AWS A5.13:2000
An American National Standard

Specification for Surfacing Electrodes for Shielded Metal Arc Welding

American Welding Society

Approved American National Standard
ANSI

Key Words—Hardfacing, weld surfacing, hard surfacing covered electrodes, wear resistance, build-up electrodes, cobalt electrodes, copper electrodes, manganese electrodes, nickel electrodes, tungsten carbide electrodes

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Approved by
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September 7, 2000

Specification for Surfacing Electrodes for Shielded Metal Arc Welding

Supersedes ANSI/AWS A5.13-80

Prepared by
AWS A5 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 the requirements for classification of surfacing electrodes for shielded metal arc welding. Classification is based upon the chemical composition of the deposited weld metal except for tungsten carbide electrodes where classification is based on the mesh range, quantity, and composition of the tungsten carbide granules. A guide is appended to the specification as a source of information as to the characteristics and applications of the classified electrodes.

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

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Foreword

(This Foreword is not a part of AWS A5.13:2000, *Specification for Surfacing Electrodes for Shielded Metal Arc Welding*, but is included for information purposes only.)

The first AWS specification for surfacing filler metals was published in 1956 as a joint ASTM/AWS specification. It was the first of what would later become a two-set series, A5.13 and A5.21.

The composite electrodes and rods classifications were removed from the 1970 revision of A5.13 and placed into a new specification, A5.21. A5.13-70 specification contained requirements for both covered and bare electrodes or rods employing solid core only. This distinction was maintained for the 1980 revision of A5.13.

The current revisions of both A5.13 and A5.21 incorporate a totally different scope. The method of manufacture of the core of the electrode or rod is no longer a factor in determining placement of a classification. Instead, the covered electrode products are classified under AWS A5.13:2000 and the bare electrode products are classified under AWS A5.21:2001.

The historical evolution of the specification is:

ASTM A 399-56T AWS A5.13-56T	Tentative Specification for Surfacing Welding Rods and Electrodes
AWS A5.13-70 ANSI W3.13-73	Specification for Surfacing Welding Rods and Electrodes
ANSI/AWS A5.13-80	Specification for Solid Surfacing Welding Rods and Electrodes

Comments and inquiries concerning this standard are welcome. They should be sent to the Secretary, AWS A5 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, 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 Surfacing Electrodes for Shielded Metal Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of surfacing electrodes for shielded metal arc welding. Solid bare electrodes and rods previously classified in ANSI/AWS A5.13-80 are now either discontinued or reclassified in AWS A5.21:2001, *Specification for Bare Electrodes and Rods for Surfacing* (see Section A8 in Annex A).

1.2 Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in Sections A5 and A9 in Annex A. Safety and health information is available from other sources, including, but not limited to ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

Part A General Requirements

2. Normative References

2.1 The following AWS standard[1] is referenced in the mandatory section of this standard:

(1) AWS A5.01, *Filler Metal Procurement Guidelines.*

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

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

(1) ASTM A 36/A 36M, *Specification for Structural Steel.*

(2) ASTM A 285/A 285M, *Specification for Pressure Vessel Plates, Carbon Steel, Low and Intermediate Tensile Strength.*

(3) ASTM B 214, *Test Method for Sieve Analysis for Granular Metal Powders.*

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

(5) ASTM DS-56/SAE HS-1086, *Metals and Alloys in the Unified Numbering System.*

3. Classification

3.1 Except for tungsten carbide electrodes, the surfacing electrodes covered by this specification are classified according to the chemical composition of the undiluted weld metal, as specified in Tables 1, 2, and 3.

3.2 Tungsten carbide surfacing electrodes are classified on the basis of size and chemical composition of the tungsten carbide granules (see Tables 4 and 5).

3.3 Electrodes classified under one classification shall not be classified under any other classification in this specification.

4. Acceptance

Acceptance[3] of the electrodes shall be in accordance with the provisions of AWS A5.01, *Filler Metal Procurement Guidelines.*

1. AWS Standards may be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

2. ASTM Standards may be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

3. See Section A3, Acceptance (in Annex A), for further information concerning acceptance, testing of material shipped, and AWS A5.01, *Filler Metal Procurement Guidelines.*

Table 1
Iron Base Surfacing Electrodes—Chemical Composition Requirements[a]

AWS Classification	Annex A Reference	UNS Number[e]	Deposit Composition, weight percent[b, c, d] C	Mn	Si	Cr	Ni	Mo	V	W	Ti	Nb(Cb)	Fe	Other Elements, Total
EFe1	A7.1.1	W74001	0.04–0.20	0.5–2.0	1.0	0.5–3.5	—	1.5	—	—	—	—	Rem	1.0
EFe2	A7.1.1	W74002	0.10–0.30	0.5–2.0	1.0	1.8–3.8	1.0	1.0	0.35	—	—	—	Rem	1.0
EFe3	A7.1.2	W74003	0.50–0.80	0.5–1.5	1.0	4.0–8.0	—	1.0	—	—	—	—	Rem	1.0
EFe4	A7.1.3	W74004	1.0–2.0	0.5–2.0	1.0	3.0–5.0	—	—	—	—	—	—	Rem	1.0
EFe5	A7.1.4	W75110	0.30–0.80	1.5–2.5	0.90	1.5–3.0	—	—	—	—	—	—	Rem	1.0
EFe6	A7.1.5	W77510	0.6–1.0	0.4–1.0	1.0	3.0–5.0	—	7.0–9.5	0.5–1.5	0.5–1.5	—	—	Rem	1.0
EFe7	A7.1.6	W77610	1.5–3.0	0.5–2.0	1.5	4.0–8.0	—	1.0	—	—	—	—	Rem	1.0
EFeMn-A	A7.1.7	W79110	0.5–1.0	12–16	1.3	—	2.5–5.0	—	—	—	—	—	Rem	1.0
EFeMn-B	A7.1.7	W79310	0.5–1.0	12–16	1.3	—	—	0.5–1.5	—	—	—	—	Rem	1.0
EFeMn-C	A7.1.7	W79210	0.5–1.0	12–16	1.3	2.5–5.0	2.5–5.0	—	—	—	—	—	Rem	1.0
EFeMn-D	A7.1.7	W79410	0.5–1.0	15–20	1.3	4.5–7.5	—	—	0.4–1.2	—	—	—	Rem	1.0
EFeMn-E	A7.1.7	W79510	0.5–1.0	15–20	1.3	3.0–6.0	1.0	—	—	—	—	—	Rem	1.0
EFeMn-F	A7.1.7	W79610	0.8–1.2	17–21	1.3	3.0–6.0	1.0	—	—	—	—	—	Rem	1.0
EFeMnCr	A7.1.8	W79710	0.25–0.75	12–18	1.3	13–17	0.5–2.0	2.0	1.0	—	—	—	Rem	1.0
EFeCr-A1A	A7.1.9	W74011	3.5–4.5	4.0–6.0	0.5–2.0	20–25	—	0.5	—	—	—	—	Rem	1.0
EFeCr-A2	A7.1.10	W74012	2.5–3.5	0.5–1.5	0.5–1.5	7.5–9.0	—	—	—	—	1.2–1.8	—	Rem	1.0
EFeCr-A3	A7.1.11	W74013	2.5–4.5	0.5–2.0	1.0–2.5	14–20	—	1.5	—	—	—	—	Rem	1.0
EFeCr-A4	A7.1.9	W74014	3.5–4.5	1.5–3.5	1.5	23–29	—	1.0–3.0	—	—	—	—	Rem	1.0
EFeCr-A5	A7.1.12	W74015	1.5–2.5	0.5–1.5	2.0	24–32	4.0	4.0	—	—	—	—	Rem	1.0
EFeCr-A6	A7.1.13	W74016	2.5–3.5	0.5–1.5	1.0–2.5	24–30	—	0.5–2.0	—	—	—	—	Rem	1.0
EFeCr-A7	A7.1.13	W74017	3.5–5.0	0.5–1.5	0.5–2.5	23–30	—	2.0–4.5	—	—	—	—	Rem	1.0
EFeCr-A8	A7.1.14	W74018	2.5–4.5	0.5–1.5	1.5	30–40	—	2.0	—	—	—	—	Rem	1.0
EFeCr-E1	A7.1.15	W74211	5.0–6.5	2.0–3.0	0.8–1.5	12–16	—	—	—	—	4.0–7.0	—	Rem	1.0
EFeCr-E2	A7.1.15	W74212	4.0–6.0	0.5–1.5	1.5	14–20	—	5.0–7.0	1.5	—	—	—	Rem	1.0
EFeCr-E3	A7.1.15	W74213	5.0–7.0	0.5–2.0	0.5–2.0	18–28	—	5.0–7.0	—	3.0–5.0	—	—	Rem	1.0
EFeCr-E4	A7.1.15	W74214	4.0–6.0	0.5–1.5	1.0	20–30	—	5.0–7.0	0.5–1.5	2.0	—	4.0–7.0	Rem	1.0

Notes:

a. Solid bare electrodes and rods previously classified in AWS A5.13-80 are now either discontinued or reclassified in AWS A5.21:2001, *Specification for Bare Electrodes and Rods for Surfacing* (see A8 in Annex A).

b. Single values are maximum. Rem = Remainder.

c. Electrodes and rods 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 limit specified for "Other Elements, Total" in the last column of the table.

d. Sulfur and phosphorus contents each shall not exceed 0.035%.

