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An American National Standard

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

American Welding Society

Key Words — Filler metal specifications, low-alloy steel welding electrodes, gas metal arc welding, plasma arc welding, low-alloy steel welding rods, metal cored electrodes, high-strength steel, solid electrode, gas tungsten arc welding, stranded electrodes

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Approved by
American National Standards Institute
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Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding

Supersedes AWS A5.28-79

Prepared by
AWS Committee on Filler Metal

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

Classification requirements are specified for solid low-alloy steel electrodes and rods, composite stranded low-alloy steel electrodes, and composite metal cored low-alloy steel electrodes for gas shielded arc welding.

The requirements for electrodes include chemical composition of the electrode for solid electrodes and rods, and of the weld metal for composite stranded and composite metal cored electrodes.

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

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Foreword

(This Foreword is not a part of ANSI/AWS A5.28-96, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*, but is included for information purposes only.)

The first edition of A5.28 was issued in 1979 as an American Welding Society (AWS) standard. This current document is the first revision issued. The format of this standard has been changed to conform to that being used for all filler metal specifications revised since 1984.

The history of the A5.28 document may be summarized as follows:

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

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, Filler Metal Committee, Technical Services Division, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.

Official interpretations of any of the technical requirements of this standard may be obtained by sending a request, in writing, to the Managing Director, Technical Services Division, American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126. A formal reply will be issued after is has been reviewed by the appropriate personnel following established procedures.

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

1. Scope

This specification prescribes requirements for the classification of low-alloy steel electrodes (solid, composite stranded, and composite metal cored) and rods (solid) for gas metal arc welding (GMAW), gas tungsten arc welding (GTAW), and plasma arc welding (PAW).

Part A
General Requirements

2. Classification

2.1 The *solid electrodes* (and rods) covered by this specification are classified according to the chemical composition of the electrode, as specified in Table 1, and the mechanical properties of the weld metal, as specified in Tables 3 and 4. The *composite metal cored and stranded electrodes* covered by this specification are classified according to the chemical composition and mechanical properties of the weld metal, as specified in Tables 2, 3, and 4, and the shielding gas employed.

2.2 Electrodes and rods under one classification shall not be classified under any other classification in this specification, except that ER80S-D2 may also be classified as ER90S-D2, provided that classification requirements for both are met.

2.3 The welding electrodes and rods classified under this specification are intended for gas shielded arc welding, but that is not to prohibit their use with any other process (or any other shielding gas or combination of shielding gases) for which they are found suitable.

3. Acceptance

Acceptance[1] of the electrodes and rods shall be in accordance with the provisions of ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.[2]

4. Certification

By affixing the AWS specification and classification designations to the packaging or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[3]

5. Units of Measure and Rounding-Off Procedure

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

1. See Section A3, Acceptance (in the Annex), for further information concerning acceptance, testing of the material shipped, and ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*.
2. AWS standards can be obtained from the American Welding Society, 550 N.W. LeJeune Road, Miami, FL 33126.
3. See Section A4, Certification (in the Annex) for further information concerning certification and the testing called for to meet this requirement.

Table 1
Chemical Composition Requirements for Solid Electrodes and Rods

AWS Classification[c]	UNS Number[d]	Weight Percent[a, b] C	Mn	Si	P	S	Ni	Cr	Mo	V	Ti	Zr	Al	Cu[e]	Other Elements Total
Carbon–Molybdenum Steel Electrodes and Rods															
ER70S-A1	K11235	0.12	1.30	0.30–0.70	0.025	0.025	0.20	—	0.40–0.65	—	—	—	—	0.35	0.50
Chromium–Molybdenum Steel Electrodes and Rods															
ER80S-B2	K20900	0.07–0.12	0.40–0.70	0.40–0.70	0.025	0.025	0.20	1.20–1.50	0.40–0.65	—	—	—	—	0.35	0.50
ER70S-B2L	K20500	0.05	0.40–0.70	0.40–0.70	0.025	0.025	0.20	1.20–1.50	0.40–0.65	—	—	—	—	0.35	0.50
ER90S-B3	K30960	0.07–0.12	0.40–0.70	0.40–0.70	0.025	0.025	0.20	2.30–2.70	0.90–1.20	—	—	—	—	0.35	0.50
ER80S-B3L	K30560	0.05	0.40–0.70	0.40–0.70	0.025	0.025	0.20	2.30–2.70	0.90–1.20	—	—	—	—	0.35	0.50
ER80S-B6[f]	S50280	0.10	0.40–0.70	0.50	0.025	0.025	0.6	4.50–6.00	0.45–0.65	—	—	—	—	0.35	0.50
ER80S-B8[g]	S50480	0.10	0.40–0.70	0.50	0.025	0.025	0.5	8.00–10.5	0.8–1.2	—	—	—	—	0.35	0.50
ER90S-B9[h,i]	S50482	0.07–0.13	1.25	0.15–0.30	0.010	0.010	1.00	8.00–9.50	0.80–1.10	0.15–0.25	—	—	0.04	0.20	0.50
Nickel Steel Electrodes and Rods															
ER80S-Ni1	K11260	0.12	1.25	0.40–0.80	0.025	0.025	0.80–1.10	0.15	0.35	0.05	—	—	—	0.35	0.50
ER80S-Ni2	K21240	0.12	1.25	0.40–0.80	0.025	0.025	2.00–2.75	—	—	—	—	—	—	0.35	0.50
ER80S-Ni3	K31240	0.12	1.25	0.40–0.80	0.025	0.025	3.00–3.75	—	—	—	—	—	—	0.35	0.50
Manganese–Molybdenum Steel Electrodes and Rods															
ER80S-D2[j] ER90S-D2	K10945	0.07–0.12	1.60–2.10	0.50–0.80	0.025	0.025	0.15	—	0.40-0.60	—	—	—	—	0.50	0.50
Other Low-Alloy Steel Electrodes and Rods															
ER100S-1	K10882	0.08	1.25–1.80	0.20–0.55	0.010	0.010	1.40–2.10	0.30	0.25–0.55	0.05	0.10	0.10	0.10	0.25	0.50
ER110S-1	K21015	0.09	1.40–1.80	0.20–0.55	0.010	0.010	1.90–2.60	0.50	0.25–0.55	0.04	0.10	0.10	0.10	0.25	0.50
ER120S-1	K21030	0.10	1.40–1.80	0.25–0.60	0.010	0.010	2.00–2.80	0.60	0.30–0.65	0.03	0.10	0.10	0.10	0.25	0.50
ERXXS-G	—	Not Specified[k]													

Notes:

a. The filler metal shall be analyzed for the 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 (excluding iron) does not exceed the limits specified for “Other Elements, Total.”

b. Single values are maximums.

c. The suffixes B2, Ni1, etc., designate the chemical composition of the electrode and rod classification.

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

e. Copper due to any coating on the electrode or rod plus the copper content of the filler metal itself, shall not exceed the stated limit.

f. Similar to former class ER502 in AWS Specification A5.9-81.

g. Similar to former class ER505 in AWS Specification A5.9-81.

h. Niobium (Columbium) 0.02–0.10%

i. Nitrogen 0.03–0.07%

j. This composition was formerly classified E70S-1B in AWS Specification A5.18-69.

k. In order to meet the requirements of the “G” classification, the electrode must have a minimum of one or more of the following: 0.50 percent nickel, 0.30 percent chromium, or 0.20 percent molybdenum. Composition shall be reported; the requirements are those agreed to by the purchaser and supplier.

Table 2
Chemical Composition Requirements for Weld Metal from Composite Electrodes[a]

AWS Classification[d]	UNS Number[e]	Weight Percent[b, c]													
		C	Mn	Si	P	S	Ni	Cr	Mo	V	Ti	Zr	Al	Cu	Other Elements Total
Manganese–Molybdenum Weld Metal															
E90C-D2	W19230	0.12	1.00–1.90	0.90	0.025	0.030	—	—	0.40–0.60	—	—	—	—	0.35	0.50
Chromium–Molybdenum Weld Metal															
E70C-B2L	W52130	0.05	0.40–1.00	0.25–0.60	0.025	0.030	0.20	1.00–1.50	0.40–0.65	—	—	—	—	0.35	0.50
E80C-B2	W52030	0.05–0.12	0.40–1.00	0.25–0.60	0.025	0.030	0.20	1.00–1.50	0.40–0.65	—	—	—	—	0.35	0.50
E80C-B3L	W53130	0.05	0.40–1.00	0.25–0.60	0.025	0.030	0.20	2.00–2.50	0.90–1.20	—	—	—	—	0.35	0.50
E90C-B3	W53030	0.05–0.12	0.40–1.00	0.25–0.60	0.025	0.030	0.20	2.00–2.50	0.90–1.20	—	—	—	—	0.35	0.50
Nickel Steel Weld Metal															
E80C-Ni1	W21030	0.12	1.50	0.90	0.025	0.030	0.80–1.10	—	0.30	—	—	—	—	0.35	0.50
E70C-Ni2	W22030	0.08	1.25	0.90	0.025	0.030	1.75–2.75	—	—	—	—	—	—	0.35	0.50
E80C-Ni2	W22030	0.12	1.50	0.90	0.025	0.030	1.75–2.75	—	—	—	—	—	—	0.35	0.50
E80C-Ni3	W23030	0.12	1.50	0.90	0.025	0.030	2.75–3.75	—	—	—	—	—	—	0.35	0.50
Other Low-Alloy Weld Metal															
EXXC-G		Not Specified[f]													

Notes:

a. Chemical requirements for composite electrodes are based on analysis of their weld metal in the as-welded condition and using the shielding gas specified in Table 3.

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 these elements shall be determined to ensure that their total (excluding iron) does not exceed the limit specified for "Other Elements, Total."

c. Single values shown are maximums.

d. Solid electrodes are generally recommended for gas tungsten arc welding (GTAW) or plasma arc welding (PAW).

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

f. In order to meet the requirements of the G classification, the electrode must have as a minimum of one or more of the following: 0.50 percent nickel, 0.30 percent chromium, or 0.20 percent molybdenum. Composition shall be reported; the requirements are those agreed to by the purchaser and supplier.

Table 3
Tension Test Requirements

AWS Classification	Shielding Gas[a]	Tensile Strength (minimum) psi	Tensile Strength (minimum) MPa	Yield Strength (minimum) psi	Yield Strength (minimum) MPa	Elongation Percent (minimum)	Testing Condition
ER70S-B2L[f] E70C-B2L[f] ER70S-A1	Argon/1–5% O_2	75 000	515	58 000	400	19	PWHT[c]
ER80S-B2 E80C-B2	Argon/1–5% O_2	80 000	550	68 000	470	19	PWHT[c]
ER80S-B3L[f] E80C-B3L[f]	Argon/1–5% O_2	80 000	550	68 000	470	17	PWHT[c]
ER90S-B3 E90C-B3	Argon/1–5% O_2	90 000	620	78 000	540	17	PWHT[c]
ER80S-B6 ER80S-B8	Argon/1–5% O_2	80 000	550	68 000	470	17	PWHT[c]
ER90S-B9	Argon/5% CO_2	90 000	620	60 000	410	16	PWHT[c]
E70C-Ni2	Argon/1–5% O_2	70 000	480	58 000	400	24	PWHT[c]
ER80S-Ni1 E80C-Ni1	Argon/1–5% O_2	80 000	550	68 000	470	24	As-Welded
ER80S-Ni2 E80C-Ni2 ER80S-Ni3 E80C-Ni3	Argon/1–5% O_2	80 000	550	68 000	470	24	PWHT[c]
ER80S-D2	CO_2	80 000	550	68 000	470	17	As-Welded
ER90S-D2 E90C-D2	Argon/1–5% O_2	90 000	620	78 000	540	17	As-Welded
ER100S-1	Argon/2% O_2	100 000	690	88 000	610	16	As-Welded
ER110S-1	Argon/2% O_2	110 000	760	95 000	660	15	As-Welded
ER120S-1	Argon/2% O_2	120 000	830	105 000	730	14	As-Welded
ER70S-G E70C-G	(d)	70 000	480	(e)	(e)	(e)	(e)
ER80S-G E80C-G	(d)	80 000	550	(e)	(e)	(e)	(e)
ER90S-G E90C-G	(d)	90 000	620	(e)	(e)	(e)	(e)
ER100S-G E100C-G	(d)	100 000	690	(e)	(e)	(e)	(e)
ER110S-G E110C-G	(d)	110 000	760	(e)	(e)	(e)	(e)
ER120S-G E120C-G	(d)	120 000	830	(e)	(e)	(e)	(e)

Notes:

a. The use of a particular shielding gas for classification purposes shall not be construed to restrict the use of shielding gas mixtures. A filler metal tested with other gas blends, such as Argon/O_2 or Argon/CO_2 may result in weld metal having different strength and elongation. Classification with other gas blends shall be as agreed upon between the purchaser and supplier.

b. Yield strength at 0.2% offset and elongation in 2 in. (51 mm) gage length.

c. Postweld heat-treated condition in accordance with Table 7.

d. Shielding gas shall be as agreed to between purchaser and supplier.

e. Not specified (As agreed to between purchaser and supplier).

f. These classifications were previously ER80S-B2, E80C-B2, ER90S-B3L, and E90C-B3L respectively in AWS A5.28-79. The strength levels have been adjusted downward as shown, in order to accurately reflect the capability of the classification's chemical composition ranges.

