alloy Welding Electrodes and Rods



American Welding Society

Key Words—Bare magnesium alloy, filler metal, gas metal arc welding, gas tungsten arc welding, magnesium electrodes, magnesium rods, oxyfuel gas welding, plasma arc welding

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Specification for Magnesium Alloy Welding Electrodes and Rods

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Prepared by the
American Welding Society (AWS) A5 Committee on Filler Metal

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification prescribes requirements for the classification of bare magnesium alloy welding electrodes and rods for use with the gas metal arc, gas tungsten arc, oxyfuel gas, and plasma arc welding processes. Classification is based upon chemical composition of the welding wire. Standard sizes, finish, winding requirements, package forms and weights, product information, and chemical composition limits are specified.



American Welding Society

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Foreword

This foreword is not a part of ANSI/AWS A5.19-92 (R2006), *Specification for Magnesium Alloy Welding Electrodes and Rods*, but is included for informational purposes only.

This document represents the fourth revision or reaffirmation of the specification initially issued in 1966 as a joint ASTM/AWS specification. Very soon after its publication, the ASTM agreed to accept the AWS as the sole society responsible for the development and publication of filler metals specifications.

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

ASTM B448-66T AWS A5.19-66T	<i>Tentative Specification for Magnesium-Alloy Welding Rods and Bare Electrodes</i>
AWS A5.19-69 ANSI W3.19-1973	<i>Specification for Magnesium-Alloy Welding Rods and Bare Electrodes</i>
ANSI/AWS A5.19-80	<i>Specification for Magnesium-Alloy Welding Rods and Bare Electrodes</i>
ANSI/AWS A5.19-90 Reaffirmation	<i>Specification for Magnesium-Alloy Welding Rods and Bare Electrodes</i>

Your comments for improving the *Specification for Magnesium Alloy Welding Electrodes and Rods* are welcome. Submit comments to the Managing Director, Technical Services Division, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126; telephone (305) 443-9353; fax (305) 443-5951; e-mail info@aws.org; or via the AWS web site <<http://www.aws.org>>.

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 Magnesium Alloy Welding Electrodes and Rods

1. Scope

This specification prescribes requirements for the classification of bare magnesium 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. Classification

2.1 The electrodes and rods covered by this specification are classified according to the chemical composition of the filler metal as specified in Table 1, and their usability as specified in Section 8, Weld Test Assemblies, and Table 2.

2.2 Electrode or rod classified under one classification shall not be classified under any other classification in this specification.

2.3 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. Acceptance

Acceptance¹ of the electrode or rod shall be in accordance with the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.²

1. See A3. Acceptance (in the Appendix) for further information concerning acceptance and testing of the material shipped.

2. AWS standards are published by the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

4. 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.³

5. Units of Measure and Rounding-Off Procedure

5.1 U.S. customary units are the standard units of measure in this specification. The SI units are given as equivalent values to the U.S. customary units. The standard sizes and dimensions in the two systems are not identical, and for this reason, conversion from a standard size or dimension in one system will not always coincide with a standard size or dimension in the other. Suitable conversions, encompassing standard sizes of both, can be made, however, if appropriate tolerances are applied in each case.

5.2 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 E29, *Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.⁴

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

4. ASTM standards are published by the American Society of Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

Table 1
Chemical Composition Requirements for Magnesium Alloy Electrodes and Rods

AWS Classi- fication	UNS Number ^c	Weight Percent ^{a,b}										Other Elements, Total	
		Mg	Al	Be	Mn	Zn	Zr	Rare Earth	Cu	Fe	Ni		Si
ER AZ61A R AZ61A	M11611	Remainder	5.8 to 7.2	0.0002 to 0.0008	0.15 to 0.5	0.40 to 1.5	—	—	0.05	0.005	0.005	0.05	0.30
ER AZ92A R AZ92A	M11922	Remainder	8.3 to 9.7	0.0002 to 0.0008	0.15 to 0.5	1.7 to 2.3	—	—	0.05	0.005	0.005	0.05	0.30
ER AZ101A R AZ101A	M11101	Remainder	9.5 to 10.5	0.0002 to 0.0008	0.15 to 0.5	0.75 to 1.25	—	—	0.05	0.005	0.005	0.05	0.30
ER EZ33A R EZ33A	M12331	Remainder	—	0.0008	—	2.0 to 3.1	0.45 to 1.0	2.5 to 4.0	—	—	—	—	0.30

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 their total does not exceed the limits specified for "Other Elements, Total".

b. Single values are maximum.

c. SAE/ASTM Unified Numbering System for Metals and Alloys.

Table 2
Required Tests

AWS Classification	Chemical Analysis	Radiographic Test* (Electrode)	Bead-On-Plate Test* (Rod)
ER AZ61A	X	X	—
R AZ61A	X	—	X
ER AZ92A	X	X	—
R AZ92A	X	—	X
ER AZ101A	X	X	—
R AZ101A	X	—	X
ER EZ33A	X	X	—
R EZ33A	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 8.1.

Part B

Tests, Procedures, and Requirements

6. 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, and the deposition characteristics of welding rods. The base metal for the weld test assemblies, the welding and testing procedure to be employed, and the results required are given in Sections 8 through 11.

7. 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 retest may be taken from the original test sample or from one or two new samples. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement.

8. Weld Test Assemblies

8.1 Two weld test assemblies are required:

- (1) The groove weld in Figure 1 for the usability of electrodes and the soundness of the weld metal
- (2) The bead-on-plate weld in 8.4.1 for the usability of rods

8.2 Usability tests shall be made using electrodes and welding rods of each size. A filler metal that 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 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.

