



Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding



American Welding Society



Key Words—Carbon steel welding electrodes, carbon steel welding rods, gas metal arc welding, gas tungsten arc welding, metal cored electrodes, plasma arc welding, stranded electrodes

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Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding

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Prepared by
AWS A5 Committee on Filler Metals and Allied Materials

Under the Direction of
AWS Technical Activities Committee

Approved by
AWS Board of Directors

Abstract

This specification prescribes the requirements for classification of solid carbon steel electrodes and rods, composite stranded carbon steel electrodes, and composite metal cored carbon 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 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.



American Welding Society

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Foreword

(This Foreword is not a part of AWS A5.18/A5.18M:2005, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*, but is included for informational purposes only.)

This document is the second of the A5.18 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 metals—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, provides for interchangeability of products in both U.S. Customary and SI Units.

The current document is the sixth revision of the initial joint ASTM/AWS document issued in 1965.

The history of A5.18 may be summarized as follows:

AWS A5.18-65T	<i>Tentative Specification for Mild Steel Electrodes for Gas Metal Arc Welding</i>
ASTM A 559-65T	
AWS A5.18-69	<i>Specification for Mild Steel Electrodes for Gas Metal Arc Welding</i>
ANSI W3.18-1973	
AWS A5.18-79	<i>Specification for Carbon Steel Filler Metals for Gas Shielded Arc Welding</i>
AWS A5.18-93	<i>Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding</i>
AWS A5.18/A5.18M:2001	<i>Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding</i>

Two lines of Figure A2 have been revised and the radiographic requirements have been updated. Vertical bars have been placed in the margins to identify these changes. Other editorial changes are not identified.

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, 550 N.W. LeJeune Road, Miami, FL 33126.

Official interpretations of any of the technical requirements of this standard may only be obtained by sending a request, in writing, to the Managing Director, Technical Services Division, American Welding Society. A formal reply will be issued after it has been reviewed by the appropriate personnel, following established procedures.

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Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of carbon 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 nonmandatory Annex Sections 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 A5.18 uses U.S. Customary Units. The specification A5.18M 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 A5.18 or A5.18M specifications.

Part A *General Requirements*

2. Normative References

2.1 ASTM Standards¹

A 36/A 36M *Specification for Carbon Structural Steel*

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

A 285/A 285M *Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*

A 515/A 515M *Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*

A 516/A 516M *Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*

E 29 *Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications*

E 350 *Standard Method for Chemical Analysis of Carbon Steel, Low Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron*

E 1032 *Standard Test Method for Radiographic Examination of Weldments*

2.2 AWS Standards²

AWS A5.01 *Filler Metal Procurement Guidelines*

AWS A5.32/A5.32M *Specification for Welding Shielding Gases*

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

AWS B4.0 or B4.0M *Standard Methods for Mechanical Testing of Welds*

2.3 ANSI Standards³

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

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

3. ANSI standards are published by the American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036.

2.4 ISO Specifications⁴

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

3. Classification

3.1 The solid electrodes (and rods) covered by the A5.18 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 as-welded 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 the A5.18M 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.

4. ISO standards are published by the International Organization for Standardization, 1, rue de Varembé, Case postale 56, CH-1211 Geneva 20, Switzerland.

Table 1
Chemical Composition Requirements for Solid Electrodes and Rods

AWS Classification ^b		UNS ^c Number	Weight Percent ^a												
A5.18	A5.18M		C	Mn	Si	P	S	Ni	Cr	Mo	V	Cu ^d	Ti	Zr	Al
ER70S-2	ER48S-2	K10726	0.07	0.90 to 1.40	0.40 to 0.70	0.025	0.035	0.15	0.15	0.15	0.03	0.50	0.05 to 0.15	0.02 to 0.12	0.05 to 0.15
ER70S-3	ER48S-3	K11022	0.06 to 0.15	0.90 to 1.40	0.45 to 0.75	0.025	0.035	0.15	0.15	0.15	0.03	0.50	—	—	—
ER70S-4	ER48S-4	K11132	0.06 to 0.15	1.00 to 1.50	0.65 to 0.85	0.025	0.035	0.15	0.15	0.15	0.03	0.50	—	—	—
ER70S-6	ER48S-6	K11140	0.06 to 0.15	1.40 to 1.85	0.80 to 1.15	0.025	0.035	0.15	0.15	0.15	0.03	0.50	—	—	—
ER70S-7	ER48S-7	K11125	0.07 to 0.15	1.50 to 2.00 ^e	0.50 to 0.80	0.025	0.035	0.15	0.15	0.15	0.03	0.50	—	—	—
ER70S-G	ER48S-G	—	Not Specified ^f												

Notes:

a. Single values are maximum.

b. The letter “N” as a suffix to a classification indicates that the weld metal is intended for the core belt region of nuclear reactor vessels, as described in the Annex to the specification. This suffix changes the limits on the phosphorus and copper as follows:

P = 0.012% maximum

Cu = 0.08% maximum

c. SAE HS-1086/ASTM DS-56, *Metals & Alloys in the Unified Numbering System*.

d. 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.

e. In this classification, the maximum Mn may exceed 2.0%. If it does, the maximum C must be reduced 0.01% for each 0.05% increase in Mn or part thereof.

f. Chemical requirements are not specified but there shall be no intentional addition of Ni, Cr, Mo, or V. Composition shall be reported. Requirements are those agreed to by the purchaser and the supplier.

Table 2
Chemical Composition Requirements for Weld Metal from Composite Electrodes

AWS Classification ^a		UNS Number ^b	Shielding Gas ^c	Weight Percent ^d									
A5.18	A5.18M			C	Mn	Si	S	P	Ni ^e	Cr ^e	Mo ^e	V ^e	Cu
Multiple Pass Classifications													
E70C-3X	E48C-3X	W07703	75–80% Ar/Balance CO ₂ or CO ₂	0.12	1.75	0.90	0.03	0.03	0.50	0.20	0.30	0.08	0.50
E70C-6X	E48C-6X	W07706	75–80% Ar/Balance CO ₂ or CO ₂	0.12	1.75	0.90	0.03	0.03	0.50	0.20	0.30	0.08	0.50
E70C-G(X)	E48C-G(X)	—	f	Not Specified ^g									
Single Pass Classifications													
E70C-GS(X)	E48C-GS(X)	—	f	Not Specified ^h									

Notes:

- a. The final X shown in the classification represents a “C” or “M” which corresponds to the shielding gas with which the electrode is classified. The use of “C” designates 100% CO₂ shielding (AWS A5.32 Class SG-C). “M” designates 75–80% Ar/ balance CO₂ (AWS A5.32 Class SG-AC-Y, where Y is 20 to 25). For E70C-G [E48C-G] and E70C-GS [E48C-GS], the final “C” or “M” may be omitted if these gases are not used for classification.
- b. SAE HS-1086/ASTM DS-56, *Metals & Alloys in the Unified Numbering System*.
- c. Use of a shielding gas other than that specified will result in different weld metal composition.
- d. Single values are maximums.
- e. The sum of Ni, Cr, Mo, and V shall not exceed 0.50%.
- f. Shielding gas shall be as agreed upon between purchaser and supplier, unless designated by the C or M suffix.
- g. Composition shall be reported; the requirements are those agreed to between purchaser and supplier.
- h. The composition of weld metal from this classification is not specified since electrodes of this classification are intended only for single pass welds. Dilution, in such welds, usually is quite high.

3.2 Electrodes and rods classified under one classification shall not be classified under any other classification in this specification, except that composite stranded electrodes or composite metal cored electrodes classified as E70C-XC [E48C-XC] may also be classified as E70C-XM [E48C-XM], or vice versa, provided the product meets the requirements of both classifications.

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

Acceptance⁵ of the electrodes and rods shall be in accordance with the provisions of AWS A5.01.

