

Specification for Carbon Steel Electrodes for Flux Cored Arc Welding



American Welding Society



Key Words—Carbon steel, flux cored electrodes,
flux cored arc welding, arc welding

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Specification for Carbon Steel Electrodes for Flux Cored 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 carbon steel electrodes for flux cored arc welding. The requirements include chemical composition and mechanical properties of the weld metal and certain usability characteristics. The AWS A5.20/A5.20M specification also includes optional, supplemental designators for improved toughness and diffusible hydrogen and to indicate conformance to special mechanical property requirements when the weld metal is deposited using both low heat input, fast cooling rate and high heat input, slow cooling rate procedures. Additional requirements are included for standard sizes, marking, manufacturing and packaging. A guide is appended to the specification as a source of information concerning the classification system employed and the intended use of carbon steel flux cored electrodes.

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

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<i>S. D. Reynolds, Jr.</i>	Consultant

*Advisor

**Deceased

***Special Contributor

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<i>H. D. Wehr</i>	Arcos Industries LLC

*Advisor

Foreword

(This Foreword is not part of AWS A5.20/A5.20M:2005, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*, but is intended for informational purposes only.)

This document is the first of the A5.20 specifications which uses both U.S. Customary Units and the International System of Units (SI) throughout. 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 554, *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 the U.S. Customary and SI Units.

The current document is the third revision of the initial joint ASTM/AWS document issued in 1969. Since it was developed by a subcommittee of the AWS Committee on Filler Metals and Allied Materials, the use of flux cored electrodes has been stimulated by developments in electrode manufacturing technology that have permitted the production of smaller diameter electrodes and by improvements in formulation of the core ingredients. This 2005 revision includes the following significant changes:

- (1) Heat input limits are now applied to the preparation of mechanical property test assemblies.
- (2) Maximum tensile strength limits have been added for all multiple pass classifications.
- (3) Mechanical property tests are required on additional electrode sizes.
- (4) Chemical composition limits have been modified.
- (5) Welding parameters are specified for diffusible hydrogen testing.
- (6) Optional supplemental designators (D and Q) have been added to identify high and low cooling rate mechanical property testing for FEMA and Navy applications.

The evolution took place as follows:

Historical Background

AWS A5.20-69	<i>Specifications for Mild Steel Electrodes for Flux Cored Arc Welding</i>
ANSI W3.20-1973	
ANSI/AWS A5.20-79	<i>Specification for Carbon Steel Electrodes for Flux Cored Arc Welding</i>
ANSI/AWS A5.20-95	<i>Specification for Carbon Steel Electrodes for Flux Cored Arc Welding</i>

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 (see Annex B).

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Specification for Carbon Steel Electrodes for Flux Cored Arc Welding

1. Scope

1.1 This specification prescribes requirements for the classification of carbon steel electrodes for flux cored arc welding (FCAW) either with or without shielding gas. (Metal cored carbon steel electrodes are classified according to AWS A5.18/A5.18M.)¹

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 A9. Safety and health information is available from other sources, including, but not limited to, ANSI Z49.1² 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 A5.20 uses U.S. Customary Units. The specification A5.20M 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 the sizing of electrodes or packaging or both under the A5.20 and A5.20M specifications.

1. AWS standards can be obtained from Global Engineering Documents, an Information Handling Services (IHS) Group Company, 15 Inverness Way East, Englewood, CO 80112-5776; telephone (800) 854-7179, (303) 397-7956; fax (303) 397-2740; internet: www.global.ihs.com.

2. ANSI standards can be obtained from the American National Standards Institute, 25 West 43rd Street, Fourth Floor, New York, NY 10036, and Global Engineering Documents, an Information Handling Services (IHS) Group Company, 15 Inverness Way East, Englewood, CO 80112-5776; telephone (800) 854-7179, (303) 397-7956; fax (303) 397-2740; internet: www.global.ihs.com.