8.3 Groove Weld for Soundness and Usability of Electrodes

8.3.1 A test assembly shall be prepared and welded, as specified in Figure 1 and 8.3.2 through 8.3.4, using base metal of the appropriate type specified in Table 3. Testing of this assembly shall be as specified in Section 10, Radiographic Test.

8.3.2 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 conditions not covered herein.

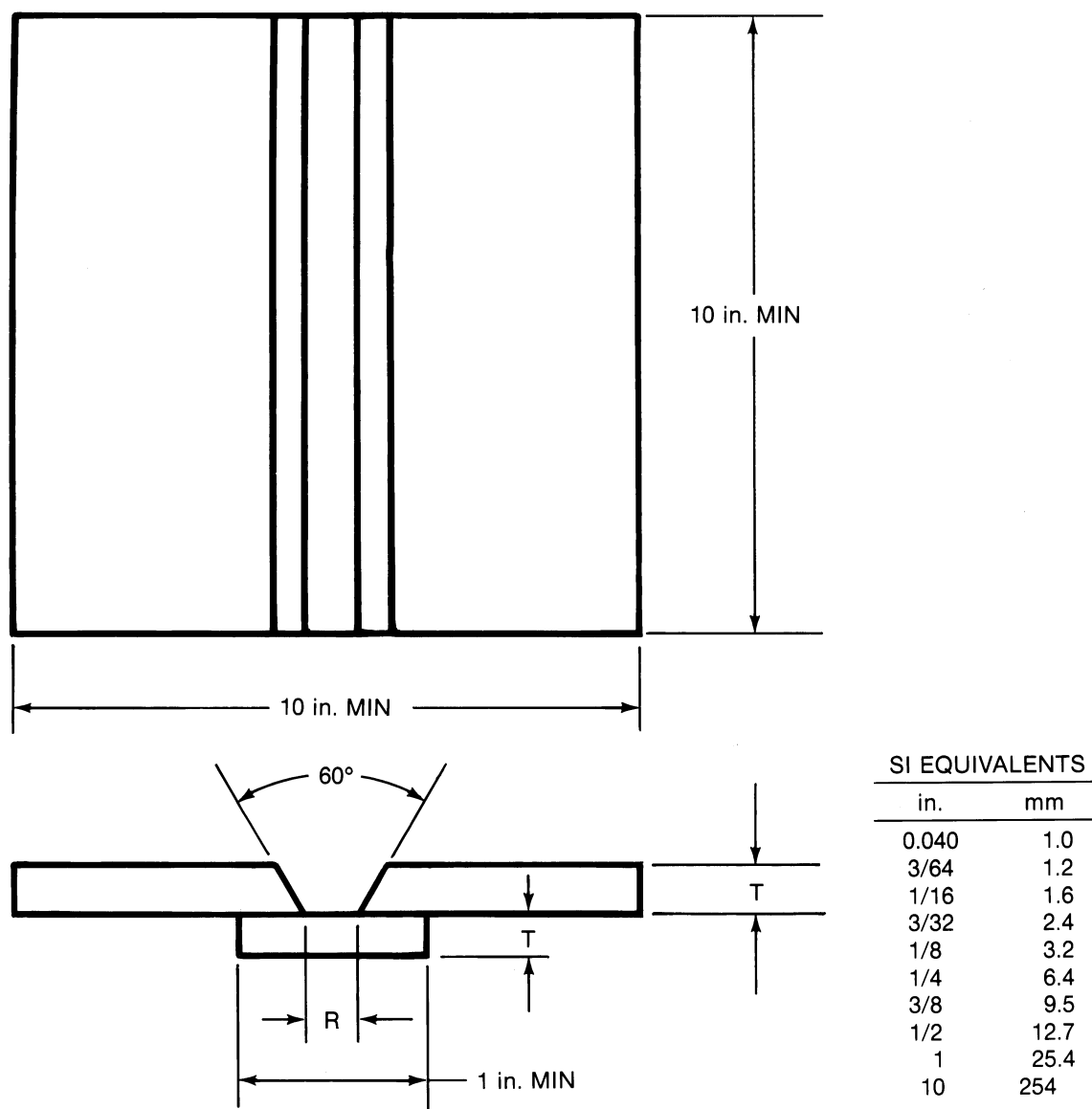
8.3.3 Dimensions of the groove weld joint and the welding position shall be as specified in Figure 1 for the electrode diameter being tested. The backing material shall be of the same type as the base metal.

8.3.4 The preheat temperature for the test assembly shall be not less than 60°F (16°C) nor greater than 150°F (66°C), and the interpass temperature shall not exceed 150°F (66°C).

Table 3
Base Metal for Test Assemblies

Electrode and Rod AWS Classification	Base Metal	
	ASTM Designation*	UNS Number
ER AZ61A, R AZ61A, ER AZ92A, or R AZ92A	AZ10A AZ61A AZ80A M1A ZE10A ZK21A	M11100 M11610 M11800 M15100 M16100 M16210
ER AZ101A or R AZ101A	AZ63A AZ81A AZ91C	M11630 M11810 M11914
ER EZ33A or R EZ33A	HM21A HM31A HZ32A K1A QE22A ZE41A	M13210 M13312 M13320 M18010 M18220 M16410

*ASTM B275, except B270 for QE22A



NOTE: ASSEMBLY MAY BE MACHINED, EXTRUDED OR CAST AS A SINGLE PIECE.