Table 4
Impact Test Requirements

AWS Classification	Average Impact Strength[a] (minimum)	Testing Condition
ER70S-A1 ER70S-B2L E70C-B2L ER80S-B2 E80C-B2 ER80S-B3L E80C-B3L ER90S-B3 E90C-B3 ER80S-B6 ER80S-B8 ER90S-B9	Not Required	—
ER80S-Ni1 E80C-Ni1	20 ft·lbf at –50°F (27 J @ –46°C)	As-Welded
ER80S-Ni2 E70C-Ni2 E80C-Ni2	20 ft·lbf at –80°F (27 J @ –62°C)	PWHT[b]
ER80S-Ni3 E80C-Ni3	20 ft·lbf at –100°F (27 J @ –73°C)	PWHT[b]
ER80S-D2 ER90S-D2 E90C-D2	20 ft·lbf at –20°F (27 J @ –29°C)	As-Welded
ER100S-1 ER110S-1 ER120S-1	50 ft·lbf at –60°F (68 J @ –51°C)	As-Welded
ERXXXS-G EXXC-G	As agreed between purchaser and supplier.	—

Notes:
a. Both the highest and lowest of the five test values obtained shall be disregarded in computing the impact strength.
For classifications requiring 20 ft·lbf (27 J): Two of the remaining three values shall equal or exceed 20 ft·lbf (27J); one of the three remaining values may be lower than 20 ft·lbf (27J) but not lower than 15 ft·lbf (20J). The average of the three shall not be less than the 20 ft·lbf (27 J) specified.
For classifications requiring 50 ft·lbf (68 J): Two of the remaining three values shall equal or exceed 50 ft·lbf (68 J); one of the three remaining values may be lower than 50 ft·lbf (68 J) but not lower than 40 ft·lbf (54 J). The average of the three shall not be less than the 50 ft·lbf (68 J) specified.
b. Postweld heat treated in accordance with Table 7.

5.2 For the purpose 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, *Recommended Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*.[4]

Part B
Tests, Procedures, and Requirements

6. Summary of Tests

6.1 The tests required for each classification are specified in Table 5. The purpose of these tests is to determine the chemical composition, the mechanical properties, and soundness of the weld metal. The base metal for the weld test assemblies, the welding and testing procedures to be employed, and the results required are given in Sections 8 through 12.

6.2 The optional test for diffusible hydrogen in Section 13, Diffusible Hydrogen Test, is not required for classification [see note (a) of Table 5].

7. Retest

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

In the event that, during preparation or after completion of any test, it is clearly determined that prescribed or proper procedures were not followed in preparing the 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.

4. ASTM specifications may be obtained from the American Society for Testing and Materials (ASTM), 100 Barr Harbor Drive, Conshohocken, PA 19428-2959.

Table 5
Required Tests

AWS Classification	Chemical Analysis		Radiographic Test	Tension Test	Impact Test	Diffusible Hydrogen Test
	Electrode	Weld Metal				
Solid Electrodes						
ER70S-A1 ER70S-B2L ER80S-B2 ER80S-B3L ER90S-B3 ER80S-B6 ER80S-B8 ER90S-B9	Required	Not Required	Required	Required	Not Required	a
ER80S-Ni1 ER80S-Ni2 ER80S-Ni3	Required	Not Required	Required	Required	Required	a
ER80S-D2 ER90S-D2	Required	Not Required	Required	Required	Required	a
ER100S-1 ER110S-1 ER120S-1	Required	Not Required	Required	Required	Required	a
ERXXS-G	Required[b]	Not Required	Required	Required	Not Required	a
Composite Metal Cored Electrodes						
E70C-B2L E80C-B2 E80C-B3L E90C-B3	Not Required	Required	Required	Required	Not Required	a
E70C-Ni2 E80C-Ni1 E80C-Ni2 E80C-Ni3	Not Required	Required	Required	Required	Required	a
E90C-D2	Not Required	Required	Required	Required	Required	a
EXXC-G	Not Required	Required[b]	Required	Required	Not Required	a

Notes:
a. Optional diffusible hydrogen test is required only when specified by the purchaser and the manufacturer puts the diffusible hydrogen designator on the label (See A2.2 and A8.2 in the Annex).
b. To be reported. See A7.15 in the Annex.

8. Weld Test Assemblies

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

(1) The groove weld in Figure 1 for mechanical properties and soundness of the weld metal for both composite and solid electrodes

(2) The weld pad in Figure 2 for chemical analysis of the weld metal from composite stranded and composite metal cored electrodes

The sample for chemical analysis of weld metal from composite electrodes may be taken from the reduced section of the fractured all-weld-metal tension test specimen or from the corresponding location in the groove weld in Figure 1, thereby avoiding the need to make a weld pad. Alternatively, the sample from the groove weld may be taken from any location in the weld metal above the tension test specimen. In case of dispute, the weld pad in Figure 2 shall be the referee method.

8.2 Preparation of each weld test assembly shall be as prescribed in 8.3, 8.4, and 8.5. The base metal for each assembly shall be as required in Table 6, and shall meet the requirements of the ASTM specification shown there, or an equivalent specification. Testing of the assembly shall be as prescribed in 9.2, 9.3, and Sections 10 through 12.

8.3 Groove Weld

8.3.1 For all classifications, a test assembly shall be prepared and welded as specified in Figure 1, using base metal of the appropriate type specified in Table 6, and the preheat and interpass temperature specified in Table 7. The electrode used shall be 0.045 in. (1.1 mm) or 1/16 in. (1.6 mm) size (or the size that the manufacturer produces that is closest to one of these, if these sizes are not produced).

Welding shall be in the flat position, and the assembly shall be restrained (or preset) during welding to prevent warpage in excess of 5 degrees. An assembly that has warped more than 5 degrees from plane shall be discarded. It shall not be straightened. The test assembly shall be tack welded, and welding shall begin at the preheat temperature specified in Table 7.

This interpass temperature shall be maintained for the remainder of the weld. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air to room temperature. The assembly shall be preheated to the temperature shown in Table 7 before welding is resumed. When welding has been completed and the assembly has cooled, the assembly shall be prepared and tested as specified in Sections 10, 11, and 12 in the as-welded or postweld heat-treated condition, as specified in Tables 3 and 4.

8.3.2 When required, the test assembly shall be postweld heat-treated before removal of mechanical test specimens. This postweld heat treatment may be done either before or after the radiographic examination.

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

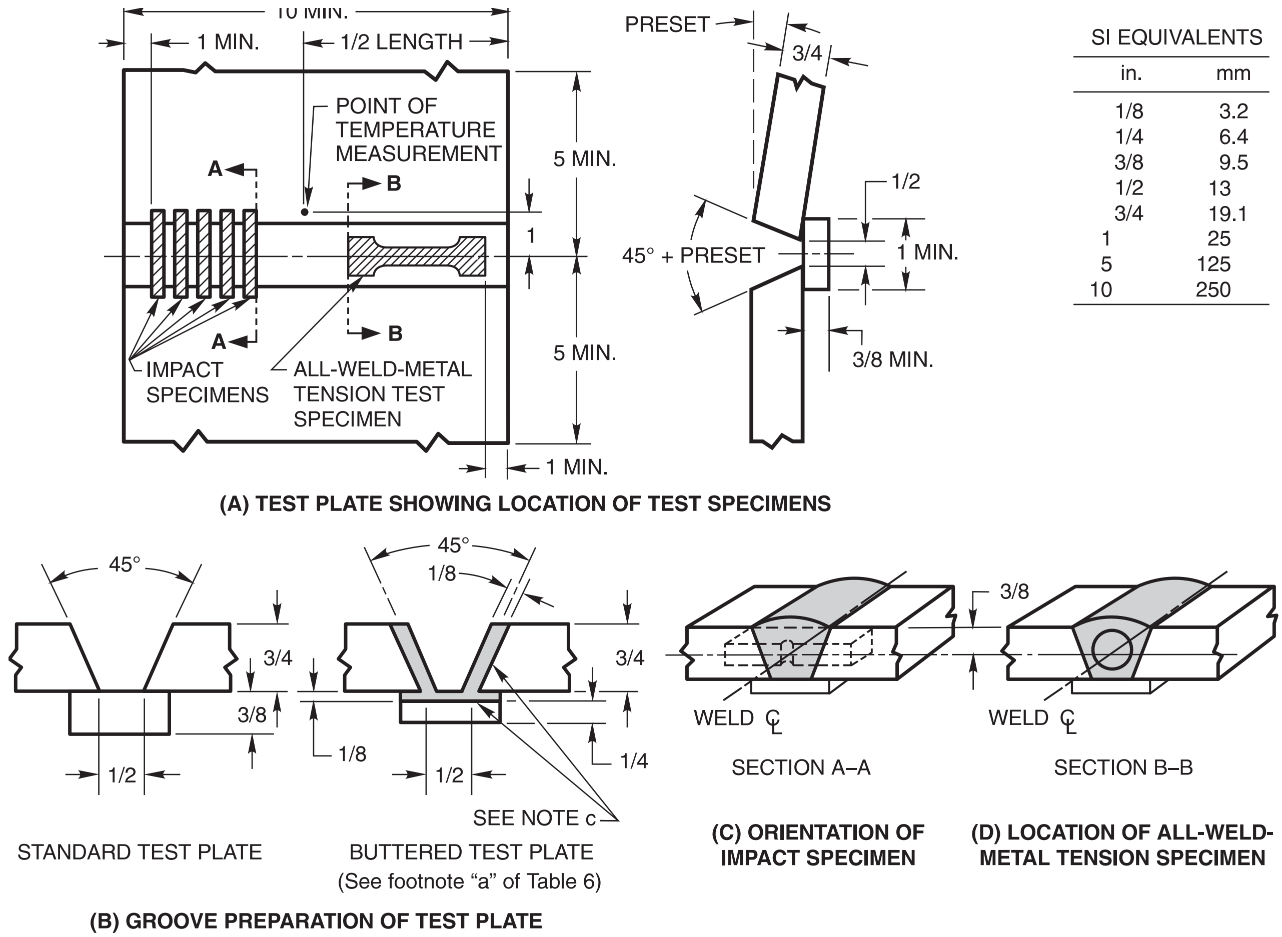
8.3.2.2 The test assembly shall be maintained at the temperature specified in Table 7 for 1 hour (–0, +15 minutes).

8.3.2.3 When the one hour holding time has been completed, the assembly shall be allowed to cool in the furnace to a temperature below 600°F (320°C) at a rate not exceeding 350°F (190°C) per hour. The assembly may be removed from the furnace at any temperature below 600°F (320°C) and allowed to cool in still air to room temperature. Testing of the assembly shall be as specified in Sections 10 through 12.

8.4 Weld Pad. A weld pad shall be prepared using composite stranded and composite metal cored electrodes as shown in Figure 2, except when, as permitted in 8.1, the sample for analysis is taken from the groove weld (Figure 1) or the fractured tension test specimen. Base metal of any convenient size which will satisfy the minimum requirements of Figure 2, and is of a type specified in Table 6, shall be used as the base for the weld pad. The surface of the base metal on which the filler metal is deposited shall be clean. The pad shall be welded in the flat position with multiple layers to obtain undiluted weld metal (4 layers minimum thickness). The electrode size shall be 0.045 in. (1.1 mm) or 1/16 in. (1.6 mm), or the size that the manufacturer produces that is closest to one of these, if these sizes are not produced. The preheat temperature shall not be less than 60°F (16°C) and the interpass temperature shall not exceed that specified in Table 7. Any slag shall be removed after each pass. The pad may be quenched in water between passes (temperature of the water is not specified). The dimensions of the completed pad shall be as shown in Figure 2. Testing of this assembly shall be as specified in 9.2 and 9.3. The results shall meet the requirements of 9.4.

