AWS A5.28/A5.28M:2005 (R2015)
An American National Standard

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

American Welding Society®

Approved American National Standard
ANSI

AWS A5.28/A5.28M:2005 (R2015)
An American National Standard

Approved by the
American National Standards Institute
July 21, 2015

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

3rd Edition

Supersedes ANSI/AWS A5.28-96

Prepared by the
American Welding Society (AWS) A5 Committee on Filler Metals and Allied Materials

Under the Direction of the
AWS Technical Activities Committee

Approved by the
AWS Board of Directors

Abstract

This specification prescribes the requirements for classification of 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. Classification is based on chemical composition of the electrode for solid electrodes and rods, chemical composition of weld metal for composite stranded and composite metal cored electrodes and the as-welded or postweld heat treated mechanical properties of the weld metal for each. Additional requirements are included for manufacture, sizes, lengths, and packaging. A guide is appended to the specification as a source of information concerning the classification system employed and the intended use of the electrodes and rods.

This specification makes use of both U.S. Customary Units and the International System of Units (SI). Since these units are not equivalent, each system must be used independently of the other.

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Foreword

This foreword is not part of AWS A5.28/A5.28M:2005 (R2015), *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*, but is included for informational purposes only.

This document is the first of the A5.28 specifications which makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore each system must be used independently of the other, without combining values in any way. In selecting rational metric units, AWS A1.1 *Metric Practice Guide for the Welding Industry* and ISO 544, *Welding consumables—Technical delivery conditions for welding filler materials—Type of product, dimensions, tolerances, and markings,* are used where suitable. Tables and figures make use of both U.S. Customary and SI Units, which, with the application of the specified tolerances, provide for interchangeability of products in both U.S. Customary and SI Units.

The current document is the second revision of the initial AWS document issued in 1979.

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

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

AWS A5.28-96 *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*

Comments and suggestions for the improvement of this standard are welcome. They should be sent to the Secretary, AWS A5 Committee on Filler Metals and Allied Materials, American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

Errata

The following Errata have been identified and incorporated into the current reprint of this document.

Page 26—Figure A2, Optional GTAW Groove Weld Test Assembly for Mechanical Properties and Soundness

Change dimensions in the Dimension table as shown below:

DIMENSIONS			
		in	mm
C	Specimen Center	~~3/8~~ 1/4	~~9.5~~ 6.5
L	Length, min.	10	250
P	Point of Temperature Measurement	1	25
R	Root Opening	~~1/2~~ 1/4	~~13~~ 6.5
S	Backup Strip Overlap, min.	~~1/4~~ 3/8	~~6~~ 9
T	Thickness	~~3/4~~ 1/2	~~19~~ 13
V	Backup Strip Thickness, min.	~~3/8~~ 1/4	~~9~~ 6.5
W	Width, min.	5	125
X	Backup Strip Width, min.	1	25
Z	Discard, min.	1	25

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

1. Scope

1.1 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 (GMAW), gas tungsten arc (GTAW), and plasma arc (PAW) welding.

1.2 Safety and health issues and concerns are beyond the scope of this standard and therefore are not fully addressed herein. Some safety and health information can be found in the informative Annex Clauses A5 and A10. Safety and health information is available from other sources, including but not limited to ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes*, and applicable federal and state regulations.

1.3 This specification makes use of both U.S. Customary Units and the International System of Units (SI). The measurements are not exact equivalents; therefore, each system must be used independently of the other without combining in any way when referring to weld metal properties. The specification with the designation A5.28 uses U.S. Customary Units. The specification A5.28M uses SI Units. The latter are shown within brackets [ ] or in appropriate columns in tables and figures. Standard dimensions based on either system may be used for sizing of electrodes or packaging or both under the A5.28 or A5.28M specifications.

2. Normative References

The following standards contain provisions which, through reference in this text, constitute provisions of this AWS standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreement based on this AWS standard are encouraged to investigate the possibility of applying the most recent editions of the documents shown below. For undated references, the latest edition of the standard applies.

2.1 ASTM Standards[1]

(1) A36/A36M, *Specification for Carbon Structural Steel*

(2) A203/A203M, *Specification for Pressure Vessel Plates, Alloy Steel, Nickel*

(3) A285/A285M, *Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*

(4) A387/A387M, *Specification for Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum*

(5) A515/A515M, *Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

(6) A516/A516M, *Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

(7) A537/A537M, *Specification for Pressure Vessel Plates, Heat-Treated, Carbon-Manganese-Silicon Steel*

[1] ASTM standards are published by ASTM International, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

(8) E29, *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

(9) E350, *Standard Test Method for Chemical Analysis of Carbon Steel, Low Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron*

(10) E1032, *Standard Test Method for Radiographic Examination of Weldments.*

2.2 AWS Standards[2]

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

(2) AWS A5.32/A5.32M, *Specification for Welding Shielding Gases*

(3) AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*

(4) AWS B4.0, *Standard Methods for Mechanical Testing of Welds*

(5) AWS B4.0M, *Standard Methods for Mechanical Testing of Welds*

2.3 ANSI Standard[3]

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

2.4 ISO Specification[4]

(1) ISO 544, *Welding consumables—Technical delivery conditions for welding filler materials—Type of product, dimensions, tolerances and markings*

2.5 Department of Defense Specification[5]

(1) MIL-S-16216, *Military Specification, Steel Plate, Alloy, Structural, High Yield Strength (HY-80 and HY-100)*

3. Classification

3.1 The solid electrodes (and rods) covered by this A5.28 specification utilize a classification system based upon U.S. Customary Units and 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 stranded electrodes and composite metal cored electrodes covered by this specification also utilize a classification system based upon U.S. Customary Units and 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.

3.1M The solid electrodes (and rods) covered by this A5.28M specification utilize a classification system based upon the International System of Units (SI) and 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 stranded electrodes and composite metal cored electrodes covered by this specification also utilize a classification system based upon the International System of Units (SI) and 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] AWS standards are published by the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.
[3] This ANSI standard is published by the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.
[4] ISO standards are published by the International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland.
[5] Department of Defense standards are published by DODSSP, Standardization Documents Order Desk, 700 Robbins Avenue, Bldg. 4D, Philadelphia, PA 19111-5094.

Table 1
Chemical Composition Requirements for Solid Electrodes and Rods

AWS Classification[c]			Weight Percent[a, b]													
A5.28	A5.28M	UNS Number[d]	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	ER49S-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	ER55S-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	ER49S-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	ER62S-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	ER55S-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]	ER55S-B6[f]	S50280	0.10	0.40–0.70	0.50	0.025	0.025	0.60	4.50–6.00	0.45–0.65	—	—	—	—	0.35	0.50
ER80S-B8[g]	ER55S-B8[g]	S50480	0.10	0.40–0.70	0.50	0.025	0.025	0.50	8.00–10.50	0.80–1.20	—	—	—	—	0.35	0.50
ER90S-B9[h,i,j]	ER62S-B9[h,i,j]	S50482	0.07–0.13	1.20	0.15–0.50	0.010	0.010	0.80	8.00–10.50	0.85–1.20	0.15–0.30	—	—	0.04	0.20	0.50
Nickel Steel Electrodes and Rods																
ER80S-Ni1	ER55S-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	ER55S-NI2	K21240	0.12	1.25	0.40–0.80	0.025	0.025	2.00–2.75	—	—	—	—	—	—	0.35	0.50
ER80S-Ni3	ER55S-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 ER90S-D2	ER55S-D2 ER62S-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	ER69S-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	ER76S-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	ER83S-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	ERXXS-G	—	Not Specified[k]													

[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 maximum.
[c] The suffixes B2, Nil, etc., designate the chemical composition of the electrode and rod classification.
[d] SAE HS-1086/ASTM DS-56H, *Metals & Alloys in the Unified Numbering System*.
[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 0.50% max.
[f] Similar to former class ER502 in AWS Specification A5.9-93.
[g] Similar to former class ER505 in AWS Specification A5.9-93.
[h] Niobium (Columbium) 0.02–0.10%.
[i] Nitrogen 0.03–0.07%.
[j] The sum of Mn and Ni shall be less than or equal to 1.50% max.
[k] In order to meet the requirement of the "G" classification, the electrode must have a minimum of one or more of the following: 0.50% Nickel, 0.30% Chromium, or 0.20% Molybdenum. The 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]			Weight Percent[b, c]													
A5.28	A5.28M	UNS Number[e]	C	Mn	Si	P	S	Ni	Cr	Mo	V	Ti	Zr	Al	Cu	Other Elements, Total
Chromium–Molybdenum Weld Metal																
E80C-B2	E55C-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	0.03	—	—	—	—	0.50
E70C-B2L	E49C-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	0.03	—	—	—	0.35	0.50
E90C-B3	E62C-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	0.03	—	—	—	0.35	0.50
E80C-B3L	E55C-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	0.03	—	—	—	0.35	0.50
E80C-B6	E55C-B6		0.10	0.40–1.00	0.25–0.60	0.025	0.025	0.60	4.50–6.00	0.45–0.65	0.03	—	—	—	0.35	0.50
E80C-B8	E55C-B8		0.10	0.40–1.00	0.25–0.60	0.025	0.025	0.20	8.00–10.50	0.80–1.20	0.03	—	—	—	0.35	0.50
E90C-B9[f]	E55C-B9		0.08–0.13	1.20[g]	0.50	0.020	0.015	0.80[g]	8.00–10.50	0.85–1.20	0.15–0.30	—	—	0.04	0.20	0.50
Nickel Steel Electrodes and Rods																
E80C-Ni1	E55C-Ni1	W21030	0.12	1.50	0.90	0.025	0.030	0.80–1.10	—	0.30	0.03	—	—	—	0.35	0.50
E70C-Ni2	E49C-Ni2	W22030	0.08	1.25	0.90	0.025	0.030	1.75–2.75	—	—	0.03	—	—	—	0.35	0.50
E80C-Ni2	E55C-Ni2	W22030	0.12	1.50	0.90	0.025	0.030	1.75–2.75	—	—	0.03	—	—	—	0.35	0.50
E80C-Ni3	E55C-Ni3	W23030	0.12	1.50	0.90	0.025	0.030	2.75–3.75	—	—	0.03	—	—	—	0.35	0.50
Manganese–Molybdenum Steel Electrodes and Rods																
E90C-D2	E62C-D2	W19230	0.12	1.00–1.90	0.90	0.025	0.030	—	—	0.40–0.60	0.03	—	—	—	0.35	0.50
Other Low-Alloy Steel Electrodes and Rods																
E90C-K3	E62C-K3		0.15	0.75–2.25	0.80	0.025	0.025	0.50–2.50	0.15	0.25–0.65	0.03	—	—	—	0.35	0.50
E100C-K3	E69C-K3		0.15	0.75–2.25	0.80	0.025	0.025	0.50–2.50	0.15	0.25–0.65	0.03	—	—	—	0.35	0.50
E110C-K3	E76C-K3		0.15	0.75–2.25	0.80	0.025	0.025	0.50–2.50	0.15	0.25–0.65	0.03	—	—	—	0.35	0.50
E110C-K4	E76C-K4		0.15	0.75–2.25	0.80	0.025	0.025	0.50–2.50	0.15–0.65	0.25–0.65	0.03	—	—	—	0.35	0.50
E120C-K4	E83C-K4		0.15	0.75–2.25	0.80	0.025	0.025	0.50–2.50	0.15–0.65	0.25–0.65	0.03	—	—	—	0.35	0.50
E80C-W2	E55C-W2		0.12	0.50–1.30	0.35–0.80	0.025	0.030	0.40–0.80	0.45–0.70	—	0.03	—	—	—	0.30–0.75	0.50
EXXC-G	EXXC-G	—	Not Specified[h]													