Electrode Diameter in.	Plate Thickness, T in.	Root Opening, R in.	Welding Position
0.040	1/4	1/4	Overhead
3/64	1/4	1/4	Overhead
1/16	3/8	3/8	Overhead
3/32	3/8	3/8	Flat
1/8	3/8	1/2	Flat

Figure 1—Groove Weld Test Assembly for Radiographic Test

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

8.4.1 The test assembly shall consist of a sheet or plate approximately 6 in. (150 mm) by 12 in. (300 mm) on which a weld shall be made as specified in 8.4.2, using base metal of the type specified in Table 3. Examination of the assembly shall be as specified in Section 11, Bead-On-Plate Test.

8.4.2 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 base metal thickness and the welding current shall be compatible with that with which the rod being tested normally is used.

8.4.3 The completed weld beads shall be examined with the unaided eye (except for correction to normal vision) and shall meet the requirements specified in Section 11, Bead-On-Plate Test.

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

9. Chemical Analysis

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

9.2 The sample shall be analyzed by accepted analytical methods. The referee method shall be ASTM E35, *Standard Test Methods for Chemical Analysis of Magnesium and Magnesium Alloys*.

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

10. Radiographic Test

10.1 The groove weld described in 8.3 and shown in Figure 1 shall be radiographed to evaluate the soundness of 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.

10.2 The weld shall be radiographed in accordance with ASTM E142, *Standard Method for Controlling Quality of Radiographic Testing*. The quality level of inspection shall be 2-2T.

10.3 The soundness of the weld metal and the usability of the electrode meet the requirements of this specification if the radiograph shows the following:

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

(2) No rounded indications in excess of those permitted by the radiographic standards in Figures 2 and 3

In evaluating the radiograph, the center 6 in. (150 mm) of the weld shall be considered, and all extra weld shall be disregarded.

10.3.1 A rounded indication is an indication on the radiograph whose length is no more than three times its width. Rounded indications may be circular, 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.

10.4 An electrode whose groove weld meets these radiographic requirements may also be classified as a welding rod under this specification without conducting the test specified in 8.4.

11. Bead-on-Plate Test

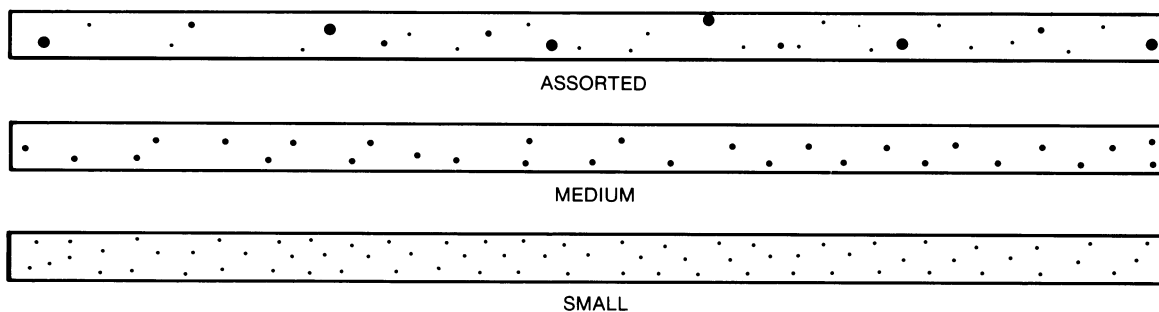
11.1 Welding rod tested in accordance with 8.4 shall produce weld metal that flows freely and uniformly without sputtering or other irregularities. The resultant weld bead shall be smooth and uniform with no visible evidence of cracks or porosity.

11.2 If a filler metal meets the weld bead test requirements when tested as a welding rod, it also shall be tested as an electrode for classification as an electrode.

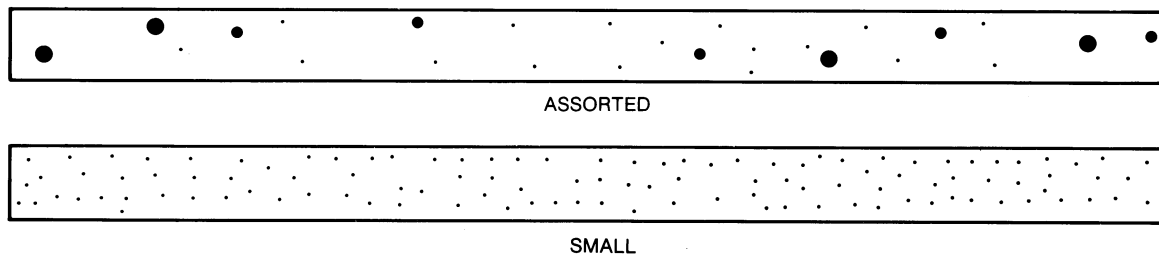
Part C *Manufacture, Identification, and Packaging*

12. 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.



**(A) RADIOGRAPHIC ACCEPTANCE STANDARD FOR 3/16 in. (4.8 mm)
AND 1/4 in. (6.4 mm) THICK TEST ASSEMBLY**



(B) RADIOGRAPHIC ACCEPTANCE STANDARD FOR 3/8 in. (9.6 mm) THICK TEST ASSEMBLY

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.

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

13. Standard Sizes

Standard sizes for filler metal in the different package forms of straight lengths and spools are as shown in Table 4.