9. Chemical Analysis

9.1 A sample of the solid electrode or rod shall be prepared for chemical analysis. Solid filler metal, when



SI EQUIVALENTS

in.	mm
1/8	3.2
1/4	6.4
3/8	9.5
1/2	13
3/4	19.1
1	25
5	125
10	250

Test Conditions for Solid Electrodes (i)		
Standard Size (h)	0.045 in. (1.1 mm)	1/16 in. (1.6 mm)
Shielding Gas (g)	See Table 3	See Table 3
Wire Feed Rate	450 in./min (190 mm/sec) ±5%	240 in./min (102 mm/sec) ±5%
Nominal Arc Voltage	27 to 32 V	25 to 30 V
Approx. Resulting Current, DCEP (d) (DCEP = electrode positive)	300 to 360A (e)	340 to 420A (e)
Tip-to-Work Distance (f)	7/8 ± 1/8 in. (22 ± 3 mm)	7/8 ± 1/8 in. (22 ± 3 mm)
Travel Speed	13 ± 2 in./min (5.5 ± 1.0 mm/sec)	13 ± 2 in./min (5.5 ± 1.0 mm/sec)
Preheat and Interpass Temperature	See Table 7	See Table 7

Notes:

a. All dimensions (excluding angles) are in inches.

b. Prior to welding, the assembly may be preset as shown so that the welded joint will be sufficiently flat to facilitate test specimen removal. As an alternative, restraint or a combination of restraint and preset may be used.

c. When required, edges of the grooves and the contacting face of the backing shall be buttered as shown. Any size of the electrode being tested may be used for buttering. See Table 6, Note (a).

d. The required combinations of electrode feed rate, arc voltage, and tip-to-work distance should produce welding currents in the ranges shown. Currents substantially outside these ranges suggest errors in feed rate, tip-to-work distance, voltage settings, or in instrumentation.

e. For ER80S-D2 classification, the amperage range for 0.045" (1.1 mm) shall be 260 to 320A and for 1/16 in. (1.6 mm) dia., 330 to 410A.

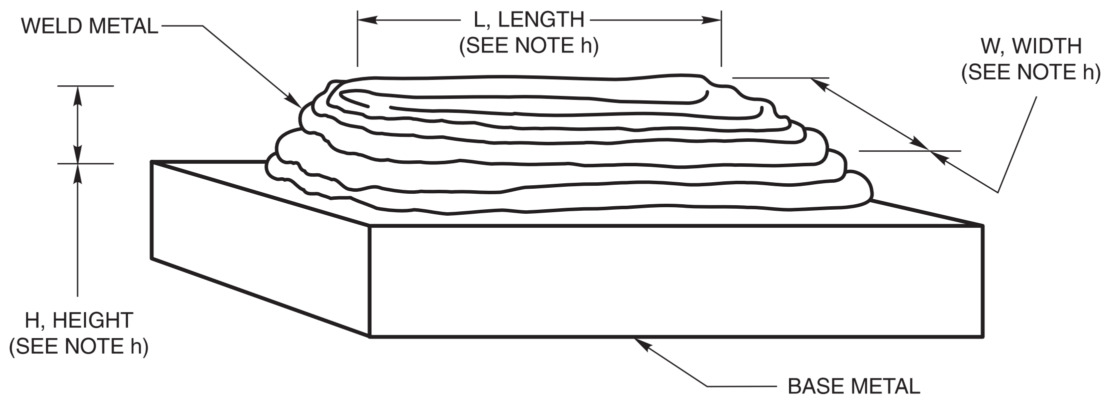
f. Distance from the contact tip to work, not from the shielding gas cup to the work.

g. If shielding gases or blends other than those shown in Table 3 are used, the wire feed speed (and resulting current), arc voltage, and travel speed are to be as agreed to between purchaser and supplier.

h. If sizes other than 0.045 in. (1.1 mm) and 1/16 in. (1.6 mm) are tested, wire feed speed (and resulting current), arc voltage, and tip-to-work distance shall be changed as needed.This joint configuration is not recommended for sizes smaller than 0.035 in. (0.9 mm).

i. Test conditions for composite stranded and metal cored electrodes shall be as recommended by the manufacturer. Preheat and inter-pass temperature shall be in accordance with Table 7.

Figure 1—Groove Weld Test Assembly for Mechanical Properties and Soundness



Notes:
a. Base metal of any convenient size, of any type, specified in Table 6, shall be used as the base metal for the weld pad.
b. The surface of the base metal on which the filler metal is to be deposited shall be clean.
c. The pad shall be welded in the flat position with successive layers to obtain weld metal of sufficient height.
d. The number and size of the beads will vary according to the size of the electrode and the width of the weave, as well as the amperage employed.
e. The preheat temperature shall not be less than 60°F (16°C) and the interpass temperature shall not exceed 325°F (164°C).
f. Any slag shall be removed after each pass.
g. The test assembly may be quenched in water between passes to control interpass temperature.
h. The minimum completed pad size shall be at least four layers in height (H). Length (L), after allowance for start and stop areas, and width (W) shall be sufficient to perform analysis. The sample for analysis shall be taken at least 3/8 in. (9 mm) above the original base metal surface.

Figure 2—Pad for Chemical Analysis of Weld Metal from Composite Electrodes

analyzed for elements that are present in a coating (copper flashing, for example), shall be analyzed without removing the coating. When the filler metal is analyzed for elements other than those in the coating, the coating shall be removed if its presence affects the results of the analysis for the other elements.

9.2 Composite stranded and metal cored electrodes shall be analyzed in the form of weld metal, not filler metal. The sample for analysis shall be taken from weld metal obtained with the electrode and a shielding gas as specified in Tables 2 and 3. The sample may be taken from the weld pad prepared in accordance with 8.4, from an area of the groove weld as specified in 8.1, or from the reduced section of the fractured tension test specimen. In case of dispute, the weld pad is the referee method.

The top surface of the pad described in 8.4 and shown in Figure 2 shall be removed and discarded. A sample for analysis shall be obtained from the underlying metal, no closer than 3/8 in. (9.5 mm) to the surface of the base metal in Figure 2, by any appropriate mechanical means. The sample shall be free of slag.

When the sample is taken from the groove weld or the reduced section of the fractured tension test specimen, that material shall be prepared for analysis by any suitable mechanical means.

9.3 The sample obtained as specified in 9.1 or 9.2 shall be analyzed by accepted analytical methods. The referee method shall be ASTM E350, *Standard Method for Chemical Analysis of Carbon Steel, Low Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron*.

9.4 The results of the analysis shall meet the requirements of Table 1 for solid electrode or Table 2 for composite electrodes for the classification of electrode under test.

10. Radiographic Test

10.1 The groove weld described in 8.3.1 and shown in Figure 1 shall be radiographed to evaluate the soundness of the weld metal. In preparation for radiography, the backing shall be removed, and both surfaces of the weld shall be machined or ground smooth. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

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

Table 6
Base Metal for Test Assemblies

AWS Classification	Base Metal ASTM Standard[a]	Base Metal UNS Number[b]
ER70S-B2L E70C-B2L ER80S-B2 E80C-B2	A387 Grade 11	K11789
ER80S-B3L E80C-B3L ER90S-B3 E90C-B3	A387 Grade 22	K21590
ER80S-B6	A387 Grade 5	S50200
ER80S-B8	A387 Grade 9	S50400
ER90S-B9	A387 Grade 91	S50460
ER80S-Ni1 E80C-Ni1	A516 Grade 60, 65, or 70	K02100, K02403, or K02700
	A537 Class 1 or 2	K12437, K21703, or K22103
	A203 Grade A or B, or HY-80 steel in accordance with MIL-S-16216	J42015
E70C-Ni2 ER80S-Ni2 E80C-Ni2	A203 Grade A or B or HY-80 steel in accordance with MIL-S-16216	K22103, K21703, or J42015
ER80S-Ni3 E80C-Ni3	A203 Grade D or E or HY80 steel in accordance with MIL-S-16216	K31718 or K32018 J42015
ER70S-A1 ER80S-D2 E90C-D2 ER90S-D2	ASTM A36, A285 Grade C, A515 Grade 70, or A516 Grade 70	K02600, K03101, K02700
ER100S-1 ER100S-G E100C-G ER110S-1 ER110S-G E110C-G ER120S-1 ER120S-G E120C-G	HY-80 or HY100 steel in accordance with MIL-S-16216	J42015 or J42240
ERXXS-G EXXC-G	See note[a]	

Notes:

a. For any weld metal classification in this specification, ASTM A36, A285 Grade C, A515 Grade 70, or A516 Grade 70 may be used. In that case, the groove faces and the contacting face of the backing shall be buttered, as shown in Figure 1, using the electrode being classified or an electrode of the same weld metal composition as that specified for the electrode being tested, or using an electrode of the specified composition classified in another AWS low-alloy steel filler metal specification. Alternately, for the indicated weld metal classification, the corresponding base metals may be used for weld test assemblies without buttering. In case of dispute, buttered A36 steel shall be the referee material.

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

Table 7
Preheat, Interpass, and Postweld Heat Treatment Temperatures

AWS Classification	Preheat and Interpass Temperature[a]		PWHT Temperature[a]	
	°F	°C	°F	°C
ER70S-A1 ER80S-B2 ER70S-B2L E80C-B2 E70C-B2L	275–325	135–165	1150 ± 25	620 ± 15
ER90S-B3 ER80S-B3L E90C-B3 E80C-B3L	375–425	185–215	1275 ± 25	690 ± 15
ER80S-B6	350–450	177–232	1375 ± 25	745 ± 15
ER80S-B8	400–500	205–260	1375 ± 25	745 ± 15
ER90S-B9	300–500	150–260	1375 ± 25	745 ± 15
ER80S-Ni2 ER80S-Ni3 E70C-Ni2 E80C-Ni2 E80C-Ni3	275–325	135–165	1150 ± 25	620 ± 15
ER80S-D2 ER90S-D2 E90C-D2 ER80S-Ni1 E80C-Ni1 ER100S-1 ER110S-1 ER120S-1	275–325	135–165	None[b]	None[b]
ERXXXS-G EXXC-G	Conditions as agreed upon between supplier and purchaser			

Notes:

a. These temperatures are specified for testing under this specification and are not to be considered as recommendations for preheat, interpass, and postweld heat treatment in production welding. The requirements for production welding must be determined by the user. They may or may not differ from those called for here.

b. These classifications are normally used in the as-welded condition.

10.3 The soundness of the weld metal meets the requirements of this specification if the radiograph shows no cracks, no incomplete fusion, and no rounded indications in excess of those permitted by the radiographic standards in Figure 3. In evaluating the radiograph, 1 in. (25 mm) of the weld on each end of the test assembly shall be disregarded.

10.3.1 A rounded indication is an indication (on the radiograph) whose length is no more than 3 times its width. Rounded indications may be circular, elliptical, conical, or irregular in shape, and they may have tails. The size of a rounded indication is the largest dimension of the indication, including any tail that may be present. The indication may be of porosity or slag. Indications whose largest dimension does not exceed 1/64 in. (0.4 mm) shall be disregarded. Test assemblies with indications larger than the largest indications permitted in the radiographic standards (Figure 3) do not meet the requirements of this specification.

11. Tension Test

11.1 One all-weld-metal tension test specimen shall be machined from the groove weld described in 8.3.1 and shown in Figure 1 as required in Table 5. The dimensions of the specimen shall be as shown in Figure 4.

11.2 Before testing, the specimen may be aged at 200 to 220°F (93 to 104°C) for up to 48 hours, then allowed to cool to room temperature. Refer to A8.3 for a discussion on the purpose of aging treatments.

11.3 The specimen shall be tested in the manner described in the tension test section of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

11.4 The results of the all-weld-metal tension test shall meet the requirements specified in Table 3. Test reports shall indicate if the specimen was tested in the aged condition.

12. Impact Test

12.1 Five Charpy V-notch impact test specimens (Figure 5) shall be machined from the test assembly shown in Figure 1, for those classifications for which impact testing is required in Table 5.

12.2 The five specimens shall be tested in accordance with the impact test section of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*. The test temperature shall be that specified in Table 4 for the classification under test.

12.3 In evaluating the test results, the lowest and the highest values obtained shall be disregarded. For classifications requiring 20 ft·lbf (27 J), two of the remaining three values shall equal, or exceed, the specified 20 ft·lbf (27 J) energy level. One of the three may be lower, but not lower than 15 ft·lbf (20 J), and the average of the three shall be not less than the required 20 ft·lbf (27 J) energy level. For classifications requiring 50 ft·lbf (68 J), two of the remaining three values shall equal, or exceed, the specified 50 ft·lbf (68 J) energy level. One of the three may be lower, but not lower than 40 ft·lbf (54 J), and the average of the three shall be not less than the required 50 ft·lbf (68 J) energy level.