5. See Section A3, Acceptance (in Annex A) for further information concerning acceptance, testing of the material shipped, and 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.⁶

6. Rounding-Off 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 E 29.

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

Table 3
Tension Test Requirements (As Welded)

AWS Classification ^a		Shielding Gas	Tensile Strength (minimum)		Yield Strength ^b (minimum)		Elongation ^b Percent (minimum)
A5.18	A5.18M		psi	MPa	psi	MPa	
ER70S-2	ER48S-2	CO ₂ ^c	70 000	480	58 000	400	22
ER70S-3	ER48S-3						
ER70S-4	ER48S-4						
ER70S-6	ER48S-6						
ER70S-7	ER48S-7						
ER70S-G	ER48S-G	d	70 000	480	58 000	400	22
E70C-3X	E48C-3X	75–80% Ar/balance CO ₂ or CO ₂	70 000	480	58 000	400	22
E70C-6X	E48C-6X						
E70C-G(X)	E48C-G(X)	d	70 000	480	58 000	400	22
E70C-GS(X)	E48C-GS(X)	d	70 000	480	Not Specified	Not Specified	Not Specified

Notes:

- a. The final X shown in the classification represents a “C” or “M” which corresponds to the shielding gas with which the electrode is classified. The use of “C” designates 100% CO₂ shielding (AWS A5.32 Class SG-C); “M” designates 75–80% Ar/balance CO₂ (AWS A5.32 Class SG-AC-Y, where Y is 20 to 25). For E70C-G [E48C-G] and E70C-GS [E48C-GS], the final “C” or “M” may be omitted.
- b. Yield strength at 0.2% offset and elongation in 2 in [50 mm] gage length (or 1.4 in [36 mm] gage length for the 0.350 in [9.0 mm] tensile specimen recommended in A4.2 for the optional acceptance test using gas tungsten arc).
- c. CO₂ = carbon dioxide shielding gas (AWS A5.32 Class SG-C). The use of CO₂ for classification purposes shall not be construed to preclude the use of Ar/CO₂ (AWS A5.32 Class SG-AC-Y) or Ar/O₂ (AWS A5.32 Class SG-AO-X) shielding gas mixtures. A filler metal tested with gas blends, such as Ar/O₂, or Ar/CO₂, may result in weld metal having higher strength and lower elongation. Testing with 100% argon shielding (AWS A5.32 Class SG-A) is required when classification testing is based on GTAW only (see A4.2 in Annex A).
- d. Shielding gas shall be as agreed to between purchaser and supplier, unless designated by the C or M suffix.

Table 4
Impact Test Requirements (As Welded)

AWS Classification		Average Impact Strength ^{a,b} (Minimum)	
A5.18	A5.18M	A5.18	A5.18M
ER70S-2	ER48S-2	20 ft·lbf at –20°F	27 J at –30°C
ER70S-3	ER48S-3	20 ft·lbf at 0°F	27 J at –20°C
ER70S-4	ER48S-4	Not Required	Not Required
ER70S-6	ER48S-6	20 ft·lbf at –20°F	27 J at –30°C
ER70S-7	ER48S-7	20 ft·lbf at –20°F	27 J at –30°C
ER70S-G	ER48S-G	As agreed between supplier and purchaser	
E70C-G(X)	E48C-G(X)		
E70C-3X	E48C-3X	20 ft·lbf at 0°F	27 J at –20°C
E70C-6X	E48C-6X	20 ft·lbf at –20°F	27 J at –30°C
E70C-GS(X)	E48C-GS(X)	Not Required	Not Required

Notes:

- a. Both the highest and lowest of the five test values obtained shall be disregarded in computing the impact strength. 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.
- b. For classifications with the “N” (nuclear) designation, three additional specimens shall be tested at room temperature. Two of the three shall equal, or exceed, 75 ft·lbf [100 J], and the third shall not be lower than 70 ft·lbf [95 J]. The average of the three shall equal, or exceed, 75 ft·lbf [100 J].

Part B

Tests, Procedures, and Requirements

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 Sections 9 through 14. See Section 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 Section 15, Diffusible Hydrogen Test, is not required for classification (see note c 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 prescribed 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 prescribed procedures. In that 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

Table 5
Required Tests

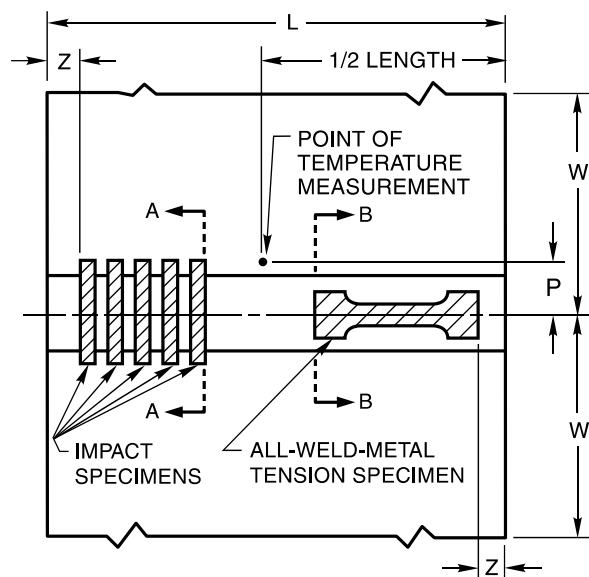
AWS Classification		Chemical Analysis		Radiographic Test	Tension Test	Bend Test	Impact Test	Diffusible Hydrogen Test
A5.18	A5.18M	Electrode	Weld Metal					
Solid Electrodes								
ER70S-2	ER48S-2	Required	Not Required	Required	Required	Not Required	Required	c
ER70S-3	ER48S-3	Required	Not Required	Required	Required	Not Required	Required	c
ER70S-4	ER48S-4	Required	Not Required	Required	Required	Not Required	Not Required	c
ER70S-6	ER48S-6	Required	Not Required	Required	Required	Not Required	Required	c
ER70S-7	ER48S-7	Required	Not Required	Required	Required	Not Required	Required	c
ER70S-G	ER48S-G	Required	Not Required	Required	Required	Not Required	Not Required	c
Composite Electrodes								
E70C-3X	E48C-3X	Not Required	Required	Required	Required	Not Required	Required	c
E70C-6X	E48C-6X	Not Required	Required	Required	Required	Not Required	Required	c
E70C-G(X)	E48C-G(X)	Not Required	Required	Required	Required	Not Required	Not Required	c
E70C-GS(X) ^a	E48C-GS(X) ^a	Not Required	Not Required	Not Required	Required ^b	Required	Not Required	c

Notes:

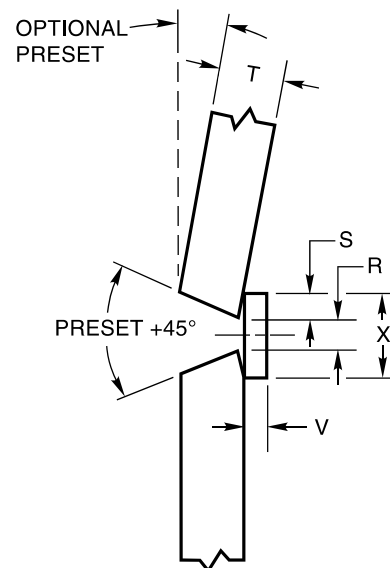
a. Intended for single pass welding.

b. Transverse tension test. All others are all-weld-metal tension tests.

c. 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).