[a] Chemical requirements for composite electrodes are based on analysis of their weld metal in the as-welded condition 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 those elements shall be determined to ensure that their total (excluding iron) does not exceed the limits specified for "Other Elements, Total."
[c] Single values are maximum.
[d] Solid electrodes are generally recommended for gas tungsten arc welding (GTAW) or plasma arc welding (PAW).
[e] SAE HS-1086/ASTM DS-56H, *Metal & Alloys in the Unified Numbering System*.
[f] Niobium (Columbium) 0.02–0.10%, Nitrogen 0.03–0.07%.
[g] The sum of Mn and Ni shall be 1.50% max.
[h] 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% Nickel, 0.30% Chromium, or 0.20% Molybdenum. The 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)		Yield Strength[b] (minimum)		Elongation[b] Percent (minimum)	Testing Condition
A5.28	A5.28M		psi	MPa	psi	MPa		
ER70S-B2L E70C-B2L ER70S-A1	ER49S-B2L E49C-B2L ER49S-A1	Argon/1–5% O_2 (Classes SG-AO-1 thru SG-AO-5)	75 000	515	58 000	400	19	PWHT[c]
ER80S-B2 E80C-B2	ER55S-B2 E55C-B2		80 000	550	68 000	470	19	
ER80S-B3L E80C-B3L	ER55S-B3L E55C-B3L		80 000	550	68 000	470	17	
ER90S-B3 E90C-B3	ER62S-B3 E62C-B3		90 000	620	78 000	540	17	
ER80S-B6	ER55S-B6		80 000	550	68 000	470	17	
E80C-B6	E55C-B6		80 000	550	68 000	470	17	
ER80S-B8	ER55S-B8		80 000	550	68 000	470	17	
E80C-B8	E55C-B8		80 000	550	68 000	470	17	
ER90S-B9	ER62S-B9	Argon/5% O_2 (Class SG-AC-5)	90 000	620	60 000	410	16	
E90C-B9	E62C-B9	Argon/5–25% CO_2 (Classes SG-AC-5 thru SG-AC-25)						
E70C-Ni2	E49C-Ni2	Argon/1–5% O_2 (Classes SG-AO-1 thru SG-AO-5)	70 000	490	58 000	400	24	PWHT[c]
ER80S-Ni1 E80C-Ni1	ER55S-Ni1 E55C-Ni1		80 000	550	68 000	470	24	As-Welded
ER80S-Ni2 E80C-Ni2 ER80S-Ni3 E80C-Ni3	ER55S-Ni2 E55C-Ni2 ER55S-Ni3 E55C-Ni3		80 000	550	68 000	470	24	PWHT[c]
ER80S-D2	ER55S-D2	CO_2 (Class SG-C)	80 000	550	68 000	470	17	As-Welded
ER90S-D2 E90C-D2	ER62S-D2 E62C-D2	Argon/1–5% O_2 (Classes SG-AO-1 thru SG-AO-5)	90 000	620	78 000	540	17	
ER100S-1	ER69S-1	Argon/2% O_2 (Class SG-AO-2)	100 000	690	88 000	610	16	
ER110S-1	ER76S-1		110 000	760	95 000	660	15	
ER120S-1	ER83S-1		120 000	830	105 000	730	14	
E90C-K3	E62C-K3	Argon/5–25% CO_2 (Classes SG-AC-5 thru SG-AC-25)	90 000	620	78 000	540	18	
E100C-K3	E69C-K3		100 000	690	88 000	610	16	
E110C-K3 E110C-K4	E76C-K3 E76C-K4		110 000	760	98 000	680	15	
E120C-K4	E83C-K4		120 000	830	108 000	750	15	
E80C-W2	E55C-W2		80 000	550	68 000	470	22	

(Continued)

Table 3 (Continued)
Tension Test Requirements

AWS Classification		Shielding Gas[a]	Tensile Strength (minimum)		Yield Strength[b] (minimum)		Elongation[b] Percent (minimum)	Testing Condition
A5.28	A5.28M		psi	MPa	psi	MPa		
ER70S-G E70C-G	ER49S-G E49C-G	(d)	70 000	490	(e)	(e)	(e)	(e)
ER80S-G E80C-G	ER55S-G E55C-G	(d)	80 000	550	(e)	(e)	(e)	(e)
ER90S-G E90C-G	ER62S-G E62C-G	(d)	90 000	620	(e)	(e)	(e)	(e)
ER100S-G E100C-G	ER69S-G E69C-G	(d)	100 000	690	(e)	(e)	(e)	(e)
ER110S-G E110C-G	ER76S-G E76C-G	(d)	110 000	760	(e)	(e)	(e)	(e)
ER120S-G E120C-G	ER83S-G E83C-G	(d)	120 000	830	(e)	(e)	(e)	(e)

[a] The use of a particular shielding gas for classification purposes shall not be construed to restrict the use of other 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).

3.2 Electrodes and rods classified under one classification shall not be classified under any other classification in this specification, except that ER80S-D2 [ER55S-D2] may also be classified as ER90S-D2 [ER62S-D2] provided the product meets the requirements of both classifications. However, material may be classified under both A5.28 AND A5.28M specifications.

3.3 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.

4. Acceptance

Acceptance[6] of the electrodes and rods shall be in accordance with the provisions of AWS A5.01.

5. Certification

By affixing the AWS specification and classification designations to the packaging, or the classification to the product, the manufacturer certifies that the product meets the requirements of this specification.[7]

[6] See Clause A3, Acceptance (in Annex A) for further information concerning acceptance, testing of the material shipped, and AWS A5.01.
[7] See Clause A4, Certification (in Annex A) for further information concerning certification and the testing called for to meet this requirement.

Table 4
Impact Test Requirements

AWS Classification		Average Impact Energy Absorbed[a, b] (Minimum)		
A5.28	A5.28M	A5.28	A5.28M	Testing Condition
ER70S-A1 ER70S-B2L E70C-B2L ER80S-B2 E80C-B2 ER80S-B3L E80C-B3L ER90S-B3 E90C-B3 ER80S-B6 E80C-B6 ER80S-B8 E80C-B8 ER90S-B9 E90C-B9	ER49S-A1 ER49S-B2L E49C-B2L ER55S-B2 E55C-B2 ER55S-B3L E55C-B3L ER62S-B3 E62C-B3 ER55S-B6 E55C-B6 ER55S-B8 E55C-B8 ER62S-B9 E62C-B9	Not Required	Not Required	—
ER80S-Nil E80C-Nil	ER55S-Nil E55C-Nil	20 ft·lbf at –50°F	27 J at –45°C	As-Welded
E70C-Ni2 ER80S-Ni2 E80C-Ni2	E49C-Ni2 ER55S-Ni2 E55C-Ni2	20 ft·lbf at –80°F	27 J at –60°C	PWHT[b]
ER80S-Ni3 E80C-Ni3	ER55S-Ni3 E55C-Ni3	20 ft·lbf at –100°F	27 J at –75°C	PWHT[b]
ER80S-D2 ER90S-D2 E90C-D2	ER55S-D2 ER62S-D2 E62C-D2	20 ft·lbf at –20°F	27 J at –30°C	As-Welded
ER100S-1 ER110S-1 ER120S-1	ER69S-1 ER76S-1 ER83S-1	50 ft·lbf at –60°F	68 J at –50°C	As-Welded
E90C-K3 E100C-K3 E110C-K3 E110C-K4 E120C-K4	E62C-K3 E69C-K3 E76C-K3 E76C-K4 E83C-K4	20 ft·lbf at –60°F	27 J at –50°C	As-Welded
E80C-W2	E55C-W2	20 ft·lbf at –20°F	27 J at –30°C	As-Welded
ERXXS-G EXXC-G	ERXXS-G EXXC-G	As agreed between supplier and purchaser	As agreed between supplier and purchaser	— —

[a] Both the highest and lowest of the five test values obtained shall be disregarded in computing the average impact energy absorbed.
For classifications requiring 20 ft·lbf [27J]: Two of the remaining three values shall equal or exceed 20 ft·lbf [27 J]; one of the three remaining values may be lower than 20 ft·lbf [27 J], but not lower than 15 ft·lbf [20 J]. The average of the three shall not be less than the 20 ft·lbf [27 J] specified.
For classification requiring 50 ft·lbf [68J]: 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.

6. Rounding Procedure

For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi [10 MPa] 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.

7. Summary of Tests

7.1 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 Clauses 9 through 13. See A4.2 in Annex A for requirements for classification based on gas tungsten arc welding (GTAW) only.

7.2 The optional test for diffusible hydrogen in Clause 14, Diffusible Hydrogen Test, is not required for classification. See Note (a) of Table 5.

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. 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 their 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 specified or proper procedures were not followed in preparing the weld test assembly or test specimens, or in conducting the test, the test shall be considered invalid, without regard to whether the test was actually completed, or whether the test results met, or failed to meet, the requirement. That test shall be repeated, following proper specified procedures. In this case, the requirement for doubling the number of test specimens does not apply.

9. Weld Test Assemblies

9.1 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 (see A4.2 in Annex A for requirements for classification based on gas tungsten arc welding only).

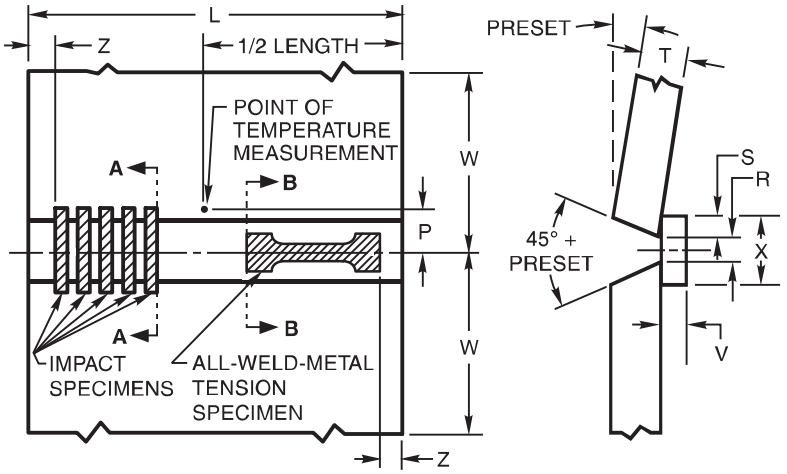
(2) The weld pad in Figure 2 for chemical analysis of the weld metal from composite stranded and composite metal cored electrodes.

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 (or any location above it) in the groove weld in Figure 1, thereby avoiding the need to make a weld pad. In case of dispute, the weld pad in Figure 2 shall be the referee method.