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

Table 2
Nickel and Cobalt Base Surfacing Electrodes—Chemical Composition Requirements

AWS Classification	Annex A Reference	UNS Number[d]	Deposit Composition, weight percent[a, b, c]											
			C	Mn	Si	Cr	Ni	Mo	Fe	W	Co	B	V	Other Elements, Total
ECoCr-A	A7.2.1	W73006	0.7–1.4	2.0	2.0	25–32	3.0	1.0	5.0	3.0–6.0	Rem	—	—	1.0
ECoCr-B	A7.2.2	W73012	1.0–1.7	2.0	2.0	25–32	3.0	1.0	5.0	7.0–9.5	Rem	—	—	1.0
ECoCr-C	A7.2.3	W73001	1.7–3.0	2.0	2.0	25–33	3.0	1.0	5.0	11–14	Rem	—	—	1.0
ECoCr-E	A7.2.4	W73021	0.15–0.40	1.5	2.0	24–29	2.0–4.0	4.5–6.5	5.0	0.50	Rem	—	—	1.0
ENiCr-C	A7.3.1	W89606	0.5–1.0	—	3.5–5.5	12–18	Rem	—	3.5–5.5	—	1.0	2.5–4.5	—	1.0
ENiCrMo-5A	A7.3.2	W80002	0.12	1.0	1.0	14–18	Rem[e]	14–18	4.0–7.0	3.0–5.0	—	—	0.40	1.0
ENiCrFeCo	A7.3.3	W83002	2.2–3.0	1.0	0.6–1.5	25–30	10–33	7.0–10.0	20–25	2.0–4.0	10–15	—	—	1.0

Notes:

a. Single values are maximum percentages. Rem = Remainder.
b. The weld metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated in the course of this work, the amount of those elements shall be determined to ensure that their total does not exceed the limit specified for "Other Elements, Total" in the last column of the table.
c. Sulfur and phosphorus contents each shall not exceed 0.03%.
d. ASTM/SAE Unified Numbering System for Metals and Alloys.
e. Includes incidental cobalt.

Table 3
Copper Base Surfacing Electrodes—Chemical Composition Requirements

AWS Classification	Annex A Reference	UNS Number[c]	Deposit Composition, weight percent[a,b]											
			Cu	Mn	P	Si	Fe	Al	Zn	Ni[d]	Pb	Sn	Ti	Other Elements, Total
ECuAl-A2[f]	A7.4.1.1	W60617	Rem	g	—	1.5	0.5–5.0	8.5–11.0	g	g	0.02	g	—	0.50
ECuAl-B[f]	A7.4.1.2	W60619	Rem	g	—	1.5	2.5–5.0	11–12	g	g	0.02	g	—	0.50
ECuAl-C	A7.4.1.2	W60625	Rem	—	—	1.0	3.0–5.0	12–13	0.02	—	0.02	—	—	0.50
ECuAl-D	A7.4.1.3	W61625	Rem	—	—	1.0	3.0–5.0	13–14	0.02	—	0.02	—	—	0.50
ECuAl-E	A7.4.1.3	W62625	Rem	—	—	1.0	3.0–5.0	14–15	0.02	—	0.02	—	—	0.50
ECuSi[f]	A7.4.1.4	W60656	Rem	1.5	g	2.4/4.0	0.50	0.01	g	g	0.02	1.5	—	0.50
ECuSn-A[f]	A7.4.1.5	W60518	Rem	g	0.05–0.35	g	0.25	0.01	g	g	0.02	4.0–6.0	—	0.50
ECuSn-C[f]	A7.4.1.5	W60521	Rem	g	0.05–0.35	g	0.25	0.01	g	g	0.02	7.0–9.0	—	0.50
ECuNi[e,f]	A7.4.1.6	W60715	Rem	1.0–2.5	0.02	0.50	0.40–0.75	—	g	29–33	0.02	g	0.50	0.50
ECuNiAl[f]	A7.4.1.7	W60632	Rem	0.5–3.5	—	1.5	3.0–6.0	8.5–9.5	g	4.0–6.0	0.02	g	—	0.50
ECuMnNiAl[f]	A7.4.1.8	W60633	Rem	11–14	—	1.5	2.0–4.0	7.0–8.5	g	1.5–3.0	0.02	g	—	0.50

Notes:

a. Single values shown are maximum percentages. Rem = Remainder.

b. The weld metal shall be analyzed for the specific elements for which values, or a "g," 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 limit specified for "Other Elements, Total" in the last column of the table.

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

d. Includes cobalt.

e. Sulfur is restricted to 0.015% maximum.

f. This AWS classification is intended to correspond to the same classification that appears in AWS A5.6, *Specification for Copper and Copper-Alloy Covered Electrodes*. Because of revision dates the composition ranges may not be identical.

g. These elements must be included in "Other Elements, Total."

Table 4
Mesh Size and Quantity of Tungsten Carbide (WC) Granules in the Core of Tungsten Carbide Electrodes

AWS Classification[a, b]	U.S. Standard Mesh Size of Tungsten Carbide Granules[c]	Quantity of Tungsten Carbide (WC1 + WC2) Granules, Weight Percent
EWCX-12/30	thru 12—on 30	60
EWCX-20/30	thru 20—on 30	60
EWCX-30/40	thru 30—on 40	60
EWCX-40	thru 40	60
EWCX-40/120	thru 40—on 120	60

Notes:
a. "X" designates the type of tungsten carbide granules; X = 1 for WC1 granules, X = 2 for WC2 granules, X = 3 for a blend of WC1 and WC2 granules.
b. These AWS classifications have been transferred to AWS A5.21:2001 without a change in classification for solid bare electrodes and rods and with the prefix "ERC" for electrode/rod made from metal or flux cored stock.
c. The mesh size of the tungsten carbide granules may vary from that specified above, provided that no more than 5% of the granules are retained on the "thru" sieve, and that no more than 20% passes the "on" sieve.

SI Equivalents

U.S. Standard Mesh Size	Opening, mm
12	1.70
20	0.85
30	0.60
40	0.43
120	0.13

Table 5
Chemical Composition of Tungsten Carbide (WC) Granules

Element	Composition, weight percent[a] WC1	WC2	WC3
C	3.6–4.2	6.0–6.2	as agreed between purchaser and supplier
Si	0.3	0.3	
Ni	0.3	0.3	
Mo	0.6	0.6	
Co	0.3	0.3	
W	94.0 min	91.5 min	
Fe	1.0	0.5	
Th	0.01	0.01	

Note:
a. Single values are maximum, unless noted otherwise.

5. Certification

By affixing the AWS specification and classification designations to the package, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[4]

6. Units of Measure and Rounding-Off Procedure

6.1 U.S. Customary Units are the standard units of measure in this specification. The International System of Units (SI) 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.

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

Part B
Tests, Procedures, and Requirements

7. Summary of Tests

7.1 Except for tungsten carbide electrodes, chemical composition of undiluted weld metal is the only test required for classification of a product under this specification (see Tables 1, 2, and 3).

7.2 Tests required for tungsten carbide electrodes include:

7.2.1 Determination of the amount and mesh size distribution of the tungsten carbide granules (see Table 4). Sieve analysis shall be in accordance with ASTM B 214, *Test Method for Sieve Analysis for Granular Metal Powders.*

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

7.2.2 Determination of the chemical composition of the tungsten carbide granules (see Table 5).

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Material, specimens, or samples for retest may be taken from the original test assembly or sample, or from one or two new test assemblies or samples. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement. If the results of one or both retest fail to meet the requirement, the material under test shall be considered as not meeting the requirements of this specification for that classification.

In the event that, during preparation or after completion of any test, it is clearly determined that prescribed or proper procedures were not followed in preparing the weld test assembly or test specimen(s) or in conducting the test, the test shall be considered invalid, without regard to whether the test was actually completed or whether test results met, or failed to meet, the requirement. That test shall be repeated, following proper prescribed procedures. In this case, the requirement for doubling the number of test specimens does not apply.