2. Normative References

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

2.1 The following AWS standards are referenced in the mandatory sections of this document:

- (1) AWS A4.3, *Standard Methods for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*.
- (2) AWS A5.01, *Filler Metal Procurement Guidelines*.
- (3) AWS A5.32/A5.32M, *Specification for Welding Shielding Gases*.
- (4) AWS B4.0 or B4.0M, *Standard Methods for Mechanical Testing of Welds*.

2.2 The following ANSI standard is referenced in the mandatory sections of this document:

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

2.3 The following ASTM standards³ are referenced in the mandatory sections of this document:

- (1) ASTM A 36/A 36M, *Specification for Carbon Structural Steel*.
- (2) ASTM A 285/A 285M, *Specification for Pressure Vessel Plates, Carbon Steel, Low- and Intermediate-Tensile Strength*.
- (3) ASTM A 515/A 515M, *Specification for Pressure Vessel Plates, Carbon Steel, for Intermediate- and Higher-Temperature Service*.

3. ASTM standards can be obtained from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

(4) ASTM A 516/A 516M, *Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service*.

(5) ASTM A 830/A 830M, *Standard Specification for Plates, Carbon Steel, Structural Quality, Furnished to Chemical Composition Requirements*.

(6) ASTM DS-56 (or SAE HS-1086), *Metals & Alloys in the Unified Numbering System*.

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

(8) ASTM E 350, *Standard Test Methods for Chemical Analysis of Carbon Steel, Low Alloy Steel, Silicon Electrical Steel, Ingot Iron and Wrought Iron*.

(9) ASTM E 1032, *Standard Test Method for Radiographic Examination of Weldments*.

2.4 The following ISO standard⁴ is referenced in the mandatory sections of this document.

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

2.5 The following FEMA (Federal Emergency Management Agency) document⁵ is referenced in the mandatory sections of this document.

(1) FEMA 353, *Recommended Specifications and Quality Assurance Guidelines for Steel Moment-Frame Construction for Seismic Applications*.

3. Classification

3.1 The flux cored electrodes covered by the A5.20 specification utilize a classification system based upon the U.S. Customary Units and are classified according to the mechanical properties of the weld metal as specified in Table 1U as shown in Figure 1.

3.1M The flux cored electrodes covered by the A5.20M specification utilize a classification system based upon the International System of Units (SI) and are classified according to the mechanical properties of the weld metal as specified in Table 1M as shown in Figure 1.

3.1.1 Flux cored electrodes classified for multiple-pass welding are classified according to the following:

(1) The as-welded mechanical properties of the weld metal obtained with a particular shielding gas, if any, as specified in Table 1U [Table 1M].

4. ISO standards may be obtained from the American National Standards Institute (ANSI), 25 West 43rd Street, Fourth Floor, New York, NY 10036.

5. FEMA documents can be obtained from FEMA Publications, P.O. Box 2012, Jessup, MD 20794. (800) 480-2520.

(2) The positions of welding for which the electrode is suitable, as shown in Table 2 and Figure 1.

(3) Certain usability characteristics of the electrode (including the presence or absence of a shielding gas) as specified in Table 2 and Figure 1.

3.1.2 Flux cored electrodes classified for single pass welding are classified in the as-welded condition according to the following:

(1) The tensile properties of the weld metal obtained with a particular shielding gas, if any, as specified in Table 1U [Table 1M].

(2) The positions of welding for which the electrode is suitable, as shown in Figure 1.

(3) Certain usability characteristics of the electrode (including the presence or absence of a shielding gas), as specified in Table 2 and Figure 1.

3.2 Electrodes classified under one classification shall not be classified under any other classification in this specification with the exceptions that (1) an electrode may be classified with 100% CO₂ (AWS A5.32/A5.32M Class SG-C) shielding gas (“C” designator) and with a 75–80% argon/balance CO₂ (AWS A5.32/A5.32M Class SG-AC-25 or SG-AC-20) gas mixture (“M” designator) and (2) an E7XT-1C, -1M [E49XT-1C, -1M] may also be classified as an E7XT-9C, -9M [E49XT-9C, -9M] and/or E7XT-12C, -12M [E49XT-12C, -12M] providing the electrode meets all the requirements of each classification.

