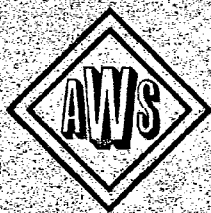


ANSI/AWS A5.6-84
An American National Standard

Specification for Covered Copper and Copper Alloy Arc Welding Electrodes



AMERICAN WELDING SOCIETY, INC.

ANSI/AWS A5.6-84
An American National Standard

Approved by
American National Standards Institute
February 17, 1984

Specification for
Covered Copper and
Copper Alloy Arc Welding
Electrodes

Superseding
AWS A5.6-76

Prepared by
AWS Committee on Filler Metal

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors, September 21, 1983

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Specification for Covered Copper and Copper Alloy Arc Welding Electrodes

Issued 1948; revised 1953, 1957, 1966, 1969, 1976, 1984

Scope

This specification prescribes requirements for the classification of covered copper and copper alloy electrodes for shielded metal arc welding. It includes compositions in which the copper content exceeds that of any other element.

Note: No attempt has been made to provide for the classification of all grades of copper and copper alloy welding electrodes. Only the more commonly used have been included.

The values stated in U.S. customary units are to be regarded as the standard. 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.

Part A General Requirements

1. Classification

1.1 The welding materials covered by this specification are classified on the basis of chemical composition of the undiluted weld metal as specified in Table 1.

1.2 Material classified under one classification shall not be classified under any other classification in this specification.

2. Acceptance

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

3. Certification

The manufacturer certifies by affixing the marking required in 18 that the material, or representative material, has passed the tests required for classification, and that the material meets also all other requirements of this specification.

4. Rounding-Off Procedure

For purposes of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi for tensile and yield strength, and to the "nearest unit" in the last right-hand place of figures used in expressing the limiting value for other quantities in accordance with the rounding-off method given in ASTM E29, *Standard Recommended Practice for Indicating Which Places of Figures are to be Considered Significant in Specified Limiting Values*.¹

1. ASTM Standards can be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

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Table 1
Chemical composition requirements for undiluted metal

AWS Classification	UNS Number ^c	Common name	Composition, weight, percent ^{a,b}											Total other elements
			Cu including Ag	Zn	Sn	Mn	Fe	Si	Ni ^d	P	Al	Pb	Ti	
ECu	W60189	Copper	Remainder	f	f	0.10	0.20	0.10	f	f	0.10	0.02	—	0.50
ECuSi	W60656	Silicon bronze (copper silicon)	Remainder	f	1.5	1.5	0.50	2.4 to 4.0	f	f	0.01	0.02	—	0.50
ECuSn-A	W60518	Phosphor bronze (copper-tin)	Remainder	f	4.0-6.0	f	0.25	f	f	0.05 to 0.35	0.01	0.02	—	0.50
ECuSn-C	W60521		Remainder	f	7.0-9.0	f	0.25	f	f	0.05 to 0.35	0.01	0.02	—	0.50
ECuNiF	W60715	Copper nickel (70/30)	Remainder	f	f	1.00-2.50	0.40-0.75	0.50	29.0-33.0	0.020	—	0.02	0.50	0.50
ECuAl-A2	W60614	Aluminum bronze	Remainder	f	f	f	0.50-5.0	1.5	f	—	6.5 to 9.0	0.02	—	0.50
ECuAl-B	W60619	Aluminum bronze	Remainder	f	f	f	2.5-5.0	1.5	f	—	7.5 to 10.0	0.02	—	0.50
ECuNiAl	W60632	Nickel aluminum bronze	Remainder	f	f	0.50-3.5	3.0-6.0	1.5	4.0-6.0	—	6.0 to 8.5	0.02	—	0.50
ECuMnNiAl	W60633	Manganese-nickel aluminum bronze	Remainder	f	f	11.0-13.0	2.0-6.0	1.5	1.0-2.5	—	5.0 to 7.5	0.02	—	0.50

Notes:

- a. Analysis shall be made for the elements for which specific values or an "f" are shown in this table. If, however, the presence of other elements is indicated in the course of routine analysis, further analysis shall be made to determine that the total of these other elements is not present in excess of the limits specified for "total other elements" in the last column in the table.
- b. Single values shown are maximum.
- c. SAE/ASTM Unified Number System for Metals and Alloys.
- d. Includes cobalt.
- e. Sulfur shall be restricted to 0.015 percent for the ECuNi classification.
- f. Those elements must be included in total of other elements.

Part B

Tests, Procedures, and Requirements

5. Summary of Tests

Tests required for each classification are specified in Table 2.

6. Retest

If any test fails to meet its requirement, that specific test must be repeated twice. The results of both tests shall meet the requirement. Specimens for retest may be taken from the original test assembly or from one or two new test assemblies.

For chemical analysis, retest shall be for the specific element which failed to meet the requirement.

7. Weld Test Assemblies

Two test assemblies are required for all except ECuNi classification. This classification requires three test assemblies as follows:

(1) A weld pad, Fig. 1, for chemical analysis of the undiluted weld metal

(2) A groove weld, Fig. 2, for mechanical properties and soundness of the weld metal

(3) A groove weld, Fig. 3, for usability of ECuNi electrodes

7.1 Weld Pad. Base metal of a convenient size, of the type specified in Table 2, and in the Chemical Analysis Column of Table 2 (including Note b to that Table), shall be used as the base for the weld pad shown in Fig. 1. The surface of the base metal on which the weld metal is deposited shall be clean.

Table 2
Summary of materials required for testing

AWS Classification	Base Metal ^a (ASTM specifications and UNS Numbers)		
	Chemical analysis	Tension test ^b	Transverse guided bend test ^b
ECu	B152 or B11 C12200	B152 or B11 C12200	B152 or B11 C12200
ECuSi	B96 or B97 C65500	B96 or B97 C65500	B96 or B97 C65500
ECuSn-A	B103 C51100	B103 C51100	B103 C51100
ECuSn-C	B130 C52100	B130 C52100	B130 C52100
ECuNi ^c	B122 C71500	B122 C71500	B122 C71500
ECuAl-A2	B169 C61400	B169 C61400	B169 C61400
ECuAl-B	B148 C95400	B148 C95400	
ECuNiAl	B148 C95800	B148 C95800	B148 C95800 ^d
ECuMnNiAl	B148 C95700	B148 C95700	B148 C95700 ^d

Notes:

a. Tests are required only where base metals are designated. All welding for chemical analysis, all-weld-metal tension tests, and transverse guided-side-bend tests shall be done with the test plates in the flat position.

b. When desired, steel, A36 or equivalent, may be substituted for the designated copper alloy. When this is done, surfacing welds shall be applied to the groove faces of the joint. Surfacing shall be accomplished with electrodes of the same classification as those being tested and may be done in the flat position.

c. Groove weld usability tests shall be conducted for the ECuNi classification as per Fig. 3.

d. Bend radius shall be in accordance with I1.