9. Weld Test Assembly

9.1 A sample for chemical analysis is the only test assembly required. The sample may be prepared by any method producing undiluted weld metal. In case of dispute, the weld pad described in 9.2 shall be the referee method.

9.2 The dimensions of the completed pad shall be as shown in Figure 1 for each size of electrode. Testing of this assembly shall be as specified in Section 10, Chemical Analysis.

9.2.1 Welding shall be done in the flat position using welding conditions specified by the manufacturer.

9.2.2 Postweld heat treatment may be used to facilitate subsequent sampling.

9.3 The base metal shall conform to one of the following specifications or its equivalent:

9.3.1 ASTM A 285/A 285M Grade A (UNS K01700).

9.3.2 ASTM A 36/A 36M (UNS K02600).

10. Chemical Analysis

10.1 For All Except Covered Tungsten Carbide Electrodes

10.1.1 Shielded metal arc welding surfacing electrodes shall be analyzed in the form of undiluted weld metal. The sample shall come from a weld metal pad or ingot.

10.1.2 The top surface of the pad described in Section 9 and shown in Figure 1 shall be removed and discarded, and a sample for analysis shall be obtained from the underlying metal by any appropriate mechanical means. The sample shall be free of slag.

For electrodes 3/32 in. (2.4 mm) in diameter and smaller, the sample shall be taken at least 1/2 in. (13 mm) from the nearest surface of the base metal.

For electrodes 1/8–3/16 in. (3.2–4.8 mm) in diameter, the sample shall be taken at least 5/8 in. (16 mm) from the nearest surface of the base metal.

For electrodes larger than 3/16 in. (4.8 mm) in diameter the sample shall be taken at least 3/4 in. (19 mm) from the nearest surface of the base metal.

10.1.3 The sample may be removed from an undiluted weld metal ingot by any convenient method.

10.1.4 The sample shall be analyzed by accepted analytical methods as agreed by the manufacturer and purchaser. The referee method shall be the appropriate ASTM method for the element being determined.

10.1.5 The results of the analysis shall meet the requirements of Tables 1, 2, or 3 for the classification of electrode under test.

10.2 For Tungsten Carbide Electrodes

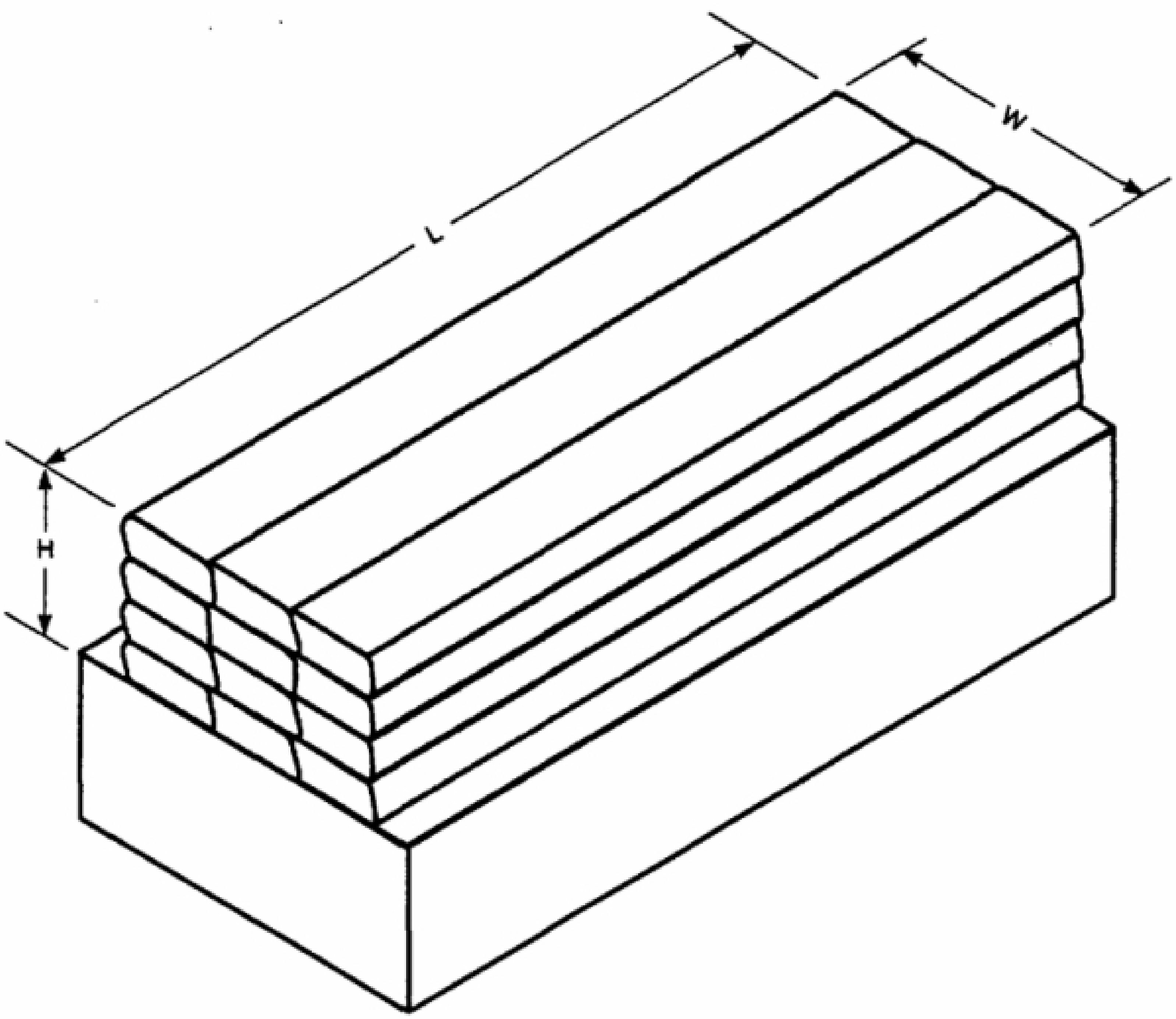
10.2.1 Chemical composition of tungsten carbide granules shall conform to the requirements of Table 5. Chemical analysis may be made by any suitable method agreed upon by the manufacturer and the purchaser.

10.2.2 Tungsten carbide granules for chemical analysis shall be free of any surface contaminant.

10.2.3 The percentage by weight of the tungsten carbide, as specified in Table 4, can be determined by the following steps:

(1) Record the weight of the tungsten carbide welding electrode after removing any covering present.

(2) Remove the tungsten carbide from the tube and clean it by washing with water and treating with 1-1 hydrochloric acid, as required, to remove any flux, powdered iron, graphite, etc. Heating of the acid may be required. A hot or cold 1-1 hydrochloric acid will not appreciably attack cast tungsten carbide in less than an hour. When



Electrode Size in.	Weld Pad Size in. minimum
5/64 (0.078) 3/32 (0.094)	L = 1-1/2 W = 1/2 H = 1/2
1/8 (0.125) 5/32 (0.156) 3/16 (0.187)	L = 2 W = 1/2 H = 5/8
7/32 (0.219) 1/4 (0.250) 5/16 (0.312)	L = 2-1/2 W = 1/2 H = 3/4

SI Equivalents	
in.	mm
5/64	2.0
3/32	2.4
1/8	3.2
5/32	4.0
3/16	4.8
7/32	5.6
1/4	6.4
5/16	8.0
1/2	13
5/8	16
3/4	19
1-1/2	38
2	50
2-1/2	64

Figure 1—Pad for Chemical Analysis of Undiluted Weld Metal

handling any acids appropriate safety precautions should be followed.

(3) Dry tungsten carbide by holding in an oven at 250° ± 25°F [120° ± 15°C].

(4) Weigh the cleaned and dried tungsten carbide granules. Calculate the percentage of tungsten carbide from the initial weight of the tube using the following formula:

$$\% \text{ tungsten carbide granules} = \frac{\text{Weight of clean and dried tungsten carbide granules}}{\text{Weight of electrode after removal of covering}} \times 100$$

Part C
Manufacture, Identification, and Packaging

11. Method of Manufacture

The electrodes classified according to this specification may be manufactured by any method that will produce material which meets the requirements of this specification. For tungsten carbide electrodes, any carbon steel sheath material (typically C1008) that will not alter the matrix significantly may be used.

12. Standard Sizes and Lengths

12.1 Standard sizes (diameter of core wire) and lengths of electrodes shall be as shown in Tables 6, 7, and 8.

12.2 The diameter of solid drawn core wire shall not vary more than ±0.003 in. (±0.08 mm) from the diameter specified. The length shall not vary more than ±1/4 in. (±6.4 mm) from that specified.