Table 5
Required Tests

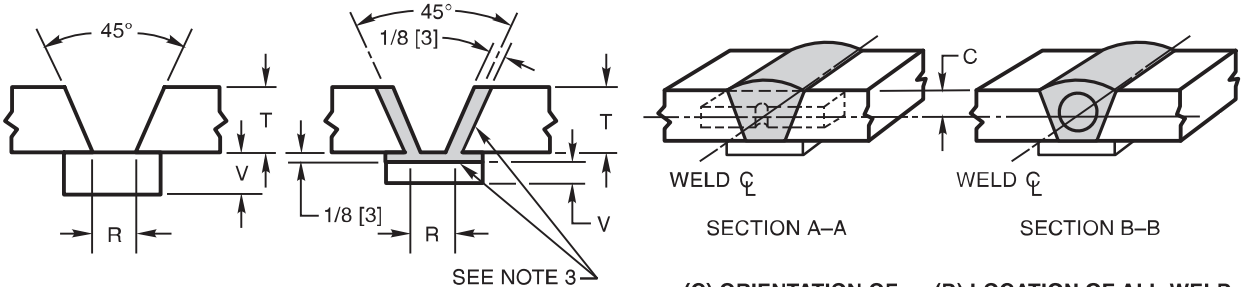
AWS Classification		Chemical Analysis		Radiographic Test	Tension Test	Impact Test	Diffusible Hydrogen Test
A5.28	A5.28M	Electrode	Weld Metal				
Solid Electrodes							
ER70S-A1 ER80S-B2 ER70S-B2L ER90S-B3 ER80S-B3L ER80S-B6 ER80S-B8 ER90S-B9	ER49S-A1 ER55S-B2 ER49S-B2L ER62S-B3 ER55S-B3L ER55S-B6 ER55S-B8 ER62S-B9	Required	Not Required	Required	Required	Not Required	(a)
ER80S-Ni1 ER80S-Ni2 ER80S-Ni3	ER55S-Ni1 ER55S-Ni2 ER55S-Ni3	Required	Not Required	Required	Required	Required	(a)
ER80S-D2 ER90S-D2	ER55S-D2 ER62S-D2	Required	Not Required	Required	Required	Required	(a)
ER100S-1 ER110S-1 ER120S-1	ER69S-1 ER76S-1 ER83S-1	Required	Not Required	Required	Required	Required	(a)
ERXXS-G	ERXXS-G	Required[b]	Not Required	Required	Required	Not Required	(a)
Composite Metal Cored Electrodes							
E80C-B2 E70C-B2L E90C-B3 E80C-B3L E80C-B6 E80C-B8 E90C-B9	E55C-B2 E49C-B2L E62C-B3 E55C-B3L E55C-B6 E55C-B8 E62C-B9	Not Required	Required	Required	Required	Not Required	(a)
E80C-Ni1 E70C-Ni2 E80C-Ni2 E80C-Ni3	E55C-Ni1 E49C-Ni2 E55C-Ni2 E55C-Ni3	Not Required	Required	Required	Required	Required	(a)
E90C-D2	E62C-D2	Not Required	Required	Required	Required	Required	(a)
E90C-K3 E100C-K3 E110C-K3 E110C-K4 E120C-K4	E62C-K3 E69C-K3 E76C-K3 E76C-K4 E83C-K4	Not Required	Required	Required	Required	Required	(a)
E80C-W2	E55C-W2	Not Required	Required	Required	Required	Required	(a)
EXXC-G	EXXC-G	Not Required	Required[b]	Required	Required	Not Required	(a)

[a] Optional diffusible hydrogen test is required only when specified by the purchaser or when the manufacturer puts the diffusible hydrogen designator on the label. (Also see A2.2 and A8.2 in Annex A.)
[b] To be reported (see A7.19 in Annex A).



DIMENSIONS			
		in	mm
C	Specimen Center	3/8	9.5
L	Length, min.	10	250
P	Point of Temperature Measurement	1	25
R	Root Opening	1/2	13
S	Backup Strip Overlap, min.	1/4	6
T	Thickness	3/4	19
V	Backup Strip Thickness, min.	3/8	9
W	Width, min.	5	125
X	Backup Strip Width, min.	1	25
Z	Discard, min.	1	25

(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



(B) GROOVE PREPARATION OF TEST PLATE

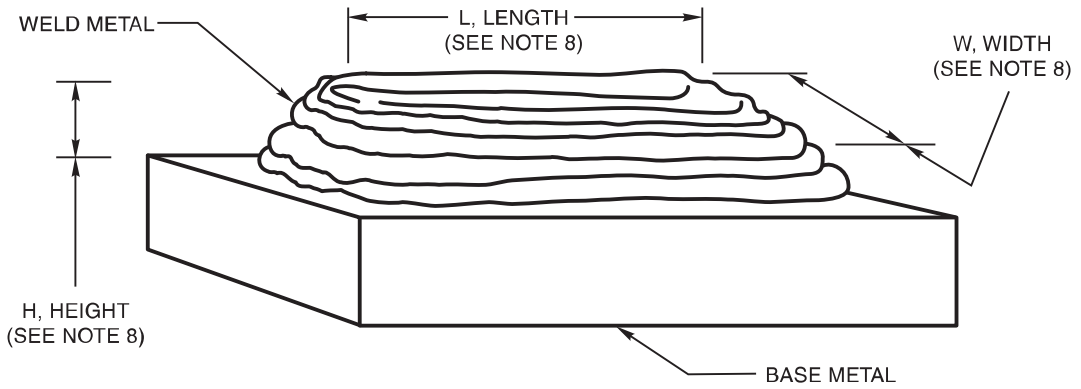
(C) ORIENTATION OF IMPACT SPECIMEN

(D) LOCATION OF ALL-WELD-METAL TENSION SPECIMEN

Test Conditions for Solid Electrodes[4, 5]		
Standard Size[7]	0.045 in [1.2 mm]	1/16 in [1.6 mm]
Shielding Gas[8]	See Table 3	See Table 3
Wire Feed Speed	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
Resulting Current, DCEP[9] (DCEP = Electrode Positive)	300 to 360A[6]	340 to 420A[6]
Contact-Tip-to-Work Distance[10]	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]

Notes:
1. Base metal shall be as specified in Table 6. The surfaces to be welded shall be clean.
2. 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.
3. 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.
4. Test conditions for composite electrodes shall be as recommended by the manufacturer.
5. Preheat and interpass temperatures for both solid and composite electrodes shall be as specified in Table 7.
6. For ER80S-D2 [ER55S-D2] classification, the amperage range for 0.045 in [1.2 mm] shall be 260 A to 320 A and for 1/16 in [1.6 mm], 330 A to 410 A.
7. If sizes other than 0.045 in and 1/16 in [1.2 mm and 1.6 mm] are tested, wire feed speed (and resulting current), arc voltage, and contact-tip-to-work distance shall be changed as needed. This joint configuration is not recommended for electrode sizes smaller than 0.035 in [0.9 mm].
8. 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.
9. The required combination of electrode feed rate, arc voltage, and contact-tip-to-work distance should produce welding currents in the ranges shown. Currents substantially outside these ranges suggest errors in feed rate, contact-tip-to-work distance, voltage settings, or in instrumentation.
10. Distance from the contact tip to the work, not from the shielding gas cup to the work.

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



Notes:
1. Base metal of any convenient size, of any type specified in Table 6, shall be used as the base for the weld pad.
2. The surface of the base metal on which the filler metal is to be deposited shall be clean.
3. The pad shall be welded in the flat position with successive layers to obtain weld metal of sufficient height.
4. 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.
5. The preheat temperature shall not be less than 60°F [15°C] and the maximum interpass temperature shall not exceed that specified in Table 7.
6. Any slag shall be removed after each pass.
7. The test assembly may be quenched in water between passes to control interpass temperature.
8. The minimum completed pad size shall be at least four layers in height (H). The sample for analysis shall be taken at least 3/8 in [9.5 mm] above the original base metal surface.The length (L), after allowance for start and stop areas, and width (W) shall be sufficient to perform analysis.

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

9.2 Preparation of each weld test assembly shall be as specified in 9.3 and 9.4. The base metal for each assembly shall be as required in Table 6 and shall meet the requirements of the specification shown there, or an equivalent specification. Testing of the assembly shall be as specified in 10.2, 10.3, and Clauses 11 through 13.

9.3 Groove Weld

9.3.1 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 or 1/16 in [1.2 mm or 1.6 mm] size (or the size the manufacturer produces that is closest to one of these, if these sizes are not produced). See A4.2 in Annex A for requirements for classification based on gas tungsten arc welding (GTAW) only.

Welding shall be in the flat position, and the assembly shall be restrained (or preset) during welding to prevent warpage in excess of 5°. An assembly that is warped more than 5° out of plane shall be discarded. Test assemblies shall not be straightened. The test assembly shall be tack welded at or above room temperature and welding shall begin at the preheat temperature specified in Table 7. Welding shall continue until the assembly has reached the interpass temperature specified in Table 7, measured by temperature indicating crayons or surface thermometers at the location shown in Figure 1.

For the remainder of the weld, the preheat temperature and interpass temperature as specified in Table 7 shall be maintained. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be preheated to the temperature specified 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 Clauses 11, Radiographic Test; 12, Tension Test; and 13, Impact Test. Testing shall be performed in the as-welded or postweld heat-treated condition, as specified in Tables 3 and 4.

Table 6
Base Metal for Test Assemblies

AWS Classification		Base Metal	
A5.28	A5.28M	ASTM Standard[a]	UNS Number[b]
ER70S-B2L E70C-B2L ER80S-B2 E80C-B2	ER49S-B2L E49C-B2L ER55S-B2 E55C-B2	A387 Grade 11	K11789
ER80S-B3L E80C-B3L ER90S-B3 E90C-B3	ER55S-B3L E55C-B3L ER62S-B3 E62C-B3	A387 Grade 22	K21590
ER80S-B6 E80C-B6	ER55S-B6 E55C-B6	A387 Grade 5	S50200
ER80S-B8 E80C-B8	ER55S-B8 E55C-B8	A387 Grade 9	S50400
ER90S-B9 E90C-B9	ER62S-B9 E62C-B9	A387 Grade 91	S50460
ER80S-Ni1 E80C-Ni1	ER55S-Ni1 E55C-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	K22103, K21702, or J42015
E70C-Ni2 ER80S-Ni2 E80C-Ni2	E49C-Ni2 ER55S-Ni2 E55C-Ni2	A203 Grade A or B, or HY-80 steel in accordance with MIL-S-16216	K22103, K21703, or J42015
ER80S-Ni3 E80C-Ni3	ER55S-Ni3 E55C-Ni3	A203 Grade D or E, or HY-80 steel in accordance with MIL-S-16216	K31718, K32018, or J42015
ER70S-A1 ER80S-D2 ER90S-D2 E90C-D2	ER49S-A1 ER55S-D2 ER62S-D2 E62C-D2	A36, A285 Grade C, A515 Grade 70, or A516 Grade 70	K02600, K03101, or K02700
ER100S-1 ER110S-1 ER120S-1	ER69S-1 ER76S-1 ER83S-1	HY-80 or HY-100 steel in accordance with MIL-S-16216	J42015 or J42240
E90C-K3 E100C-K3 E110C-K3 E110C-K4 E120C-K4	E62C-K3 E69C-K3 E76C-K3 E76C-K4 E83C-K4	A514 or A517, any grade, or HY-80 or HY-100 steel in accordance with MIL-S-16216	K11511, K11576, K11625, K11630, K11646, K11683, K11856, K21604, or K21650 or J42015 or J42240
E80C-W2	E55C-W2	A572 or A588, any grade in these specifications, or A709 Gr. 50W	K02303, K02304, K02305, K02306, K11430, K12040, K12043, or K11538
ERXXS-G EXXC-G	ERXXS-G EXXC-G	See Note (a)	—

[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. Weld pads for chemical analysis meeting minimum height requirements of Figure 2 are not subject to additional buttering requirements. 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] SAE-HS-1086/ASTM DS-58H, *Metals & Alloys in the Unified Numbering System*.