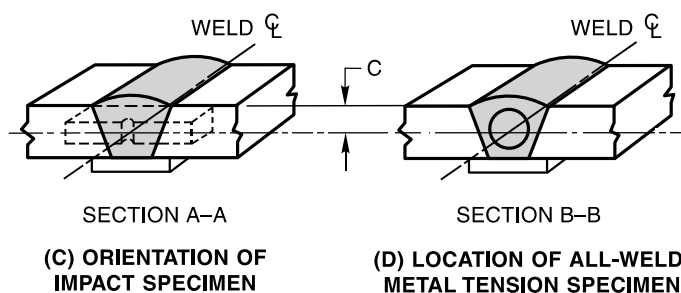


(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



(B) GROOVE PREPARATION OF TEST PLATE

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
V	Backup Strip Thickness, min.	3/8	9
X	Backup Strip Width, min.	1	25
T	Thickness	3/4	19
W	Width, min.	5	125
Z	Discard, min.	1	25

(C) ORIENTATION OF
IMPACT SPECIMEN(D) LOCATION OF ALL-WELD-
METAL TENSION SPECIMENTEST CONDITIONS FOR SOLID ELECTRODES^{4,5}

Standard size ⁶	0.045 in	[1.2 mm]	1/16 in	[1.6 mm]
Shielding gas ⁷	CO ₂	CO ₂	CO ₂	CO ₂
Wire feed speed	450 in/min ± 5%	[190 mm/sec] ± 5%	240 in/min ± 5%	[100 mm/sec] ± 5%
Nominal arc voltage	27 to 31 V	27 to 31 V	26 to 30 V	26 to 30 V
Resulting current, DCEP ⁸ (DCEP = electrode positive)	260 to 290 A	260 to 290 A	330 to 360 A	330 to 360 A
Tip-to-work distance ⁹	3/4 ± 1/8 in	[19 ± 3 mm]	3/4 ± 1/8 in	[19 ± 3 mm]
Travel speed	13 ± 1 in/min	[5.5 ± 0.5 mm/sec]	13 ± 1 in/min	[5.5 ± 0.5 mm/sec]

Notes:

- Base metal shall be as specified in Table 6.
- The surfaces to be welded shall be clean.
- 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.
- Test conditions for composite electrodes shall be as recommended by the manufacturer.
- Preheat and interpass temperatures for both solid and composite electrodes shall be as specified in 9.3.1.
- 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 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].
- If shielding gases or blends other than CO₂ (AWS A5.32 Class SG-C) are used, the wire feed speed (and resulting current), arc voltage, and travel speed are to be as agreed to between purchaser and supplier.
- The required combination of electrode feed rate, arc voltage, and tip-to-work distance should produce welding currents in the ranges shown. Currents substantially outside these ranges suggest errors in feed rate, tip-to-work distance, voltage settings, or in instrumentation.
- 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

composite and solid electrodes (see Section A4.2 in Annex A for requirements for classification based on gas tungsten arc welding only), or the groove weld in Figure 2 for mechanical properties of composite stranded and composite metal cored electrodes designated for single pass applications only.

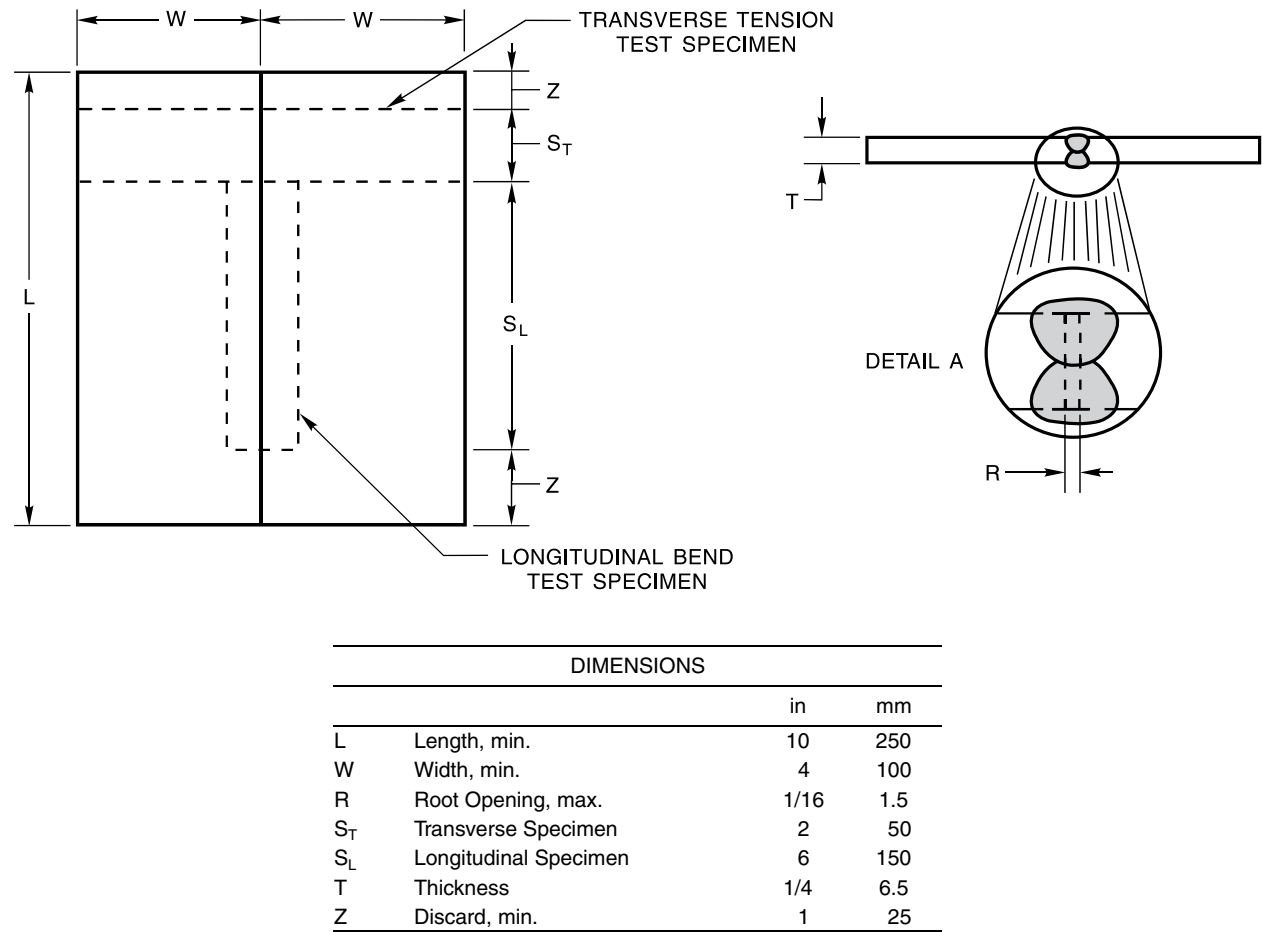
(2) The weld pad in Figure 3 for chemical analysis of the weld metal from composite stranded and composite metal cored electrodes.

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 avoid-

ing the need to make a weld pad. In case of dispute, the weld pad in Figure 3 shall be the referee method.

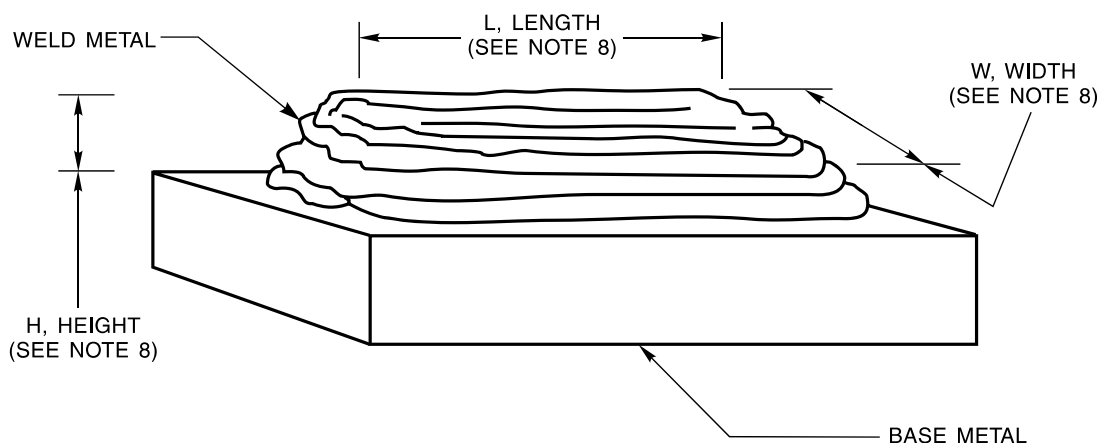
Chemical analysis of weld metal from composite stranded and composite metal cored electrodes designated for single pass applications should not be obtained from the groove weld in Figure 2 due to the high amount of base metal dilution.

9.2 Preparation of each weld test assembly shall be as prescribed 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 ASTM specification shown there, or an equivalent specification. Testing of the assembly shall be as prescribed in 10.2, 10.3, and Sections 11 through 14.



- Notes:
1. Base metal shall be as specified in Table 6.
 2. The surfaces to be welded shall be clean.
 3. Detail A shows the completed joint and approximate weld configuration.
 4. Test conditions shall be as recommended by the manufacturer and shall be made available to the purchaser upon request.