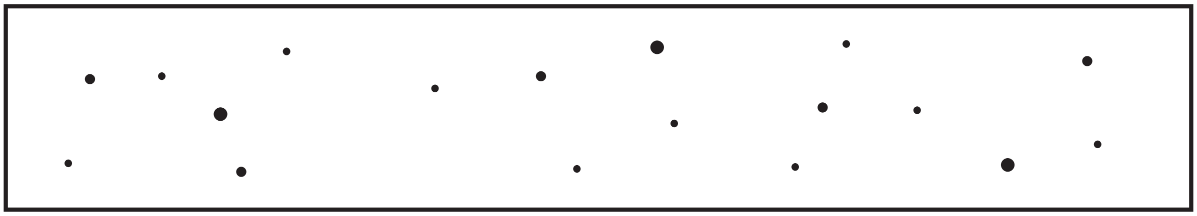
13. Diffusible Hydrogen Test

13.1 For each electrode to be identified by an optional diffusible hydrogen designator, the 0.045 in. (1.1 mm) or 1/16 in. (1.6 mm) size (or the size that the manufacturer produces that is closest to one of these, if these sizes are not produced) shall be tested according to one of the methods given in ANSI/AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*. The optional supplemental diffusible hydrogen designator may be added to the classification according to the average test value as compared to the requirements of Table 8. If the actual test results for an electrode meet the requirements for the lower or lowest hydrogen designator as specified in Table 8, the electrode also meets the requirements for all higher hydrogen designators in Table 8 without the need for retest.

Table 8
Optional Diffusible Hydrogen Requirements[a]

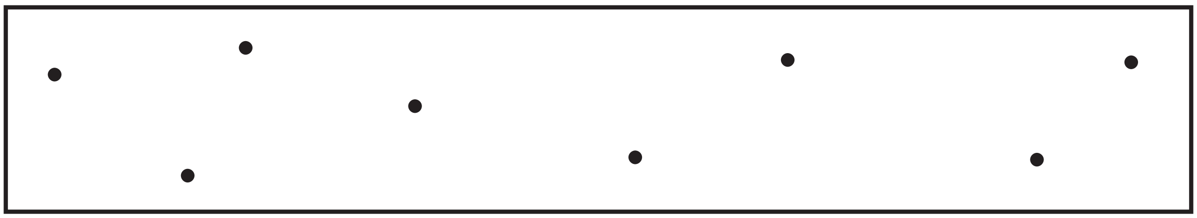
AWS Electrode Classification	Optional Supplemental Diffusible Hydrogen Designator[b]	Average Diffusible Hydrogen, Maximum (ml/100g Deposited Metal)[c]
All	H16	16.0
All	H8	8.0
All	H4	4.0
All	H2	2.0

Notes:
a. See Note a to Table 5.
b. This designator is added to the end of the complete electrode classification designation.
c. Some classifications may not meet the lower average diffusible hydrogen levels (H8, H4, and H2).



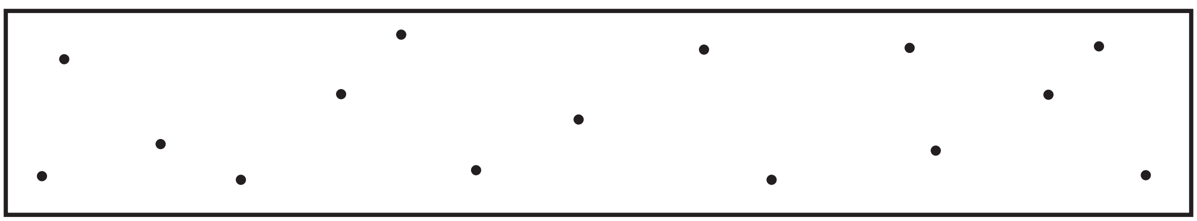
(A) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in. (0.4 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 18, WITH THE FOLLOWING RESTRICTIONS:
MAXIMUM NUMBER OF LARGE 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM 1/32 in. (0.8 mm) TO 3/64 in. (1.2 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 5.
MAXIMUM NUMBER OF SMALL 1/64 in. (0.4 mm) TO 1/32 in. (0.8 mm) IN DIAMETER OR IN LENGTH INDICATIONS = 10.



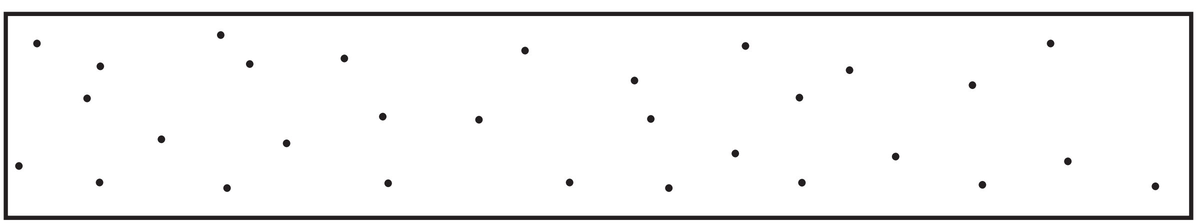
(B) LARGE ROUNDED INDICATIONS

SIZE 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 8.



(C) MEDIUM ROUNDED INDICATIONS

SIZE 1/32 in. (0.8 mm) TO 3/64 in. (1.2 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 15.

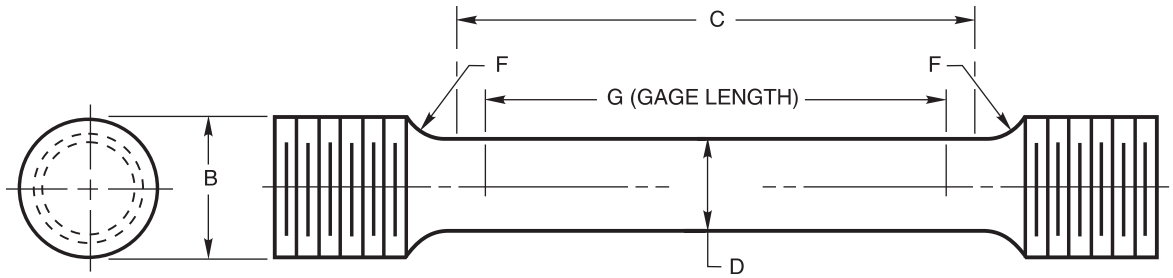


(D) SMALL ROUNDED INDICATIONS

SIZE 1/64 in. (0.4 mm) TO 1/32 in. (0.8 mm) IN DIAMETER OR IN LENGTH.
MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in. (150 mm) OF WELD = 30.

Notes:
1. In using these standards, the chart which is most representative of the size of the rounded indications present in the test specimen radiograph shall be used for determining conformance to these radiographic standards.
2. Since these are test welds specifically made in the laboratory for classification purposes, the radiographic requirements for these test welds are more rigid than those which may be required for general fabrication.
3. Indications whose largest dimension does not exceed 1/64 in. (0.4 mm) shall be disregarded.
4. These standards are equivalent to the Grade 1 standards of ANSI/AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*.

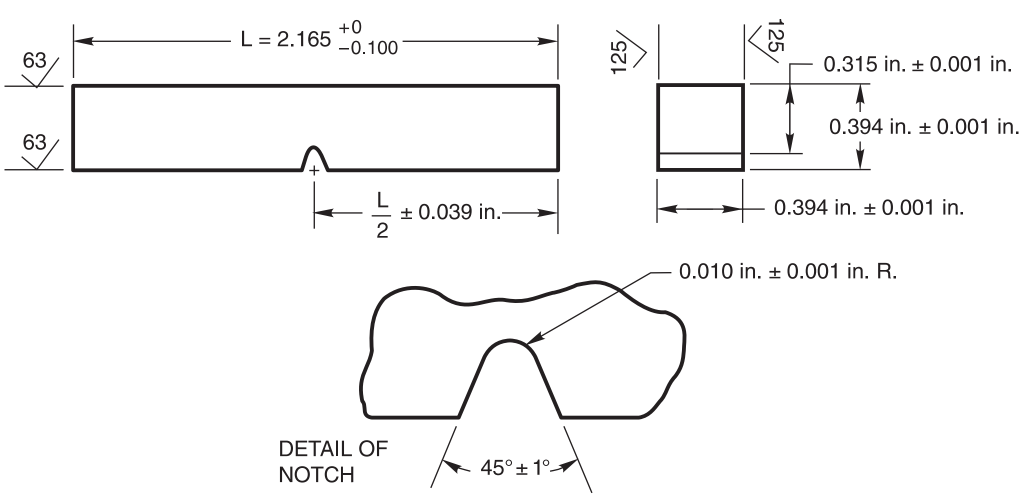
Figure 3—Radiographic Acceptance Standards



Dimensions of Specimen, in.				
D	G	C	B	F, min.
0.500 ± 0.010	2.000 ± 0.005	2-1/4	3/4	0.375
Dimensions of Specimen, mm				
D	G	C	B	F, min.
12.7 ± 0.2	50.8 ± 0.1	57	19	9.5

Notes:
a. Dimensions G and C shall be as shown, but ends may be of any shape to fit the testing machine holders as long as the load is axial.
b. The diameter of the specimen within the gage length shall be slightly smaller at the center than at the ends. The difference shall not exceed one percent of the diameter.
c. When the extensometer is required to determine yield strength, dimension C may be increased. However, the percent of the elongation shall be based on dimension G.
d. The surface finish within the C dimension shall be no rougher than 63 µin. (1.6 µm).

Figure 4—Tension Test Specimen



SI EQUIVALENTS	
in.	mm
0.001	0.025
0.010	0.255
0.039	1.0
0.100	2.5
0.315	8.0
0.394	10.0
2.165	55.0

Notes:
1. The notched surface and the surface to be struck shall be parallel within 0.002 in. (0.05 mm) and have at least 63 µin. (1.6 µm) finish. The other two surfaces shall be square with the notched or struck surface within ±10 minutes of the degree and have at least 125 µin. (3.2 µm) finish.
2. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.
3. The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at minimum 50 times magnification on either a shadowgraph or a metallograph.
4. The correct location of the notch shall be verified by etching before or after machining.
5. If a specimen does not break upon being struck, the value for energy absorbed shall be reported as the capacity of the impact testing machine followed by a plus sign (+).

Figure 5—Charpy V-Notch Impact Test Specimen

13.2 Testing shall be done without rebaking, or otherwise conditioning the electrode, unless the manufacturer recommends otherwise. If the electrode is rebaked, that fact, along with the method used for rebaking, shall be noted on the test report.

13.3 For purposes of certifying compliance with optional diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of 10 grains of water vapor per pound (1.43 g/kg) of dry air at the time of welding. The actual atmospheric conditions shall be reported, along with the average value for the test according to ANSI/AWS A4.3.[5]

13.4 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification, provided the actual test results satisfy the diffusible hydrogen requirements for the applicable optional supplemental designator.

Part C
Manufacture, Identification, and Packaging

14. Method of Manufacture

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

15. Standard Sizes

15.1 Standard sizes for electrodes and rods in the different package forms (straight lengths, coils with support, coils without support, drums and spools—see Section 17, Standard Package Forms) are shown in Table 9.

16. Finish and Uniformity

16.1 All electrodes and rods shall have a smooth finish which is free from slivers, depressions, scratches, scale, seams, laps (exclusive of the longitudinal joint in composite metal cored electrodes), and foreign matter that would adversely affect the welding characteristics, the operation of the welding equipment, or the properties of the weld metal.

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

16.3 The components in composite electrodes (including the core ingredients in metal cored electrodes) shall be distributed with sufficient uniformity throughout the length of the electrode so as not to adversely affect the performance of the electrode or the properties of the weld metal.

16.4 A suitable protective coating may be applied to any filler metal in this specification. Copper may be used as a coating for any classification.

17. Standard Package Forms

17.1 Standard package forms are straight lengths, coils with support, coils without support, spools, and drums. Standard package dimensions and weights for each form are given in Table 10. Package forms, sizes, and weights other than these shall be as agreed between purchaser and supplier.

17.2 The liners in coils with support shall be designed and constructed to prevent distortion of the coil during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal.

17.3 Spools shall be designed and constructed to prevent distortion of the filler metal during normal handling and use and shall be clean and dry enough to maintain the cleanliness of the filler metal.

18. Winding Requirements

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

18.2 The cast and helix of electrodes in coils, spools, and drums shall be such that the electrode will feed in an uninterrupted manner in automatic and semiautomatic equipment.