Table 7
Preheat, Interpass, and Postweld Heat Treatment Temperatures

AWS Classification		Preheat and Interpass Temperature[a]		PWHT Temperature[a]	
A5.28	A5.28M	°F	°C	°F	°C
ER70S-A1 ER80S-B2 E80C-B2 ER70S-B2L E70C-B2L	ER49S-A1 ER55S-B2 E55C-B2 ER49S-B2L E49C-B2L	275–325	135–165	1150 ± 25	620 ± 15
ER90S-B3 E90C-B3 ER80S-B3L E80C-B3L	ER62S-B3 E62C-B3 ER55S-B3L E55C-B3L	375–425	185–215	1275 ± 25	690 ± 15
ER80S-B6 E80C-B6	ER55S-B6 E55C-B6	350–450	177–232	1375 ± 25	745 ± 15
ER80S-B8 E80C-B8	ER55S-B8 E55C-B8	400–500	205–260	1375 ± 25	745 ± 15
ER90S-B9 E90C-B9	ER62S-B9 E62C-B9	400–600	205–320	1400 ± 25[c]	760 ± 15[c]
E70C-Ni2 ER80S-Ni2 E80C-Ni2 ER80S-Ni3 E80C-Ni3	E49C-Ni2 ER55S-Ni2 E55C-Ni2 ER55S-Ni3 E55C-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 E90C-K3 E100C-K3 E110C-K3 E110C-K4 E120C-K4 E80C-W2	ER55S-D2 ER62S-D2 E62C-D2 ER55S-Ni1 E55C-Ni1 ER69S-1 ER76S-1 ER83S-1 E62C-K3 E69C-K3 E76C-K3 E76C-K4 E83C-K4 E55C-W2	275–325	135–165	None[b]	None[b]
ERXXS-G EXXC-G	ERXXS-G EXXC-G	Conditions as agreed upon between supplier and purchaser			

[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.
[c] Prior to PWHT, allow the weldment to cool in still air to below 200°F [100°C]. Hold at specified temperature for two hours.

9.3.2 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.

9.3.2.1 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 holding temperature specified in Table 7, shall not exceed 400°F per hour [220°C per hour].

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

9.3.2.3 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 per hour [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 Clauses 11 through 13.

9.4 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 9.1, the sample for analysis is taken from the groove weld (Figure 1) or the fractured all weld metal 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 or 1/16 in [1.2 mm or 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 [15°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 not specified). The dimensions of the completed pad shall be as shown in Figure 2. Testing of this assembly shall be as specified in 10.2 and 10.3. The results shall meet the requirements of Table 2.

10. Chemical Analysis

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

10.2 Composite stranded or 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 the shielding gas as specified in Table 3. The sample may be taken from the weld pad prepared in accordance with 9.4, from an area of the groove weld as specified in 9.1, 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 9.4 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.

10.3 The sample obtained as specified in 10.1 or 10.2 shall be analyzed by accepted analytical methods. The referee method shall be ASTM E350.

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

11. Radiographic Test

11.1 The groove weld described in 9.3.1 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. It is permitted on both sides of the test assembly to remove base metal to a depth of 1/16 in [1.5 mm] nominal below the original base metal surface in order to facilitate backing and/or buildup removal. Thic

of the weld metal shall not be reduced by more than 1/16 in [1.5 mm] less than the nominal base metal thickness. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

11.2 The weld shall be radiographed in accordance with ASTM E1032. The quality level of inspection shall be 2-2T.

11.3 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.

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.

12. Tension Test

12.1 One all-weld-metal round tension test specimen, as specified in the Tension Tests section of AWS B4.0 [AWS B4.0M], shall be machined from the groove weld described in 9.3.1, and shown in Figure 1, as required in Table 5. The tensile specimen shall have a nominal diameter of 0.500 in [12.5 mm] and a nominal gage length-to-diameter ratio of 4:1. Other dimensions of the tension test specimen shall be as specified in the Tension Test section of AWS B4.0 [AWS B4.0M].

12.1.1 After machining, but before testing, the specimen may be aged at 200 to 220°F [95 to 105°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.

12.1.2 The specimen shall be tested in the manner described in the tension test section of AWS B4.0, [AWS B4.0M].

12.1.3 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.

13. Impact Test

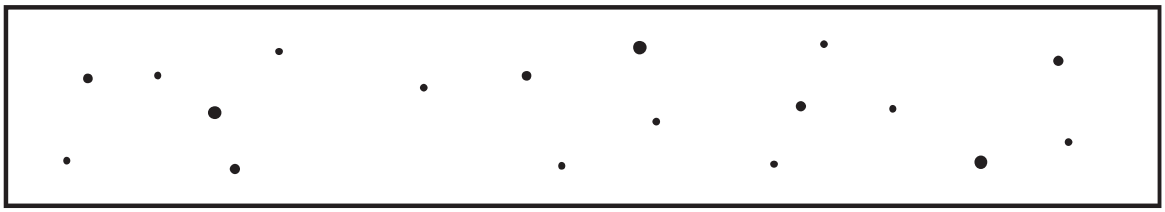
13.1 For those classifications for which impact testing is required in Table 5, five Charpy V-notch impact test specimens, as specified in the Fracture Toughness Testing of Welds section of AWS B4.0 [AWS B4.0M], shall be machined from the test assembly shown in Figure 1.

The Charpy V-Notch specimens shall have the notched surface and the surface to be struck parallel within 0.002 in [0.05 mm]. The other two surfaces shall be square with the notched or struck surface within ±10 minutes of a degree. The notch shall be smoothly cut by mechanical means and shall be square with the longitudinal edge of the specimen within one degree.

The geometry of the notch shall be measured on at least one specimen in a set of five specimens. Measurement shall be done at a minimum 50 times magnification on either a shadowgraph or metallograph. The correct location of the notch shall be verified by etching before or after machining.

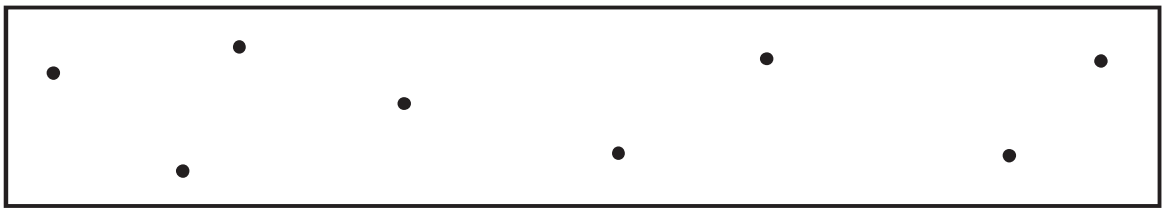
13.2 The five specimens shall be tested in accordance with the fracture toughness test section of AWS B4.0 [AWS B4.0M]. The test temperature shall be that specified in Table 4 for the classification under test.

13.3 In evaluating the test results, the lowest and the highest values obtained shall be disregarded. 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.



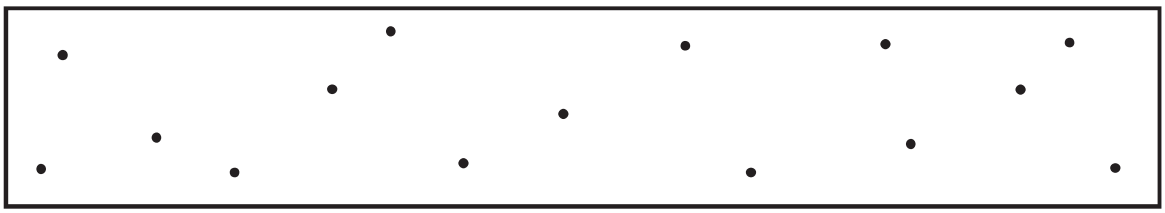
(A) ASSORTED ROUNDED INDICATIONS

SIZE 1/64 in TO 1/16 in [0.4 mm TO 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 TO 1/16 in [1.2 mm TO 1.6 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 3.
MAXIMUM NUMBER OF MEDIUM 1/32 in TO 3/64 in [0.8 mm TO 1.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 5.
MAXIMUM NUMBER OF SMALL 1/64 in TO 1/32 in [0.4 mm TO 0.8 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 10.



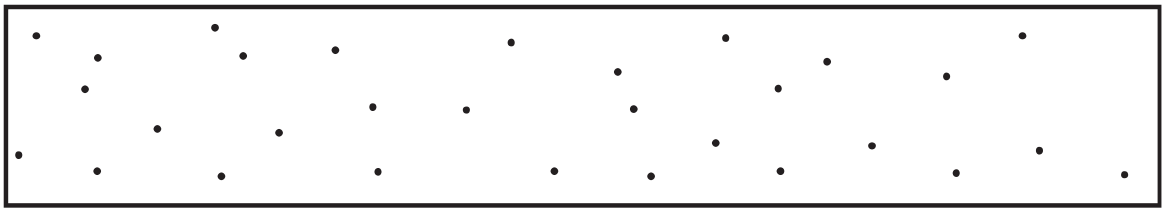
(B) LARGE ROUNDED INDICATIONS

SIZE 3/64 in TO 1/16 in [1.2 mm TO 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 TO 3/64 in [0.8 mm TO 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 TO 1/32 in [0.4 mm TO 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 AWS A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*.

Figure 3—Radiographic Acceptance Standards

Table 8
Optional Diffusible Hydrogen Requirements

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

[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 be capable of meeting the lower average diffusible hydrogen levels (H8, H4, and H2).

14. Diffusible Hydrogen Test

14.1 For each electrode to be designated by an optional supplemental diffusible hydrogen designator, the 0.045 in or 1/16 in [1.2 mm or 1.6 mm] size, or the size that the manufacturer produces that is closest to one of these sizes if the specified sizes are not produced, shall be tested according to one of the methods given in AWS A4.3. Based upon the average value of test results which satisfy the requirements of Table 8, the appropriate diffusible hydrogen designator may be added at the end of the classification.

14.2 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.

14.3 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 AWS A4.3.[8]

14.4 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 designator. Likewise, 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 of all higher hydrogen designators in Table 8 without need to retest.

15. 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.

16. Standard Sizes

Standard sizes for electrodes and rods in the different package forms (straight lengths, coils with support, coils without support, drums, and spools—see Clause 18, Standard Package Forms) are as shown in Table 9.

[8] See A8.2 (in Annex A).