12.3 The diameter of composite or cast core wire (except tungsten carbide) shall not vary more than ±0.02 in. (±0.5 mm). The length shall not vary more than ±3/8 in. (±9.6 mm) from that specified.

12.4 The diameter of tungsten carbide core wire shall not vary more than ±0.04 in. (±1.0 mm) from the nominal diameter. The length shall not vary more than ±3/8 in. (±9.6 mm) from that specified.

Table 6
Standard Sizes and Lengths of Covered Electrodes Using Solid Drawn Core Wire[a]

Electrode Sizes Diameter of Solid Drawn Core Wire[b]		Standard Lengths	
in.	mm	in.	mm
5/64 (0.078)	2.0	9 ± 1/4	230 ± 6.4
3/32 (0.094)	2.4	9 ± 1/4 12 ± 1/4	230 ± 6.4 300 ± 6.4
1/8 (0.125)	3.2	14 ± 1/4	350 ± 6.4
5/32 (0.156)	4.0	14 ± 1/4	350 ± 6.4
3/16 (0.187)	4.8	14 ± 1/4 18 ± 1/4	350 ± 6.4 450 ± 6.4
1/4 (0.250)	6.4	14 ± 1/4 18 ± 1/4	350 ± 6.4 450 ± 6.4
5/16 (0.312)	8.0	14 ± 1/4 18 ± 1/4	350 ± 6.4 450 ± 6.4

Notes:
a. Other electrode diameters and lengths may be supplied as agreed between the manufacturer and purchaser.
b. Tolerance on the diameter shall be ± 0.003 in. (± 0.08 mm).

13. Core Wire and Covering

Core wire and covering shall be free of defects that would interfere with uniform deposition of the electrode.

14. Exposed Core

14.1 The grip end of each electrode shall be bare (free of covering) for a distance of not less than 1/2 in. (13 mm), nor more than 1-1/2 in. (38 mm), to provide for electrical contact with the electrode holder.

14.2 The arc end of each electrode shall be sufficiently bare and the covering sufficiently tapered to permit easy striking of the arc. The length of the bare portion (measured from the end of the core wire to the location where the full cross-section of the covering is obtained) shall not exceed 1/8 in. (3.2 mm) or the diameter of the core wire, whichever is less. Electrodes with chipped coverings near the arc end, baring the core wire slightly more than the prescribed distance, may be accepted provided

Table 7
Standard Sizes and Lengths for Covered Cast and Composite Tubular Electrodes[a]

Electrode Sizes, Nominal Diameter of Core Wire[b]		Standard Lengths			
		For Cast Electrodes		For Composite Tubular Electrodes	
in.	mm	in.	mm	in.	mm
1/8 (0.125)	3.2	9 to 14 ± 3/8	230 to 350 ± 9.6	9 to 14 ± 3/8	230 to 350 ± 9.6
5/32 (0.156)	4.0	9 to 14 ± 3/8	230 to 350 ± 9.6	9 to 14 ± 3/8	230 to 350 ± 9.6
3/16 (0.187)	4.8	9 to 14 ± 3/8	230 to 350 ± 9.6	9 to 14 ± 3/8	230 to 350 ± 9.6
1/4 (0.250)	6.4	12 to 14 ± 3/8	300 to 350 ± 9.6	14 ± 3/8	350 ± 9.6
1/4 (0.250)	6.4	12 to 14 ± 3/8	300 to 350 ± 9.6	18 ± 3/8	450 ± 9.6
5/16 (0.312)	8.0	12 to 14 ± 3/8	300 to 350 ± 9.6	14 ± 3/8	350 ± 9.6
5/16 (0.312)	8.0	12 to 14 ± 3/8	300 to 350 ± 9.6	18 ± 3/8	450 ± 9.6

Notes:
a. Other diameter and lengths of electrodes may be supplied as agreed between the manufacturer and the purchaser.
b. Diameter tolerance shall be ±0.02 in. (±0.5 mm) from the nominal diameter.

Table 8
Standard Sizes and Lengths for Covered Tungsten Carbide (WC) Electrodes

Electrode Sizes, Nominal Diameter of Core Wire[a]		Standard Lengths	
in.	mm	in.	mm
3/32 (0.094)	2.4	9 ± 3/8 14 ± 3/8	225 ± 9.6 350 ± 9.6
1/8 (0.125)	3.2	9 ± 3/8 14 ± 3/8	225 ± 9.6 350 ± 9.6
5/32 (0.156)	4.0	9 ± 3/8 14 ± 3/8	225 ± 9.6 350 ± 9.6
3/16 (0.187)	4.8	9 ± 3/8 14 ± 3/8	225 ± 9.6 350 ± 9.6
1/4 (0.250)	6.4	14 ± 3/8 18 ± 3/8	350 ± 9.6 450 ± 9.6
5/16 (0.312)	8.0	14 ± 3/8 18 ± 3/8	350 ± 9.6 450 ± 9.6

Note:
a. Diameter shall not vary more than ±0.04 in. (±1.0 mm) from the nominal diameter.

no chip uncovers more than 50% of the circumference of the core.

14.3 Electrodes with electrically conductive coverings or strike tips may be exempt from the requirements of 14.2 providing they are capable of easy arc starting without stripping.

15. Electrode Identification

15.1 All electrodes, except dip-covered electrodes, shall be identified as follows:

15.1.1 At least one imprint of the electrode classification shall be applied to the electrode covering within 2-1/2 in. (64 mm) of the grip end of the electrode.

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

15.1.3 The ink used for imprinting shall provide sufficient contrast with the electrode covering so that, in normal use, the numbers and letters are legible both before and after welding.

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

15.2 Identification of dip-covered electrodes shall be as agreed between the purchaser and supplier. Imprinting is not mandatory.

16. Packaging

16.1 Electrodes shall be suitably packaged to protect them against damage during shipment and storage under normal conditions.

16.2 Standard package weights shall be as agreed between purchaser and supplier.

17. Marking of Packages

17.1 The following product information (as a minimum) shall be legibly marked on the outside of each unit package:

(1) AWS specification and classification designations (year of issue may be excluded)

(2) Supplier's name and trade designation

(3) Size and net weight

(4) Lot, control, or heat number

17.2 The appropriate precautionary information[5] as given in ANSI Z49.1,[6] latest edition, (as a minimum) or its equivalent, shall be prominently displayed in legible print on all packages of electrodes, including individual unit packages enclosed within a larger package.

5. Typical examples of "warning labels" are shown in figures in ANSI Z49.1 for some common or specific consumables used with certain processes.

6. ANSI Z49.1 may be obtained from The American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Annex A

Guide to AWS Specification for Surfacing Electrodes for Shielded Metal Arc Welding

(This Annex is not a part of AWS A5.13:2000, *Specification for Surfacing Electrodes for Shielded Metal Arc Welding*, but is included for information purposes only.)

A1. Introduction

This guide has been prepared as an aid to prospective users of the electrodes covered by the specification in determining the classification of filler metal best suited for a particular application, with due consideration to the particular requirements for that application.

A2. Classification System

A2.1 The system for identifying the electrode classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The letter E at the beginning of each classification designation stands for electrode. The letters immediately after the E are the chemical symbols for the principal elements in the classification. Thus, CoCr is a cobalt-chromium alloy, CuAl is a copper-aluminum alloy, etc. 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 subdividing is done by using a 1, 2, etc., after the last letter, as the 2 in ECuAl-A2. An additional letter or number has been added to some designations if the composition requirements in this specification differ somewhat from those of the earlier versions for electrodes of the same basic classification.

A2.2 Refer to Table A1 for a comparison of covered electrode classifications used in ANSI/AWS A5.13-80 and those used in the current document; some classifications have been changed and some have been discontinued.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with 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, shall be clearly stated in the purchase order, according to the provisions of AWS A5.01. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing he normally conducts on material of that classification, as specified in Schedule F, Table 1, of the 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 any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were

Table A1
Electrode Classification Comparison—A5.13-80 and A5.13:2000

A5.13-80 Classification	A5.13:2000 Classification[a]
EFe5-A	Deleted
EFe5-B	Similar to EFe6
EFe5-C	Deleted
EFeMn-A	Similar to EFeMn-A
EFeMn-B	Similar to EFeMn-B
EFeCr-A1	Similar to EFeCr-A1A
ECoCr-A	ECoCr-A
ECoCr-B	ECoCr-B
ECoCr-C	ECoCr-C
ECuSi	ECuSi
ECuAl-A2	Similar to ECuAl-A2
ECuAl-B	Similar to ECuAl-B
ECuAl-C	Similar to ECuAl-C
ECuAl-D	Similar to ECuAl-D
ECuAl-E	Similar to ECuAl-E
ECuSn-A	ECuSn-A
ECuSn-C	ECuSn-C
ENiCr-A	Deleted
ENiCr-B	Deleted
ENiCr-C	ENiCr-C

Note:
a. The new classification for bare electrodes and rods for surfacing are in the AWS A5.21:2001.