18.3 The cast and helix of solid filler metal in 4 in. (100 mm) spools shall be such that a specimen long

5. See A8.2 (in the Annex).

Table 9
Standard Sizes[a]

Standard Package Form	Diameter			Tolerance (±)			
				Solid		Composite	
	in.		mm	in.	mm	in.	mm
Straight Lengths[b]		0.045	1.1	0.001	0.02	0.002	0.05
	1/16	0.062	1.6	0.002	0.05	0.002	0.05
	5/64	0.078	2.0	0.002	0.05	0.003	0.08
	3/32	0.094	2.4	0.002	0.05	0.003	0.08
	1/8	0.125	3.2	0.002	0.05	0.003	0.08
	5/32	0.156	4.0	0.002	0.05	0.003	0.08
	3/16	0.188	4.8	0.002	0.05	0.003	0.08
Coils with and without Support		0.030	0.8	0.001	0.02	0.002	0.05
		0.035	0.9	0.001	0.02	0.002	0.05
		0.045	1.1	0.001	0.02	0.002	0.05
		0.052	1.3	0.002	0.05	0.002	0.05
	1/16	0.062	1.6	0.002	0.05	0.002	0.05
	5/64	0.078	2.0	0.002	0.05	0.003	0.08
	3/32	0.094	2.4	0.002	0.05	0.003	0.08
	7/64	0.109	2.8	0.002	0.05	0.003	0.08
	1/8	0.125	3.2	0.002	0.05	0.003	0.08
Drums		0.035	0.9	0.001	0.02	0.002	0.05
		0.045	1.1	0.001	0.02	0.002	0.05
		0.052	1.3	0.002	0.05	0.002	0.05
	1/16	0.062	1.6	0.002	0.05	0.002	0.05
	5/64	0.078	2.0	0.002	0.05	0.003	0.08
	3/32	0.094	2.4	0.002	0.05	0.003	0.08
	7/64	0.109	2.8	0.002	0.05	0.003	0.08
	1/8	0.125	3.2	0.002	0.05	0.003	0.08
Spools		0.020	0.5	0.001	0.02	0.002	0.05
		0.025	0.6	0.001	0.02	0.002	0.05
		0.030	0.8	0.001	0.02	0.002	0.05
		0.035	0.9	0.001	0.02	0.002	0.05
		0.045	1.1	0.001	0.02	0.002	0.05
		0.052	1.3	0.002	0.05	0.002	0.05
	1/16	0.062	1.6	0.002	0.05	0.002	0.05
	5/64	0.078	2.0	0.002	0.05	0.003	0.08
	3/32	0.094	2.4	0.002	0.05	0.003	0.08
	7/64	0.109	2.8	0.002	0.05	0.003	0.08
	1/8	0.125	3.2	0.002	0.05	0.003	0.08

Notes:
a. Dimensions, sizes, tolerances, and package forms other than those shown shall be as agreed by purchaser and supplier.
b. Length shall be 36 in. ± 1/2 in. (approximately 900 mm ± 15 mm).

Table 10
Packaging Requirements[a]

Type of Package		Package Size in.	Package Size mm	Net Weight of Electrode[b] lb.	Net Weight of Electrode[b] kg (approx.)
Coils without Support	As Specified by Purchaser[c]				
Coils with Support (See below)	ID	6-3/4	170	14	6.4
	ID	12	300	25, 30, 50, and 60	11, 14, 23, and 27
Spools[d]	OD	4	100	1-1/2 and 2-1/2	0.7 and 1.1
	OD	8	200	10, 12, and 15	4.5, 5.5, and 6.8
	OD	12	300	25, 30, 35 and 44	11, 14, 16, and 20
	OD	14	360	50 and 60	23 and 27
	OD	22	560	250	110
	OD	24	610	300	140
	OD	30	760	600, 750, and 1000	270, 340, and 454
Drums	OD	15-1/2	400	As Specified by Purchaser[c]	
	OD	20	500		
	OD	23	600	300 and 600	140 and 270
Straight Lengths		36 (long)	900 (long)	10 and 50	4.5 and 22.7

Coils with Support—Standard Dimensions and Weights

Electrode Size	Coil Net Weight lb	Coil Net Weight kg (approx.)	Inside Diameter of Liner in.	Inside Diameter of Liner mm	Width of Wound Electrode in., max.	Width of Wound Electrode mm, max.
All	14	6.4	6-3/4 ± 1/8	170 ± 3	3	75
	25 and 30	11 and 14	12 ± 1/8	305 ± 3	2-1/2 or 4-5/8	65 or 120
	50, 60, and 65	23, 27, and 30	12 ± 1/8	305 ± 3	4-5/8	120

Notes:
a. Sizes and net weights other than those specified may be supplied as agreed between supplier and purchaser.
b. Tolerance on net weight shall be ±10 percent.
c. As agreed between supplier and purchaser.
d. See Figure 6.

enough to produce a single loop, when cut from the spool and laid unrestrained on a flat surface, will:

(1) form a circle not less than 4 in. (100 mm) nor more than 9 in. (230 mm) in diameter, and

(2) rise above the flat surface no more than 1/2 in. (13 mm) at any location.

18.4 The cast and helix of solid filler metal on all other package forms shall be such that a specimen long enough to produce a single loop, when cut from the package and laid unrestrained on a flat surface, will:

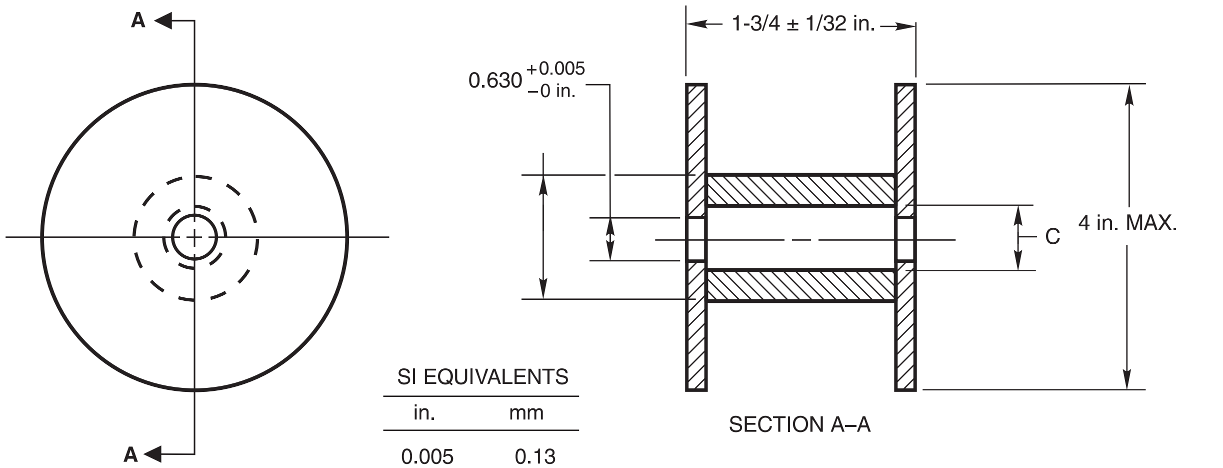
(1) form a circle not less than 12 in. (305 mm) for 0.030 in (0.8 mm) and smaller sizes; or not less than 15 in. (380 mm) for 0.035 in. (0.9 mm) and larger sizes, and

(2) rise above the flat surface no more than 1 in. (25 mm) at any location.

Certain bulk packages may contain wire that has been elastically twisted or otherwise mechanically treated in order to provide straighter wire feed. The wire from these packages will not form a circle when cut. Traditional cast and helix measurements may have no relevance. Wire thus treated shall conform to the winding requirements of 18.1 and 18.2. Any method of wire form inspection shall be as agreed between purchaser and supplier.

19. Filler Metal Identification

19.1 The product information and the precautionary information required in Section 21 for marking each package shall also appear on each coil, spool, and drum.



SI EQUIVALENTS

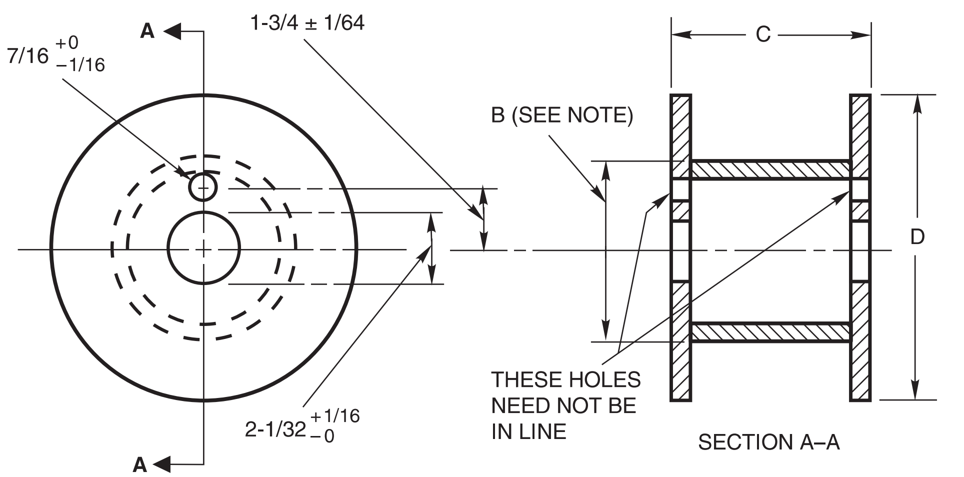
in.	mm
0.005	0.13
1/32	0.8
0.630	16
1-3/4	45
4	102

Notes:

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

b. Dimension C, inside diameter of barrel, shall be such that swelling of the barrel or misalignment of the barrel and flanges will not result in the inside diameter of the barrel being less than the inside diameter of the flanges.

Figure 6(a)—Standard Spools—Dimensions of 4 in. Spools



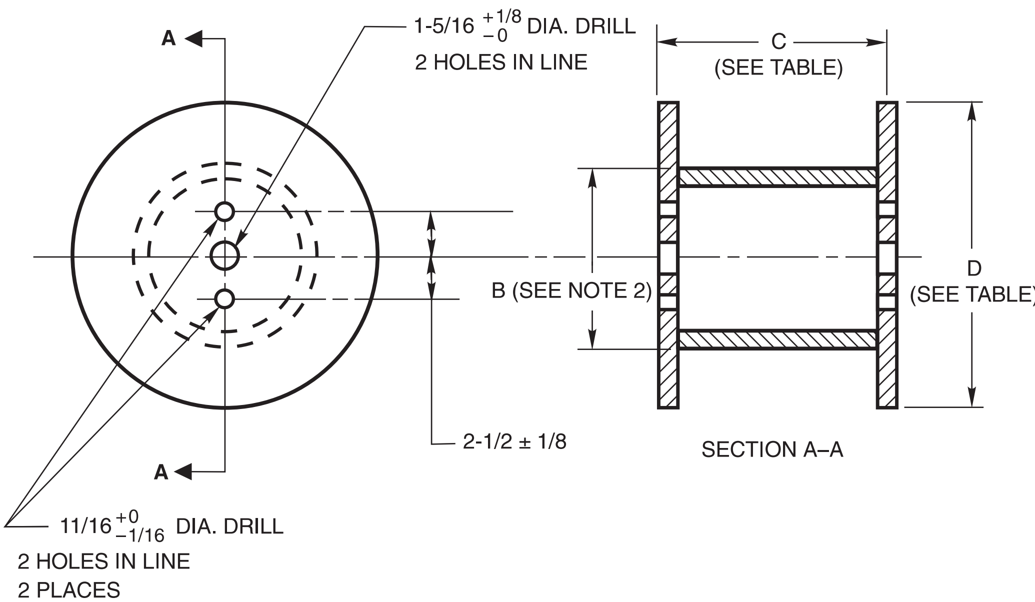
SI EQUIVALENTS

in.	mm
1/64	0.4
1/32	0.8
1/16	1.6
7/16	11
1-3/4	44
2-1/32	52
2-5/32	55
4	100
8	200
12	300
14	360

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

Dimensions		
Spool Size, in.	C, in.	D, maximum, in.
8	2-5/32 ± 1/32	8
12	4 ± 1/16	12
14	4 ± 1/16	14

Figure 6(b)—Standard Spools—Dimensions of 8, 12, and 14 in. Spools



SI EQUIVALENTS

in.	mm
1/16	1.6
1/8	3
1/2	13
11/16	18
1-5/16	33
2-1/2	63
12	305
13-1/2	345
22	560
24	610
30	760

Dimensions		
Spool Size, in.	D, in.	C, maximum, in.
22	22 ± 1/2	12
24	24 ± 1/2	13-1/2
30	30 ± 1/2	13-1/2

Notes:
1. All dimensions are in inches.
2. Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the electrode.

Figure 6(c)—Standard Spools—Dimensions of 22, 24, and 30 in. Spools

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

19.3 Coils with support shall have the information securely affixed in a prominent location on the support.

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

19.5 Drums shall have the information securely affixed in a prominent location on the side of the drum.

20. Packaging

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

21. Marking of Packages

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

(1) AWS specification (year of issue may be excluded) and AWS classification numbers, along with any optional supplemental designators, if applicable

(2) Supplier's name and trade designation

(3) Size and net weight

(4) Lot, control, or heat number

21.2 The following precautionary information (as a minimum) shall be prominently displayed in legible print on all packages of electrodes and rods, including individual unit packages enclosed within a larger package:

WARNING:

- Protect yourself and others. Read and understand this information. FUMES AND GASES can be hazardous to your health. ARC RAYS can injure eyes and burn skin. ELECTRIC SHOCK can kill.
- Before use, read and understand the manufacturer's instructions, Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch live electrical parts.
- See American National Standard Z49.1, *Safety in Welding, Cutting, and Allied Processes*, published by the American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33126; *OSHA Safety and Health Standards*, 29 CFR 1910, available from the U.S. Government Printing Office, Washington, DC 20402.