Electrodes may be classified under A5.20 using U.S. Customary Units or under A5.20M using the International System of Units (SI), or they may be classified under both systems. Electrodes classified under either classification systems must meet all requirements for classification under that system. The classification system is shown in Figure 1.

3.3 The electrodes classified under this specification are intended for flux cored arc welding, either with or without an external shielding gas. Electrodes intended for use without external shielding gas, or with the shielding gas specified in Table 2, are not prohibited from use with any other process or shielding gas for which they are found suitable.

4. Acceptance

Acceptance⁶ of the welding electrodes shall be in accordance with the provisions of AWS A5.01.

6. See Section A3 (in Annex A) for further information concerning acceptance, testing of the material shipped, and AWS A5.01.

Table 1U
A5.20 Mechanical Property Requirements

AWS Classification(s)	Tensile Strength (ksi)	Minimum Yield Strength ^a (ksi)	Minimum % Elongation ^b	Minimum Charpy V-Notch Impact Energy
E7XT-1C, -1M	70–95	58	22	20 ft-lbf at 0°F
E7XT-2C ^c , -2M ^c	70 min.	Not Specified	Not Specified	Not Specified
E7XT-3 ^c	70 min.	Not Specified	Not Specified	Not Specified
E7XT-4	70–95	58	22	Not Specified
E7XT-5C, -5M	70–95	58	22	20 ft-lbf at –20°F
E7XT-6	70–95	58	22	20 ft-lbf at –20°F
E7XT-7	70–95	58	22	Not Specified
E7XT-8	70–95	58	22	20 ft-lbf at –20°F
E7XT-9C, -9M	70–95	58	22	20 ft-lbf at –20°F
E7XT-10 ^c	70 min.	Not Specified	No Specified	Not Specified
E7XT-11	70–95	58	20 ^d	Not Specified
E7XT-12C, -12M	70–90	58	22	20 ft-lbf at –20°F
E6XT-13 ^c	60 min.	Not Specified	Not Specified	Not Specified
E7XT-13 ^c	70 min.	Not Specified	Not Specified	Not Specified
E7XT-14 ^c	70 min.	Not Specified	Not Specified	Not Specified
E6XT-G	60–80	48	22	Not Specified
E7XT-G	70–95	58	22	Not Specified
E6XT-GS ^c	60 min.	Not Specified	Not Specified	Not Specified
E7XT-GS ^c	70 min.	Not Specified	Not Specified	Not Specified

Notes:

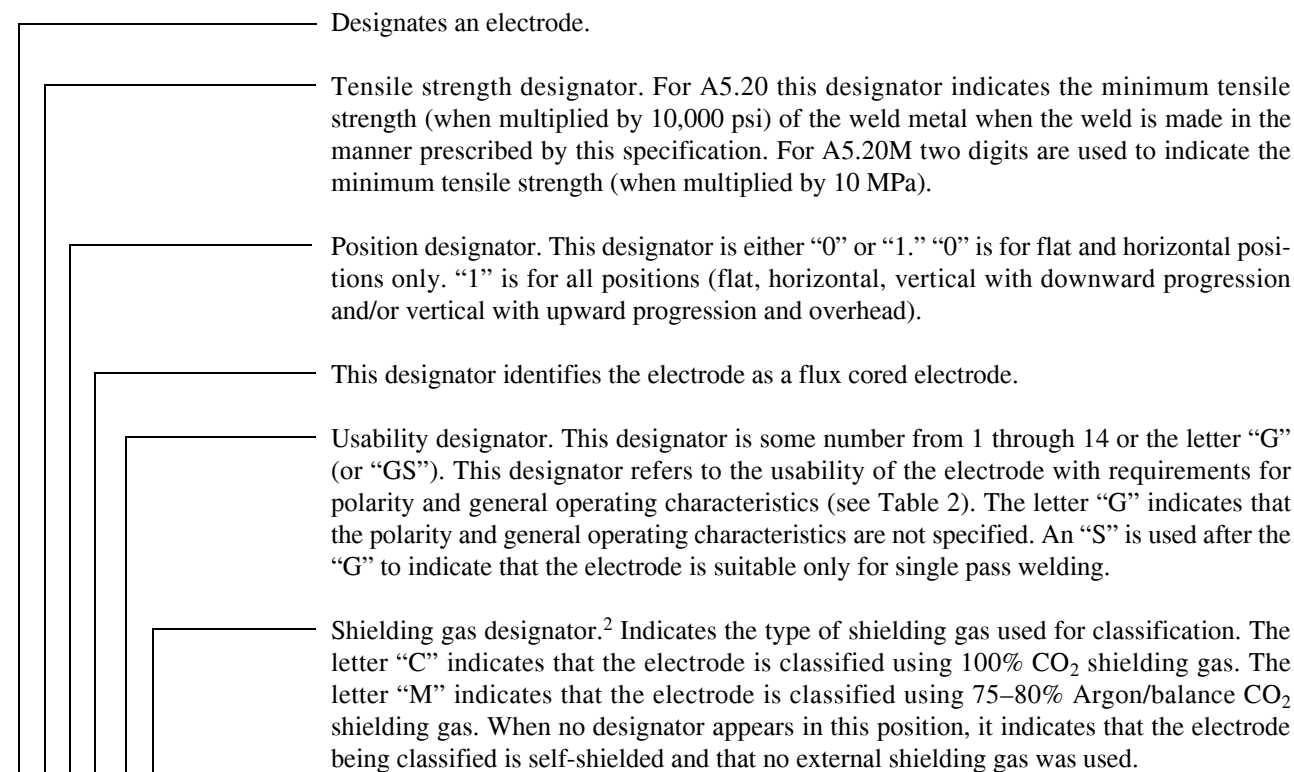
- Yield strength at 0.2% offset.
- In 2 in gage length when a 0.500 in nominal diameter tensile specimen and nominal gage length to diameter ratio of 4:1 (as specified in the Tension Tests section of AWS B4.0) is used.
- These classifications are intended for single pass welding. They are not for multiple pass welding. Only tensile strength is specified and, for this reason, only transverse tension and longitudinal guided bends are required (see Table 3).
- In 1 in gage length when a 0.250 in nominal diameter tensile specimen is used as permitted for 0.045 in and smaller sizes of the E7XT-11 classification.

Table 1M
A5.20M Mechanical Property Requirements

AWS Classification(s)	Tensile Strength (MPa)	Minimum Yield Strength ^a (MPa)	Minimum % Elongation ^b	Minimum Charpy V-Notch Impact Energy
E49XT-1C, -1M	490–670	390	22	27 Joules at –20°C
E49XT-2C ^c , -2M ^c	490 min.	Not Specified	Not Specified	Not Specified
E49XT-3 ^c	490 min.	Not Specified	Not Specified	Not Specified
E49XT-4	490–670	390	22	Not Specified
E49XT-5C, -5M	490–670	390	22	27 Joules at –30°C
E49XT-6	490–670	390	22	27 Joules at –30°C
E49XT-7	490–670	390	22	Not Specified
E49XT-8	490–670	390	22	27 Joules at –30°C
E49XT-9C, -9M	490–670	390	22	27 Joules at –30°C
E49XT-10 ^c	490 min.	Not Specified	No Specified	Not Specified
E49XT-11	490–670	390	20 ^d	Not Specified
E49XT-12C, -12M	490–620	390	22	27 Joules at –30°C
E43XT-13 ^c	430 min.	Not Specified	Not Specified	Not Specified
E49XT-13 ^c	490 min.	Not Specified	Not Specified	Not Specified
E49XT-14 ^c	490 min.	Not Specified	Not Specified	Not Specified
E43XT-G	430–600	330	22	Not Specified
E49XT-G	490–670	390	22	Not Specified
E43XT-GS ^c	430 min.	Not Specified	Not Specified	Not Specified
E49XT-GS ^c	490 min.	Not Specified	Not Specified	Not Specified