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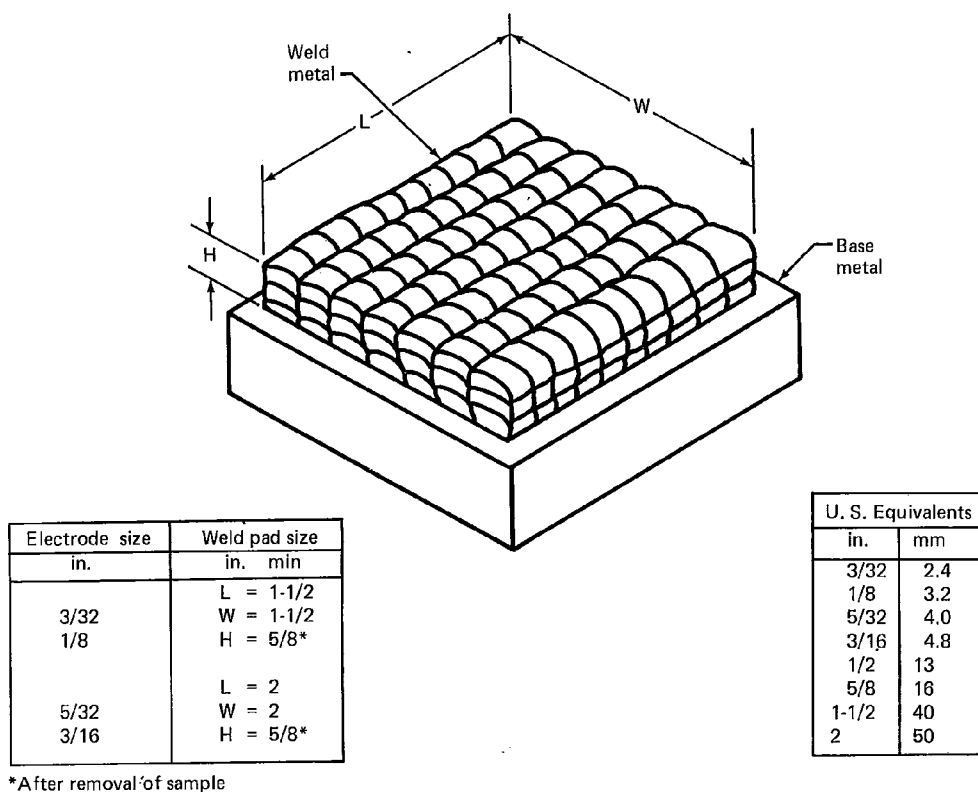


Fig. 1—Dimensions of weld for chemical analysis test pad

The pad shall be made with multiple passes and layers of weld metal deposited in the flat position. The slag shall be removed after each pass. The temperature of the base metal shall be not less than 60° F (16° C) prior to welding, and the interpass temperature shall not exceed 300° F (150° C). The dimensions of the completed pad shall be as shown in Fig. 1 for each size of electrode. Testing of this assembly shall be as specified in 8.

7.2 Groove Weld for Mechanical Properties and Soundness. A test assembly shall be prepared and welded as shown in Fig. 2 using base metal of the appropriate type specified in Table 2 and the Tension test and Bend test columns of Table 2. Testing of this assembly shall be as specified in 9 and 10.

7.3 Groove Weld for Usability Test. A test assembly shall be prepared for electrodes of the ECuNi classification and welded as shown in Fig. 3, using base metal of the appropriate type specified in Table 2 including Notes. The welding position shall be as specified in the Usability test column of Table 3 for the different sizes of electrodes of the ECuNi classification. Testing of the assembly shall be as specified in 11.

8. Chemical Analysis

8.1 Details of the test are specified in 8.2 and 8.3.

8.2 Weld deposits or fractured portions of all-weld-metal tension test specimens may be employed for the determination of weld metal chemical analysis. Weld metal shall be deposited in layers in the flat position using the base material specified in Table 2. In case of dispute, deposit dimensions shall be as specified in Fig. 1.

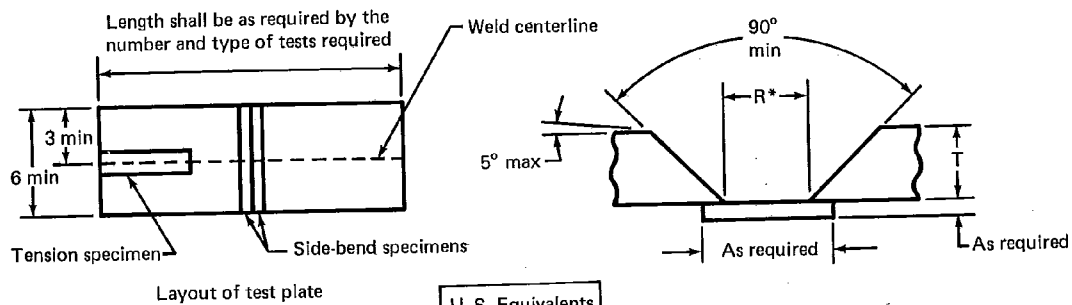
8.3 Samples for analysis shall be free from all foreign matter. To avoid dilution, a minimum height of 5/8 in. (16 mm) of weld metal shall remain after removal of the sample for analysis.

8.4 Weld metal analysis may be made by any suitable method. In case of dispute, the chemical analysis procedure in the latest edition of the following ASTM specifications² shall be the referee method:

E62-XX Photometric Methods for Chemical Analysis of Copper and Copper-Base Alloys

E75-XX Chemical Analysis of Copper-Nickel and Copper-Nickel-Zinc Alloys

2. ASTM op. cit.



U. S. Equivalents	
in.	mm
1/8	3.2
5/32	4.0
1/4	6.4
1/2	12.7
3/4	19
3	75
6	150

Groove preparation of test plate

Electrode size in.	Minimum test plate thickness T in.	Root opening R in.	Number of layers minimum
1/8 and less	1/2	1/4	10
5/32 and larger	3/4	1/2	10

Notes:

1. Weld test plates for all-weld-metal tension and bend specimens shall be prepared using the plate base metal shown in Table 2.

2. The surfaces to be welded shall be clean.

3. Welding shall be performed with the plate in the flat position, using the current values and welding techniques recommended by the electrode manufacturer.

4. Preheat temperature shall be 60°F (16°C) minimum. The interpass temperature shall not exceed 300°F (150°C). For the ECuSi classifications, the interpass temperature shall not exceed 150°F (65°C).

5. The weld metal shall have a maximum bead width equal to six (6) times the core wire diameter. The completed weld shall be at least flush with the surface of the test plate.

6. For the ECuNi classification, the minimum groove angle shall be 60 degrees. The number of layers for the 3/32 in. (2.4 mm) and 1/8 in. (3.2 mm) electrodes shall be recorded and reported. The 5/32 in. (4.0 mm) and 3/16 in. (4.8 mm) electrodes shall have a minimum of 6 layers and maximum of 9 layers.