DO NOT REMOVE THIS INFORMATION

Annex

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

(This Annex is not a part of ANSI/AWS A5.28-96, *Specification for Low-Alloy Electrodes and Rods for Gas Shielded Arc Welding*, but is included for information only.)

A1. Introduction

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

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 as shown in Figure A1.

A2.2 The prefix "E" designates an electrode as in other specifications. The letters "ER" indicate that the filler metal may be used either as an electrode or a rod. The digits following (70, 80, 90, 100, 110, or 120) indicate the required minimum tensile strength of the weld metal in multiples of 1000 psi [6.9 MPa]; the minimum tensile strength is determined from a test weld made using the electrode in accordance with the welding conditions in the specification. The letter "S" designates a solid electrode or rod. The letter "C" designates a composite stranded or metal cored electrode. The suffix following the hyphen indicates the chemical composition of the filler metal itself, in the case of solid electrodes and rods, or the weld metal under certain test conditions, in the case of the composite stranded or metal cored electrodes.

An optional supplemental diffusible hydrogen designator (H16, H8, H4, or H2) may follow, indicating whether the electrode will meet a maximum diffusible hydrogen level of 16, 8, 4, or 2 ml/100 g of weld metal when tested as outlined in this specification.

A2.3 "G" Classification and the Use of "Not Specified" and "Not Required"

A2.3.1 This specification includes filler metals classified as ERXXS-G, and EXXC-G. The "G" indicates that the filler metal is of a general classification. It is "general" because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent in establishing these classifications is to provide a means by which filler metals that differ in one respect or another (chemical composition, for example) from all other classifications (meaning that the composition of the filler metal, in the case of the example, does not meet the composition specified for any of the classifications in the specification) can still be classified according to the specification. The purpose is to allow a useful filler metal, one that otherwise would have to await a revision of the specification, to be classified immediately under the existing specification. This means, then, that two filler metals, each bearing the same "G" classification, may be quite different in some particular respect (chemical composition, again, for example).

A2.3.2 The point of difference (although not necessarily the amount of the difference) referred to above will

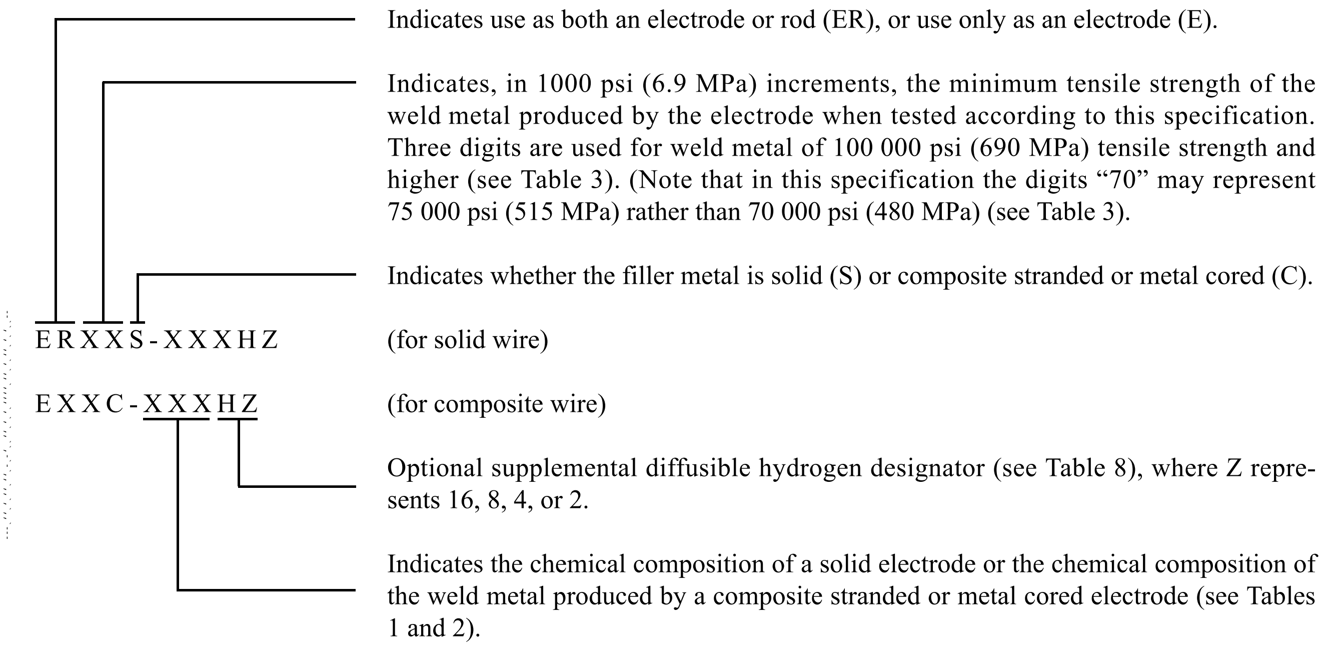


Figure A1—Classification System

be readily apparent from the use of the words "not required" and "not specified" in the specification. The use of these words is as follows:

Not Specified is used in those areas of the specification that refer to the results of some particular test. It indicates that the requirements for that test are not specified for that particular classification.

Not Required is used in those areas of the specification that refer to the tests that must be conducted in order to classify a filler metal. It indicates that the test is not required because the requirements (results) for the test have not been specified for that particular classification. Restating the case, when a requirement is not specified, it is not necessary to conduct the corresponding test in order to classify a filler metal to that classification. When a purchaser wants the information provided by that test, in order to consider a particular product of that classification for a certain application, the purchaser will have to arrange for that information with the supplier of the product. The purchaser will have to establish with that supplier just what the testing procedures and the acceptance requirements are to be for that test. The purchaser may want to incorporate that information (via ANSI/AWS A5.01, *Filler Metal Procurement Guidelines*) into the purchase order.

A2.3.3 Request for Filler Metal Classification

A2.3.3.1 When a filler metal cannot be classified according to some classification other than a "G" classification, the manufacturer may request that a classification be established for that filler metal. The manufacturer may do this by following the procedure given here. When the manufacturer elects to use the "G" classification, the Filler Metal Committee recommends that the manufacturer still request that a classification be established for that filler metal, as long as the filler metal is of commercial significance.

A2.3.3.2 A request to establish a new filler metal classification shall be a written request, and it needs to provide sufficient detail to permit the Filler Metal Committee or the Subcommittee to determine whether a new classification or the modification of an existing classification is more appropriate, and whether either is necessary to satisfy the need. The request shall state the variables and their limits for such a classification or modification. The request should contain some indication of the time by which completion of the new classification or modification is needed.

A2.3.3.3 The request should be sent to the Secretary of the Filler Metal Committee at AWS Headquarters. Upon receipt of the request, the Secretary will:

(1) Assign an identifying number to the request. This number shall include the date the request was received.

(2) Confirm receipt of the request and give the identification number to the person who made the request.

(3) Send a copy of the request to the Chairman of the Filler Metal Committee and to the Chairman of the particular Subcommittee involved.

(4) File the original request.

(5) Add the request to the log of outstanding requests.

A2.3.3.4 All necessary action on each request will be completed as soon as possible. If more than 12 months lapse, the Secretary shall inform the requestor of the status of the request, with copies to the Chairman of the Committee and the Subcommittee. Requests still outstanding after 18 months shall be considered not to have been answered in a "timely manner" and the Secretary shall report these to the Chairman of the Filler Metal Committee, for action.

A2.3.3.5 The Secretary shall include a copy of the log of all requests pending and those completed during the preceding year with the agenda for each Filler Metal Committee meeting. Any other publication of requests that have been completed will be at the option of the American Welding Society, as deemed appropriate.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with ANSI/AWS A5.01 *Filler Metal Procurement Guidelines,* as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of ANSI/AWS A5.01 *Filler Metal Procurement Guidelines*. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing the supplier normally conducts on material of that classification, as specified in Schedule F, Table 1, of ANSI/AWS A5.01 *Filler Metal Procurement Guidelines*. Testing in accordance with any other schedule in that table must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

A4.1 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 the certification is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped, and that the material met the requirements of the specification.

Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been made. The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance System" in ANSI/AWS A5.01 *Filler Metal Procurement Guidelines*.

A4.2 (Optional) At the option and expense of the purchaser, acceptance may be based on the results of any or all of the tests required by this specification made on the gas tungsten arc welding (GTAW) test assembly described in Figure A2, with tension specimen as described in Figure A3 (and the impact specimen described in Figure 5). Solid Electrodes are generally recommended for GTAW and PAW.

A5. Ventilation During Welding

A5.1 Five major factors govern the quantity of fumes in the atmosphere to which welders and welding operators are exposed during welding:

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

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

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

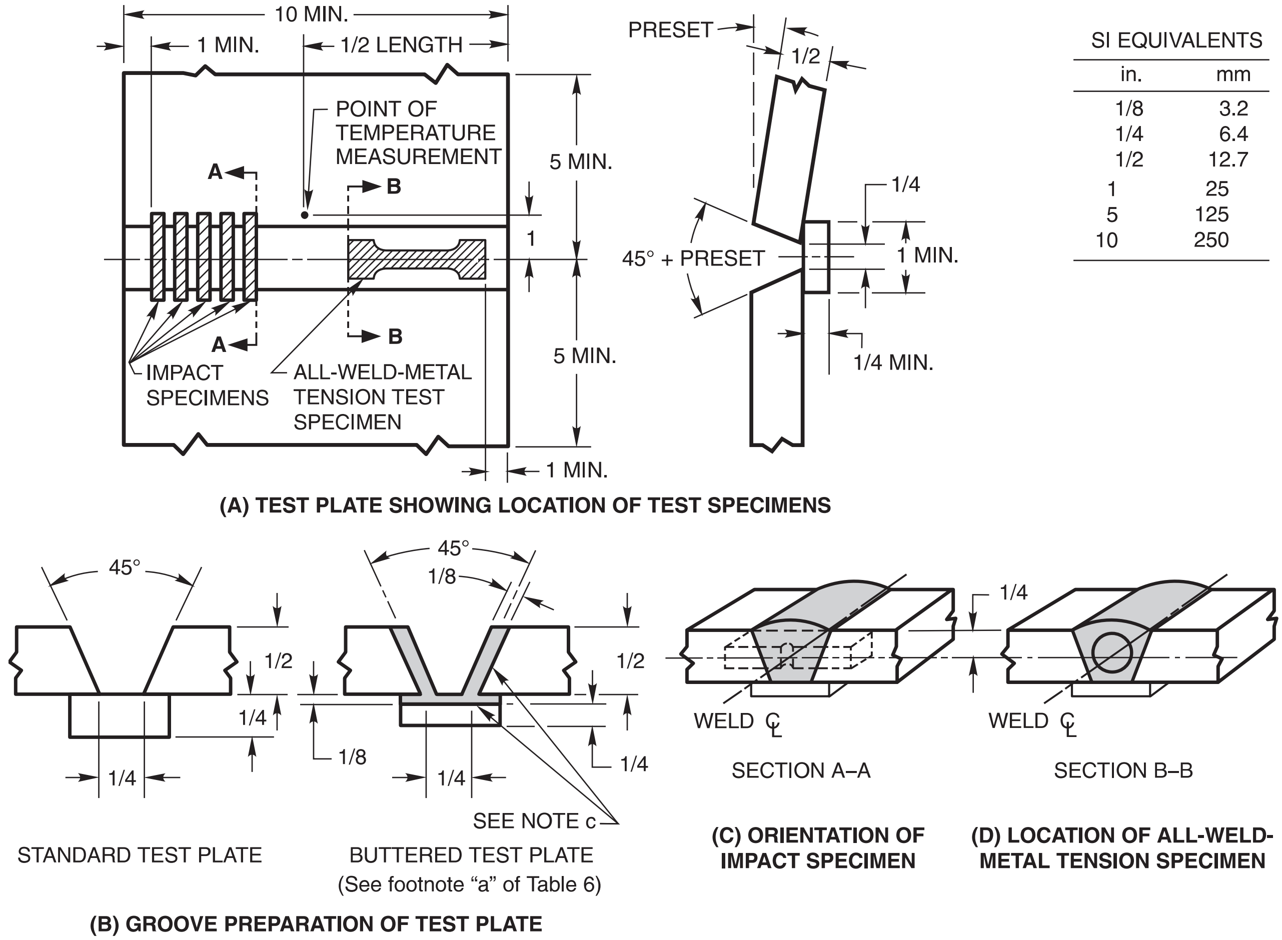
(4) The proximity of the welders or welding operators to the fumes as the fumes issue from the welding zone, and to the gases and dusts in the space in which they are working

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

A5.2 American National Standard 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 entitled "Health Protection and Ventilation."