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 System" in AWS A5.01.

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fume 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 fume, gases, or dust, according to the materials and processes used

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

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

A5.2 American National Standard ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is particularly drawn to the section of that document on Health Protection and Ventilation.

A6. Welding Considerations

A6.1 Role of Hydrogen in Surfacing. Hydrogen can be detrimental to surfacing deposits. The effect varies widely from one alloy type to another. In general, hydrogen's detrimental effect on microstructure is the most pronounced for martensitic types, with austenitic types being the least affected. Other factors influencing hydrogen's effect include carbon and alloy contents plus in-service welding variables.

In welding there are many sources for hydrogen contamination. Coating moisture is one of the most important. Most electrodes are manufactured and packaged to control moisture. When received, consideration must be given to proper storage to prevent moisture pick-up. During use, improper regard to welding procedure and environmental variables can result in spalling or "hydrogen-induced" (underbead) cracking.

A6.2 Low equipment cost, great versatility, and general convenience make manual shielded metal arc welding very popular. The welding machine, which is essentially a power conversion device, is usually the main item of equipment needed. It may be a motor-generator, transformer, transformer-rectifier combination, or fuel-operated engine combined with a generator. The arc power may be either direct or alternating current. The filler metal is in the form of covered electrodes. (Bare electrode arc welding is a rarity today, though it is feasible with austenitic manganese steel electrodes.) Welding can be done in almost any location and is practicable for a variety of work, ranging from very small to quite large. For some applications, it is the only feasible method; and, for many others (especially where continuous methods do not offer significant benefits), it is the economical choice.

The operation is under the observation and control of the welder, who can easily cover irregular areas and often correct for adverse conditions. It is also helpful if the welder exercises judgment in other matters, such as holding the arc power down to minimize cracking; keeping a short arc and avoiding excessive puddling to minimize the loss of expensive alloying elements in the filler metal; minimizing dilution with base metal; and restricting hydrogen pickup. This process is used extensively for hardfacing, buttering, buildup, and cladding.

Surfacing of carbon and low-alloy steels, high-alloy steels, and many nonferrous metals may be done with the shielded metal arc process. Base metal thicknesses may range from below 1/4–18 in. (6–450 mm) or more. The surfacing metals employed include low- and high-alloy steels, the stainless steels, nickel-base alloys, cobalt-base alloys, and copper-base alloys.

The welding conditions for surfacing are not fundamentally different from those used in welding a joint. The arc and weld pool are shielded by the slag or the gases, or both, produced by the electrode. The type of covering on the electrode has considerable effect on the characteristics of the weld metal. Surfacing can be done on work ranging in size from very small to quite large.

Table A2 shows how the various shielded metal arc process variables affect the three most important surfacing characteristics: dilution, deposition rate, and deposit thickness.

The table indicates only general trends and does not cover questions of weldability or weld soundness. These factors may make it unwise to change only the indicated variable; this in turn may mean that the desired change in dilution, deposition rate, or deposit thickness may not be achieved. For example, a given welding procedure with a small electrode diameter may produce high dilution. The table indicates that a change to a large size electrode will decrease dilution. This is true, however, only if the amperage, travel speed, position, etc., also remain constant. In many cases, a larger amperage value must be used with the larger electrode size to obtain acceptable weld quality. In this case, the dilution may remain constant or even increase with the change to the larger electrode size.

The process usually achieves a deposition rate from 1–4 lb (0.5–2 kg) per hour at dilution levels from 30–50%.

A7. Description and Intended Use of Surfacing Electrodes

A7.1 Iron-Base Electrodes

A7.1.1 EFe1 and EFe2 Electrodes

A7.1.1.1 Characteristics. Deposits made with these electrodes are a machinery grade steel suitable for application on carbon and alloy steels. With care, they

Table A2
The Effect of Shielded Metal Arc Variables on the Three Most Important Characteristics of Surfacing

		Influence of Change on		
Variable	Change of Variable[a]	Dilution	Deposition Rate	Deposit Thickness
Polarity	AC	Intermediate	Intermediate	Intermediate
	DCEP	High	Low	Thin
	DCEN	Low	High	Thick
Amperage	High	High	High	Thick
	Low	Low	Low	Thin
Technique	Stringer	High	No effect	Thick
	Weave	Low	No effect	Thin
Bead spacing	Narrow	Low	No effect	Thick
	Wide	High	No effect	Thin
Electrode diameter	Small	High	High	Thick
	Large	Low	Low	Thin
Arc length	Long	Low	No effect	Thin
	Short	High	No effect	Thick
Travel speed	Fast	High	No effect	Thin
	Slow	Low	No effect	Thick

Note:
a. This table assumes that only one variable at a time is changed. However, for acceptable surfacing conditions, a change in one variable may require a change in one or more other variables.

can be applied crack-free. Deposits are machinable with carbide tipped tools. Deposit hardness generally is in the range of 25–50 HRC with EFe2 electrodes providing weld metal with the higher hardness. These deposits contain sufficient alloy to attain full hardness without the need of heat treatment. Abrasion resistance is comparable to heat-treated steels of equal hardness.

A7.1.1.2 Applications. These electrodes are used to restore worn machinery parts to their original dimensions. Deposit surfaces are suitable for metal-to-metal rolling and sliding contact, such as occurs on large, low speed gear teeth, shafts, etc. High compressive strength makes these materials suitable as a base for more abrasion-resistant materials.

A7.1.2 EFe3 Electrodes

A7.1.2.1 Characteristics. Weld metal deposited by these electrodes is an air-hardening tool steel type with high room temperature hardness (55–60 HRC). Deposits can be applied crack-free with careful procedures. The deposits cannot be machined and generally are ground when finishing is required.

A7.1.2.2 Applications. EFe3 electrodes are used to overlay surfaces and edges requiring high hardness and crack-free deposits, such as the edges of tools and dies. Deposits are compatible with many tool steels. Although generally used for metal-to-metal applications, EFe3 weld metal performs well in earth abrasion applications where high impact is encountered.

A7.1.3 EFe4 Electrodes

A7.1.3.1 Characteristics. These electrodes will have a graphitic (black) coating and are suitable for application on cast iron. Although the deposited metal is relatively brittle, crack-free deposits can be made with controlled procedures. Deposits can be machined providing they are slow cooled from an annealing temperature.

A7.1.3.2 Applications. EFe4 weld metal is used to rebuild worn cast iron machinery parts subject to metal-to-metal rolling or sliding contact. Although EFe4 weld deposits are compatible with carbon and low-alloy steel, EFe2 electrodes generally are preferred for such applications.

A7.1.4 EFe5 Electrodes

A7.1.4.1 Characteristics. EFe5 electrodes deposit a cold work type of tool steel. Hardness as-deposited should be in the range of 50–55 HRC. Weld metal deposited by EFe5 electrodes is air-hardening and machinable only after annealing.

A7.1.4.2 Applications. Typical applications include those requiring high compressive strength with moderate abrasion and metal-to-metal wear, such as machine components, shafts, and brake drums.

A7.1.5 EFe6 Electrodes

A7.1.5.1 Characteristics. Weld metal deposited by EFe6 electrodes is a high-speed tool steel with a hardness in range of 60 HRC or higher. The deposit maintains a high degree of hardness to 1100°F (593°C). Weld metal deposited by EFe6 electrodes is air-hardening and is machinable only after annealing.

A7.1.5.2 Applications. Weld deposits may be used for metal-to-metal wear applications at temperatures up to 1100°F (593°C). Typical applications combine high temperature service with severe abrasion and metal-to-metal wear and include shear blades, trimming dies, and punching dies.

A7.1.6 EFe7 Electrodes

A7.1.6.1 Characteristics. EFe7 series electrodes are essentially a higher carbon modification of EFe3 electrodes. Abrasion resistance of the weld deposit is improved with some sacrifice in resistance to impact. Deposits air harden, and a two-layer deposit can be expected to have a hardness of 60 HRC or higher. Stress-relief cracks (checks) typically occur through the overlay. Deposits cannot be machined.