7. Tests shall be conducted in the as-welded condition.

*R = Tolerance $\pm 1/16$ in.

Fig. 2—Test assembly for tensile and bend test

9. Radiographic Test

9.1 Radiographic examination for classification is required only for ECuNi electrodes.

9.2 The groove weld for radiographic test shall be made in accordance with Fig. 3. Test assemblies for the $\frac{3}{32}$ in. (2.4 mm) and $\frac{1}{8}$ in. (3.2 mm) electrodes shall be welded in the vertical position. Test assemblies for the $\frac{5}{32}$ in. (4.0 mm) and $\frac{3}{16}$ in. (4.8 mm) diameter electrodes shall be welded in the flat position. The groove weld for tensile and bend tests for $\frac{5}{32}$ in. (4.0 mm) and $\frac{3}{16}$ in. (4.8 mm) electrodes (Fig. 2) may be radiographed in lieu of the assembly in Fig. 3.

9.3 The test assemblies shall be prepared and evaluated in accordance with 9.3.1, 9.3.2 and 9.3.3.

9.3.1 The weld shall merge smoothly with the surface of the plate. Any reinforcement must be reasonably uniform and shall not exceed $\frac{3}{32}$ in. (2.4 mm).

9.3.2 In preparation for radiography, the backing strip and any excessive reinforcement shall be removed from the test assembly. Any surface irregularities that might mask or be confused with radiographically rejectable indications shall be removed from the face and root of the weld by any suitable mechanical means.

9.3.3 The weld shall be radiographed in accordance with ASTM Method E142, *Controlling Quality of Radiographic Testing*. The sensitivity level shall be 2-2T.

9.3.4 The usability of the electrode is acceptable if the radiograph shows no cracks, no zones of incomplete fusion, and no rounded indications in excess of those permitted by Figs. 4A, B, C and D according to the thickness of the test assembly. A rounded indication is an indication whose length is no more than three times its width on the radiograph. Rounded indications may be circular, elliptical, conical, or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present. Slag indications shall be evaluated as porosity. When evaluating the radiograph, 1 in. (25 mm) on each end of the weld, and rounded indications less than $\frac{1}{64}$ in. (0.4 mm) shall be disregarded.

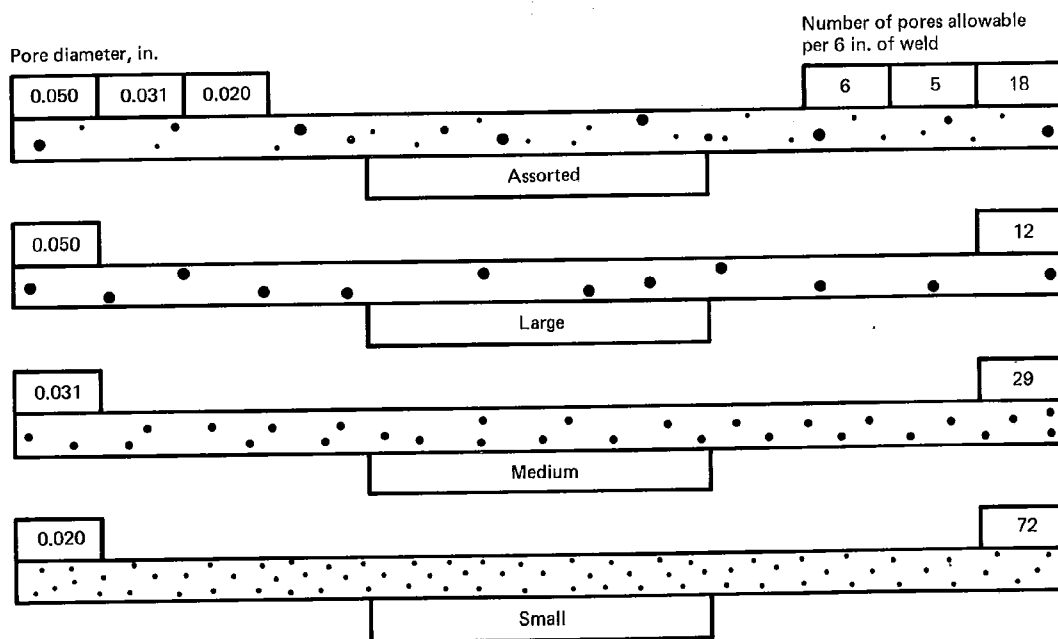
10. Tension Test

10.1 One all-weld-metal tension test specimen shall be machined from the groove weld described in 7.2 and shown in Fig. 2. The welding shall be done in the flat position, as stated in Table 2. Tension tests shall be conducted in the as-welded condition and in accordance with the tension test section of the latest edition of AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. Test specimen dimensions shall be as shown in Fig. 5.

Table 3
Mechanical property requirements

AWS Classification	Tensile strength, min		Elongation in. $4 \times D$ gage length, percent, min.
	ksi	MPa	
ECu	25	170	20
ECuSi	50	350	20
ECuSn-A	35	240	20
ECuSn-C	40	280	20
ECuNi	50	350	20
ECuAl-A2	60	410	20
ECuAl-B	65	450	10
ECuNiAl	72	500	10
ECuMnNiAl	75	520	15

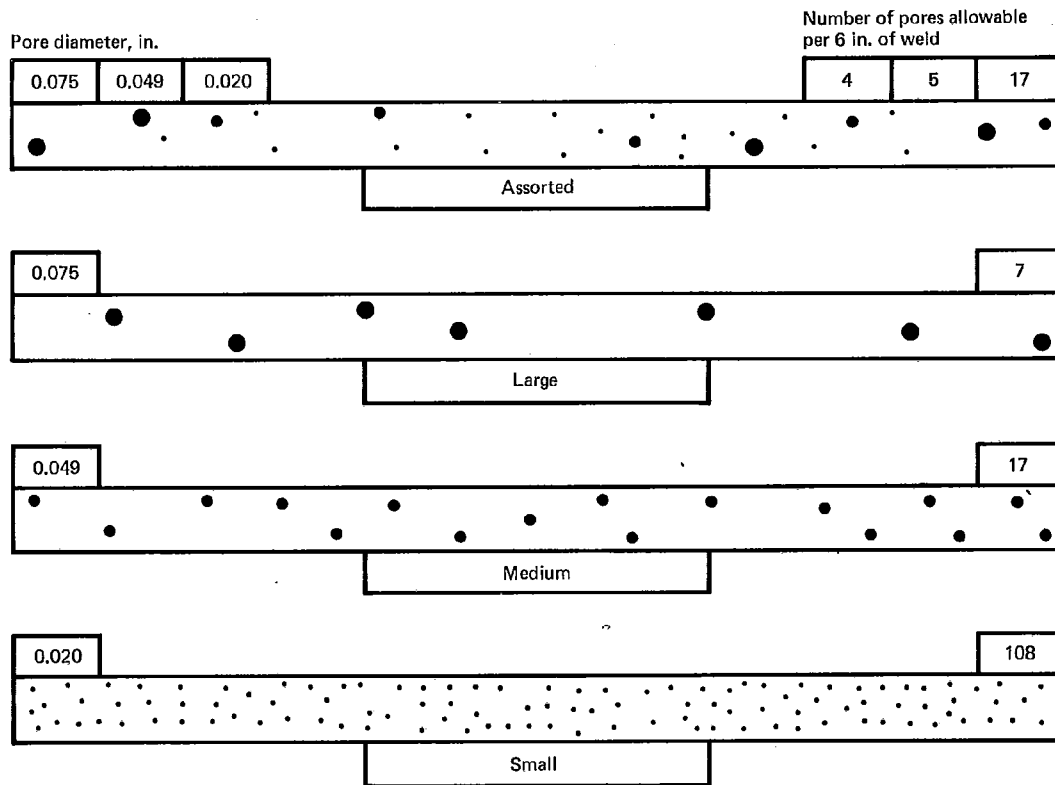
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SI Equivalents	
in.	mm
0.020	0.51
0.031	0.79
0.050	1.27
1/4	6.4
6	150