A6. Welding Considerations

A6.1 Gas metal arc welding (GTAW) can be divided into four categories based on the mode of metal transfer: (1) spray, (2) pulsed spray, (3) globular, and (4) short circuiting transfer. In the spray, pulsed spray, and globular modes, transfer occurs as distinct droplets that are detached from the electrode, transferring along the arc column into the weld pool. In the short circuiting mode,



SI EQUIVALENTS

in.	mm
1/8	3.2
1/4	6.4
1/2	12.7
1	25
5	125
10	250

Test Conditions		
Standard Size	3/32 in. (2.4 mm)	1/8 in. (3.2 mm)
Shielding Gas	Argon	Argon
Travel Speed	4 to 6 in./min (0.17 to 0.25 mm/sec)	4 to 6 in./min (0.17 to 0.25 mm/sec)
Nominal Arc Voltage	13 to 16 V	16 to 19 V
Nominal Current, DCEN) (DCEN = electrode negative)	220 to 250 A	250 to 280 A
Preheat and Interpass Temperature	See Table 7	See Table 7

Notes:

a. All dimensions (excluding angles) are in inches.

b. Prior to welding, the assembly may be preset as shown so that the welded joint will be sufficiently flat to facilitate test specimen removal. As an alternative, restraint or a combination of restraint and preset may be used.

c. When required, edges of the grooves and the contacting face of the backing shall be buttered as shown. Any size of the electrode or rod being tested may be used for buttering. See Table 6, Note (a).

d. If sizes other than those shown above are used, nominal current and arc voltage shall be changed as needed.

e. Postweld heat treatment shall be as specified in Table 7 for the classification under test.

Figure A2—Optional GTAW Groove Weld Test Assembly for Mechanical Properties and Soundness

the metal is deposited during frequent short circuiting of the electrode in the molten pool.

A6.2 Spray Transfer

A6.2.1 The spray transfer mode, for low-alloy steel, is most commonly obtained with argon shielding gas mixtures with up to 5 percent oxygen or carbon dioxide. A characteristic of these shielding gas mixtures is the smooth arc plasma through which hundreds of very fine droplets are transferred to the weld pool each second.

A6.2.2 Spray transfer with argon-oxygen or argon-carbon dioxide shielding gas is, primarily, a function of current density, polarity, and resistance heating of the electrode. The high droplet rate (approximately 250 droplets per second) develops suddenly above a critical current level, commonly referred to as the *transition current* (for each size electrode). Below this current, the metal is transferred in drops generally larger in diameter than the electrode at a rate of from 10 to 20 per second (globular transfer). The transition current is also dependent, to some extent, on the chemical composition of the electrode. For 1/16 in. (1.6 mm) diameter low-alloy steel electrodes, a transition current of 270 amperes (direct current electrode positive [DCEP]) is common. Alternating current is not recommended for this type of welding because it does not produce a stable arc.

A6.2.3 Pulsed Spray Transfer. Metal transfer in pulsed spray welding is similar to that of the spray transfer described above, but it occurs at a lower average current. The lower average current is made possible by rapid pulsing of the welding current between a high level, where metal will transfer rapidly in the spray mode, and a low level, where no transfer will take place. At a typical rate of 60 to 120 pulses per second, a melted drop is formed by the low-current arc, which is then "squeezed off" by the high-current pulse. This permits all-position welding.

A6.3 Globular Transfer. The mode of transfer that characterizes 100 percent CO_2 as a shielding gas is globular. Common practice with globular transfer is to use low arc voltage to minimize spatter. This buries the arc and produces deep penetration. Electrodes of 0.045 and 1/16 in. (1.1 and 1.6 mm) diameter normally are used at welding currents in the range of 275–400 amperes (DCEP), for this type of transfer. The rate at which droplets (globules) are transferred ranges from 20 to 70 per second, depending on the size of the electrode, the amperage, polarity, and arc voltage.

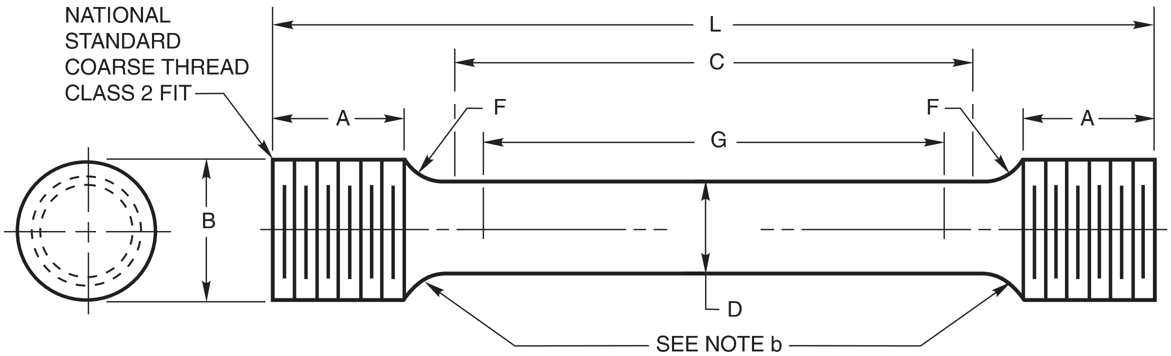
A6.4 Short Circuiting Transfer. This mode of transfer is obtained with small diameter electrodes (0.030 to 0.045 in. [0.8 to 1.1 mm]) using low arc voltages and amperages, and a power source designed for short circuiting transfer. The electrode short-circuits to the weld metal, usually at a rate of from 50 to 200 times per second. Metal is transferred with each short circuit, but not across the arc. Short circuiting gas metal arc welding of low-alloy steel is done most commonly with mixtures of argon and CO_2 as the shielding gas, with CO_2 alone, and occasionally with mixtures of helium-argon-CO_2. Penetration of welds made with CO_2 shielding gas is greater than with argon-CO_2 mixtures, but mixtures containing substantial amounts of argon or helium generally result in superior weld metal impact properties. Shielding gas mixtures of 50 to 90 percent argon-remainder CO_2 or 50 to 90 percent helium-remainder CO_2 result in higher short circuiting rates and lower minimum currents and voltages than does CO_2 shielding alone. This can be an advantage when welding thin plate or in the achievement of superior impact properties.

A7. Description and Intended Use of Electrodes and Rods

A7.1 The following is a description of the characteristics and intended use of the filler metals classified by this specification. The designations and the chemical composition requirements for all classifications are given in Tables 1 and 2 of this specification. The mechanical properties of weld metals from filler metals of the various classifications will conform to the minimum requirements stated in Tables 3 and 4 of the specification.

A7.2 It should be noted that weld properties may vary appreciably depending on filler metal size and current used, plate thickness, joint geometry, preheat and interpass temperatures, surface conditions, base-metal composition and extent of alloying with the filler metal, and shielding gas. For example, when filler metals having an analysis within the range of Table 1 are deposited, the weld metal chemical composition will not vary greatly from the as-manufactured composition of the filler metal when used with argon-oxygen shielding gas. However, they will show a considerable reduction in the content of manganese, silicon, and other deoxidizers when used with CO_2 as the shielding gas.

A7.3 ER70S-A1 Classification (1/2 Mo). Filler metal of this classification is similar to many of the carbon steel filler metals classified in ANSI/AWS A5.18, except that 1/2 percent molybdenum has been added. This addition increases the strength of the weld metal, especially at elevated temperatures, and provides some increase in corrosion resistance; however, it will likely reduce the notch toughness of the weld metal. Typical applications



Dimensions of Specimen, in.				
D	G	C	B	F, min.
0.350 ± 0.007	1.400 ± 0.005	1-3/4	1/2	0.25
Dimensions of Specimen, mm				
D	G	C	B	F, min.
8.90 ± 0.1	35.5 ± 0.1	44	12.7	6.4

Notes:
a. Dimensions G and C shall be as shown, but ends may be of any shape to fit the testing machine holders as long as the load is axial.
b. The diameter of the specimen within the gage length shall be slightly smaller at the center than at the ends. The difference shall not exceed one percent of the diameter.
c. When the extensometer is required to determine yield strength, dimension C may be increased. However, the percent of the elongation shall be based on dimension G.
d. The surface finish within the C dimension shall be no rougher than 63 µin. (1.6 µm).

Figure A3—Optional Tension Test Specimen for Gas Tungsten Arc Welding

include the welding of C-Mo base metals such as ASTM 204 plate and A335-P1 pipe.

A7.4 ER80S-B2 and E80C-B2 Classifications (1-1/4 Cr-1/2 Mo). Filler metals of these classifications are used to weld 1/2Cr-1/2Mo, 1Cr-1/2Mo, and 1-1/4Cr-1/2Mo steels for elevated temperatures and corrosive service. They are also used for joining dissimilar combinations of Cr-Mo and carbon steels. All transfer modes of the GMAW process may be used. Careful control of preheat, interpass temperatures, and postheat is essential to avoid cracking. These electrodes are classified after postweld heat treatment. Special care must be used when using them in the as-welded condition due to higher strength levels.

A7.5 ER70S-B2L and E70C-B2L Classifications (1-1/4 Cr-1/2 Mo). These filler metals are identical to the types ER80S-B2 and E80C-B2 except for the low-carbon content (0.05 percent maximum) and thus the lower strength levels. This alloy exhibits greater resistance to cracking and is more suitable for welds to be left in the as-welded condition or when the accuracy of the postweld heat treatment operation is questionable. These classifications were previously ER80S-B2L and E80C-B2L in the previous edition of this specification. The strength requirements and classification designator have been changed to reflect the true strength capabilities of the chemical composition.

A7.6 ER90S-B3 and E90C-B3 Classifications (2-1/4 Cr-1 Mo). Filler metals of these classifications are used to weld the 2-1/4Cr-1Mo steels used for high-temperature/high-pressure piping and pressure vessels. These may also be used for joining combinations of Cr-Mo and carbon steel. All GMAW modes may be used. Careful control of preheat, interpass temperatures, and postweld heat treatment is essential to avoid cracking. These electrodes are classified after postweld heat treatment. Special care must be used when using them in the as-welded condition due to higher strength levels.

A7.7 ER80S-B3L and E80C-B3L Classifications (2-1/4 Cr-1 Mo). These filler metals are identical to the types ER90S-B3 and E90C-B3 except for the low-carbon content (0.05 percent maximum) and, therefore, the lower strength levels. These alloys exhibit greater resistance to cracking and are more suitable for welds to be left in the as-welded condition. These classifications were previously ER90S-B3L and E90C-B3L in the previous edition of this specification. The strength requirements and classification designator have been changed to reflect the true strength capabilities of the chemical composition.

A7.8 ER80S-Ni1 and E80C-Ni1 Classifications (1.0 Ni). These filler metals deposit weld metal similar to E8018-C3 covered electrodes, and are used for welding low-alloy high-strength steels requiring good toughness at temperatures as low as –50°F (–46°C).

A7.9 ER80S-Ni2, E70C-Ni2, and E80C-Ni2 Classifications (2-1/4 Ni). These filler metals deposit weld metal similar to E8018-C1 electrodes. Typically, they are used for welding 2-1/2 percent nickel steels and other materials requiring good toughness at temperatures as low as –80°F (–62°C).

A7.10 ER80S-Ni3 and E80C-Ni3 Classifications (3-1/4 Ni). These filler metals deposit weld metal similar to E8018-C2 electrodes. Typically they are used for welding 3-1/2 percent nickel steels for low-temperature service.

A7.11 ER80S-D2, ER90S-D2, and E90C-D2 Classifications (1/2 Mo). The ER80S-D2 and ER90S-D2 classifications have the same chemical requirements as the E70S-1B classification of AWS A5.18-69. The differences between the ER80S-D2 and the ER90S-D2 classifications are the change in shielding gas and the mechanical property requirements specified in Table 3. Filler metals of these classifications contain molybdenum for increased strength and a high level of deoxidizers (Mn and Si) to control porosity when welding with CO2 as the shielding gas. They will give radiographic quality welds with excellent bead appearance in both ordinary and difficult-to-weld carbon and low-alloy steels. They exhibit excellent out-of-position welding characteristics with the short circuiting and pulsed arc processes.