Table 9
Standard Sizes[a]

Standard Package Form	Diameter			Tolerances			
				Solid		Composite	
	in		mm	in	mm	in	mm
Straight Lengths[b]		0.045	—	±0.001	—	±0.002	—
		—	1.2	—	+0.01, –0.04	—	+0.02, –0.05
	1/16	0.062	1.6	±0.002	+0.01, –0.04	±0.002	+0.02, –0.06
	5/64	0.078	2.0	±0.002	+0.01, –0.04	±0.003	+0.02, –0.06
	3/32	0.094	2.4	±0.002	+0.01, –0.04	±0.003	+0.02, –0.06
	1/8	0.125	3.2	±0.002	+0.01, –0.07	±0.003	+0.02, –0.07
	5/32	0.156	4.0	±0.002	+0.01, –0.07	±0.003	+0.02, –0.07
	3/16	0.188	4.8[c]	±0.002	+0.01, –0.07	±0.003	+0.06, –0.08
Coils With and Without Support	0.030		0.8	±0.001	+0.01, –0.04	±0.002	+0.02, –0.05
	0.035		0.9	±0.001	+0.01, –0.04	±0.002	+0.02, –0.05
	—		1.0	—	+0.01, –0.04	—	+0.02, –0.05
	0.045		—	±0.001	—	±0.002	—
	—		1.2	—	+0.01, –0.04	—	+0.02, –0.05
	0.052		—	±0.002	—	±0.002	—
	—		1.4	—	+0.01, –0.04	—	+0.02, –0.05
	1/16	0.062	1.6	±0.002	+0.01, –0.04	±0.002	+0.02, –0.06
	5/64	0.078	2.0	±0.002	+0.01, –0.04	±0.003	+0.02, –0.06
	3/32	0.094	2.4	±0.002	+0.01, –0.04	±0.003	+0.02, –0.06
	7/64	0.109	2.8	±0.002	+0.01, –0.07	±0.003	+0.02, –0.06
	1/8	0.125	3.2	±0.002	+0.01, –0.07	±0.003	+0.02, –0.07
Drums	0.035		0.9	±0.001	+0.01, –0.04	±0.002	+0.02, –0.05
	—		1.0	—	+0.01, –0.04	—	+0.02, –0.05
	0.045		—	±0.001	—	±0.002	—
	—		1.2	—	+0.01, –0.04	—	+0.02, –0.05
	0.052		—	±0.002	—	±0.002	—
	—		1.4	—	+0.01, –0.04	—	+0.02, –0.05
	1/16	0.062	1.6	±0.002	+0.01, –0.04	±0.002	+0.02, –0.06
	5/64	0.078	2.0	±0.002	+0.01, –0.04	±0.003	+0.02, –0.06
	3/32	0.094	2.4	±0.002	+0.01, –0.04	±0.003	+0.02, –0.06
	7/64	0.109	2.8	±0.002	+0.01, –0.07	±0.003	+0.02, –0.06
	1/8	0.125	3.2	±0.002	+0.01, –0.07	±0.003	+0.02, –0.07
Spools	0.020		0.5[c]	±0.001	+0.01, –0.03	±0.002	+0.02, –0.05
	0.025		0.6	±0.001	+0.01, –0.03	±0.002	+0.02, –0.05
	0.030		0.8	±0.001	+0.01, –0.04	±0.002	+0.02, –0.05
	0.035		0.9	±0.001	+0.01, –0.04	±0.002	+0.02, –0.05
	—		1.0	—	+0.01, –0.04	—	+0.02, –0.05
	0.045		—	±0.001	—	±0.002	—
	—		1.2	—	+0.01, –0.04	—	+0.02, –0.05
	0.052		—	±0.002	—	±0.002	—
	—		1.4	—	+0.01, –0.04	—	+0.02, –0.05
	1/16	0.062	1.6	±0.002	+0.01, –0.04	±0.002	+0.02, –0.06
	5/64	0.078	2.0	±0.002	+0.01, –0.04	±0.003	+0.02, –0.06
	3/32	0.094	2.4	±0.002	+0.01, –0.04	±0.003	+0.02, –0.06
	7/64	0.109	2.8	±0.002	+0.01, –0.07	±0.003	+0.02, –0.06
	1/8	0.125	3.2	±0.002	+0.01, –0.07	±0.003	+0.02, –0.07

[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 [900 mm +25, –0 mm].
[c] Not shown as standard metric size in ISO 544.

17. Finish and Uniformity

17.1 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.

17.2 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.

17.3 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.

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

18. Standard Package Forms

18.1 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.

18.2 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.

18.3 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. Standard spools are shown in Figures 4A and 4B.

19. Winding Requirements

19.1 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.

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

19.3 The cast and helix of solid filler metal on 4 in [100 mm] spools shall be such that a specimen long 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

(2) Rise above the flat surface no more than 1/2 in [13 mm] at any location

19.4 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 [300 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

(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 treated to provide straight wire feed. 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 only to the winding requirements of 19.1 and 19.2. Any method of wire form inspection shall be as agreed between purchaser and supplier.

Table 10
Packaging Requirements[a]

Type of Package	Package Size[d]			Net Weight of Electrode[b]	
	in		mm	lb	kg
Coils without Support	As specified by purchaser[c]			As specified by purchaser[c]	
Coils with Support (See below)	6-3/4	ID	170	14	6
	12	ID	300	25, 30, 50, 60, and 65	10, 15, 20, 25, and 30
Spools	4	OD	100	1-1/2 and 2-1/2	0.5 and 1.0
	8	OD	200	10, 12, and 15	4.5, 5.5, and 7
	12	OD	300	25, 30, 35 and 44	10, 15, and 20
	14	OD	360	50 and 60	20 and 25
	22	OD	560	250	100
	24	OD	610	300	150
	30	OD	760	600, 750, and 1000	250, 350, and 450
Drums	15-1/2	OD	400	As specified by purchaser[c]	
	20	OD	500	As specified by purchaser[c]	
	23	OD	600	300 and 600	150 and 300
Straight Lengths	36 long		900 long	2, 5, 10, and 50	1, 2, 5, and 20

Coils with Support—Standard Dimensions and Weights

Electrode Size	Coil Net Weight[b]		Coil Dimensions			
			Inside Diameter of Liner		Width of Wound Electrode	
	lb	kg	in	mm	in, max.	mm, max.
	14	6	6-3/4 ± 1/8	170 ± 3	3	75
	25 and 30	10 and 15	12 ± 1/8	300 +3, –10	2-1/2 or 4-5/8	65 or 120
	50, 60, and 65	20, 25, and 30	12 ± 1/8	300 +3, –10	4-5/8	120

[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%.
[c] As agreed between supplier and purchaser.
[d] ID = inside diameter
OD = outside diameter

20. Filler Metal Identification

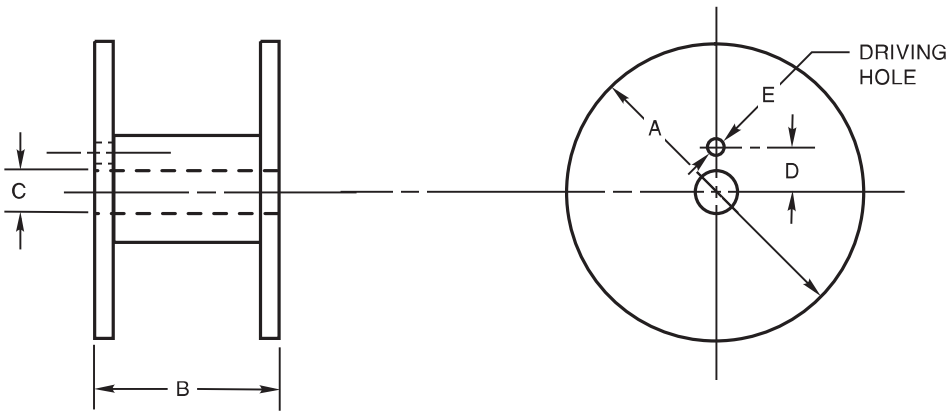
20.1 The product information and the precautionary information required in Clause 22 for marking each package shall also appear on each coil, spool, and drum.

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

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

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

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



		DIMENSIONS							
		4 in [100 mm] Spools		8 in [200 mm] Spools		12 in [300 mm] Spools		14 in [350 mm] Spools	
		in	mm	in	mm	in	mm	in	mm
A	Diameter, max (Note 4)	4.0	102	8.0	203	12	305	14	355
B	Width	1.75	46	2.16	56	4.0	103	4.0	103
	Tolerance	±0.03	+0, –2	±0.03	+0, –3	±0.06	+0, –3	±0.06	+0, –3
C	Diameter	0.63	16	2.03	50.5	2.03	50.5	2.03	50.5
	Tolerance	+0.01, –0	+1, –0	+0.06, –0	+2.5, –0	+0.06, –0	+2.5, –0	+0.06, –0	+2.5, –0
D	Distance Between Axes	—	—	1.75	44.5	1.75	44.5	1.75	44.5
	Tolerance	—	—	±0.02	±0.5	±0.02	±0.5	±0.02	±0.5
E	Diameter (Note 3)	—	—	0.44	10	0.44	10	0.44	10
	Tolerance	—	—	+0, –0.06	+1, –0	+0, –0.06	+1, –0	+0, –0.06	+1, –0

Notes:
1. Outside diameter of barrel shall be such as to permit feeding of the filler metals.
2. Inside diameter of the barrel shall be such that swelling of the barrel or misalignment of the barrel and flanges will not result in the inside of the diameter of the barrel being less than the inside diameter of the flanges.
3. Holes are provided on each flange, but they need not be aligned. No driving holes required for 4 in (100 mm) spools.
4. Metric dimensions and tolerances conform to ISO 544 except that "A" specifies ± tolerances on the nominal diameter, rather than a plus tolerance only, which is shown here as a maximum.

Figure 4A—Standard Spools—Dimensions of 4 in, 8 in, 12 in, and 14 in [100 mm, 200 mm, 300 mm, and 350 mm] Spools

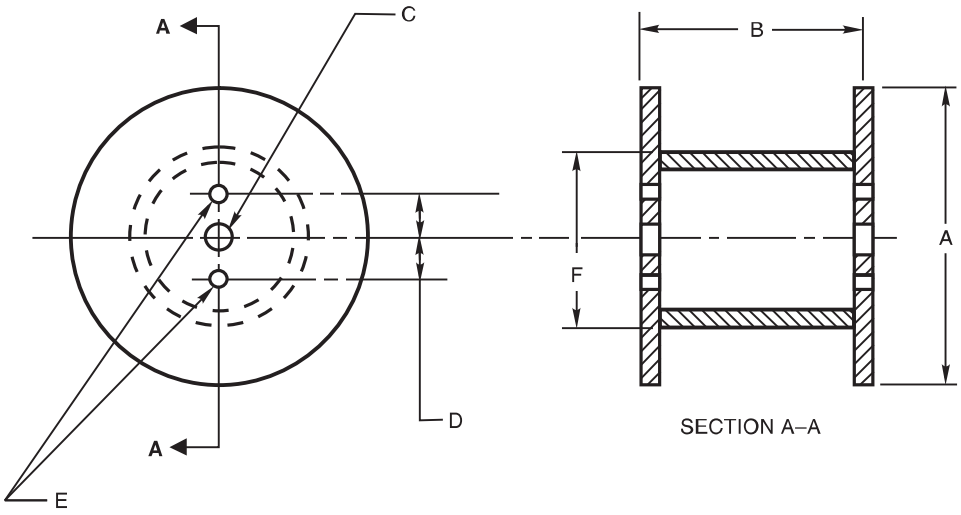
21. Packaging

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

22. Marking of Packages

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

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



		DIMENSIONS					
		22 in [560 mm] Spools		24 in [610 mm] Spools		30 in [760 mm] Spools	
		in	mm	in	mm	in	mm
A	Diameter, max.	22	560	24	610	30	760
B	Width, max.	12	305	13.5	345	13.5	345
C	Diameter Tolerance	1.31 +0.13, –0	35.0 ±1.5	1.31 +0.13, –0	35.0 ±1.5	1.31 +0.13, –0	35.0 ±1.5
D	Distance, Center-to-Center Tolerance	2.5 ±0.1	63.5 ±1.5	2.5 ±0.1	63.5 ±1.5	2.5 ±0.1	63.5 ±1.5
E	Diameter (Note 3) Tolerance	0.69 +0, –0.06	16.7 ±0.7	0.69 +0, –0.06	16.7 ±0.7	0.69 +0, –0.06	16.7 ±0.7

Notes:
1. Outside diameter of barrel, dimension F, shall be such as to permit proper feeding of the electrode.
2. 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 of the diameter of the barrel being less than the inside diameter of the flanges.
3. Two holes are provided on each flange and shall be aligned on both flanges with the center hole.