Note: In using these porosity standards, the chart which is most representative of the size of porosity present in the test specimen radiograph shall be used for determining conformance to these Radiographic Acceptance Standards.

Fig. 4A—Acceptance standard for 1/4 in. (6.4 mm) test plate



SI Equivalents	
in.	mm
0.020	0.51
0.049	1.25
0.075	1.90
3/8	9.5
6	150

Note: In using these porosity standards, the chart which is most representative of the size of porosity present in the test specimen radiograph shall be used for determining conformance to these Radiographic Acceptance Standards.

Fig. 4B—Acceptance standard for $\frac{3}{8}$ in. (9.5 mm) test plate

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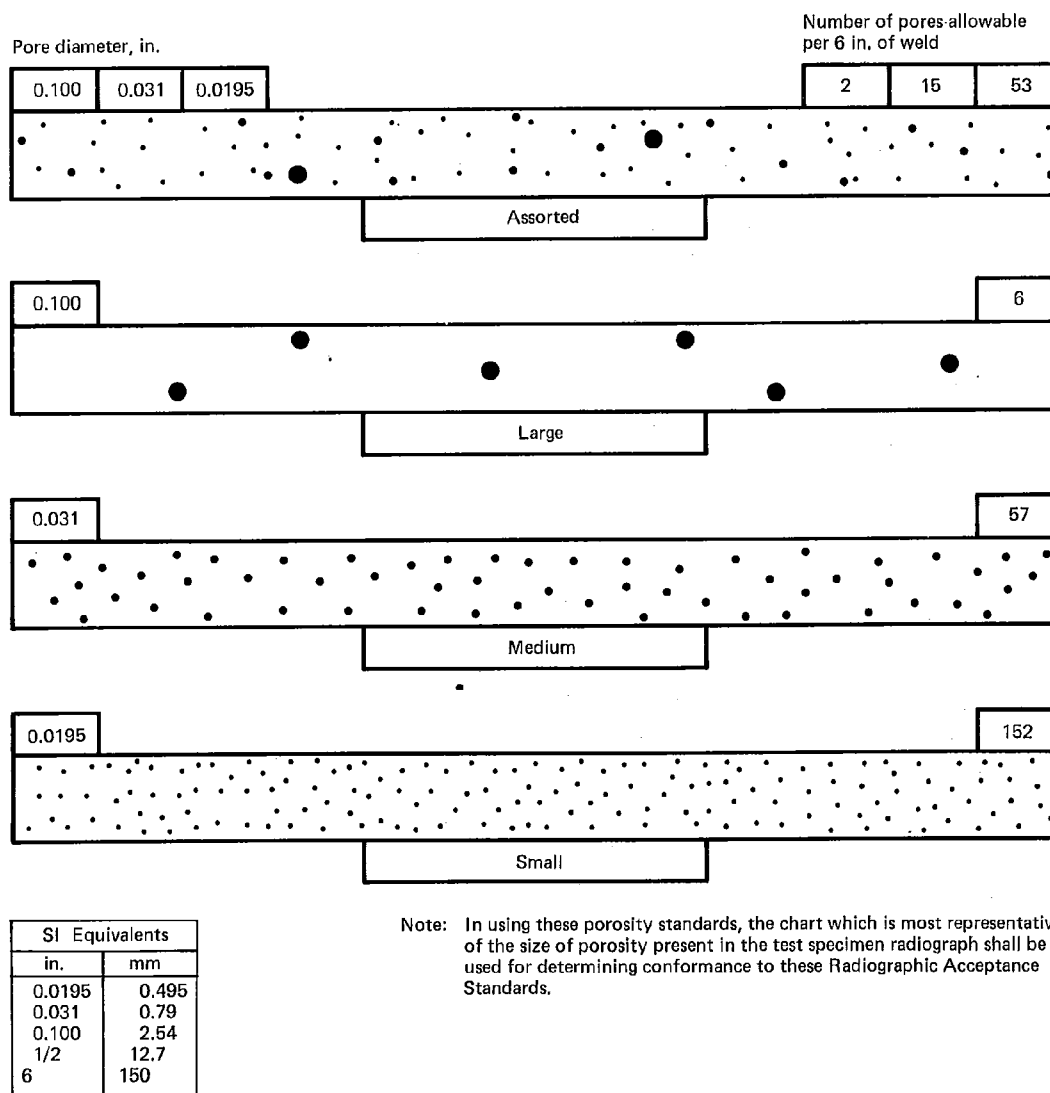
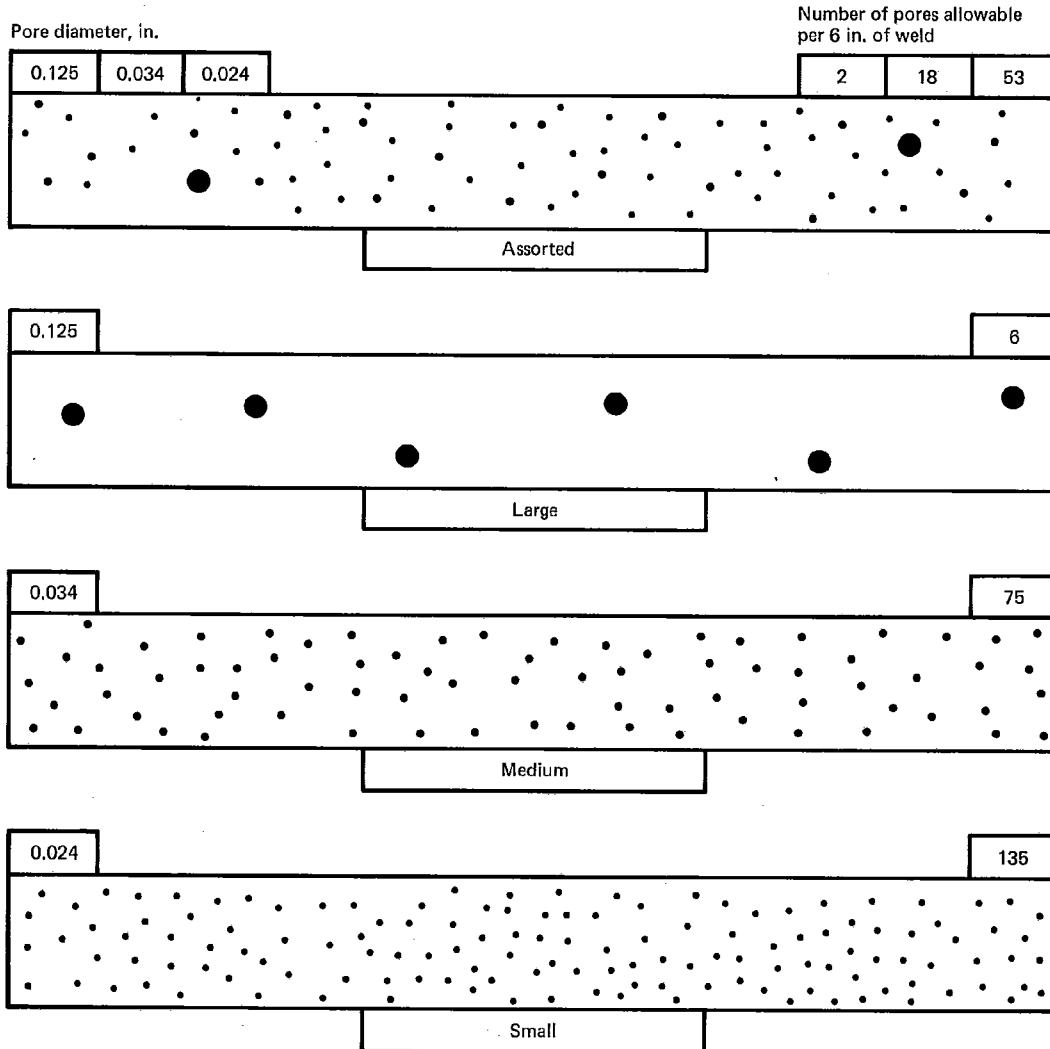