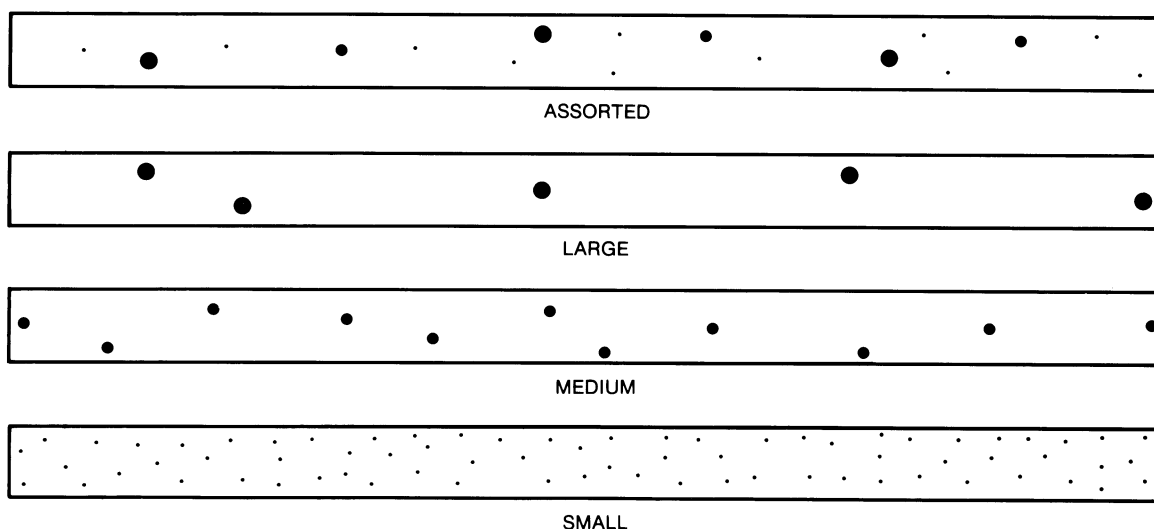
14. Finish and Uniformity

14.1 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.

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

15. Standard Package Forms

15.1 Standard package forms are straight lengths and spools. Standard package dimensions and weights for each form are given in Table 5. Package forms, sizes, and weights other than these shall be as agreed between purchaser and supplier.

**Notes:**

1. In using these standards, the chart that is most representative of the size of the rounded indications present in the radiograph shall be used for determining conformance to this radiographic standard.
2. Indications that do not exceed 1/64 in. (0.4 mm) diameter or length shall be disregarded.

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

**Table 4
Standard Sizes^a**

Package Form	Diameter		Tolerance	
	in.	mm	in.	mm
Straight lengths ^b	1/16	(0.062)	1.6	±0.007 0.18
	3/32	(0.094)	2.4	
	1/8	(0.125)	3.2	
	5/32	(0.156)	4.0	
	3/16	(0.187)	4.8	
Spools ^c	0.040		1.0	+0.003 0.08 -0.004 0.10
	3/64	(0.047)	1.2	
	1/16	(0.062)	1.6	
	3/32	(0.094)	2.4	
	1/8	(0.125)	3.2	

Notes:

- a. Dimensions, tolerances, and package forms other than those shown shall be as agreed by purchaser and supplier.
- b. Length shall be 36 in., +0, -1/2 in. (approximately 900 ±20 mm).
- c. Diameters greater than 1/16 in. (1.6 mm) are available only on 12 in. (300 mm) and 13-1/2 in. (340 mm) spools.

**Table 5
Standard Packages, Dimensions,
and Weights**

Package Form ^a	Nominal Net Weight	
	lb.	kg
Straight Lengths ^b	1	0.45
	5	2.3
	50	23
Spools ^c		
	in.	mm
4	100	3/4 0.34
8	200	3 1.35
12	300	10 4.5
13-1/2	340	20 9.0

Notes:

- a. Filler metal diameters for all forms are given in Table 4.
- b. No more than one classification or size shall be included in each unit package.
- c. Dimensions of standard spools are shown in Figures 4, 5 and 6.

15.2 Dimensions of the standard spool sizes shall be as shown in Figures 4, 5, and 6. Spools shall be designed and constructed to prevent distortion of the filler metal during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal. Spools shall electrically insulate the filler metal from the spindle.

16. Winding Requirements

16.1 Filler metal on spools 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.

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

16.3 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.

17. Filler Metal Identification

17.1 The product information and the precautionary information required in Section 19, Marking of Packages, for marking each package shall also appear on each spool.