Figure 4B—Standard Spools—Dimensions of 22 in, 24 in, and 30 in [560 mm, 610 mm, and 760 mm] Spools

- Supplier's name and trade designation
- Size and net weight (see 1.3)
- Lot, control, or heat number

22.2 The appropriate precautionary information[9] given in ANSI Z49.1, latest edition (as a minimum), shall be prominently displayed in legible print on all packages, including individual unit packages within a larger package.

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

Annex A (Informative)

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

This annex is not part of AWS A5.28/A5.28M:2005 (R2015), *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*, but is included for informational purposes 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 A.1.

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. For A5.28, the number 70, for example, indicates the required minimum tensile strength, as a multiple of 1000 psi, of the weld metal in a test weld made in accordance with specification A5.28. Similarly, for A5.28M, the number 49, for example, indicates the required minimum tensile strength, as a multiple of 10 MPa, of the weld metal in a test weld made in accordance with specification A5.28M.

The letter "S" designates a solid electrode or rod.

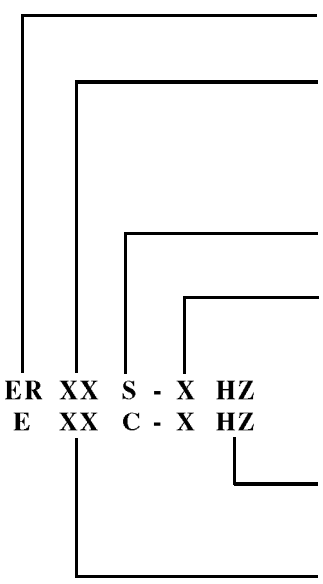
The letter "C" designates a composite electrode

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 specified test conditions, in the case of composite stranded or metal cored electrodes.

Optional designators are also used in this specification in order to identify electrodes and rods that have met mandatory classification requirements and certain supplementary requirements as agreed to between the supplier and purchaser. An optional supplemental diffusible hydrogen designator (H16, H8, H4, or H2) may follow the classification designation, indicating whether the electrode will meet a maximum hydrogen level of 16, 8, 4, or 2 ml/100g of weld metal when tested as outlined in AWS A4.3. 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 hydrogen limits without necessarily being designated as such.

A2.3 "G" Classification

A2.3.1 These specifications include filler metals classified as ER80S-G [ER55S-G], E80C-G [E55C-G], etc. 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,



Designates use as either an electrode or rod (**ER**), or use only as an electrode (**E**).

Indicates in 1000 psi increments, the minimum tensile strength of the weld metal produced by the electrode when tested according to the A5.28 specification. Three digits are used for weld metal of 100 000 psi and higher (see Table 3). (Note that in this specification the digits "70" may represent 75 000 psi, rather than 70 000 psi (see Table 3).

Indicates whether the filler metal is solid (**S**) or composite stranded or metal cored (**C**).

Indicates the chemical composition of a solid electrode or the chemical composition of the weld metal produced by a composite electrode (see Tables 1 and 2).

Optional supplemental diffusible hydrogen designator (see Table 8), where "Z" represents 16, 8, 4, or 2.

Indicates in 10 MPa increments, the minimum tensile strength of the weld metal produced by the electrode when tested according to the A5.28M specification. (Note that in this specification the digits "49" may represent 515 MPa rather than 490 MPa [see Table 3].)

Figure A.1—Classification System

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 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, they will have to arrange for that information with the supplier of the product. They will have to establish with that supplier just what the testing procedure and the acceptance requirements are to be, for that test. They may want to incorporate that information (via 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. They may do this by followir

procedure given here. When the manufacturer elects to use the "G" classification, the Committee on Filler Metals and Allied Materials 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 must be a written request and it needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials 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.

In particular, the request needs to include:

(1) All classification requirements as given for existing classifications, such as, chemical composition ranges, and mechanical property requirement.

(2) Any testing conditions for conducting the tests used to demonstrate that the product meets the classification requirements. (It would be sufficient, for example, to state that welding conditions are the same as for other classifications.)

(3) Information on "Description and Intended Use," which parallels that for existing classifications, for that section of Annex A.

A request for a new classification without the above information will be considered incomplete. The Secretary will return the request to the requestor for further information.

A2.3.3.3 The request should be sent to the Secretary of the A5 Committee on Filler Metals and Allied Materials 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 Chair of the Committee on Filler Metals and Allied Materials and the Chair 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 Chairs of the Committee and of 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 Chair of the Committee on Filler Metals and Allied Materials, 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 Committee on Filler Metals and Allied Materials 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 AWS A5.01, *Filler Metal Procurement Guidelines*, as the specification states. Any testing a purchaser requires of the supplier, for material shipped in accordance with this specification, shall be clearly stated in the purchase order, according to the provisions of AWS A5.01. In the absence of any such statement in the purchase order, the supplier may ship the material with whatever testing is normally conducted on material of that classification, as specified in Schedule F, Table 1, of AWS A5.01. Testing in accordance with any other schedule in that table must be specifically required by the purchase order. In such cases, acceptance of the material shipped will be in accordance with those requirements.

A4. Certification

A4.1 The act of placing the AWS specification and classification designations and optional supplemental designators, if applicable, on the packaging enclosing the product, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of the specification.

The only testing requirement implicit in this "certification" is that the manufacturer has actually conducted the tests required by the specification on material that is representative of that being shipped, and that the material met the requirements of the specification. Representative material, in this case, is any production run of that classification using the same formulation. "Certification" is not to be construed to mean that tests of any kind were necessarily conducted on samples of the specific material shipped. Tests on such material may or may not have been conducted. The basis for the certification required by the specification is the classification test of "representative material" cited above, and the "Manufacturer's Quality Assurance System" in AWS A5.01, *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 GTAW test assembly described in Figure A.2.

One all-weld-metal round tension test specimen, as specified in the Tension Tests section of AWS B4.0 [AWS B4.0M], *Standard Methods for Mechanical Testing of Welds*, shall be machined from the groove weld described in Figure A.2. The tensile specimen shall have a nominal diameter of 0.350 in [9.0 mm] and a nominal gage length-to-diameter ratio of 4:1. The specimen shall be tested as specified in 12.1. Other dimensions of the tension test specimen shall be as specified in the Tension Test section of AWS B4.0 [AWS B4.0M].

The Charpy V-Notch specimens shall be as specified in Clause 13. Composite electrodes are normally not recommended for GTAW or 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

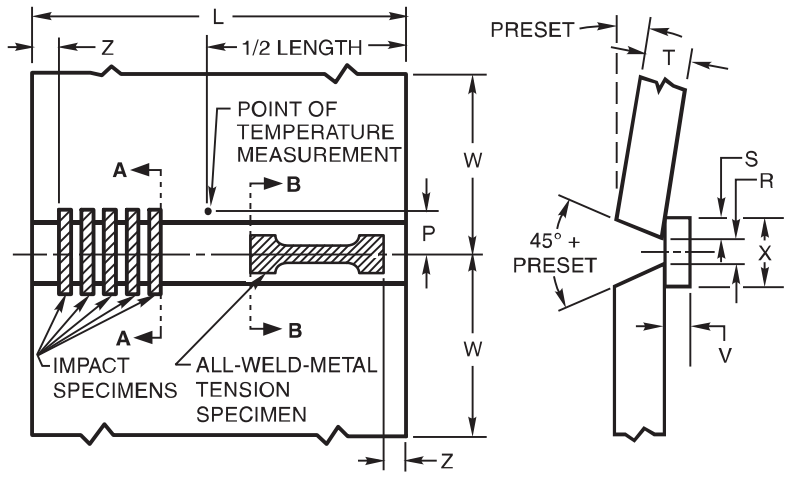
A5.2 American National Standard Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the Section on Health Protection and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

A6. Welding Considerations

A6.1 Gas metal arc welding (GMAW) can be divided into three categories based on the mode of metal transfer. These modes are (1) spray (conventional or pulsed), (2) globular, and (3) 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, the metal is deposited during frequent short circuiting of the electrode in the molten pool.

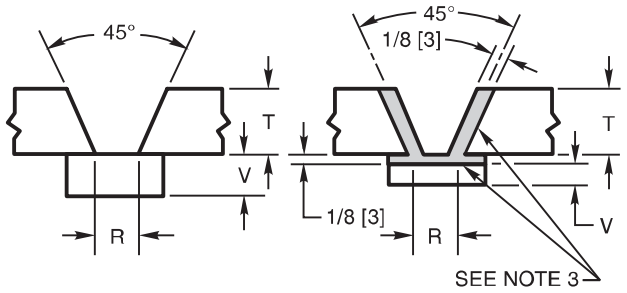
A6.2 Spray Transfer

A6.2.1 The spray transfer mode, for carbon steel, is most commonly obtained with argon shielding gas mixtures with up to 5% of oxygen (AWS A5.32 Class SG-AO-X, where X is 1 to 5) or up to 15% carbon dioxide (AWS A5.32

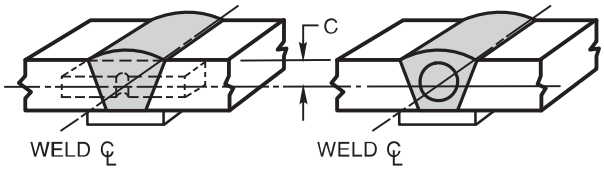


DIMENSIONS			
		in	mm
C	Specimen Center	1/4	6.5
L	Length, min.	10	250
P	Point of Temperature Measurement	1	25
R	Root Opening	1/4	6.5
S	Backup Strip Overlap, min.	3/8	9
T	Thickness	1/2	13
V	Backup Strip Thickness, min.	1/4	6.5
W	Width, min.	5	125
X	Backup Strip Width, min.	1	25
Z	Discard, min.	1	25

(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



(B) GROOVE PREPARATION OF TEST PLATE



(C) ORIENTATION OF IMPACT SPECIMEN

(D) LOCATION OF ALL-WELD-METAL TENSION SPECIMEN

Test Conditions for Solid Rods[4, 5]		
Standard Size[5]	3/32 in (2.4 mm]	1/8 in (3.2 mm]
Shielding Gas	Argon[6]	Argon[6]
Nominal Arc Voltage	13 V to 16 V	16 V to 19 V
Nominal Current, DCEN) (DCEN = Electrode Negative)	220 A to 250 A	250 A to 280 A
Preheat/Interpass Temperature	See Table 7	See Table 7
Travel Speed	4 in/min to 6 in/min [2.0 mm/sec ± 0.4 mm/sec]	4 in/min to 6 in/min [2.0 mm/sec ± 0.4 mm/sec]

Notes:
1. Base metal shall be as specified in Table 6.
2. The surfaces to be welded shall be clean.
3. 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. 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.
4. Test conditions for composite electrodes used as rods shall be as recommended by the manufacturer.
5. If sizes other than those shown above are tested, nominal current and arc voltage shall be changed as needed.
6. AWS A5.32 Class SG-A.
7. Postweld heat treatment shall be as specified in Table 7 for the classification under test.