Fig. 4C—Acceptance standard for ½ in. (12.7 mm) test plate

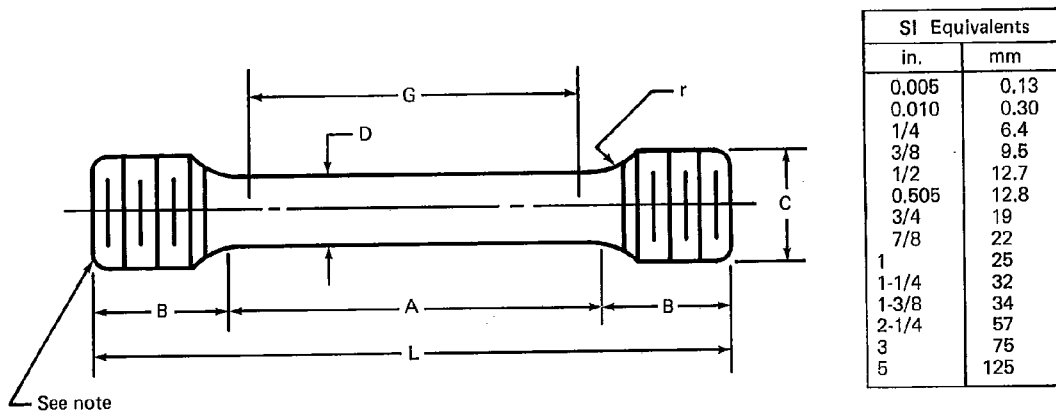


SI Equivalents	
in.	mm
0.024	0.61
0.034	0.86
0.125	3.18
3/4	19

Note: In using these porosity standards, the chart which is most representative of the size of porosity present in the test specimen radiograph shall be used for determining conformance to these Radiographic Acceptance Standards.

Fig. 4D—Acceptance standard for 3/4 in. (19 mm) test plate

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Standard dimensions, in.		
	(A)	(B)
	0.505 Specimen	0.252 Specimen
G = Gage length	2.000 ± 0.005	1.000 ± 0.005
D = Diameter	0.505 ± 0.010	0.252 ± 0.005
r = Radius of fillet	3/8 min	3/16 min
A = Length of reduced section	2-1/4 min	1-1/4 min
L = Overall length	5 approx	3 approx
B = Length of end section	1-3/8 approx	7/8 approx
C = Diameter of end section	As required	As required

Note: End sections may or may not be threaded. Threads, when employed, should be machined to fit available fixtures.

Fig. 5—All-weld-metal tension test specimen dimensions

11. Bend Test

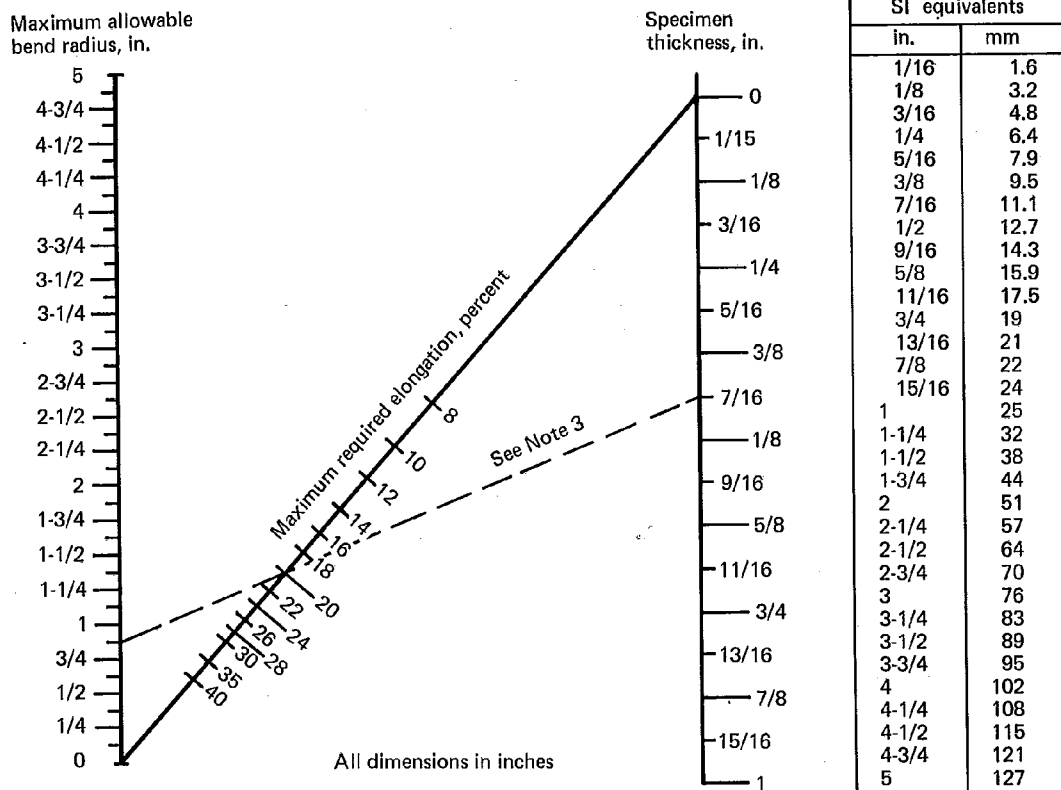
11.1 Test specimens shall be prepared in accordance with Fig. 2.