The combination of weld soundness and strength makes filler metals of these classifications suitable for single and multiple-pass welding of a variety of carbon and low-alloy, higher strength steels in both the as welded and postweld heat-treated conditions. The chemical composition of these classifications differs from those of the "-D2" type electrodes in AWS A5.5.

A7.12 ER100S-1, ER110S-1, and ER120S-1 Classifications. These filler metals deposit high-strength, very tough weld metal for critical applications. Originally developed for welding HY80 and HY100 steels for military applications, they are also used for a variety of structural applications where tensile strength requirements exceed 100 ksi (690 MPa), and excellent toughness is required to temperatures as low as –60°F (–51°C). Mechanical properties obtained from weld deposits made with electrodes of these classifications will vary depending on the heat input used.

A7.13 ER80S-B6 Classification (5 Cr-1/2 Mo). This classification contains 4.0 to 6.0 percent chromium and about 0.50 percent molybdenum. It is used for welding material of similar composition, usually in the form of pipe or tubing. The alloy is an air-hardening material and, therefore, when welding with this filler metal, preheat and postweld heat treatment are required. This electrode is similar to that previously classified as ER502 in AWS A5.9-81.

A7.14 ER80S-B8 Classification (9 Cr-1 Mo). This classification contains 8.0 to 10.5 percent chromium and about 1.0 percent molybdenum. Filler metal of this classification is used for welding base metal of similar compositions, usually in the form of pipe or tubing. The alloy is an air-hardening material and, therefore, when welding with this filler metal, preheating and postweld heat treatment are required. This electrode is similar to that previously classified as ER505 in AWS A5.9-81.

A7.15 ER90S-B9 Classification (9 Cr-1 Mo-0.2V-0.07Nb(Cb)). ER90S-B9 is a 9Cr-1Mo solid wire modified with niobium (columbium) and vanadium designed to provide strength, toughness, fatigue life, oxidation resistance and corrosion resistance at elevated temperatures. Due to the higher elevated temperature properties of this alloy, components that are now fabricated from stainless and ferritic steels may be fabricated from a single alloy, eliminating problems associated with dissimilar welds.

In addition to the classification requirements in this specification, either impact toughness or high-temperature creep strength properties should be determined. Due to the influence of various levels of carbon and niobium (columbium), specific values and testing must be agreed to by the supplier and purchaser.

A7.16 ERXXS-G and EXXC-G Classifications. Electrodes and rods of the ERXXS-G and electrodes of the EXXC-G classifications are those filler metals not included in the preceding classes and for which only certain mechanical property requirements are specified. The electrodes are intended for single and multiple-pass applications. The filler metal supplier should be consulted for the composition, properties, characteristics, and intended use of these classifications (see A2.3 for further information).

A8. Special Tests

A8.1 It is recognized that supplementary tests may be required to determine suitability of these filler metals for certain applications involving properties not considered in this specification. In such cases, additional tests to determine specific properties of the weld metal, such as hardness, corrosion resistance, mechanical properties at higher or lower service temperatures, may be required. Those tests may be conducted as agreed between supplier and purchaser. ANSI/AWS A5.01 contains provisions for ordering such tests.

A8.2 Diffusible Hydrogen. Solid, composite stranded, and composite metal cored GMAW electrodes are generally considered to be low hydrogen consumables. When joining carbon steels containing 0.30 percent or less carbon, hydrogen-assisted cracking is unlikely to be of concern. However, when joining high-strength, low-alloy steel, weld metal or heat-affected-zone cracking associated with diffusible hydrogen tends to become more of a problem. Crack susceptibility increases as does the alloy content, weld metal strength, heat-affected-zone hardness, and diffusible hydrogen content. Susceptibility to hydrogen cracking is also greater when the preheat and interpass temperatures are decreased, or the time at or above the interpass temperature is shortened during welding. The appearance of hydrogen cracking is usually delayed some hours after cooling. It may appear as transverse weld cracks, longitudinal cracks (especially in root beads), and toe or underbead cracks in the heat-affected zone.

Since the available diffusible hydrogen level strongly influences the tendency towards hydrogen-assisted cracking, it may be desirable to measure the diffusible hydrogen content resulting from a particular electrode. Accordingly, the use of optional supplemental designators for diffusible hydrogen is introduced to indicate the maximum average value obtained under a clearly defined test condition in ANSI/AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*. Electrodes that are designated as meeting the lower or lowest hydrogen limits, as specified in Table 8, are also understood to be able to meet any higher electrode hydrogen limits, even though these are not necessarily designated along with the electrode classification. Therefore, as an example, an electrode being designated as "H4" also meets "H8" requirements without being designated as such.

The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values than those indicated by the designator.

The use of a reference atmospheric condition during welding is necessary because the arc always is imperfectly shielded. Moisture from the air, distinct from that in the electrode or gas, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. This effect can be minimized by maintaining a suitable gas-flow rate and as short an arc length as possible, consistent with a steady arc. At times, some air will mix with the gas and add its moisture to the other sources of diffusible hydrogen. It is possible for this extra diffusible hydrogen to significantly affect the outcome of a diffusible hydrogen test. For this reason, it is appropriate to specify a reference atmospheric condition. The reference atmospheric condition of 10 grains of moisture per pound (1.43 grams per kilogram) of dry air is equivalent to 10 percent relative humidity at 70°F (21°C) at 29.92 in. Hg (760 mm) barometric pressure. Actual conditions, measured using a calibrated psychrometer that equal or exceed this reference condition, provide assurance that the conditions during welding will not diminish the final results of the test.

A8.3 Aging of Tensile Specimens. Weld metals may contain significant quantities of hydrogen for some time after they have been made. Most of this hydrogen gradually escapes over time. This may take several weeks at room temperature or several hours at elevated temperatures. As a result of this eventual change in hydrogen level, ductility of the weld metal increases towards its inherent value, while yield, tensile, and impact strengths remain relatively unchanged. This specification permits the aging of the tensile test specimens at elevated temperatures up to 220°F (104 °C) for up to 48 hours before subjecting them to tension testing. The purpose of this treatment is to facilitate removal of hydrogen from the test specimen in order to minimize discrepancies in testing.

Aging treatments are sometimes used for low-hydrogen electrode deposits, especially when testing high-strength deposits. Note that aging may involve holding test specimens at room temperature for several days or holding at a higher temperature for a shorter period of time. Consequently, users are cautioned to employ adequate preheat and interpass temperatures to avoid the deleterious effects of hydrogen in production welds.

A9. Discontinued Classifications

The following classifications have been discontinued over the life of this specification:

Discontinued Classification	Published	Replaced With
ER100S-2	1979	—
ER80S-B2L	1979	ER70S-B2L
E80C-B2L	1979	E70C-B2L
ER90S-B3L	1979	ER80S-B3L
E90C-B3L	1979	E80C-B3L

A10. General Safety Considerations

A10.1 Burn Protection. Molten metal, sparks, slag, and hot-work surfaces are produced by welding, cutting, and allied processes. These can cause burns if precautionary measures are not used. Workers should wear protective clothing made of fire-resistant material. Pant cuffs, open pockets, or other places on clothing that can catch and retain molten metal or sparks should not be worn. High-top shoes or leather leggings and fire-resistant gloves should be worn. Pant legs should be worn over the outside of high-top shoes. Helmets or hand shields that provide protection for the face, neck, and ears, and a head covering to protect the head should be used. In addition, appropriate eye protection should be used.

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

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

Before leaving a work area, hot workpieces should be marked to alert other persons of this hazard. No attempt should be made to repair or disconnect electrical equipment when it is under load.

Disconnection under load produces arcing of the contacts and may cause burns or shock, or both. *Note: Burns can be caused by touching hot equipment such as electrode holders, tips, and nozzles. Therefore, insulated gloves should be worn when these items are handled, unless an adequate cooling period has been allowed before touching.*

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

(1) American National Standards Institute. ANSI Z41.1, *Safety-Toe Footwear*. New York: American National Standards Institute.[6]

(2) ——. ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*. Miami, FL: American Welding Society.

(3) ——. ANSI Z87.1, *Practice for Occupational and Educational Eye and Face Protection*. New York: American National Standards Institute.

(4) Occupational Safety and Health Administration. *Code of Federal Regulations*, Title 29 Labor, Chapter XVII, Part 1910. Washington, DC: U.S. Government Printing Office.[7]

A10.2 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 workpiece should not be mistaken for a ground connection.

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

To prevent shock, the work area, equipment, and clothing should be kept dry at all times. Welders should wear dry gloves and rubber-soled shoes, or stand on a dry board or insulated platform. Cables and connections should be kept in good condition. Improper or worn electrical connections may create conditions that could cause electrical shock or short circuits. Worn, damaged, or bare cables should not be used. Open-circuit voltage should be avoided. When several welders are working with arcs of different polarities, or when a number of alternating current machines are being used, the open-circuit voltages can be additive. The added voltages increase the severity of the shock hazard.

In case of electric shock, the power should be turned off. If the rescuer must resort to pulling the victim from the live contact, nonconducting materials should be used. If the victim is not breathing, cardiopulmonary resuscitation (CPR) should be administered as soon as contact with the electrical source is broken. A physician should

6. ANSI documents are available from the American National Standards Institute, 11 West 42 Street, New York, NY 10036

7. OSHA documents are available from U.S. Government Printing Office, Washington, DC 20402

be called and CPR continued until breathing has been restored, or until a physician has arrived. Electrical burns are treated as thermal burns; that is, clean, cold (iced) compresses should be applied. Contamination should be avoided; the area should be covered with a clean, dry dressing; and the patient should be transported to medical assistance.

Recognized safety standards such as ANSI/ASC Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and NFPA No. 70, *National Electrical Code*, should be followed.[8]

A10.3 Fumes and Gases. Many welding, cutting, and allied processes produce fumes and gases which may be harmful to health. Fumes are solid particles which originate from welding filler metals and fluxes, the base metal, and any coatings present on the base metal. Gases are produced during the welding process or may be produced by the effects of process radiation on the surrounding environment. Management personnel and welders alike should be aware of the effects of these fumes and gases. The amount and composition of these fumes and gases depend upon the composition of the filler metal and base metal, welding process, current level, arc length, and other factors.

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

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

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

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

(2) The recommended threshold limit values for 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).[9]

(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 for the product.

A10.4 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.

A10.4.1 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.

A10.4.2 Nonionizing Radiation. The intensity and wavelengths of nonionizing radiant energy produced depend on many factors, such as the process, welding parameters, electrode and base-metal composition, fluxes, and any coating or plating on the base metal. Some processes such as resistance welding and cold pressure welding ordinarily produce negligible quantities of radiant energy. However, most arc welding and cutting processes (except submerged arc when used properly), laser welding and torch welding, cutting, brazing, or soldering can produce quantities of nonionizing radiation such that precautionary measures are necessary.

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

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

(2) Exposed skin should be protected with adequate gloves and clothing as specified in ANSI Z49.1, *Safety in*

8. NFPA documents are available form the National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269.

9. ACGIH documents are available form the American Conference of Governmental Industrial Hygienists, Kemper Woods Center, 1330 Kemper Meadow Drive, Cincinnati, OH 45240.

Welding, Cutting, and Allied Processes, published by American Welding Society.

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

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

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

A10.4.3 Ionizing radiation information sources include the following:

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

(2) Manufacturer's product information literature.

A10.4.4 The following include nonionizing radiation information sources:

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

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

(3) ——. ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*. (published by AWS) Miami, FL: American Welding Society.

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

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

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

(7) Marshall, W. J., Sliney, D. H. and others. "Optical radiation levels produced by air-carbon arc cutting processes." *Welding Journal*, March 1980.

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

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

AWS Filler Metal Specifications Listed by Material and Welding Process

Relationships of A5 Documents	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	A5.9	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, A5.3
Aluminum Alloys	—	A5.3	A5.10	—	—	—	—	A5.8, A5.3
Copper Alloys	—	A5.6	A5.7	—	—	—	—	A5.8, A5.3
Titanium Alloys	—	—	A5.16	—	—	—	—	A5.8, A5.31
Zirconium Alloys	—	—	A5.24	—	—	—	—	A5.8, A5.31
Magnesium Alloys	—	—	A5.19	—	—	—	—	A5.8, A5.31
Tungsten Electrodes	—	—	A5.12	—	—	—	—	—
Brazing Alloys and Fluxes	—	—	—	—	—	—	—	A5.8, A5.31
Surfacing Alloys	A5.13, A5.21	A5.13, A5.21	A5.13, A5.21	—	—	—	—	—
Consumable Inserts			A5.30					
Shielding Gases			A5.32	A5.32			A5.32	

AWS Filler Metal Specifications and Related Documents

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

For ordering information, contact the Order Department, American Welding Society, 550 N.W. LeJeune Road Miami, FL 33126. Phone: 1-800-334-9353.