Figure A.2—Optional GTAW Groove Weld Test Assembly for Mechanical Properties and Soundness

SG-AC-Y, where Y is 5 to 15). 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 (AWS A5.32 Class SG-AO-X) or argon-carbon dioxide (AWS A5.32 Class SG-AC-Y) 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 of electrode). Below this current, the metal is transferred in drops generally larger in diameter than the electrode and 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 carbon 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. 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% CO_2 (AWS A5.32 Class SG-C) as a shielding gas is globular. Common practice with globular transfer is to use low arc voltage to minimize spatter. This shortens the arc length causing the arc to be "buried" and results in deeper penetration and better containment of spatter within the weld pool. Electrodes of 0.045 in through 1/16 in [1.2 mm through 1.6 mm] diameter normally are used at welding currents in the range of 275 amperes to 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 in to 0.045 in [0.8 mm to 1.2 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 carbon steel is done most commonly with mixtures of argon and CO_2 (AWS A5.32 Class SG-AC-Y) as the shielding gas or with CO_2 (AWS A5.32 Class SG-C) alone. The penetration of such welds is greater with CO_2 than it is with argon-CO_2 mixtures. Mixtures of 50% to 80% argon with CO_2 remainder (AWS A5.32 Class SG-AC-Y, where Y is 20 to 50) can be advantageous for thin material. However shielding gas mixtures of 50% to 70% argon with CO_2 remainder (AWS A5.32 Class SG-AC-Y, where Y is 30 to 50) are unstable in the gaseous state and must be mixed from single gas components immediately prior to use. They provide low penetration, higher short circuiting rates, and lower minimum currents and voltages than CO_2 alone does. This can be an advantage in welding thin plate.

Regardless of gas used, the total heat input limits fusion and penetration. Therefore, many users limit this process to material thickness not exceeding 1/2 in [13 mm].

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 [ER49S-A1] Classification (1/2 Mo). Filler metal of this classification is similar to many of the carbon steel filler metals classified in AWS A5.18/A5.18M, except that 0.5% molybdenum has been added. This addition increases the strength of the weld metal, especially at elevated temperatures, and provides some increase in corr

resistance; however, it will likely reduce the notch toughness of the weld metal. Typical applications include the welding of C-Mo base metals such as ASTM 204 plate and A335-P1 pipe.

A7.4 ER80S-B2 [ER55S-B2] and E80C-B2 [E55C-B2] Classification (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 [ER49S-B2L] and E70C-B2L [E49C-B2L] Classifications (1-1/4 Cr-1/2 Mo). These filler metals are identical to the types ER80S-B2 [ER55S-B2] and E80C-B2 [E55C-B2] except for the low-carbon content (0.05% maximum) and thus the lower strength levels. This also reduces hardness and under some conditions improves corrosion resistance. 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 A5.28-79 specification. The strength requirements and classification designator have been changed to reflect the true strength capabilities of the chemical composition.

A7.6 ER90S-B3 [ER62S-B3] and E90C-B3 [E62C-B3] Classifications (2-1/4Cr-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 [ER55S-B3L] and E80C-B3L [E55C-B3L] Classifications (2-1/4 Cr-1 Mo). These filler metals are identical to the types ER90S-B3 [ER62S-B3] and E90C-B3 [E62C-B3] except for the low-carbon content (0.05% 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 A5.28-79 specification. The strength requirements and classification designator have been changed to reflect the true strength capabilities of the chemical composition.

A7.8 ER80S-Ni1 [ER55S-Ni1] and E80C-Ni1 [E55C-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 [–45°C].

A7.9 ER80S-Ni2 [ER55S-Ni2], E70C-Ni2 [E49C-Ni2], and E80C-Ni2 [E55C-Ni2] Classifications (2-1/4 Ni). These filler metals deposit weld metal similar to E8018-C1 electrodes. Typically, they are used for welding 2.5 nickel steels and other materials requiring good toughness at temperatures as low as –80°F [–60°C].

A7.10 ER80S-Ni3 [ER55S-Ni3] and E80C-Ni3 [E55C-Ni3] Classifications (3-1/4 Ni). These filler metals deposit weld metal similar to E8018-C2 electrodes. Typically they are used for welding 3.5 nickel steels for low-temperature service.

A7.11 ER80S-D2 [ER55S-D2], ER90S-D2 [ER62S-D2], and E90C-D2 [E62C-D2] Classifications (1/2 Mo). The ER80S-D2 [ER55S-D2] and ER90S-D2 [ER62S-D2] classifications have the same chemical requirements as the E70S-1B classification of AWS A5.18-69. The differences between the ER80S-D2 [ER55S-D2] and the ER90S-D2 [ER62S-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 CO_2 (AWS A5.32 Class SG-C) 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 [ER69S-1], ER110S-1 [ER76S-1], and ER120S-1 [ER83S-1] Classifications. These filler metals deposit high-strength, very tough weld metal for critical applications. Originally developed for welding HY-80 and HY-100 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 [–50°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 [ER55S-B6], E80C-B6 [E55C-B6] Classification (5 Cr-1/2 Mo). This classification contains about 4.5% to 6.0% chromium and about 0.5% 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 A5.9-93.

A7.14 ER80S-B8 [ER55S-B8], E80C-B8 [E55C-B8] Classification (9 Cr-1 Mo). This classification contains 8.0 to 10.5% chromium and about 1.0% 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 A5.9-93.

A7.15 ER90S-B9 [ER62S-B9], E90C-B9 [E62C-B9] Classification (9 Cr-1 Mo-0.2V-0.07Nb(Cb)). ER90S-B9 [ER62S-B9] and E90C-B9 [E62C-B9] are 9Cr-1Mo wires 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.

Thermal treatment of this alloy is critical and must be closely controlled. The temperature at which the microstructure has complete transformation into martensite (M_f) is relatively low; therefore, upon completion of welding and before post weld heat treatment, it is recommended to allow the weldment to cool to at least 200°F [93°C] to maximize transformation to martensite. The maximum allowable temperature for post weld heat treatment is also critical in that the lower transformation temperature (Ac_1) is also comparably low. To aid in allowing for an adequate post weld heat treatment, the restriction of Mn + Ni has been imposed (see Table 1 footnote j, and Table 2 footnote g). The combination of Mn and Ni tends to lower the Ac_1 temperature to the point where the PWHT temperature approaches the Ac_1, possibly causing partial transformation of the microstructure. By restricting the Mn + Ni, the PWHT temperature will be sufficiently below the Ac_1 to avoid this partial transformation.

A7.16 E90C-K3 [E62C-K3], E100C-K3 [E69C-K3], E110C-K3 [E76C-K3] Classifications. Some electrodes in these classifications produce weld metal with a typical composition of 1.5% nickel and up to 0.35% molybdenum. These electrodes are used on many high-strength applications ranging from 80 ksi–110 ksi (550 MPa–760 MPa) minimum yield strength and are primarily intended for as-welded applications. Typical applications would include the welding of ships, offshore structures, and many other structural applications where low-temperature toughness is required. Steels welded would include HY-80, HY-100, ASTM A710, A514, A517, and other similar high-strength steels. Other electrodes of these types produce weld deposits with higher levels of manganese, nickel and molybdenum and usually have higher strength levels. Typical applications include the welding of HY-100, A514, and A517 steels.

A7.17 E110C-K4 [E76C-K4], E120C-K4 [E83C-K4] Classifications. Electrodes of these types produce weld deposits similar to that of the EXXC-K3 electrodes, with the addition of approximately 0.5% chromium. The additional alloy provides the higher strength necessary for many applications needing in excess of 120 000 psi [830 MPa] tensile, such as armor plate.

A7.18 E80C-W2 [E55C-W2] Classification (Weathering Steel). This classification has been designed to produce weld metal that matches the corrosion resistance and the coloring of the ASTM weathering-type structural steels such as A242, A588, and A709 Gr. 50W. These special properties are achieved by the addition of about 0.5% copper to the weld metal. To meet strength, ductility, and notch toughness in the weld metal, chromium and nickel additions are also introduced.

A7.19 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 Table 5 and A2.3 for further information).

A8. Special Tests

A8.1 It is recognized that supplementary tests may be required for certain applications. In such cases, additional tests to determine specific properties such as hardness, corrosion resistance, mechanical properties at higher or lower service temperatures, may be required. AWS A5.01, *Filler Metal Procurement Guidelines,* contains provisions for ordering such tests. This section is included for the guidance of those who desire to specify such special tests. Those tests may be conducted as agreed by supplier and purchaser.

A8.2 Diffusible Hydrogen

A8.2.1 Hydrogen induced cracking of weld metal or the heat-affected zone (HAZ) generally is not a problem with plain carbon steels containing 0.3% or less carbon, nor with lower strength alloy steels. However, the electrodes classified in this specification are used to join higher carbon steels or low-alloy, high strength steels where hydrogen-induced cracking may be a serious problem.

A8.2.2 Gas metal arc welding (GMAW) and gas tungsten arc welding (GTAW) are generally considered to be low hydrogen welding processes. However, as the weld metal or heat-affected zone strength or hardness increases, the concentration of diffusible hydrogen that will cause cracking under given conditions of restraint and heat input becomes lower. It may be appropriate to evaluate the diffusible hydrogen produced during welding with these processes. This cracking (or its detection) 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.

A8.2.3 Since the available diffusible hydrogen level strongly influences the tendency towards hydrogen-induced cracking, it may be desirable to measure the diffusible hydrogen content resulting from welding with a particular electrode. This specification has, therefore, included the use of optional supplemental designators for diffusible hydrogen to indicate the maximum average value obtained under a clearly defined test condition in 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 meet any higher electrode hydrogen limits, even though these are not necessarily designated along with the electrode classification. Therefore, for example an electrode designated as "H4" also meets the "H8" and "H16" requirements without being designated as such.

A8.2.4 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values than those indicated by the designator.

A8.2.4.1 Surface Contamination. The welding consumable is not the only source of diffusible hydrogen in the process. For example, rust, primer coating, antispatter compounds, dirt and grease can all contribute to diffusible hydrogen levels in practice. Consequently, standard diffusible hydrogen tests for designation of welding consumables require test base material to be free from contamination. AWS A4.3 is specific as to the cleaning procedure for test base material. Surface contamination on the welding consumable being tested should always be representative of the product being delivered.