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

18. Packaging

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

19. Marking of Packages

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

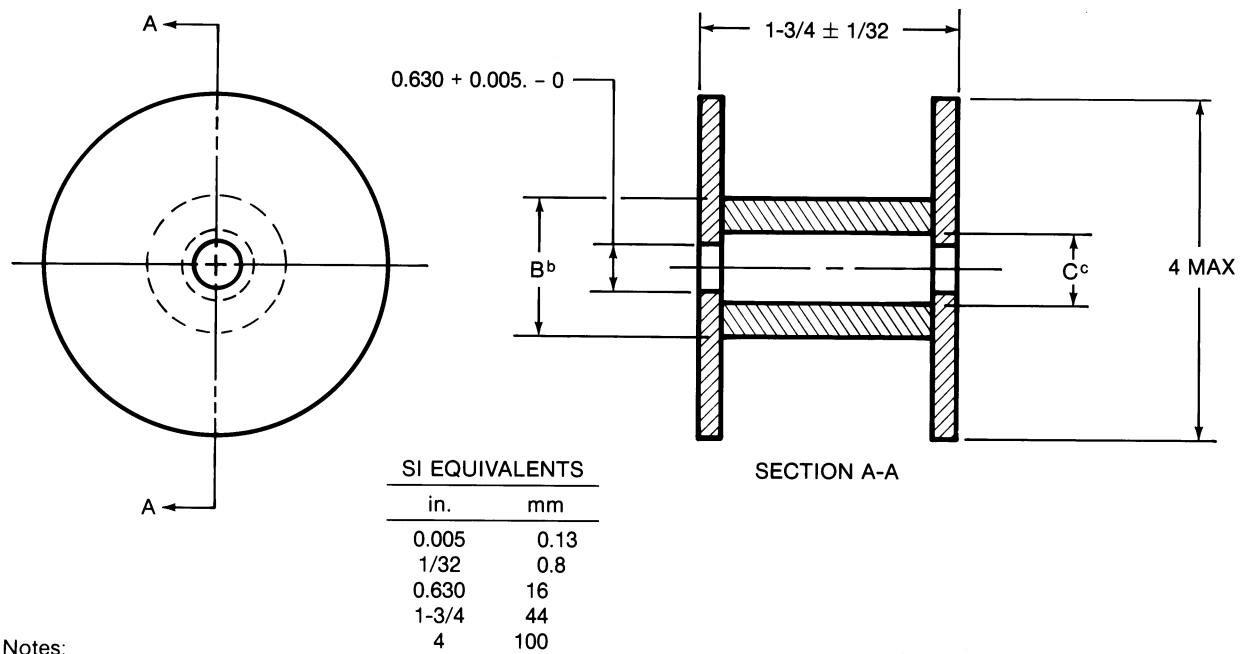
- (1) AWS specification and classification designation (year of issue may be excluded)
- (2) Supplier's name and trade designation
- (3) Size and net weight
- (4) Lot, control, or heat number

19.2 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:

WARNING

- Protect yourself and others. Read and understand this information. **FUMES AND GASES** can be dangerous to your health. **ARC RAYS** can injure eyes and burn skin. **HEAT 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 flame, 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 Z49.1, *Safety in Welding and Cutting*, published by the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135; OSHA Safety and Health Standards, 29 CFR 1910, available from the U.S. Government Printing Office, Washington, DC 20402.

DO NOT REMOVE THIS INFORMATION



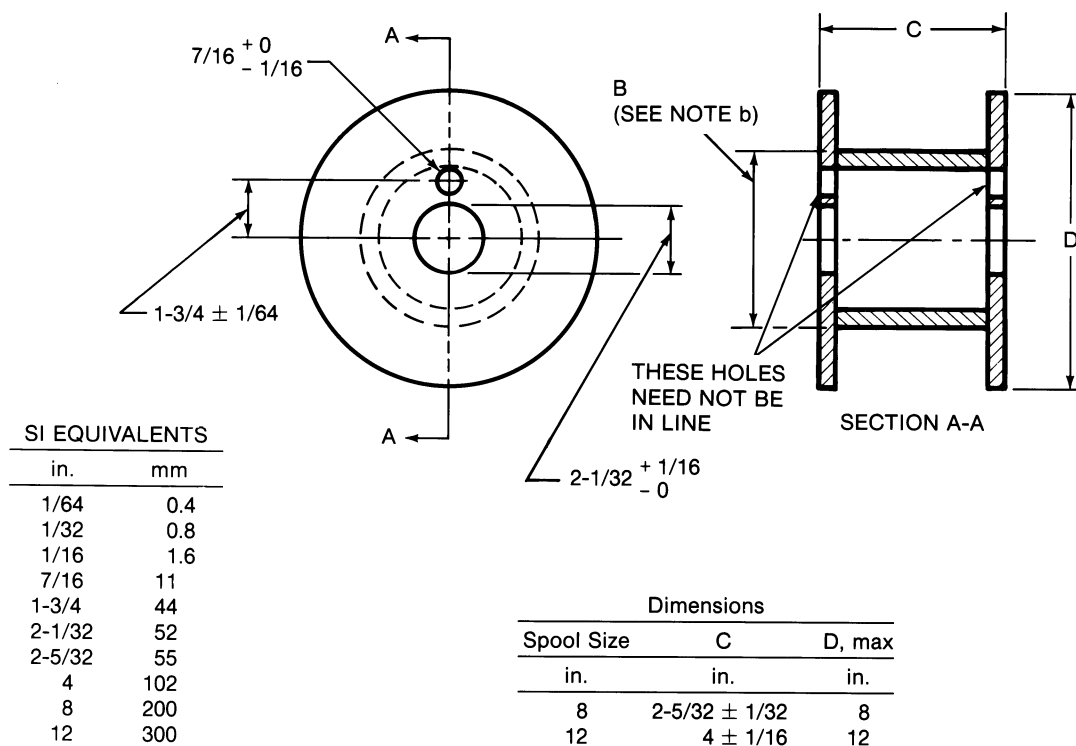
Notes:

a. All dimensions are in inches.

b. Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the filler metals.

c. Dimension C, inside diameter of 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.

Figure 4—Dimensions of 4 in. (100 mm) Diameter Spool



Notes:

a. All dimensions are in inches.

b. Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the filler metals.