Figure 2—Groove Weld Test Assembly for Transverse Tension and Longitudinal Guided Bend Tests



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 interpass temperature shall not exceed 325°F [165°C].
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). Length (L), after allowance for start and stop areas, and width (W) shall be sufficient to perform analysis. The sample for analysis shall be taken at least 3/8 in [9.5 mm] above the original base metal surface.

Figure 3—Pad for Chemical Analysis of Weld Metal from Composite Electrodes

Table 6
Base Metal for Test Assemblies

AWS Classifications	ASTM Specification	UNS Number
All, except E70C-GS(X) [E48C-GS(X)]	A36, A285 Grade C, A515 Grade 70, or A516 Grade 70	K02600 K02801 K03101 K02700
E70C-GS(X) [E48C-GS(X)]	A515 Grade 70 or A516 Grade 70	K03101 K02700

9.3 Groove Weld

9.3.1 For all classifications except E70C-GS(X) [E48C-GS(X)], a test assembly shall be prepared and welded as specified in Figure 1, using base metal of the appropriate type specified in Table 6. 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 Section 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 degrees. An assembly that is warped more than 5 degrees out of plane shall be discarded. Test assemblies shall not be straightened. The test assembly shall be tack welded at room temperature and welding shall begin at that temperature (60°F [15°C] minimum). Welding shall continue until the assembly has reached a maximum interpass temperature of 325°F [165°C], measured by temperature indicating crayons or surface thermometers at the location shown in Figure 1.

For the remainder of the weld, a minimum preheat temperature of 275°F [135°C] and maximum interpass temperature of 325°F [165°C] 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 a temperature of 300° ± 25°F [150° ± 15°C] before welding is resumed. When welding has been completed and the assembly has cooled, the assembly shall be prepared and tested as specified in Sections 11, Radiographic Test; 12, Tension Test; and 14, Impact Test. All testing will be performed in the as-welded condition except for the optional aging of the all-weld-metal tension test specimen specified in 12.1.1.

9.3.2 For single-pass electrodes classification E70C-GS(X) [E48C-GS(X)] a test assembly using base metal as specified in Table 6 shall be prepared and welded as shown in Figure 2. After tack welding the plates at each

end, the test assembly shall be welded in the flat position, with one bead on each side. Welding shall begin with the assembly at room temperature (60°F [15°C] minimum). When the weld bead has been completed on one side, the assembly shall be turned over and the bead deposited on that side, as shown in Figure 2. This sequence shall not be interrupted. The electrode size shall be 0.045 in or 1/16 in [1.2 mm or 1.6 mm] (or the size the manufacturer produces that is closest to one of these, if these sizes are not produced).

After welding has been completed and the assembly has cooled in still air at room temperature, the assembly shall be prepared and tested as specified in 12.2 and Section 13, Bend Test. All testing shall be performed in the as-welded condition except for the optional aging of the bend test specimen specified in 13.2.

9.4 Weld Pad. A weld pad shall be prepared using composite stranded and composite metal cored electrodes as shown in Figure 3, 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 3, 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 325°F [165°C]. 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 3. Testing of this assembly shall be as specified in 10.2 and 10.3. The results shall meet the requirements of 10.4.

10. Chemical Analysis

10.1 A sample of the solid electrode or rod 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 For composite stranded or metal cored filler metals, the sample for analysis shall be taken from weld metal produced with the filler metal, not the filler metal itself.

The sample for analysis shall be taken from weld metal obtained with the electrode and a shielding gas as specified in Tables 2 and 3. The sample may be taken from the weld pad prepared in accordance with 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 3 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 3, 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 E 350.

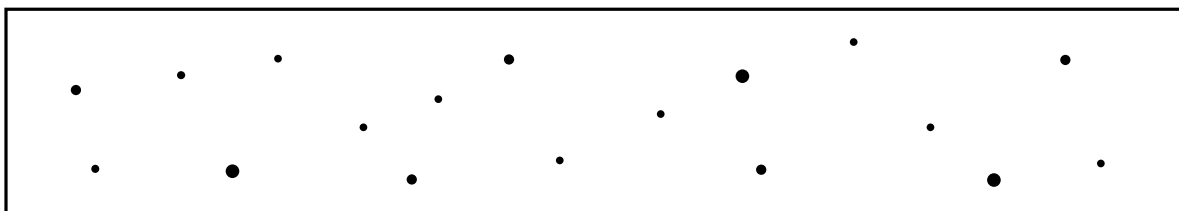
10.4 The results of the analysis shall meet the requirements of Table 1 for solid electrodes or Table 2 for composite electrodes for the classification of electrode under test.

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 and flush with the original surfaces of the base metal or with a uniform reinforcement not exceeding 3/32 in [2.5 mm]. 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. Thickness 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 E 1032. 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 4. In evaluating the radiograph, 1 in [25 mm] of the weld on each end of the test assembly shall be disregarded.

**(A) ASSORTED ROUNDED INDICATIONS**

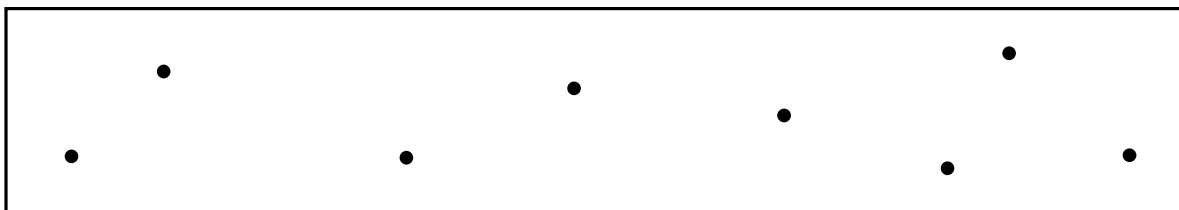
SIZE 1/64 in [0.4 mm] TO 1/16 in [1.6 mm] IN DIAMETER OR IN LENGTH.

MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 18, WITH THE FOLLOWING RESTRICTIONS:

MAXIMUM NUMBER OF LARGE 3/64 in [1.2 mm] TO 1/16 in [1.6 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 3.

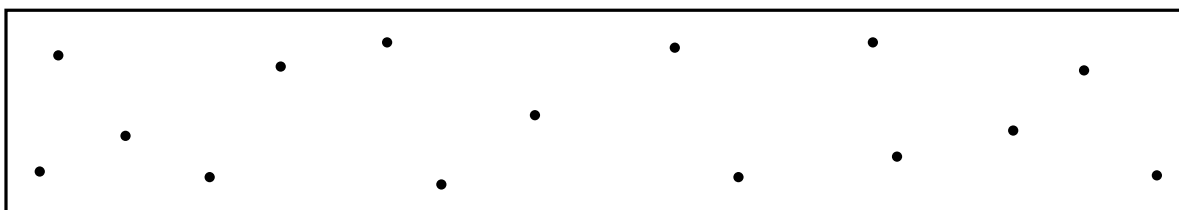
MAXIMUM NUMBER OF MEDIUM 1/32 in [0.8 mm] TO 3/64 in [1.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 5.

MAXIMUM NUMBER OF SMALL 1/64 in [0.4 mm] TO 1/32 in [0.8 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 10.

**(B) LARGE ROUNDED INDICATION**

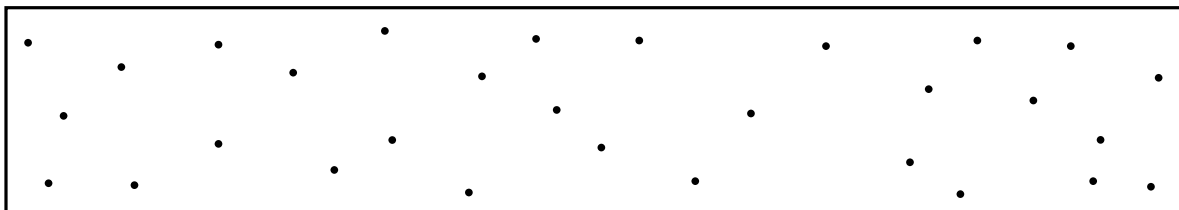
SIZE 3/64 in [1.2 mm] TO 1/16 in [1.6 mm] IN DIAMETER OR IN LENGTH.

MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 8.

**(C) MEDIUM ROUNDED INDICATIONS**

SIZE 1/32 in [0.8 mm] TO 3/64 in [1.2 mm] IN DIAMETER OR IN LENGTH.

MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 15.

**(D) SMALL ROUNDED INDICATIONS**

SIZE 1/64 in [0.4 mm] TO 1/32 in [0.8 mm] IN DIAMETER OR IN LENGTH.

MAXIMUM NUMBER OF INDICATIONS IN ANY 6 in [150 mm] OF WELD = 30.

Notes:

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

Figure 4—Radiographic Acceptance Standards

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 4) 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 or 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 or B4.0M.

12.1.1 After machining, but before testing, the specimens from composite electrodes only 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 or 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 (composite electrodes only).

12.2 One transverse rectangular tension test specimen, as specified in the Tension Tests section of AWS B4.0 or B4.0M, shall be machined from the groove weld described in 9.3.2, and shown in Figure 2, as required in Table 5. The transverse tensile specimen shall have a nominal thickness of 1/4 in [6.5 mm] and reduced width of 1-1/2 in [38 mm] and a minimum length of 8 in [200 mm]. Other dimensions of the transverse tension test specimen shall be as specified in the Tension Test section of AWS B4.0 or B4.0M.

12.2.1 The specimen shall be tested in the as-welded (unaged) condition in the manner described in the tension test section of AWS B4.0 or B4.0M.

12.2.2 The results of the transverse tension test shall meet the requirements specified in Table 3. A test specimen that fractures in the base metal shall be considered to have met those requirements.

13. Bend Test

13.1 One longitudinal face bend test specimen, as specified in the Bend Tests section of AWS B4.0 or B4.0M, shall be machined from the groove weld test assembly described in 9.3.2, and shown in Figure 2, as required in Table 5. The longitudinal face bend specimen shall have a nominal thickness of 1/4 in [6.5 mm], a specimen width of 1-1/2 in [38 mm] and a minimum length of 6 in [150 mm]. Other dimensions of the longitudinal bend test specimen shall be as specified in the Bend Test section of AWS B4.0 or B4.0M.

13.2 After machining, but before bending, 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.

13.3 The specimen shall be tested in the manner described in the bend test section of AWS B4.0 or B4.0M, by bending it on any of the standard bend test jigs shown there. The bend radius shall be 3/4 in [19 mm]. Positioning of the specimen shall be such that the bead with the greater surface discontinuities, if any, is in tension.

13.4 After bending, each specimen shall conform to the 3/4 in [19 mm] radius, with appropriate allowance for springback, and the weld metal shall not contain openings in excess of 1/8 in [3.2 mm] on the convex surface.

14. Impact Test

14.1 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 or 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.

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

14.3 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.

14.4 For classifications with the “N” (nuclear) designation, three additional specimens shall be prepared. These specimens shall be tested at room temperature. Two of the three shall equal, or exceed, 75 ft-lbf [100 J], and the third shall not be lower than 70 ft-lbf [95 J]. The average of the three shall equal, or exceed, 75 ft-lbf [100 J].

15. Diffusible Hydrogen Test

15.1 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 7, the optional supplemental diffusible hydrogen designator may be added at the end of the classification.

15.2 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.

15.3 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 A4.3.⁷

7. See A8.2 (in Annex A).

Table 7
Optional Diffusible Hydrogen Requirements

AWS Classifications	Optional Supplemental Diffusible Hydrogen Designator ^{a,b}	Average Diffusible Hydrogen, Maximum (mL/100g Deposited Metal) ^c
All	H16	16.0
All	H8	8.0
All	H4	4.0

Notes:

- a. See Note c 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 and H4).

15.4 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification, provided the actual test results satisfy the diffusible hydrogen requirements for the applicable optional supplemental designator. Likewise, if the actual test results for an electrode meet the requirements for the lower, or lowest hydrogen designator, as specified in Table 7, the electrode also meets the requirements of all higher hydrogen designators in Table 7 without need to retest.

Part C

Manufacture, Identification, and Packaging

16. 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.

17. 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 Section 19, Standard Package Forms) are as shown in Table 8.

Table 8
Standard Sizes^a

Standard Package Forms	Tolerances					
	Diameter		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	±0.002	+0.01, -0.04	±0.002	+0.02, -0.06
	5/64	0.078	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	3/32	0.094	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	1/8	0.125	±0.002	+0.01, -0.07	±0.003	+0.02, -0.07
	5/32	0.156	±0.002	+0.01, -0.07	±0.003	+0.02, -0.07
	3/16	0.188	±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	±0.002	+0.01, -0.04	±0.002	+0.02, -0.06
	5/64	0.078	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	3/32	0.094	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	7/64	0.109	±0.002	+0.01, -0.07	±0.003	+0.02, -0.06
	1/8	0.125	±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	±0.002	+0.01, -0.04	±0.002	+0.02, -0.06
	5/64	0.078	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	3/32	0.094	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	7/64	0.109	±0.002	+0.01, -0.07	±0.003	+0.02, -0.06
	1/8	0.125	±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	±0.002	+0.01, -0.04	±0.002	+0.02, -0.06
	5/64	0.078	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	3/32	0.094	±0.002	+0.01, -0.04	±0.003	+0.02, -0.06
	7/64	0.109	±0.002	+0.01, -0.07	±0.003	+0.02, -0.06

Notes:

a. Dimensions, sizes, tolerances, and package forms other than those shown shall be as agreed by purchaser and supplier.

b. Length shall be 36 in ± 1/2 in [900 +25, -0 mm].

c. Not shown as standard metric size in ISO 544:2003.

18. Finish and Uniformity

18.1 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.

18.2 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.

18.3 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.

18.4 A suitable protective coating may be applied to any filler metal in this specification. Copper may be used as a coating for any classification except one that carries the suffix “N” (nuclear) in its designation.

19. Standard Package Forms

19.1 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 9. Package forms, sizes, and weights other than these shall be as agreed between purchaser and supplier.

19.2 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.

19.3 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 5A and 5B.

20. Winding Requirements

20.1 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.

20.2 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.

20.3 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

20.4 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 20.1 and 20.2. Any method of wire form inspection shall be as agreed between purchaser and supplier.

21. Filler Metal Identification

21.1 The product information and the precautionary information required in Section 23 for marking each package shall also appear on each coil, spool, and drum.

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

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

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

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

Table 9
Packaging Requirements^a

	Package Size ^d			Net Weight of Electrode ^b	
Type of Package	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 12	ID ID	170 300	14 25, 30, 50, 60, and 65	6 10, 15, 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	350	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					
	Coil Dimensions				
	Coil Net Weight ^b		Inside Diameter of Liner		Width of Wound Electrode
Electrode Size	lb.	kg	in	mm	in, max. mm, max.
	14	6	6-3/4 ± 1/8	170 ± 3	3 75
All	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

Notes:

- a. Sizes and net weights other than those specified may be supplied as agreed between supplier and purchaser.
b. Tolerance on net weight shall be ± 10 percent.
c. As agreed between supplier and purchaser.
d. ID = inside diameter
OD = outside diameter

22. Packaging

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

23. Marking of Packages

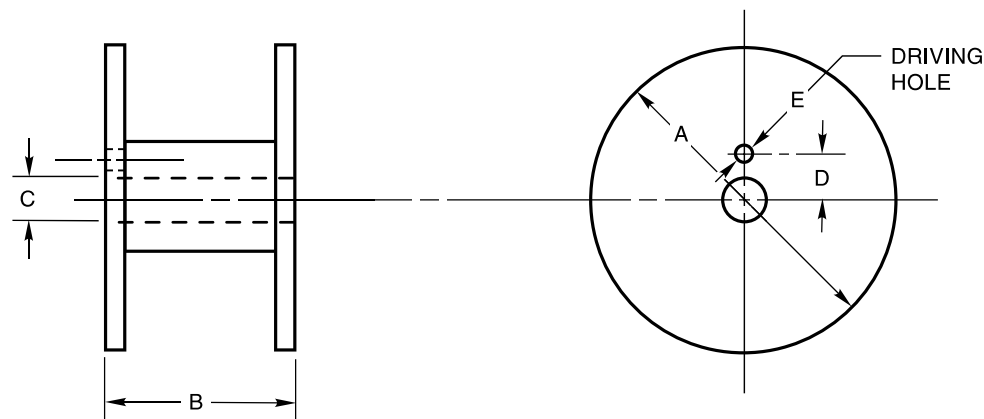
23.1 The following product information (as a minimum) shall be legibly marked so as to be visible from the outside of each unit package:

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

- Supplier's name and trade designation
- Size and net weight (see 6.1)
- Lot, control, or heat number

23.2 The appropriate precautionary information⁸ 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.

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

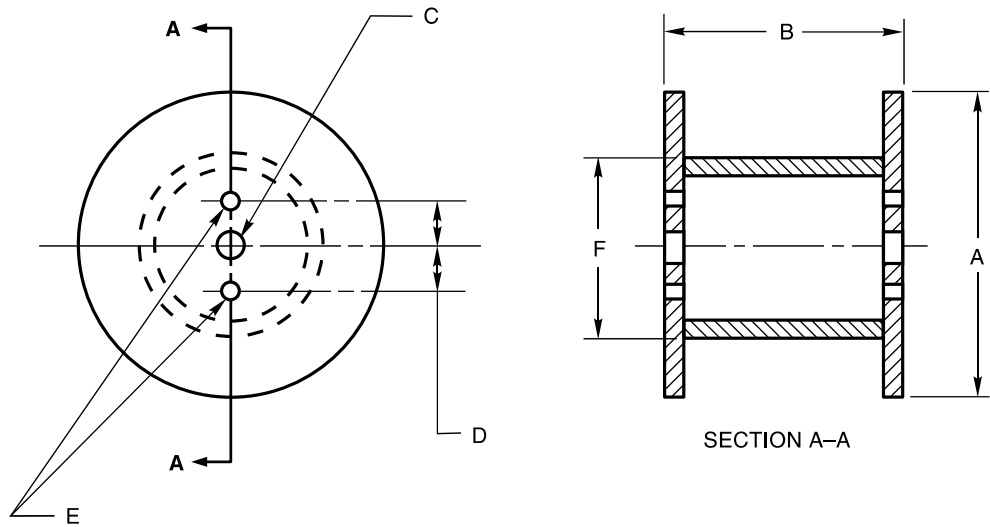


DIMENSIONS									
		4 in [100 mm] Spools		8 in [200 mm] Spools		12 in [300 mm] Spools		14 in [350 mm] Spools	
		in	mm	in	mm	in	mm	in	mm
A	Diameter, max. (Note 4)	4.0	102	8.0	203	12	305	14	355
B	Width	1.75	46	2.16	56	4.0	103	4.0	103
	Tolerance	± 0.03	$+0, -2$	± 0.03	$+0, -3$	± 0.06	$+0, -3$	± 0.06	$+0, -3$
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 864 except that "A" specifies $\pm$ tolerances on the nominal diameter, rather than a plus tolerance only, which is shown here as a maximum.

**Figure 5A—Standard Spools—Dimensions of 4, 8, 12, and 14 in
[100, 200, 300, and 350 mm] Spools**



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 5B—Standard Spools—Dimensions of 22, 24, and 30 in [560, 610, and 760 mm] Spools

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Nonmandatory Annexes

Annex A

Guide to AWS Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding

(This Annex is not a part of AWS A5.18/A5.18M:2005, *Specification for Carbon 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 A1.

A2.2 The prefix “E” designates an electrode as in other specifications. The letters “ER” indicate that the filler metal may be used either as an electrode or a rod. For A5.18, the number 70 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 A5.18. Similarly, for A5.18M, the number 48 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 A5.18M.

The letter “S” designates a solid electrode or rod.

The letter “C” designates a composite electrode. The digit following the hyphen, 2, 3, 4, 6, 7, G, or GS, indicates the chemical composition and/or impact testing requirements specified in Tables 1–5.

In the case of some composite stranded and metal cored electrodes, the letter “M” or “C” will follow, indicating the type of shielding gas.

The addition of the letter “N” as a suffix to a classification indicates that the electrode is intended for certain very special welds in nuclear applications. These welds are found in the core belt region of the reactor vessel. This region is subject to intense neutron radiation, and it is necessary, therefore, that the phosphorus, vanadium, and copper contents of the weld metal be limited in order to resist neutron radiation-induced embrittlement. It is also necessary that the weld metal has a high upper shelf energy level in order to withstand some embrittlement, yet remain serviceable over the years.

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, or H4) may follow the classification designation, indicating whether the electrode will meet a maximum hydrogen level of 16, 8, or 4 mL/100g of deposited 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 7, 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 This specification includes filler metals classified as ER70S-G [ER48S-G], E70C-G [E48C-G], and E70C-GS [E48C-GS]. The “G” (multiple pass) or “GS” (single pass) 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

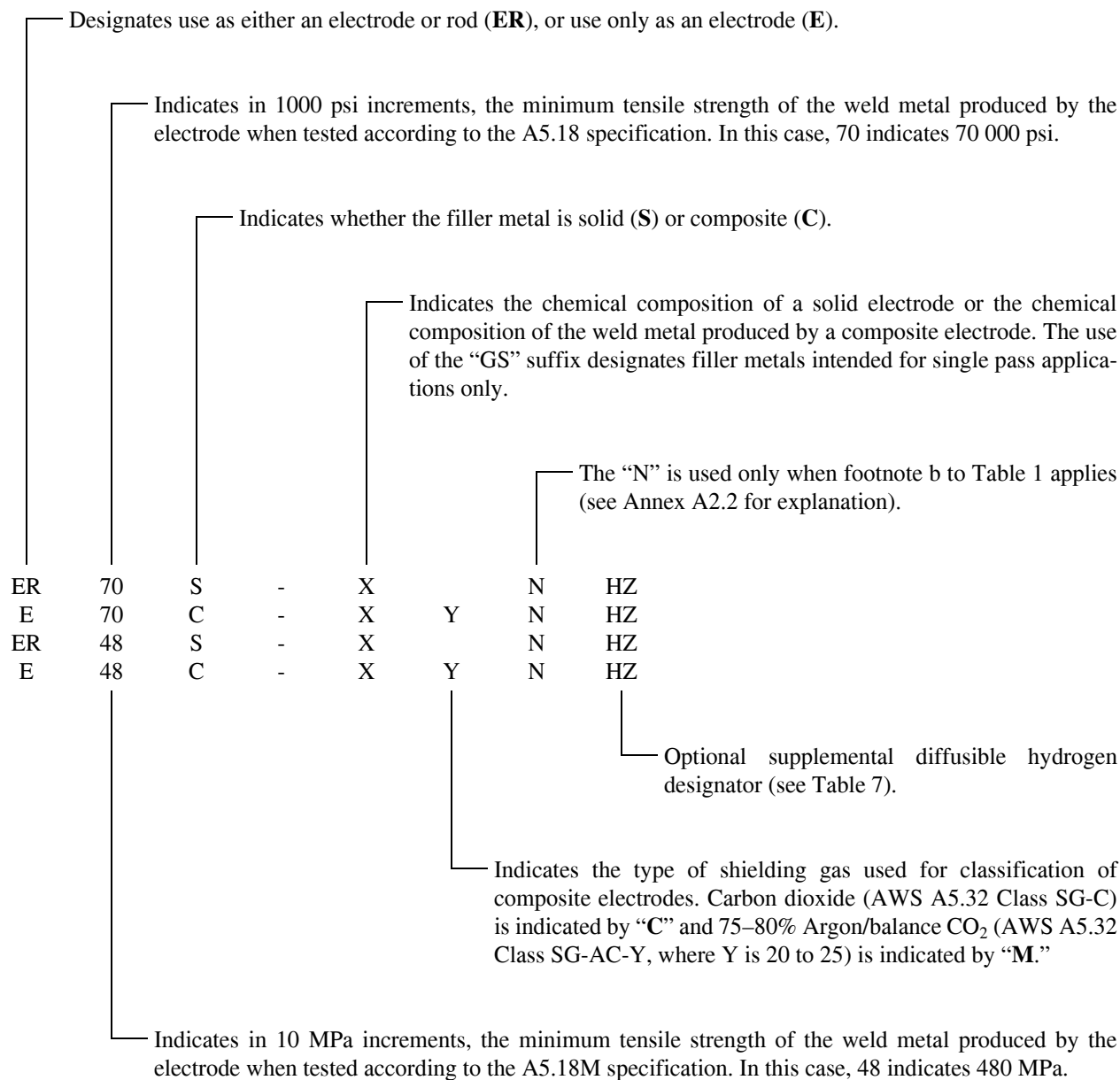


Figure A1—Classification System

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

A2.3.2 The point of difference (although not necessarily the amount of the difference) referred to above will be readily apparent from the use of the words “not required” and “not specified” in the specification. The use of these words is as follows:

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

“Not Required” is used in those areas of the specification that refer to the tests that must be conducted in order to classify a filler metal. It indicates that the test is *not required* because the requirements (results) for the test have not been specified for that particular classification.