11.2 When required in Table 2, test specimens (in the as-welded condition) shall be bent in conformance with the side-bend test sections of the latest edition of AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. A 3/8 in. (9.5 mm) thick specimen shall be uniformly bent through 180 degrees over 3/4 in. (19 mm) radius in any suitable jig except that ECuAl-A2, ECuNiAl and ECuMnNiAl specimens shall be uniformly bent using the radius specified in Fig. 6. Positioning of the specimens for bending shall be such that the welded joint will conform to this radius after bending. The side of the bend

with the greater discontinuities, if any, shall be in tension, and the weld shall be at the center of the bend. Figures 7A and 7B show two typical bending jigs from the latest edition of AWS B4.0 and are dimensioned for bending a 3/8 in. (9.5 mm) thick specimen over a 2T radius.

11.3 After bending in accordance with 11.2, the convex surface of the transverse guided-side-bend test specimens shall exhibit no cracks or open discontinuities in the weld metal exceeding 1/8 in. (3 mm) measured in any direction. Small checks or cracks at the edges of the test specimen shall be disregarded.

11.3.1 The guided-bend test jig, Fig. 7B is recommended when steel is used as base metal for the test assembly (see Table 2, Note b).

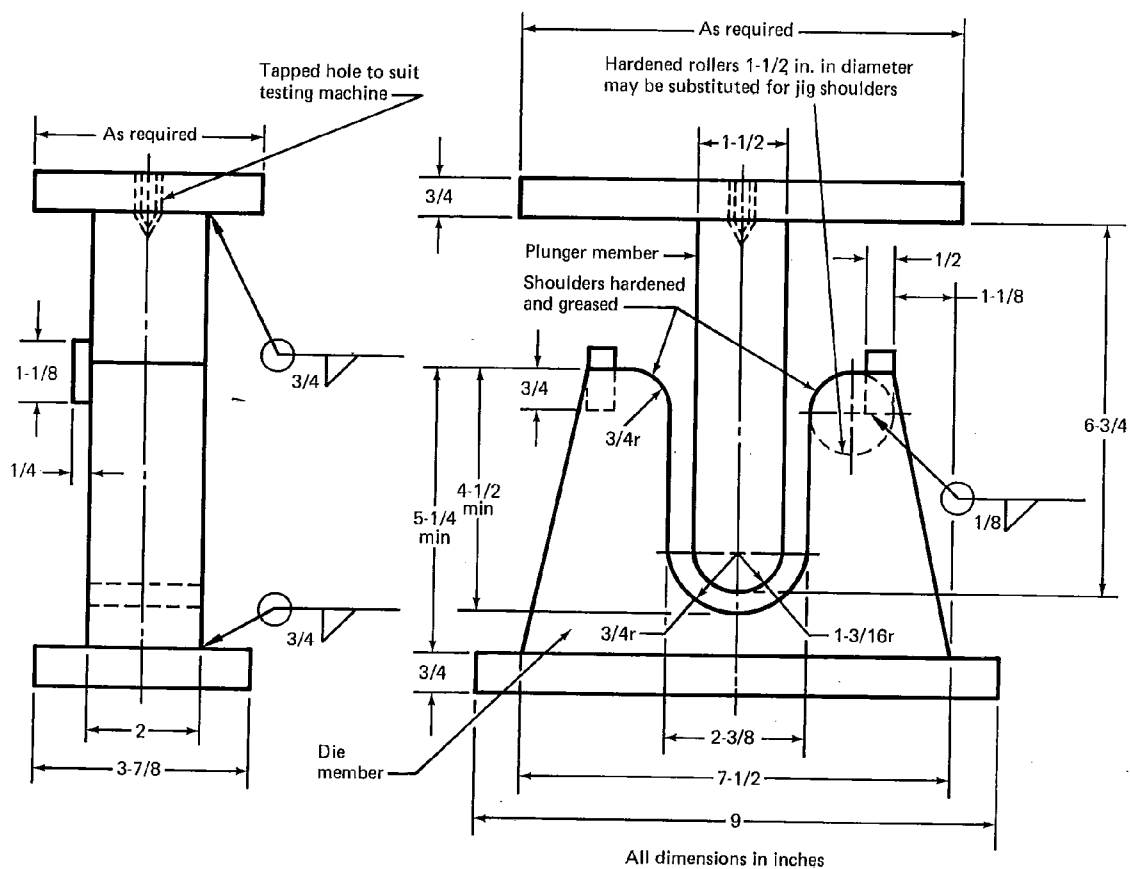


Notes:

1. In general, it is recommended that the specimen thickness for the bend tests be approximately 3/8 in. (9.5 mm). However, the specimen thickness may be any value within the range given above.
2. Required accuracy of measurement is as follows:
 - (a) Specimen thickness: $\pm 1/64$ in. (0.4 mm).
 - (b) Bend radius: $\pm 1/16$ in. (1.6 mm).
3. Example: a standard requires a minimum elongation of 20 percent. Thus, if a 7/16 in. (11.1 mm) thick specimen is desired, a line is drawn between these two points and extended to determine the appropriate bend radius, which would be 7/8 in. (22 mm).
4. When applying the nomogram data, it is considered satisfactory to use the 20 percent elongation fixtures (dies) for any metal over 20 percent elongation.
5. The minimum required elongation is that specified in Table 3.