A8.2.4.2 Moisture in Shielding Gas The shielding gas can also be a source of moisture entering the arc. Shielding gases as classified in AWS A5.32/A5.32M have a maximum dew point specified which is considered "dry" enough for welding. Utilizing shielding gases with a specified maximum dew point ensures that the shielding gas does not become a source of moisture contamination. The shielding gas delivery conduit must also be designed and maintained to prevent the ingress of moisture into the shielding gas while the gas is being transported to the arc from its source.

A8.2.5 The use of a reference atmospheric condition during welding is necessary because the arc is always 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% relative humidity at 70°F [18°C] at 29.92 in Hg [760 mm Hg] 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 for up to 48 hours before subjecting them to 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. The purchaser may, by mutual agreement with the supplier, have the thermal aging of the specimens prohibited for all mechanical testing done to Schedule I or J of AWS A5.01.

A9. Discontinued Classifications

Some classifications have been discontinued, from one revision of this specification to another. This results either from changes in commercial practice or changes in the classification system used in the specification. The following classifications have been discontinued over the life of this specification (along with the year in which they were last included in the specification):

Discontinued Classification	Year Last Published	Replaced With
ER100S-2	1979	None
ER80S-B2L	1979	ER70S-B2L
E80C-B2L	1979	E70C-B2L
ER90S-B3L	1979	ER80S-B3L
E90C-B3L	1979	E80C-B3L

A10. General Safety Considerations

NOTE: Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not fully addressed herein. Some safety and health information can be found in Clause A5. Safety and health information is available from other sources, including, but not limited to Safety and Health Fact Sheets listed in A10.2, ANSI Z49.1, Safety in Welding, Cutting, and Allied Processes,[10] *and applicable federal and state regulations.*

[10] This ANSI standard is published by the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

A10.1 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at http://www.aws.org. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A10.2 AWS Safety and Health Fact Sheets Index (SHF)[11]

No.	Title
1	*Fumes and Gases*
2	*Radiation*
3	*Noise*
4	*Chromium and Nickel in Welding Fume*
5	*Electrical Hazards*
6	*Fire and Explosion Prevention*
7	*Burn Protection*
8	*Mechanical Hazards*
9	*Tripping and Falling*
10	*Falling Objects*
11	*Confined Spaces*
12	*Contact Lens Wear*
13	*Ergonomics in the Welding Environment*
14	*Graphic Symbols for Precautionary Labels*
15	*Style Guidelines for Safety and Health Documents*
16	*Pacemakers and Welding*
17	*Electric and Magnetic Fields (EMF)*
18	*Lockout/Tagout*
19	*Laser Welding and Cutting Safety*
20	*Thermal Spraying Safety*
21	*Resistance Spot Welding*
22	*Cadmium Exposure from Welding and Allied Processes*
23	*California Proposition 65*
24	*Fluxes for Arc Welding and Brazing: Safe Handling and Use*
25	*Metal Fume Fever*
26	*Arc Viewing Distance*
27	*Thoriated Tungsten Electrodes*
28	*Oxyfuel Safety: Check Valves and Flashback Arrestors*
29	*Grounding of Portable and Vehicle Mounted Welding Generators*
30	*Cylinders: Safe Storage, Handling, and Use*
31	*Eye and Face Protection for Welding and Cutting Operations*
33	*Personal Protective Equipment (PPE) for Welding and Cutting*
34	*Coated Steels: Welding and Cutting Safety Concerns*
35	*Welding Safety in Education and Schools*
36	*Ventilation for Welding and Cutting*
37	*Selecting Gloves for Welding and Cutting*
38	*Respiratory Protection Basics for Welding Operations*
40	*Asbestos Hazards Encountered in the Welding and Cutting Environment*
41	*Combustible Dust Hazards in the Welding and Cutting Environment*

[11] AWS standards are published by the American Welding Society, 8669 NW 36 St, # 130, Miami, FL 33166.

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Annex B (Informative)

Guidelines for the Preparation of Technical Inquiries

This annex is not part of AWS A5.28/A5.28M:2005 (R2015), *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*, but is included for informational purposes only.

B1. Introduction

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

B2. Procedure

All inquiries shall be directed to:

Managing Director
Technical Services Division
American Welding Society
8669 NW 36 St, # 130
Miami, FL 33166

All inquiries shall contain the name, address, and affiliation of the inquirer, and they shall provide enough information for the committee to understand the point of concern in the inquiry. When the point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be typewritten and in the format specified below.

B2.1 Scope. Each inquiry shall address one single provision of the standard unless the point of the inquiry involves two or more interrelated provisions. The provision(s) shall be identified in the scope of the inquiry along with the edition of the standard that contains the provision(s) the inquirer is addressing.

B2.2 Purpose of the Inquiry. The purpose of the inquiry shall be stated in this portion of the inquiry. The purpose can be to obtain an interpretation of a standard's requirement or to request the revision of a particular provision in the standard.

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

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

B3. Interpretation of Provisions of the Standard

Interpretations of provisions of the standard are made by the relevant AWS technical committee. The secretary of the committee refers all inquiries to the chair of the particular subcommittee that has jurisdiction over the portion of the standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire committee for review and approval. Upon approval by the committee, the interpretation is an official interpretation of the Society, and the secretary transmits the response to the inquirer and to the *Welding Journal* for publication.

B4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal* and will be posted on the AWS web site.

B5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The *AWS Board Policy Manual* requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the information that such an interpretation can be obtained only through a written request. Headquarters staff cannot provide consulting services. However, the staff can refer a caller to any of those consultants whose names are on file at AWS Headquarters.

B6. AWS Technical Committees

The activities of AWS technical committees regarding interpretations are limited strictly to the interpretation of provisions of standards prepared by the committees or to consideration of revisions to existing provisions on the basis of new data or technology. Neither AWS staff nor the committees are in a position to offer interpretive or consulting services on (1) specific engineering problems, (2) requirements of standards applied to fabrications outside the scope of the document, or (3) points not specifically covered by the standard. In such cases, the inquirer should seek assistance from a competent engineer experienced in the particular field of interest.

AWS Filler Metal Specifications by Material and Welding Process

	OFW	SMAW	GTAW GMAW PAW	FCAW	SAW	ESW	EGW	Brazing
Carbon Steel	A5.2	A5.1	A5.18, A5.36	A5.20, A5.36	A5.17	A5.25	A5.26	A5.8, A5.31
Low-Alloy Steel	A5.2	A5.5	A5.28, A5.36	A5.29, A5.36	A5.23	A5.25	A5.26	A5.8, A5.31
Stainless Steel		A5.4	A5.9, A5.22	A5.22	A5.9	A5.9	A5.9	A5.8, A5.31
Cast Iron	A5.15	A5.15	A5.15	A5.15				A5.8, A5.31
Nickel Alloys		A5.11	A5.14	A5.34	A5.14	A5.14		A5.8, A5.31
Aluminum Alloys		A5.3	A5.10					A5.8, A5.31
Copper Alloys		A5.6	A5.7					A5.8, A5.31
Titanium Alloys			A5.16					A5.8, A5.31
Zirconium Alloys			A5.24					A5.8, A5.31
Magnesium Alloys			A5.19					A5.8, A5.31
Tungsten Electrodes			A5.12					
Brazing Alloys and Fluxes								A5.8, A5.31
Surfacing Alloys	A5.21	A5.13	A5.21	A5.21	A5.21			
Consumable Inserts			A5.30					
Shielding Gases			A5.32	A5.32			A5.32	

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AWS Filler Metal Specifications and Related Documents

Designation	Title
UGFM	*User's Guide to Filler Metals*
A4.2M (ISO 8249 MOD)	*Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*
A4.3	*Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*
A4.4M	*Standard Procedures for Determination of Moisture Content of Welding Fluxes and Welding Electrode Flux Coverings*
A4.5M/A4.5 (ISO 15792-3 MOD)	*Standard Methods for Classification Testing of Positional Capacity and Root Penetration of Welding Consumables in a Fillet Weld*
A5.01M/A5.01 (ISO 14344 MOD)	*Welding Consumables — Procurement of Filler Metals and Fluxes*
A5.02/A5.02M	*Specification for Filler Metal Standard Sizes, Packaging, and Physical Attributes*
A5.1/A5.1M	*Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding*
A5.2/A5.2M	*Specification for Carbon and Low-Alloy Steel Rods for Oxyfuel Gas Welding*
A5.3/A5.3M	*Specification for Aluminum and Aluminum-Alloy Electrodes for Shielded Metal Arc Welding*
A5.4/A5.4M	*Specification for Stainless Steel Electrodes for Shielded Metal Arc Welding*
A5.5/A5.5M	*Specification for Low-Alloy Steel Electrodes for Shielded Metal Arc Welding*
A5.6/A5.6M	*Specification for Copper and Copper-Alloy Electrodes for Shielded Metal Arc Welding*
A5.7/A5.7M	*Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes*
A5.8M/A5.8	*Specification for Filler Metals for Brazing and Braze Welding*
A5.9/A5.9M	*Specification for Bare Stainless Steel Welding Electrodes and Rods*
A5.10/A5.10M (ISO 18273 MOD	*Welding Consumables — Wire Electrodes, Wires and Rods for Welding of Aluminum and Aluminum-Alloys — Classification*
A5.11/A5.11M	*Specification for Nickel and Nickel-Alloy Welding Electrodes for Shielded Metal Arc Welding*
A5.12M/A5.12 (ISO 6848 MOD)	*Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting*
A5.13/A5.13M	*Specification for Surfacing Electrodes for Shielded Metal Arc Welding*
A5.14/A5.14M	*Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods*
A5.15	*Specification for Welding Electrodes and Rods for Cast Iron*
A5.16/A5.16M	*Specification for Titanium and Titanium-Alloy Welding Electrodes and Rods*
A5.17/A5.17M	*Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*
A5.18/A5.18M	*Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*
A5.19	*Specification for Magnesium Alloy Welding Electrodes and Rods*
A5.20/A5.20M	*Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*
A5.21/A5.21M	*Specification for Bare Electrodes and Rods for Surfacing*
A5.22/A5.22M	*Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods*
A5.23/A5.23M	*Specification for Low-Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*
A5.24/A5.24M	*Specification for Zirconium and Zirconium-Alloy Welding Electrodes and Rods*
A5.25/A5.25M	*Specification for Carbon and Low-Alloy Steel Electrodes and Fluxes for Electroslag Welding*
A5.26/A5.26M	*Specification for Carbon and Low-Alloy Steel Electrodes for Electrogas Welding*
A5.28/A5.28M	*Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*
A5.29/A5.29M	*Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*
A5.30/A5.30M	*Specification for Consumable Inserts*
A5.31M/A5.31	*Specification for Fluxes for Brazing and Braze Welding*
A5.32M/A5.32 (ISO 14175 MOD)	*Welding Consumables—Gases and Gas Mixtures for Fusion Welding and Allied Processes*
A5.34/A5.34M	*Specification for Nickel-Alloy Electrodes for Flux Cored Arc Welding*
A5.35/A5.35M	*Specification for Covered Electrodes for Underwater Wet Shielded Metal Arc Welding*
A5.36/A5.36M	*Specification for Carbon and Low-Alloy Steel Flux Cored Electrodes for Flux Cored Arc Welding and Metal Electrodes for Gas Metal Arc Welding*

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