A7.1.6.2 Applications. EFe7 electrodes are used for overlaying surfaces that require good low-stress abrasion resistance. Applications include cement chutes, fan blades, bulldozer blades, and other parts and equipment used for earthmoving or construction. Carbon and alloy steels, tool steels, and stainless steels are compatible base metals.

A7.1.7 EFeMn Series Electrodes. (EFeMn-A through EFeMn-F)

A7.1.7.1 Characteristics. Deposits made with EFeMn series electrodes nominally contain 14% manganese, although they may vary from 12–21%. This is an amount sufficient to yield austenitic weld deposits. Austenite is a nonmagnetic, tough form of steel. To preserve the toughness, excessive heat must be avoided during welding. Stringer beads and a block sequence are recommended. The additions of other elements, such as 4% nickel, are made to give more stability to the austenite; chromium, molybdenum, and vanadium are also added singly or in combination of 0.5–8% to increase the yield strength. Abrasion resistance is only a little better than that of low-carbon steel unless there has been sufficient impact to cause work hardening. As-deposited surfaces generally are no harder than HRC 20, but can work harden to HRC 55. Since deposits are difficult to machine, grinding is preferred for finishing.

A7.1.7.2 Applications. These electrodes are used for the rebuilding, repair, and joining of Hadfield austenitic manganese steel. Ability to absorb high impact makes such deposits ideal for the rebuilding of worn rock crushing equipment and parts subject to impact loading, such as railroad frogs.

A7.1.8 EFeMnCr Electrodes

A7.1.8.1 Characteristics. Weld metal deposited by EFeMnCr electrodes have characteristics similar to austenitic manganese deposits. The high chromium content imparts stainless steel qualities. These deposits cannot be flame cut. Although care must be taken in application to avoid heat build-up, deposits are more stable than FeMn series electrodes.

A7.1.8.2 Applications. Like EFeMn type electrodes, EFeMnCr electrodes are used for rebuilding, repair, and joining of equipment made of Hadfield austenitic manganese steel. EFeMnCr electrodes offer the added advantage of being usable for joining austenitic manganese steel both to itself and to carbon steel. EFeMnCr weld metals often are used as a base for surfacing with EFeCr types for parts subject to both wear and impact.

A7.1.9 EFeCr-A1A and EFeCr-A4 Electrodes

A7.1.9.1 Characteristics. Weld metal deposited by these electrodes will contain massive chromium carbides in an austenitic matrix providing excellent wear resistance and toughness. Surface checks are typical and give some degree of stress relief. Deposits cannot be machined and must be ground when finishing is required. To assure the desired deposit composition, two layers are recommended. Additional layers invite spalling and must be applied with caution. Electrodes are suitable for welding on carbon, alloy, and austenitic steels as well as cast irons. The weld metal deposited by EFeCr-A1A electrodes generally provides greater resistance to impact but slightly less abrasion resistance than weld metal deposited by EFeCr-A4 electrodes.

A7.1.9.2 Applications. Deposits frequently are used to surface parts and equipment involved in sliding and crushing of rock, ore, etc., such as bucket lips and teeth, impact hammers, and conveyors. Very low coefficients of friction develop as a result of scouring by earth products.

A7.1.10 EFeCr-A2 Electrodes

A7.1.10.1 Characteristics. The weld metal deposit contains titanium carbide in an austenitic matrix. It is machinable only by grinding. Build-up should be limited to three layers to minimize relief check cracking.

A7.1.10.2 Applications. This weld metal group may be applied to both carbon steel and austenitic manganese base metal. Deposits frequently are used to hardface mining, construction, earth moving, and quarrying equipment subject to abrasion and moderate impact.

A7.1.11 EFeCr-A3 Electrodes

A7.1.11.1 Characteristics. Filler metal deposited by EFeCr-A3 electrodes is similar to a deposit made using EFeCr-A1A electrodes except, due to the lower manganese content, a martensitic matrix is present, rendering the deposit somewhat brittle. These deposits are not machinable but may be finished by grinding where necessary.

A7.1.11.2 Applications. This weld metal is a general purpose hardfacing alloy for earth abrasion applications and is suitable for low stress scratching abrasion with low impact.

A7.1.12 EFeCr-A5 Electrodes

A7.1.12.1 Characteristics. The weld deposit contains chromium carbide in an austenitic matrix. The nonmagnetic weld metal has fair machinability. Build-up should be restricted to three layers to minimize stress relief checking.

A7.1.12.2 Applications. Surfaced components frequently are used for applications involving frictional metal-to-metal wear or earth scouring under low stress abrasion.

A7.1.13 EFeCr-A6 and EFeCr-A7 Electrodes

A7.1.13.1 Characteristics. These are a higher carbon version of EFeCr-A5 electrodes. The deposit contains hexagonal chromium carbides in an austenitic carbide matrix and has a hardness of 50–60 HRC. Deposits develop stress-relief checks. The addition of molybdenum increases wear resistance to high stress abrasion. The weld metal may be applied on carbon, alloy, or austenitic manganese steel base metal.

A7.1.13.2 Applications. Weld metal is frequently used for applications involving low stress abrasive wear combined with moderate impact.

A7.1.14 EFeCr-A8 Electrodes

A7.1.14.1 Characteristics. EFeCr-A8 is a higher chromium version of EFeCr-A3. The deposit contains hexagonal chromium carbides in an austenitic matrix and has a hardness of 50–60 HRC. The increased chromium content tends to decrease the toughness while increasing the abrasion resistance. Maximum relief checking can be expected. The weld metal may be applied to carbon, alloy, or austenitic manganese base metals.

A7.1.14.2 Applications. Weld metal is frequently used for applications involving low stress abrasion combined with minimum impact.

A7.1.15 EFeCr-EX Series Electrodes

A7.1.15.1 Characteristics. This family of electrodes deposits weld metal containing finely dispersed chromium carbides plus one or more metallic carbides (vanadium, niobium [columbium], tungsten, or titanium). The resultant deposits are not machinable, and maintain their hot hardness and abrasion resistance to 1200°F (650°C). Deposits stress-relief check readily.

A7.1.15.2 Applications. Equipment subjected to severe high stress abrasion combined with moderate impact may be surfaced with one of the specific grades. Selection of the specific grade will be dependent on local service conditions and the specific application.

A7.2 Cobalt-Base Surfacing Electrodes

A7.2.1 ECoCr-A Electrodes

A7.2.1.1 Characteristics. Weld metal deposited by ECoCr-A electrodes is characterized by a hypereutectic structure consisting of a network of about 13% eutectic chromium carbides distributed in a cobalt-chromium-tungsten solid solution matrix. The result is a material with a combination of overall resistance to low stress abrasive wear coupled with the necessary toughness to resist some degree of impact. Cobalt alloys also are inherently good for resisting metal-to-metal wear, particularly in high load situations that are prone to galling. The high-alloy content of the matrix also affords excellent resistance to corrosion, oxidation, and elevated temperature retention of hot hardness up to a maximum of 1200°F (650°C). These alloys are not subject to allotropic transformation and therefore do not lose their properties if the base metal subsequently is heat treated.

A7.2.1.2 Applications. The alloy is recommended for cases where wear is accompanied by elevated temperatures and where corrosion is involved, or both. Typical applications include automotive and fluid flow valves, chain saw guides, hot punches, shear blades, extruder screws, etc.

A7.2.2 ECoCr-B Electrodes

A7.2.2.1 Characteristics. Weld metal deposited by ECoCr-B electrodes is similar in composition to ECoCr-A deposits except for a slightly higher carbide content (approximately 16 percent). The alloy also has a slightly higher hardness coupled with better abrasive and metal-to-metal wear resistance. Impact and corrosion resistance are lowered slightly. Deposits can be machined with carbide tools.

A7.2.2.2 Applications. ECoCr-B electrodes are used interchangeably with ECoCr-A. Choice will depend on the specific application.

A7.2.3 ECoCr-C Electrodes

A7.2.3.1 Characteristics. This alloy's deposits have a higher carbide content (19%) than those made using either ECoCr-A or ECoCr-B electrodes. In fact, the composition is such that primary hypereutectic carbides are found in the microstructure. This characteristic gives the alloy higher wear resistance, accompanied by reductions in the impact and corrosion resistance. The higher hardness also means a greater tendency to stress crack during cooling. The cracking tendency may be minimized by closely monitoring preheating, interpass temperature, and postheating techniques.

While the cobalt-chromium deposits soften somewhat at elevated temperatures, they normally are considered immune to tempering.

A7.2.3.2 Applications. Weld metal deposited by ECoCr-C electrodes is used to build up mixer rotors and items that encounter severe abrasion and low impact.