Fig. 6—Nomogram for selecting maximum bend radius for allowable specimen thickness (for classifications ECUAl-A2, ECUAl and ECUAlNiAl)

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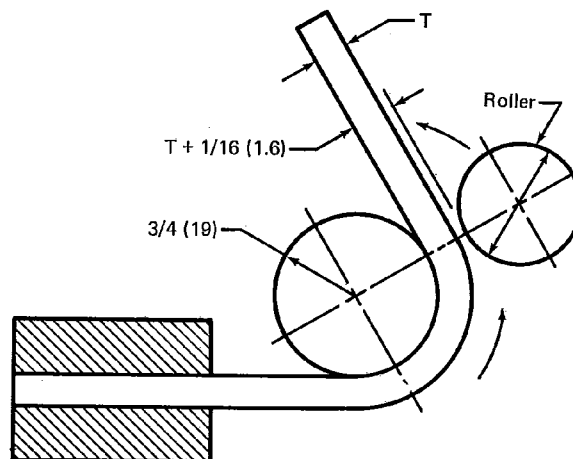


Notes:

1. The dimensions of this guided-bend test jig are in accordance with AWS B4.0-76, *Standard Methods for Mechanical Testing of Welds*.
2. The side of the specimen turned toward the die shall be the side with the greater discontinuities.
3. r = radius; all dimensions are in inches.

SI Equivalents	
in.	mm
1/8	3.2
1/4	6.4
1/2	12.7
3/4	19
1-1/8	28.6
1-3/16	30
1-1/2	38
2	51
2-3/8	60
3-7/8	98
4-1/2	113
5-1/4	133
6-3/4	171
7-1/2	191
9	229

Fig. 7A—Guided-bend test jig

**Notes:**

1. Dimensions not shown are the option of the designer. It is essential to have adequate rigidity so that the jig parts will not spring.
2. The specimen shall be firmly clamped on one end so that it does not slide during the bending operation. The weld and heat-affected zone in the case of the transverse weld bend specimens shall be completely within the bent portion of the specimen after testing.
3. Test specimens shall be removed from the jig when the outer roll has been rotated 180 degrees from the starting point.
4. When using the wraparound jig, the side of the specimen turned toward the roller shall be the side with the greater discontinuities.

Fig. 7B—Alternate guided-bend test jig

Part C

Manufacture, Identification, and Packaging

12. Method of Manufacture

The welding materials classified by this specification may be made by any method yielding product conforming to the requirements of this specification.

13. Standard Sizes and Lengths

Standard sizes and lengths of electrodes shall be as shown in Tables 4 and 5. In all cases, standard size refers to the diameter of the core wire.

14. Core Wire and Covering

14.1 Diameter of the core wire shall not vary more than ± 0.003 in. (± 0.08 mm) from the standard size specified. Length shall not vary more than $\pm \frac{3}{8}$ in. (± 10 mm).

14.2 The core wire and covering shall be concentric to the extent that the maximum core-plus-one covering dimension shall not exceed the minimum core-plus-one covering dimensions by more than 7 percent of the mean

dimension for $\frac{3}{32}$ in. (2.4 mm); 5 percent of the mean dimension for sizes $\frac{1}{8}$ and $\frac{3}{32}$ in. (3.2 and 4.0 mm); and 4 percent of the mean dimension for $\frac{3}{16}$ in. (4.8 mm). The concentricity may be measured by any suitable means.

14.3 Core wire and covering shall be free of defects which would interfere with uniform performance of the electrode.

Table 4
Standard sizes of electrodes

AWS Classification	Standard sizes, diameter of core wire, in. (mm)			
	$\frac{3}{32}$ (2.4)	$\frac{1}{8}$ (3.2)	$\frac{3}{32}$ (4.0)	$\frac{3}{16}$ (4.8)
ECu	X	X	X	X
ECuSi				
ECuSn-A				
ECuSn-C				
ECuNi	X	X	X	X
ECuAl-A2				
ECuAl-B				
ECuNiAl				
ECuMnNiAl	X	X	X	X

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Table 5
Standard lengths of electrodes

Diameter of core wire		Standard length	
in.	mm	in.	mm
$\frac{3}{32}$ (0.093)	2.4	{ 9 and 12	230 and 300
$\frac{1}{8}$ (0.125)	3.2		
$\frac{3}{32}$ (0.156)	4.0	14	350
$\frac{1}{16}$ (0.187)	4.8		

15. Exposed Core

15.1 The exposed core on the grip end (for making contact with the electrode holder) shall be as shown in Table 6.

Table 6
Exposed core on grip end of the electrode

Electrode diameter		Bare portion (minimum)		Distance from grip end to full thickness of covering (maximum)	
in.	mm	in.	mm	in.	mm
$\frac{3}{32}$ and smaller	4.0	$\frac{1}{2}$	13	$1\frac{1}{4}$	30
$\frac{1}{16}$	4.8	$\frac{3}{4}$	19	$1\frac{1}{2}$	40

15.2 The arc end of each electrode shall be sufficiently bare and the covering sufficiently tapered to permit easy striking of the arc. The covering shall cover the core wire for at least one-half of the circumference of the electrode at a distance of two-thirds the diameter of the core wire, or $\frac{3}{32}$ in. (2.4 mm), whichever is smaller.

16. Electrode Identification

All electrodes shall be identified as follows:

16.1 At least one legible imprint of the AWS classification shall be applied to the electrode covering within $2\frac{1}{2}$ in. (65 mm) of the grip end of the electrode.

16.2 The number and letters of the imprint shall be of bold block type of a size large enough to be legible.

16.3 The ink used for imprinting shall provide sufficient contrast with the electrode covering so that the numbers and letters are legible, both before and after welding as it is normally done.

16.4 The prefix letter E in the electrode classification may be omitted from the imprint.

17. Packaging

17.1 Welding materials shall be packaged to protect against damage during shipment and storage under normal conditions.

17.2 Standard packages shall be as agreed upon between the supplier and purchaser.

18. Package Marking

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

18.1.1 AWS specification and classification numbers.
(Year of issue may be excluded.)

18.1.2 Supplier's name and trade designation.

18.1.3 Standard size and net weight.

18.1.4 Lot, control, or heat number.

18.2 All packages of welding materials, including individual unit packages enclosed within a larger package, shall carry (as a minimum) the following precautionary information prominently displayed in legible type:

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. **ELECTRIC SHOCK** can kill.

- Read and understand the manufacturer's instructions 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 Z49.1 *Safety in Welding and Cutting* published by the American Welding Society, 550 N.W. LeJeune Rd., P.O. Box 351040, Miami, Florida 33135; OSHA Safety and Health Standards, 29 CFR 1910, available from U.S. Government Printing Office, Washington, DC 20402.

DO NOT REMOVE THIS INFORMATION

Appendix

Guide to AWS Classification of Copper and Copper Alloy Arc Welding Electrodes

This Appendix is not a part of AWS A5.6-84 Specification for Covered Copper and Copper Alloy Arc Welding Electrodes, but is included for information only.

viding is done by using a 1, 2, etc., after the last letter, as the 2 in ECuAl-A2.

A1 Introduction

A1.1 The specification itself is intended to provide both the manufacturer and the purchaser of copper and copper alloy welding electrodes with a means of production control and a basis of acceptance through mutually acceptable, sound, standard requirements.