Notes:

- Yield strength at 0.2% offset.
- In 50 mm gage length when a 12.5 mm nominal diameter tensile specimen and nominal gage length to diameter ratio of 4:1 (as specified in the Tension Tests section of AWS B4.0M) is used.
- These classifications are intended for single pass welding. They are not for multiple pass welding. Only tensile strength is specified and, for this reason, only transverse tension and longitudinal guided bends are required (see Table 3).
- In 25 mm gage length when a 6.5 mm nominal diameter tensile specimen is used as permitted for 1.2 mm and smaller sizes of the E49XT-11 classification.

Mandatory Classification Designators¹**E X X T - X X - J X H X****Optional Supplemental Designators³**

Optional supplemental diffusible hydrogen designator (see Table 8).

The letter “D” or “Q” when present in this position indicates that the weld metal will meet supplemental mechanical property requirements with welding done using low heat input, fast cooling rate procedures and using high heat input, slow cooling rate procedures as prescribed in Section 17 (see Tables 9 and 10).

The letter “J” when present in this position designates that the electrode meets the requirements for improved toughness and will deposit weld metal with Charpy V-Notch properties of at least 20 ft-lbf at –40°F [27J at –40°C] when the welds are made in a manner prescribed by this specification.

Notes:

1. The combination of these designators constitutes the flux cored electrode classification.
2. See AWS A5.32/A5.32M.
3. These designators are optional and do not constitute a part of the flux cored electrode classification.

Figure 1—A5.20/A5.20M Classification System

Table 2
Electrode Usability Requirements

Usability Designator	AWS Classification		Position of Welding ^{a, b}	External Shielding ^c	Polarity ^d	Application ^e
	A5.20	A5.20M				
1	E70T-1C	E490T-1C	H, F	CO ₂	DCEP	M
	E70T-1M	E490T-1M	H, F	75–80 Ar/bal CO ₂		
	E71T-1C	E491T-1C	H, F, VU, OH	CO ₂		
	E71T-1M	E491T-1M	H, F, VU, OH	75–80 Ar/bal CO ₂		
2	E70T-2C	E490T-2C	H, F	CO ₂	DCEP	S
	E70T-2M	E490T-2M	H, F	75–80 Ar/bal CO ₂		
	E71T-2C	E491T-2C	H, F, VU, OH	CO ₂		
	E71T-2M	E491T-2M	H, F, VU, OH	75–80 Ar/bal CO ₂		
3	E70T-3	E490T-3	H, F	None	DCEP	S
4	E70T-4	E490T-4	H, F	None	DCEP	M
5	E70T-5C	E490T-5C	H, F	CO ₂	DCEP	M
	E70T-5M	E490T-5M	H, F	75–80 Ar/bal CO ₂		
	E71T-5C	E491T-5C	H, F, VU, OH	CO ₂	DCEP or DCEN ^f	
E71T-5M	E491T-5M	H, F, VU, OH	75–80 Ar/bal CO ₂			
6	E70T-6	E490T-6	H, F	None	DCEP	M
7	E70T-7	E490T-7	H, F	None	DCEN	M
	E71T-7	E491T-7	H, F, VU, OH			
8	E70T-8	E490T-8	H, F	None	DCEN	M
	E71T-8	E491T-8	H, F, VU, OH			
9	E70T-9C	E490T-9C	H, F	CO ₂	DCEP	M
	E70T-9M	E490T-9M	H, F	75–80 Ar/bal CO ₂		
	E71T-9C	E491T-9C	H, F, VU, OH	CO ₂		
	E71T-9M	E491T-9M	H, F, VU, OH	75–80 Ar/bal CO ₂		
10	E70T-10	E490T-10	H, F	None	DCEN	S
11	E70T-11	E490T-11	H, F	None	DCEN	M
	E71T-11	E491T-11	H, F, VD, OH			
12	E70T-12C	E490T-12C	H, F	CO ₂	DCEP	M
	E70T-12M	E490T-12M	H, F	75–80 Ar/bal CO ₂		
	E71T-12C	E491T-12C	H, F, VU, OH	CO ₂		
	E71T-12M	E491T-12M	H, F, VU, OH	75–80 Ar/bal CO ₂		
13	E61T-13	E431T-13	H, F, VD, OH	None	DCEN	S
14	E71T-14	E491T-14	H, F, VD, OH	None	DCEN	S
G	E60T-G	E430T-G	H, F	Not Specified	Not Specified	M
	E70T-G	E490T-G				
	E61T-G	E431T-G	H, F, VD or VU, OH	Not Specified	Not Specified	M
	E71T-G	E491T-G				
	E60T-GS	E430T-GS	H, F	Not Specified	Not Specified	S
	E70T-GS	E490T-GS				
	E61T-GS	E431T-GS	H, F, VD or VU, OH	Not Specified	Not Specified	S
	E71T-GS	E491T-GS				