Restating the case, when a requirement is not specified, it is not necessary to conduct the corresponding test in order to classify a filler metal to that classification. When a purchaser wants the information provided by that test in order to consider a particular product of that classification for a certain application, the purchaser will have to arrange for that information with the supplier of the product. The purchaser will have to establish with that supplier just what the testing 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. The manufacturer may do this by following the 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 requirements.

(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 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 designations, 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 A2.

One all-weld-metal round tension test specimen, as specified in the Tension Tests section of AWS B4.0 or B4.0M, *Standard Methods for Mechanical Testing of Welds*, shall be machined from the groove weld described in Figure A2. 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 ten-

sion test specimen shall be as specified in the Tension Test section of AWS B4.0 or B4.0M.

The Charpy V-Notch specimen shall be as specified in Section 14. 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

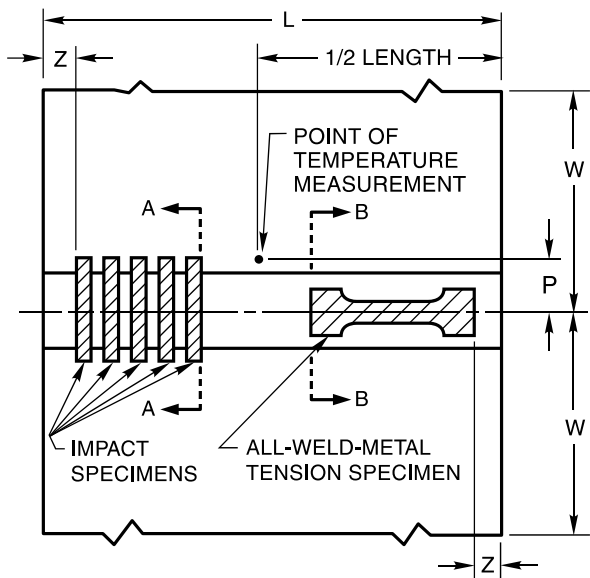
A5.2 ANSI Z49.1, *Safety in Welding, Cutting, and Allied Processes* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the Section on Health Protection and Ventilation in that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

A6. Welding Considerations

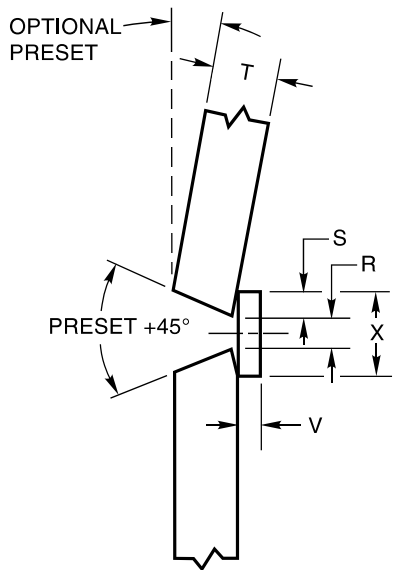
A6.1 Gas metal arc welding (GMAW) can be divided into three categories based on the mode of metal transfer. These modes are (1) spray (conventional or pulsed), (2) globular, and (3) short circuiting transfer. In the spray, pulsed spray, and globular modes, transfer occurs as distinct droplets that are 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 Class SG-AC-Y, where Y is 5 to 15). A characteristic of this shielding gas is the smooth arc plasma through which hundreds of very fine droplets are transferred to the weld pool each second.

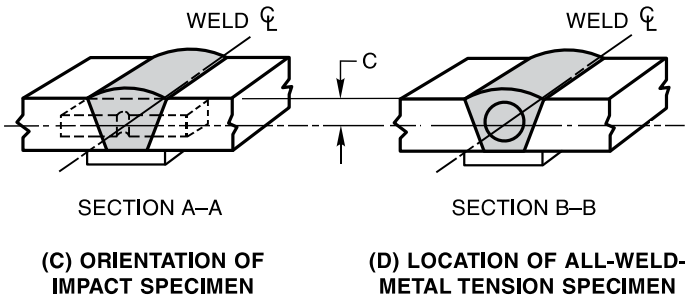


(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



(B) GROOVE PREPARATION OF TEST PLATE

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
V	Backup Strip Thickness, min.	1/4	6.5
X	Backup Strip Width, min.	1	25
T	Thickness	1/2	13
W	Width, min.	5	125
Z	Discard, min.	1	25



(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 ⁶	Argon	Argon	Argon	Argon
Nominal arc voltage	13 to 16 V	13 to 16 V	16 to 19 V	16 to 19 V
Nominal current, DCEN (DCEN = electrode negative)	220 to 250 A	220 to 250 A	250 to 280 A	250 to 280 A
Preheat Temperature	275°F minimum	[135°C] minimum	275°F minimum	[135°C] minimum
Interpass Temperature	325°F maximum	[165°C] maximum	325°F maximum	[165°C] maximum
Travel speed	4 to 6 in/min	[2.0 ± 0.4 mm/sec]	4 to 6 in/min	[2.0 ± 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.
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.

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

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% CO₂ (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 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 to 0.045 in [0.8 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 CO₂ (AWS A5.32 Class SG-AC-Y) as the shielding gas or with CO₂ (AWS A5.32 Class SG-C) alone. The penetration of such welds is greater with CO₂ than it is with

argon-CO₂ mixtures. Mixtures of 50 to 80% argon with CO₂ 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 CO₂ 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 CO₂ alone does. This can be an advantage in welding thin plate.

A7. Description and Intended Use of Electrodes and Rods

A7.1 ER70S-2 [ER48S-2]. Electrodes and rods of the ER70S-2 [ER48S-2] classification are primarily used for single-pass welding of killed, semi-killed, and rimmed steels, but may be used for some multipass applications. Because of the added deoxidants, these filler metals can be used for welding steels that have a rusty or dirty surface, with a possible sacrifice of weld quality depending on the condition of the surface. ER70S-2 [ER48S-2] filler metals are used extensively to produce high quality, high toughness welds with the GTAW process. These filler metals are also well suited for use in single side, melt through welding without a protective root shielding gas on the backside of the joint. Typical specifications for these steels are ASTM A 36, A 285-C, A 515-55, and A 516-70, which have UNS numbers K02600, K02801, K02001, and K02700, respectively.

A7.2 ER70S-3 [ER48S-3]. Electrodes and rods of the ER70S-3 [ER48S-3] classification are intended for welding single-pass and multi-pass welds. Typical base metal specifications are often the same as those for the ER70S-2 [ER48S-2] classification. Electrodes of the ER70S-3 [ER48S-3] classification are the most widely used of the GMAW electrodes classified under this specification.

A7.3 ER70S-4 [ER48S-4]. Electrodes and rods of the ER70S-4 [ER48S-4] classification are intended for welding steel where conditions require more deoxidation than is provided by the ER70S-3 [ER48S-3] filler metal. Typical base metal specifications are often the same as those for the ER70S-2 [ER48S-2] classification. This classification does not require impact testing.