A1.2 This guide has been prepared as an aid to prospective users of the copper and copper alloy electrodes covered by this specification in determining which classification of electrode is best suited for a particular application, with due consideration to the particular requirements for that application. Each of the basic classification groups is discussed in the parts of this guide that follow.

A1.3 Tests for hardness are not included in this specification. For reference, however, a chart of typical hardness values is included as Table A1.

A1.4 It is recognized that supplementary tests may be necessary to determine the suitability of these electrodes 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 low and high temperatures, and suitability for welding combinations of dissimilar metals may be required upon agreement between the purchaser and supplier.

A2 Method of Identification

A2.1 The system for identifying the electrode classifications is as follows:

A2.1.1 The letter E at the beginning of each number indicates a covered electrode.

A2.1.2 The chemical symbol Cu is used to identify the electrodes as copper-base alloys, and the additional chemical symbol, such as Si in ECuSi, Sn in ECuSn, etc., indicates the principal alloying element of each classification or group of similar classifications. Where more than one classification is included in a basic group, the individual classifications in the group are identified by the letters A, B, C, etc., as in ECuSn-A. Further subdi-

Table A1
Hardness of copper and copper alloy weld metal deposited using covered electrodes

AWS Classification	Brinell Hardness	
ECu	20 to 40	Rockwell F
ECuSi	80 to 100	(500 kg load)
ECuSn-A	70 to 85	(500 kg load)
ECuSn-C	85 to 100	(500 kg load)
ECuNi	60 to 80	(500 kg load)
ECuAl-A2	130 to 150	(3000 kg load)
ECuAl-B	140 to 180	(3000 kg load)
ECuNiAl	160 to 200	(3000 kg load)
ECuMnNiAl	160 to 200	(3000 kg load)

Note: Hardness values as listed above are average values for undiluted weld metal deposited in accordance with this specification. This table is included for information only; hardness testing is not required under this specification.

A3 Ventilation During Welding

A3.1 Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators are exposed during welding. These are:

A3.1.1 Dimensions of the space in which welding is done (with special regard to the height of the ceiling).

A3.1.2 Number of welders and welding operators working in that space.

A3.1.3 Rate of evolution of fumes, gases, or dust, according to the materials and processes involved.

A3.1.4 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.

A3.1.5 The ventilation provided to the space in which the welding is done.

A3.2 American National Standard Z49.1, *Safety in Welding and Cutting* (published by the American Welding Society), discusses the ventilation that is required during the welding, and should be referred to for details. Attention is particularly drawn to the Section of that document entitled "Ventilation."

A4 Description and Intended Use of Filler Metal

A4.1 Copper and copper alloy covered electrodes generally operate with deep and the coverings often are hygroscopic.

A4.1.1 The supplier should be consulted regarding:

- (a) Specific operating parameters and positions
- (b) Recommended storage conditions and reconditioning temperatures

A4.1.2 The weld area shall be free from moisture and other contaminants.

A4.2 ECu Classification (Copper Electrodes). ECu electrodes are generally manufactured from deoxidized copper wire (essentially pure copper with small amounts of deoxidizers added) and may be used for shielded metal arc welding of deoxidized coppers, oxygen-free coppers, and tough pitch (electrolytic) coppers. The electrodes are also used to repair or surface these base metals as well as to surface steel and cast iron. Mechanically and metallurgically sound joints can best be made in deoxidized coppers. Reactions with hydrogen in oxygen-free copper, and the segregation of copper oxide in tough pitch copper may detract from joint efficiency. However, when highest quality is not required, ECu electrodes may be successfully used on these base metals. ECu electrodes may also be used for clad restoration on copper-clad vessels if precautions are taken to minimize dilution effects. Preheats to 1000° F (540° C) may be required.

A4.3 ECuSi Classification (Silicon Bronze). ECuSi electrodes contain approximately three percent silicon plus small percentages of manganese and tin. They are used primarily for welding copper-silicon alloys. ECuSi electrodes are occasionally used for the joining of copper, dissimilar metals, and some iron-base metals. Silicon bronze weld metal seldom is used to surface bearing surfaces, but often is used to surface areas subjected to corrosion.

A4.4 ECuSn Classification (Phosphor Bronze). ECuSn electrodes are used to join phosphor bronzes of similar compositions. They are also useful for joining brasses and, in some cases, for welding them to cast iron and carbon steel.

ECuSn weld metals tend to flow sluggishly, requiring preheat and interpass temperatures of at least 400° F (205° C) on heavy sections. Postweld heat treatment may not be necessary, but it is desirable for maximum ductility, particularly if the weld metal is cold worked.

A4.4.1 ECuSn-A electrodes are used primarily to join base metal of similar composition. They also may be used to weld copper if the resultant weld metal has adequate electrical conductivity and corrosion resistance for the specific application.

A4.4.2 ECuSn-C electrodes have higher tin content resulting in weld metals of higher hardness, tensile and yield strength than ECuSn-A weld metal.

A4.5 ECuNi Classification (Copper-Nickel) Electrodes of the ECuNi classification are used for shielded metal arc welding of wrought or cast 70/30, 80/20, and 90/10 copper-nickel alloys to themselves or to each other. They also are used for welding the clad side of copper-nickel clad steel. Preheating generally is not necessary.

A4.6 ECuAl Classification (Aluminum Bronze)

A4.6.1 The copper-aluminum electrodes are used only in the flat position. For butt joints, a 90 degree single V-groove is recommended for plate thicknesses up to and including 7/16 in. (11 mm), and a modified U- or double V-groove is recommended for the heavier plate thicknesses. Preheat and interpass temperature should be as follows:

A4.6.1.1 For iron-base materials, 200 to 300° F (95 to 150° C).

A4.6.1.2 For bronzes, 300 to 400° F (150 to 210° C).

A4.6.1.3 For brasses, 500 to 600° F (260 to 315° C).

A4.6.2 ECuAl-A2 electrodes are used in joining aluminum bronzes of similar composition, high strength copper-zinc alloys, silicon bronzes, manganese bronzes, some nickel alloys, many ferrous metals and alloys, and combinations of dissimilar metals. The weld metal is also suitable for surfacing wear- and corrosion-resistant bearing surfaces.

A4.6.3 ECuAl-B electrodes deposit weld metal having higher tensile strength, yield strength, and hardness with a correspondingly lower ductility than ECuAl-A2 weld metal. ECuAl-B electrodes are used for repairing aluminum bronze and other copper alloy castings. ECuAl-B weld metal also is used for high strength surfacing of wear- and corrosion-resistant bearing surfaces.

A4.6.4 ECuNiAl electrodes are used to join or repair cast or wrought nickel-aluminum bronze materials. These weld metals also may be used for applications requiring high resistance to corrosion, erosion, or cavitation in salt and brackish water.

A4.6.5 ECuMnNiAl electrodes are used to join or repair cast or wrought manganese-nickel-aluminum bronze materials. These weld metals exhibit excellent resistance to corrosion, erosion and cavitation.