A7.2.4 ECoCr-E Electrodes

A7.2.4.1 Characteristics. Welds made using ECoCr-E electrodes have very good strength and ductility at temperatures up to 1600°F (871°C). Deposits are resistant to thermal shock, and oxidizing and reducing atmospheres. Early applications of these types of alloys were found in jet engine components such as turbine blades and vanes.

The deposit is a solid-solution-strengthened alloy with a relatively low weight-percent carbide phase in the microstructure. Hence, the alloy is very tough and will work harden. Deposits possess excellent self-mated galling resistance and also are very resistant to cavitation erosion.

A7.2.4.2 Applications. Welds made using ECoCr-E electrodes are used where resistance to thermal shock is important. Typical applications, similar to those of ECoCr-A deposits, include guide rolls, hot extrusion and forging dies, hot shear blades, tong bits, and valve trim.

A7.2.5 Typical hardness values for multilayer welds made using cobalt base electrodes are:

ECoCr-A	23–47 HRC
ECoCr-B	34–47 HRC
ECoCr-C	43–58 HRC
ECoCr-E	20–32 HRC

Hardness values for single layer deposits will be lower because of dilution from the base metal.

A7.3 Nickel Base Surfacing Electrodes

A7.3.1 ENiCr-C Electrodes

A7.3.1.1 Characteristics. Undiluted weld metal of this composition exhibits a structure consisting of chromium carbides and chromium borides in a nickel-rich matrix. The nickel base and high chromium content give these deposits good heat and corrosion resistance. Care should be taken when cooling hardfacing deposits because of a tendency to stress crack. This alloy possesses excellent resistance to low stress abrasion.

A7.3.1.2 Applications. ENiCr-C weld metal flows very easily, has very high abrasion resistance, and normally takes on a high polish. Typical applications include cultivator sweeps, plow shares, extrusion screws, pump sleeves, pistons, and impellers, capstan rings, glass mold faces, centrifuge filters, sucker pump rods, etc. The deposits have high corrosion resistance and normally require grinding for finishing. Single layer deposits typically have a hardness of 35–45 HRC. Multilayer deposits typically have a hardness of 49–56 HRC.

A7.3.2 ENiCrMo-5A Electrodes

A7.3.2.1 Characteristics. Undiluted weld metal deposited by ENiCrMo-5A electrodes is a solid-solution-strengthened alloy with relatively low weight-percent carbide phase produced through secondary hardening. The resultant deposit is tough and work hardenable.

Deposits have the ability to retain hardness up to 1400°F (760°C). Deposits are machinable with high-speed tool bits and have excellent resistance to high-temperature wear and impact.

A7.3.2.2 Applications. These electrodes are used to rebuild and repair hot extrusion dies, hot forging dies, sizing punches, hot shear blades, guide rolls, tong bits, blast furnace bells, etc.

A7.3.3 ENiCrFeCo Electrodes

A7.3.3.1 Characteristics. Weld metal deposited by these electrodes contain a fairly large volume fraction of hypereutectic chromium carbides distributed throughout the microstructure. The alloy offers many of the same high-performance characteristics of deposits made using ECoCr-C or ENiCr-C electrodes in terms of abrasive wear resistance. The reduced nickel or cobalt content, or both, lowers corrosion properties and galling resistance. The high volume fraction of carbides makes this alloy sensitive to cracking during cooling.

A7.3.3.2 Applications. Welds made using ENiCrFeCo electrodes are preferred where high abrasion (low impact) is a major factor. Typical applications are feed screws, slurry pumps, and mixer components.

A7.4 Copper-Base Alloy Electrodes

A7.4.1 Introduction. The copper-base alloy electrodes classified by this specification are used to deposit overlays and inlays for bearing, corrosion-resistant, or wear-resistant surfaces.

A7.4.1.1 ECuAl-A2 electrodes are used for surfacing bearing surfaces between the hardness ranges of 130 to 150 HB as well as corrosion-resistant surfaces.

A7.4.1.2 ECuAl-B and ECuAl-C electrodes are used primarily for surfacing bearing surfaces requiring hardness in the range of 140–220 HB. These alloys are not recommended for applications that require resistance to corrosion.

A7.4.1.3 ECuAl-D and ECuAl-E electrodes are used to surface bearing and wear-resistant surfaces requiring hardness in the range of 230–320 HB, such as gears, cams, sheaves, wear plates, dies, etc. These alloys are also used to surface dies that form or draw titanium, low-carbon and stainless steels. These alloys are not recommended for applications that require resistance to corrosion.

A7.4.1.4 The ECuSi electrodes are used primarily for surfacing corrosion-resistant surfaces. Copper-silicon deposits generally are not recommended for bearing service.

A7.4.1.5 Copper-tin (ECuSn) electrodes are used primarily to surface bearing surfaces where the lower hardness of these alloys is required, for surfacing corrosion-resistant surfaces, and, occasionally, for applications requiring wear resistance.

A7.4.1.6 Copper-nickel electrodes (ECuNi) are used for rebuilding 70/30, 80/20, and 90/10% copper-nickel alloy or the clad side of copper-nickel clad steel. Preheating generally is not necessary.

A7.4.1.7 Copper-nickel-aluminum electrodes (ECuNiAl) are used to rebuild nickel-aluminum-bronze castings or wrought components. Typical applications are those requiring a high resistance to corrosion, erosion, or cavitation in salt or brackish water.

A7.4.1.8 ECuMnNiAl electrodes are used to rebuild or surface cast manganese-nickel-aluminum bronze castings or wrought material. Typical applications include those requiring excellent resistance to corrosion, erosion, and cavitation.

A7.4.2 Applications

A7.4.2.1 Hardness Ranges. See Table A3 for typical hardness ranges.

A7.4.2.2 Hot Hardness. The copper-base alloy filler metals are not recommended for use at elevated temperatures. Mechanical properties, especially hardness,

Table A3
Approximate Weld Deposit Hardness (SMAW)

AWS Classification	Brinell Hardness[a] 3000 kg Load	Brinell Hardness[a] 500 kg Load
ECuAl-A2	130–150	—
ECuAl-B	140–180	—
ECuAl-C	180–220	—
ECuAl-D	230–270	—
ECuAl-E	280–320	—
ECuSi	—	80–100
ECuSn-A	—	70–85
ECuSn-C	—	85–100
ECuNi	—	60–80
ECuNiAl	160–200	—
ECuMnNiAl	160–200	—

Note:
a. As-welded condition.

will tend to decrease consistently as the temperature increases above 400°F (205°C).

A7.4.2.3 Impact. In general, as the aluminum content increases, impact resistance decreases rapidly. The impact resistance of deposits made by using ECuAl-A2 electrodes will be the highest of the copper-base alloy classifications. Deposits made using ECuSi electrodes have good impact properties. Deposits made using ECuSn electrodes have low impact values.

A7.4.2.4 Oxidation Resistance. Weld metal deposited by any of the ECuAl family of electrodes forms a protective oxide coating upon exposure to the atmosphere. Oxidation resistance of the copper-silicon deposit is fair, while that of copper-tin deposits is comparable to the oxidation resistance of pure copper.

A7.4.2.5 Corrosion Resistance. Several copper base alloy filler metals are used rather extensively to surface areas subject to corrosion from reducing type acids, mild alkalies, and salt water. They should not be used in the presence of oxidizing acids, such as HNO_3, or when sulfur compounds are present. Filler metals producing deposits of higher hardness may be used to surface areas subject to corrosive action as well as erosion from liquid flow for such applications as condenser heads and turbine runners.

A7.4.2.6 Abrasion. None of the copper-base alloy deposits is recommended for use where severe abrasion is encountered in service.

A7.4.2.7 Metal-to-Metal Wear. Copper-aluminum deposits with hardnesses of 130 to approximately 320 HB are used to overlay surfaces subjected to excessive wear from metal-to-metal contact. For example, ECuAl-E electrodes are used to surface dies, and to draw and form stainless and carbon steels and aluminum.

All of the copper-base alloy filler metals classified by this specification are used to deposit overlays and inlays for bearing surfaces, with the exception of the CuSi filler metals. Silicon bronzes are considered poor bearing alloys. Copper-base alloy filler metals selected for a bearing surface should produce a deposit of 50–75 HB under that of the mating part. Equipment should be designed so that the bearing will wear in preference to the mating part.

A7.4.2.8 Mechanical Properties in Compression. Deposits of the ECuAl filler metals have high elastic limits and ultimate strengths in compression ranging from 25 000–65 000 psi (172–448 MPa) and 120 000–171 000 psi (827–1179 MPa), respectively. The elastic limit of ECuSi deposits is around 22 000 psi (152 MPa) with an ultimate strength in compression of 60 000 psi (414 MPa). The ECuSn deposits will have an elastic limit of 11 000 psi (76 MPa) and an ultimate strength of 32 000 psi (221 MPa).