A7.4 ER70S-6 [ER48S-6]. Electrodes and rods of the ER70S-6 [ER48S-6] classification are intended for both single- and multiple-pass welding. They are especially suited for sheet metal applications, where smooth weld beads are desired, and structural and plate steels that have moderate amounts of rust or mill scale. These electrodes permit the use of higher current ranges with either

CO₂ (AWS A5.32 Class SG-C) shielding gas or with mixtures of argon and oxygen (AWS A5.32 Class SG-AO-X) or argon and carbon dioxide (AWS A5.32 Class SG-AC-Y). However, these electrodes do require a higher level of oxidation than the previously described electrodes when using either binary or ternary argon shielding gas mixtures per the AWS A5.32 specification. Typical base metal specifications are often the same as those for the ER70S-2 [ER48S-2] classification.

A7.5 ER70S-7 [ER48S-7]. Electrodes and rods of the ER70S-7 [ER48S-7] classification are intended for single- and multiple-pass welding. They may permit welding with higher travel speeds compared with ER70S-3 filler metals. They also provide somewhat better wetting action and bead appearance when compared with those filler metals. These electrodes permit the use of higher current ranges with either CO₂ (AWS A5.32 Class SG-C) shielding gas or with mixtures of argon and oxygen (AWS A5.32 Class SG-AO-X) or argon and carbon dioxide (AWS A5.32 Class SG-AC-Y). However, these electrodes do require a higher level of oxidation (more CO₂ or O₂) like the previously described electrode when using either binary or ternary argon shielding gas mixtures per the AWS A5.32 specification. Typical base metal specifications are often the same as those for the ER70S-2 [ER48S-2] classifications.

A7.6 ER70S-G [ER48S-G] and E70C-G [E48C-G]. Electrodes and rods of the ER70S-G [ER48S-G] and electrodes of the E70C-G [E48C-G] classifications are those filler metals not included in the preceding classes and for which only certain mechanical property requirements are specified. Electrodes of the E70C-G [E48C-G] classification may be classified with either CO₂ (AWS A5.32 Class SG-C) or 75–80% Ar/balance CO₂ (AWS A5.32 Class SG-AC-Y, where Y is 20 to 25) as shown by the “C” or “M” suffix. Absence of the C or M suffix means that the shielding gas used for testing was not one of the above AWS classes and the electrode manufacturer should be consulted for the recommended shielding gas to be used. The electrodes are intended for both single- and multiple-pass applications. The filler metal supplier should be consulted for the composition, properties, characteristics, and intended use of these classifications (see A2.3 for further information).

A7.7 E70C-GS [E48C-GS]. Electrodes of the E70C-GS [E48C-GS] classification are composite stranded or metal cored electrodes intended for only single-pass applications. The electrodes may be classified with either CO₂ (AWS A5.32 Class SG-C) or 75–80% Ar/balance CO₂ (AWS A5.32 Class SG-AC-Y, where Y is 20 to 25) as shown by the “C” or “M” suffix. Absence of the C or M suffix means that the shielding gas used for testing was not one of the above AWS classes and the electrode

manufacturer should be consulted for the recommended shielding gas to be used. The filler metal supplier should be consulted for the properties, characteristics, and intended use of these classifications. These electrodes may have higher alloy contents which improve single pass applications (such as tolerance to mill scale, etc.) but could preclude their use on multiple-pass applications due to higher alloy recovery.

A7.8 E70C-3 [E48C-3] and E70C-6 [E48C-6]. Electrodes of the E70C-3 [E48C-3] and E70C-6 [E48C-6] classifications are composite stranded or metal cored electrodes intended for both single- and multiple-pass applications. They are characterized by a spray arc and excellent bead wash characteristics. The electrodes may be classified with either CO₂ (AWS A5.32 Class SG-C) or 75–80% Ar/balance CO₂ (AWS A5.32 Class SG-AC-Y, where Y is 20 to 25) as shown by the “C” or “M” suffix. Classification E70C-3 [E48C-3] requires impacts at 0°F [–20°C] while E70C-6 [E48C-6] requires impacts at –20°F [–30°C].

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 generally is not a problem with plain carbon steels containing 0.3 percent or less carbon, nor with lower strength alloy steels. However, the electrodes classified in this specification are sometimes 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 7, 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.

A8.2.5 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] 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 and Bend 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 and bend test specimens (from composite electrodes only) 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 inter-pass temperatures to avoid the deleterious effects of hydrogen in production welds.

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	Last Published	Discontinued Classification	Last Published
E-60S-1	1965	E70S-1	1969
E-60S-2	1965	E70S-1B ^b	1969
E-60S-3	1965	E70S-2 ^c	1969
E-70T-1 ^a	1965	E70S-3 ^c	1969
E-70T-2 ^a	1965	E70S-4 ^c	1969
E-70T-3 ^a	1965	E70S-5	1969
E-70T-4 ^a	1965	E70S-6 ^c	1969
E-70T-5 ^a	1965	E70S-G ^c	1969
E-70T-G ^a	1965	E70U-1	1969
		ER70S-5	1993

Notes:

- These flux-cored electrode classifications were transferred to AWS A5.20-69 and continue to be included in the revisions to that specification.
- This electrode classification was transferred to the new AWS A5.28 specification where it is classified as ER80S-D2.
- These electrode classifications were changed to the new classification ER70S-X and remain in the current revision of the specification as such.

A10. General Safety Considerations

A10.1 *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 annex Section A5. Safety and health information is available from other sources, including, but not limited to Safety and Health Fact Sheets listed in A10.3, ANSI Z49.1, Safety in Welding, Cutting, and Allied Processes,⁹ and applicable federal and state regulations.*

A10.2 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.

A10.3 AWS Safety and Health Fact Sheets Index (SHF)¹⁰

No.	Title
1	Fumes and Gases
2	Radiation

9. ANSI documents are published by the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.

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

No.	Title
3	Noise
4	Chromium and Nickel in Welding Fume
5	Electric Hazards
6	Fire and Explosion Prevention
7	Burn Protection
8	Mechanical Hazards
9	Tripping and Falling
10	Falling Objects
11	Confined Space
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 & Allied Processes
23	California Proposition 65
24	Fluxes for Arc Welding and Brazing: Safe Handling and Use
25	Metal Fume Fever
27	Thoriated Tungsten Electrodes
29	Grounding of Portable and Vehicle Mounted Welding Generators

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Annex B

Guidelines for Preparation of Technical Inquiries for AWS Technical Committees

(This Annex is not a part of AWS A5.18/A5.18M:2005, *Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*, but is included for informational purposes only.)

B1. Introduction

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

B2. Procedure

All inquiries must be directed to:

Managing Director, Technical Services
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

All inquiries must contain the name, address, and affiliation of the inquirer, and they must provide enough information for the committee to fully understand the point of concern in the inquiry. Where that point is not clearly defined, the inquiry will be returned for clarification. For efficient handling, all inquiries should be type-written and should also be in the format used here.

B2.1 Scope. Each inquiry must address one single provision of the standard, unless the point of the inquiry involves two or more interrelated provisions. That provision must be identified in the scope of the inquiry, along

with the edition of the standard that contains the provisions or that the inquirer is addressing.

B2.2 Purpose of the Inquiry. The purpose of the inquiry must be stated in this portion of the inquiry. The purpose can be either to obtain an interpretation of a standard'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 quickly and fully understand the point of the inquiry. Sketches should be used when appropriate and all paragraphs, figures, and tables (or the Annex) which bear on the inquiry must be cited. If the point of the inquiry is to obtain a revision of the standard, the inquiry must provide technical justification for that revision.

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

B3. Interpretation of Provisions of the Standard

Interpretations of provisions of the standard are made by the relevant AWS Technical Committee. The secretary of the committee refers all inquiries to the 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 will be an official interpretation of the Society, and the secretary will transmit the response to the inquirer and to the *Welding Journal* for publication.

B4. Publication of Interpretations

All official interpretations will appear in the *Welding Journal*.

B5. Telephone Inquiries

Telephone inquiries to AWS Headquarters concerning AWS standards should be limited to questions of a general nature or to matters directly related to the use of the standard. The Board of Directors' policy requires that all AWS staff members respond to a telephone request for an official interpretation of any AWS standard with the

information that such an interpretation can be obtained only through a written request. The Headquarters staff cannot provide consulting services. The staff can, however, refer a caller to any of those consultants whose names are on file at AWS Headquarters.

B6. The AWS Technical Committee

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

AWS Filler Metal Specifications by Material and Welding Process

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

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AWS Filler Metal Specifications and Related Documents

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

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