Figure 5—Dimensions of 8 and 12 in. (200 and 300 mm) Diameter Spools

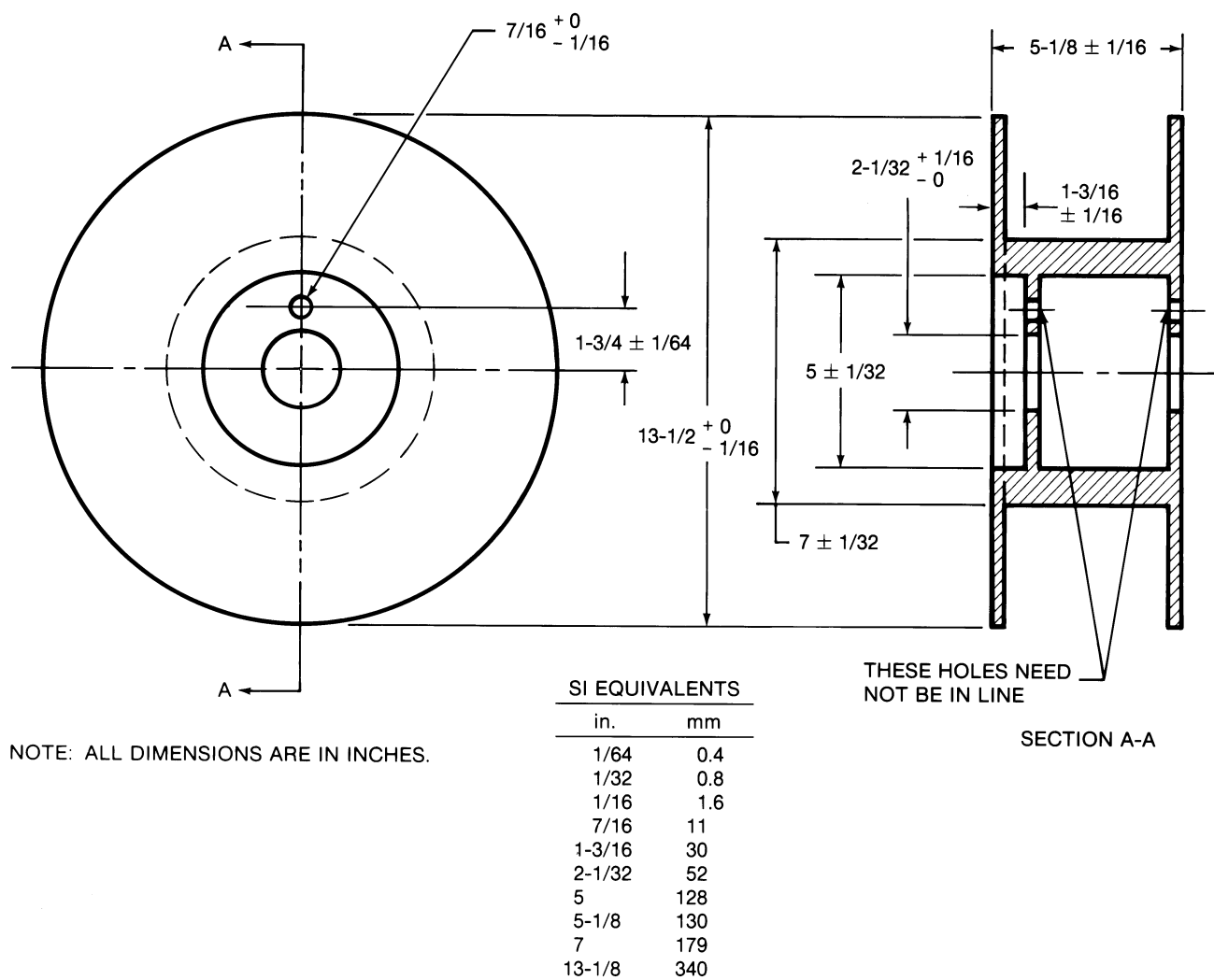


Figure 6—Dimensions of 13-1/2 in. (340 mm) Diameter Spool

Appendix

Guide to AWS Specification for Magnesium Alloy Welding Electrodes and Rods

This appendix is not a part of ANSI/AWS A5.19-92 (R2006), *Specification for Magnesium Alloy Welding Electrodes and Rods*, but is included for informational purposes only.

A1. Introduction

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

A2. Classification System

A2.1 The welding electrodes and rods are classified upon the basis of the chemical composition. The alloys are designated by the same standard system used for base metals. That consists of a combination letter-number system composed of three parts. The first part indicates the two principal alloying elements by code letters arranged in order of decreasing percentage. The second part indicates the percentages of the two principal alloying elements in the same order as the code letters. The percentages are rounded to the nearest whole number. The third part is an assigned letter to distinguish different alloys with the same percentages of the two principal alloying elements.

A2.2 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.

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 specification, needs to be clearly stated in the purchase order, according to the provisions of ANSI/AWS A5.01. 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. 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 material from any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been 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.

A5. Ventilation During Welding

A5.1 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 used
- (4) The proximity of the welders or welding operators to the fumes as these fumes issue from the welding zone, and to the gases and dusts in the space in which they are working
- (5) The ventilation provided to the space in which the welding is done

A5.2 ANSI/ASC Z49.1, *Safety in Welding and Cutting*, 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 section covering ventilation and confined spaces.

A6. Welding Considerations

A6.1 Gas tungsten arc and gas metal arc welding are the most commonly used processes for welding magnesium alloys. Plasma arc welding is also suitable for magnesium alloys. Oxyfuel gas welding should be used only for temporary repair work, when suitable arc welding equipment is not available.

A6.2 Magnesium alloys are welded by the gas tungsten arc welding (GTAW) process using techniques and equipment similar to those used for aluminum. Argon, helium, or mixtures of these gases are used for shielding. Alternating current is preferred because of a combination of good arc cleaning action and good joint penetration, although

direct current is also used. Direct current with the electrode positive provides excellent cleaning action but is limited to thin base metal. Direct current with the electrode negative is sometimes used for mechanized welding with helium shielding gas to provide deep joint penetration. GTAW is generally recommended for the welding of magnesium alloy castings. Welding is usually limited to the repair of defects in clean castings.