A7.4.2.9 Machinability. All of these copper-base alloy deposits are machinable.

A7.4.2.10 Heat Treatment. Ordinarily, no heat treatment is needed in surfacing with copper-base alloy filler metals.

A7.4.2.11 Welding Characteristics. To minimize dilution from the base metal when surfacing with copper-base electrodes, the first layer should be deposited using as low an amperage as practical. Excessive base metal dilution can result in reduced machinability and service performance. The manufacturer should be consulted for specific welding parameters.

A7.4.2.12 Preheat. Generally, a preheat is not necessary unless the part is exceptionally large; in this case, a 200°F (93°C) preheat may be desirable to facilitate the smooth flow of the weld metal. At no time should the preheat temperature be above 400°F (205°C) when applying the first layer. On subsequent layers, an interpass temperature of approximately 200°–600°F (93°–316°C) will simplify deposition of the weld metal.

A7.5 Tungsten Carbide Electrodes

A7.5.1 Characteristics. Tungsten carbide covered electrodes contain 60 percent by weight tungsten carbide granules. The WC1 carbide is a mixture of WC and

W_2C. The WC2 carbide is macrocrystalline WC. Hardness of the matrix of the deposit can be varied from 30 HRC to 60 HRC depending on welding technique. Hardness of individual carbide particles typically is about 2400 HV20. The abrasion resistance of tungsten carbide deposits is outstanding.

A7.5.2 Applications. Tungsten carbide deposits are applied on surfaces subjected to sliding abrasion combined with limited impact. Such applications are encountered in earth drilling, digging, and farming. Specific tools that may require this type of a surfacing overlay include oil drill bits and tool joints, earth handling augers, excavator teeth, farm fertilizer applicator knives, and cultivator shares.

A8. Discontinued Classifications

Some classifications have been discontinued from one revision of this specification to another. This results either from changes in commercial practice or changes in the classification system used in the specification. The classifications that have been discontinued are listed in Table A4, along with the year in which they were last included in the specification.

A9. General Safety Considerations

Note: Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in section A5 and below. Safety and health information is available from other sources, including but not limited to ANSI Z49.1, Safety in Welding, Cutting, and Allied Processes, *and applicable federal and state regulations.*

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 the

Table A4
Discontinued Electrode and Rod Classifications[a]

AWS Classification	Last A5.13 (ASTM A 399) Publication Date	AWS Classification	Last A5.13 (ASTM A 399) Publication Date
RFeCr-A2	1956	ERCuAl-A3[c]	1980
EFeCr-A2	1956	RCuAl-C[b]	1980
ECuZn-E	1956	RCuAl-D[b]	1980
RCuAl-B	1970	RCuAl-E[b]	1980
RCuSn-E	1970	ERCuSn-A	1980
ECuSn-E	1970	RCuSn-D[b]	1980
RFe5-A	1980	RNiCr-A[b]	1980
RFe5-B	1980	RNiCr-B[b]	1980
RFeCr-A1	1980	RNiCr-C[b]	1980
RCoCr-A[b]	1980	EFe5-A	1980
RCoCr-B[b]	1980	EFe5-B	1980
RCoCr-C[b]	1980	EFe5-C	1980
RCuZn-E	1980	EFeCr-A1	1980
ERCuSi-A[c]	1980	ENiCr-A	1980
ERCuAl-A2[c]	1980	ENiCr-B	1980

Notes:

a. See A8, Discontinued Classifications (in Annex A), for information on discontinued classifications.

b. These AWS classifications have been transferred to AWS A5.21:2001 with the revised prefix of "ER" for electrode/rod made from solid stock or prefix of "ERC" for electrode/rod made from metal or flux cored composite stock.

c. These AWS classifications have been transferred to AWS A5.21:2001 without a change in the classification designation for solid bare electrodes and rods or with the prefix "ERC" for electrode/rod made from metal of flux cored stock.

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 flames. 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) American National Standards Institute. ANSI Z41, *American National Standard for Personal Protection—Protective Footwear.* New York, N.Y.: ANSI.[7]

(2) American Welding Society. ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes.* Miami, Fla.: American Welding Society.[8]

(3) OSHA. *Code of Federal Regulations,* Title 29—Labor, Chapter XVII, Part 1910. Washington, D.C.: U.S. Government Printing Office.[9]

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 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.

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 correct cable size should be used since sustained overloading will cause cable failure and can 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 Z49.1, *Safety in Welding, Cutting, and Allied Processes,* and NFPA No. 70, *The National Electrical Code,* should be followed.[10]

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, welders, and other personnel should be aware of the effects of these fumes and gases. The amount and composition of these fumes

7. ANSI Standards may be obtained from the American National Standards Institute, 11 West 42 Street, New York, NY 10036.

8. AWS Standards may be obtained from the American Welding Society, 550 N.W. LeJeune Rd., Miami, FL 33126.

9. OSHA Standards may be obtained from the U.S. Government Printing Office, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954.

10. NFPA documents are available from National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269.

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 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 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.

Special precautions should be used when surfacing with electrodes of the EFeMn series and ECuMnNiAl classification. As a group, the fumes from these electrodes are rather voluminous and contain a significant concentration of manganese. Cumulative excessive overexposure to manganese present in welding fumes may affect the central nervous system. Effects may include muscular weakness, poor coordination, difficulty in speaking, and tremors of the arms or legs. These effects are considered irreversible.

The potential short term health effects resulting from excessive overexposure to copper welding fumes can include metal fume fever, muscle ache and respiratory irritation. The long term effects are not known.

The potential short term health effects resulting from excessive overexposure to cobalt welding fumes can include pulmonary irritation, coughing and dermatitis. The possible long term effects include lung fibrosis and respiratory hypersensitivity.

The potential short term effects resulting from excessive overexposure to chromium and nickel in the fume are symptoms such as nausea, headaches, respiratory irritation and skin rash. Some forms of hexavalent chromium and nickel are considered as carcinogens by the National Institute for Occupational Safety and Health (NIOSH). Additional information on the possible effects of exposure to chromium and nickel in the welding fume can be obtained from AWS *Safety and Health Fact Sheet No. 4*.

The omission of special precautions for other hazardous compounds found in welding fumes is not intended to minimize their potentially harmful effect on one's health.

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

(1) The permissible exposure limits required by OSHA can be found in *Code of Federal Regulations (CFR)*, Title 29—Labor, 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).[11]

(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.

(4) Manufacturer's Material Safety Data Sheet (MSDS) for the product.

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 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.

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 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 beam 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 Educational Eye and Face Protection*. It should be noted that transparent welding curtains are not intended

11. ACGIH documents are available from the American Conference of Governmental Industrial Hygienists, 1330 Kemper Meadow Drive, Suite 600, Cincinnati, OH 45240-1634.

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.*

(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) American Welding Society. AWS F2.1, *Recommended Safe Practices for Electron Beam Welding and Cutting*. Miami, Fla.: American Welding Society.

(2) Manufacturer's product information literature.

A9.4.4 Nonionizing radiation information sources include:

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

(2) __________. ANSI/ASC Z87.1, *Practice for Occupational and Educational Eye and Face Protection*. New York: American National Standards Institute.

(3) American Welding Society. ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*. Miami, Fla.: American Welding Society.

(4) Hinrichs, J. F. "Project Committee on Radiation—Summary Report." *Welding Journal* 57(1): 62–65.

(5) Marshall, W. J., D. H. Sliney, *et al.* Optical radiation levels produced by air-carbon arc cutting processes. *Welding Journal* 59(3): 43–46.

(6) Moss, C. E. and Murray, W. E. Optical radiation levels produced in gas welding, torch brazing, and oxygen cutting. *Welding Journal* 58(9): 37–46.

(7) Moss, C. E. Optical radiation transmission levels through transparent welding curtains. *Welding Journal* 58(3): 69-s to 75-s.

(8) National Technical Information Service. 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*. Springfield, Va.: National Technical Information Service.[12]

(9) __________. 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*. Springfield, Va.: National Technical Information Service.

12. National Technical Information documents are available from the National Technical Information Service, Springfield, VA 22161.

Annex B

Guidelines for Preparation of Technical Inquiries for AWS Technical Committees

(This Annex is not a part of AWS A5.13:2000, *Specification for Surfacing Electrodes for Shielded Metal Arc Welding*, 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 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	A5.21	A5.13	A5.21	A5.21	A5.21			
Consumable Inserts			A5.30					
Shielding Gases			A5.32	A5.32			A5.32	