A6.3 The basic principles for gas metal arc welding (GMAW) of magnesium alloys are the same as for other base metals. The higher filler metal deposition rate of this process reduces the welding time, thereby reducing weld distortion and fabrication costs. Argon is generally used as a shielding gas; occasionally mixtures of argon and helium are used. Pulsed GMAW and short circuit GMAW are both used for magnesium alloys. Higher welding current, to produce spray transfer of the filler metal without pulsing, is also used. Globular transfer is not suitable.

A7. Description and Use of Magnesium Alloy Electrodes and Rods

A7.1 The weldability of most magnesium alloys is good when the proper filler metal is employed. A filler metal with a lower melting point and a wider freezing range than the base metal will provide good weldability and minimize weld cracking. AZ61A or AZ92A filler metals may be used to weld base metals of similar composition and also ZK21A base metal.

AZ61A filler metal is generally preferred for welding wrought base metals of those alloys because of lower cracking tendency. However, welds made in cast Mg-Al-Zn and AM100A base metals with AZ92A filler metal show less crack sensitivity. The weld metal will respond to the precipitation heat treatments normally applied to repaired castings. AZ101A filler metal may also be used to weld those cast base metals. EZ33A filler metal is used to weld wrought and cast base metals designed for elevated-temperature service; however, this filler metal should not be used for welding aluminum-bearing magnesium alloys because of severe weld cracking problems. When no other filler metal is available, most base metals may be welded with strips cut from the base metal.

A7.2 Additional information on filler metals suitable for welding specific base metals and combinations of base metals is given in Table A1. Cast base metals are generally welded with filler metal of the same or similar composition. When such filler metals are not available, the commercially available filler metals listed here may be used, but with the possibility of some disadvantage in weld properties. If it is desired to weld other combinations than

those listed in Table A1, they should be evaluated as to suitability for the purpose intended. The base metal 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 filler metal or base metal supplier is recommended.

A7.3 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 oxides. Experience has demonstrated that undesirable storage conditions may adversely affect filler metal performance.

A7.4 The possibility of ignition when welding magnesium alloys in thicknesses greater than 0.01 in. is very remote. Magnesium alloy will not ignite in air until it is at fusion temperature. Then, sustained burning will occur only if the ignition temperature is maintained. Inert gas shielding during welding prevents ignition of the weld pool.

Magnesium fires usually occur with accumulations of grinding dust or machining chips. Accumulations of grinding dust on clothing should be avoided. Graphite-base or salt-base powders, recommended for extinguishing magnesium fires, should be conveniently located in the work area. If large amounts of fine powders are produced, they should be collected in a waterwash-type dust collector designed for use with magnesium. Special precautions pertaining to the handling of wet magnesium fines must be followed.

A8. Special Tests

This specification classifies those magnesium 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.

A9. General Safety Considerations

A9.1 Burn Protection. Molten metal, sparks, slag, and hot work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used.

Workers should wear protective clothing made of fire resistant material. Pant cuffs, open pockets, or other

places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

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

Where welding or cutting of unusually thick base metal is involved, sheet metal shields should be used for extra protection. Mechanization of highly hazardous processes or jobs should be considered. Other personnel in the work area should be protected by the use of noncombustible screens or by the use of appropriate protection as described in the previous paragraph.

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

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

(1) ANSI/ASC Z41.1, *Safety-Toe Footwear*, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036.

(2) ANSI/ASC Z49.1, *Safety in Welding and Cutting*, published by the American Welding Society, 550 N. W. LeJeune Road, P. O. Box 351040, Miami, FL 33135.

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

(4) *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.

A9.2 Electrical Hazards. Electric shock can kill. However, it can be avoided. Live electrical parts should not be touched. The manufacturer's instructions and recom-

Table A1
Guide to the Choice of Filler Metal for General Purpose Welding

Base Metal		Base Metal											
		AM100A	AZ10A	AZ31B AZ31C	AZ61A	AZ63A	AZ80A	AZ81A	AZ91C	AZ92A	EK41A	EZ33A	HK31A
Base Metal	Filler Metal ^{a,b}												
AM100A	{ AZ101A AZ92A												
AZ10A	AZ92A { AZ61A AZ92A												
AZ31B	AZ92A { AZ61A AZ61A AZ92A AZ92A												
AZ31C													
AZ61A	AZ92A { AZ61A AZ61A AZ61A AZ92A AZ92A AZ92A												
AZ63A	c c c c { AZ101A AZ92A												
AZ80A	AZ92A { AZ61A AZ61A AZ61A } c { AZ61A AZ92A AZ92A AZ92A }												
AZ81A	AZ92A AZ92A AZ92A AZ92A c AZ92A { AZ101A AZ92A }												
AZ91C	AZ92A AZ92A AZ92A AZ92A c AZ92A AZ92A { AZ101A AZ92A }												
AZ92A	AZ92A AZ92A AZ92A AZ92A c AZ92A AZ92A AZ92A AZ101A												
EK41A	AZ92A AZ92A AZ92A AZ92A c AZ92A AZ92A AZ92A AZ92A EZ33A												
EZ33A	AZ92A AZ92A AZ92A AZ92A c AZ92A AZ92A AZ92A AZ92A EZ33A EZ33A												
HK31A	AZ92A AZ92A AZ92A AZ92A c AZ92A AZ92A AZ92A AZ92A EZ33A EZ33A EZ33A												
HM21A	AZ92A AZ92A AZ92A AZ92A c AZ92A AZ92A AZ92A AZ92A EZ33A EZ33A EZ33A												
HM31A	AZ92A AZ92A AZ92A AZ92A c AZ92A AZ92A AZ92A AZ92A EZ33A EZ33A EZ33A												
HZ32A	AZ92A AZ92A AZ92A AZ92A c AZ92A AZ92A AZ92A AZ92A EZ33A EZ33A EZ33A												
K1A	AZ92A AZ92A AZ92A AZ92A c AZ92A AZ92A AZ92A AZ92A EZ33A EZ33A EZ33A												
LA141A	d d EZ33A c c c c c d d d												
M1A	AZ92A { AZ61A AZ61A AZ61A } c { AZ61A } AZ92A AZ92A AZ92A AZ92A AZ92A AZ92A												
MG1													
QE22A	d d AZ92A d c d d d d EZ33A EZ33A EZ33A												
ZE10A	AZ92A { AZ61A AZ61A AZ61A } c { AZ61A } AZ92A AZ92A AZ92A { EZ33A EZ33A EZ33A AZ92A AZ92A AZ92A }												
ZE41A	d d d d c d d d d EZ33A EZ33A EZ33A												
ZK21A	AZ92A { AZ61A AZ61A AZ61A } c { AZ61A } AZ92A AZ92A AZ92A AZ92A AZ92A AZ92A												
ZH62A	{ c c c c c c c c c c c c }												
ZK51A													
ZK60A													
ZK61A													

(continued)

Table A1 (continued)

Base Metal											
Base Metal	Filler Metal ^{a,b}										
	HM21A	HM31A	HZ32A	K1A	LA141A	M1A	MG1	QE22A	ZE10A	ZE41A	ZK21A
HM21A	EZ33A										ZH62A
HM31A	EZ33A	EZ33A									ZK51A
HZ32A	EZ33A	EZ33A									ZK60A
K1A	EZ33A	EZ33A	EZ33A	EZ33A							ZK61A
LA141A	EZ33A	d	d	d	EZ33A						
M1A	AZ92A	AZ92A	AZ92A	AZ92A	d	{	AZ61A				
MG1						{	AZ92A				
QE22A	EZ33A	EZ33A	EZ33A	EZ33A	EZ33A	c	EZ33A				
ZE10A	{	EZ33A	EZ33A	EZ33A	EZ33A	{	AZ61A	EZ33A	AZ61A		
	AZ92A	AZ92A	AZ92A	AZ92A		AZ92A	AZ92A	AZ92A	AZ92A		
ZE41A	EZ33A	EZ33A	EZ33A	EZ33A	d	d	EZ33A	d	EZ33A		
ZK21A	AZ92A	AZ92A	AZ92A	AZ92A	d	{	AZ61A	AZ92A	{	AZ61A	{
						AZ92A			AZ92A	AZ92A	AZ92A
ZH62A											
ZK51A	c	c	c	c	c	c	c	c	c	c	EZ33A
ZK60A											
ZK61A											

Notes:

- When more than one filler metal is given, they are listed in order of preference.
- The letter prefix (ER or R), designating usability of the filler metal, has been deleted, to reduce clutter in the table.
- Welding not recommended.
- No data available.

mended safe practices should be read and understood. Faulty installation, improper grounding, and incorrect operation and maintenance of electrical equipment are all sources of danger.

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

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

Moisture can conduct electricity. To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber soled shoes, or stand on a dry board or insulated platform. Cables and connections should be kept in good condition.

Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used.

Open circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating current machines are being used, the open circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

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

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

A9.3 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, current level, arc length, and other factors.

The possible effects of over-exposure 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 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.

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

(1) The permissible exposure limits required by OSHA can be found in *CFR Title 29, Chapter XVII Part 1910*.

(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), 6550 Glenway Avenue, Building D-5, Cincinnati, OH 45211.

(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.

A9.4 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 non-ionizing (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.

A9.4.1 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.

A9.4.2 Non-Ionizing Radiation. The intensity and wavelengths of non-ionizing 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 non-ionizing radiation such that precautionary measures are necessary.

Protection from possible harmful effects caused by non-ionizing radiant energy from welding include the following measures:

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

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

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

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

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

A9.4.3 Ionizing radiation information sources include the following:

(1) ANSI/AWS F2.1, *Recommended Safe Practices for Electron Beam Welding and Cutting*, available from the American Welding Society.

(2) Manufacturer's product information literature.

A9.4.4 The following include non-ionizing radiation information sources:

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

(2) ———. ANSI/ASC Z87.1, *Practice for occupational and educational eye and face protection*. New York: National Standards Institute.

(3) American Welding Society. ANSI/ASC Z49.1, *Safety in welding and cutting*. Miami, FL: American Welding Society.

(4) Hinrichs, J. F. "Project committee on radiation-summary report." *Welding Journal*, January 1978.

(5) Moss, C. E. "Optical radiation transmission levels through transparent welding curtains." *Welding Journal*, March 1979.

(6) Moss, C. E. and Murray, W. E. "Optical radiation levels produced in gas welding, torch brazing, and oxygen cutting." *Welding Journal*, September 1979.

(7) National Technical Information Service. *Non-ionizing radiation protection special study no. 42-0053-77, evaluation of the potential hazards from actinic ultraviolet radiation generated by electric welding and cutting arcs*. Springfield, VA: National Technical Information Service. ADA-033768.

(8) ———. *Non-ionizing radiation protection special study No. 42-0312-77, evaluation of the potential retina hazards from optical radiation generated by electrical welding and cutting arcs*. Springfield, VA: National Technical Information Service. ADA-043023.

(9) "Optical radiation levels produced by air-carbon arc cutting processes." *Welding Journal*, March 1980.

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AWS Filler Metal Specifications and Related Documents

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

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