(continued)

Table 2 (Continued)
Electrode Usability Requirements

Notes:

- a. H = horizontal position, F = flat position, OH = overhead position, VU = vertical position with upward progression, VD = vertical position with downward progression.
- b. Electrode sizes suitable for out-of-position welding, i.e., welding positions other than flat or horizontal, are usually those sizes that are smaller than the 3/32 in [2.4 mm] size or the nearest size called for in 9.4.1 for the groove weld. For that reason, electrodes meeting the requirements for the groove weld tests and the fillet weld tests may be classified as EX1T-XX (where X represents the tensile strength, usability and shielding gas, if any, designators) regardless of their size. See Section A7 in the Annex and Figure 1 for more information.
- c. Properties of weld metal from electrodes that are used with external shielding gas will vary according to the shielding gas employed. Electrodes classified with a specific shielding gas should not be used with other shielding gases without first consulting the manufacturer of the electrodes.
- d. The term “DCEP” refers to direct current electrode positive (dc, reverse polarity). The term “DCEN” refers to direct current electrode negative (dc, straight polarity).
- e. M = single or multiple pass, S = single pass only (see Section A7 in the Annex).
- f. Some EX1T-5C and EX1T-5M electrodes may be recommended for use on DCEN for improved out-of-position welding. Consult the manufacturer for the recommended polarity.

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 specification⁷.

6. Rounding-Off Procedure

For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1,000 psi for tensile and yield strength for A5.20 [or to the nearest 10 MPa for tensile and yield strength for A5.20M] and to the nearest unit in the last right-hand place of figures used in expressing the limiting values for other quantities in accordance with the rounding-off method given in ASTM E 29.

7. Summary of Tests

7.1 The tests required for each classification are specified in Table 3. The purpose of these tests is to determine the mechanical properties, soundness, and chemical composition of the weld metal, and the usability of the electrode. 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 15.

7.2 This document provides for four supplemental tests which are not required for classification but which are

⁷ See Section A4 (in Annex A) for further information concerning certification and the testing called for to meet this requirement.

included for optional supplemental designators as agreed to between the purchaser and supplier.

7.2.1 The supplemental test for diffusible hydrogen is described in Section 16 and utilizes designators H16, H8, or H4.

7.2.2 The optional supplemental designator “J” may be used to indicate that the electrode being classified meets the requirements for improved toughness and will deposit weld metal with Charpy V-Notch properties at least 20 ft-lbf at -40°F [27J at -40°C] when welds are made in a manner prescribed by this specification.

7.2.3 The optional supplemental designators “D” or “Q” may be used to indicate conformance to the radiographic requirements of this specification and to the all-weld mechanical property requirements specified in Table 10 when the weld metal is deposited (1) using the low heat input, fast cooling rate procedure and (2) using the high heat input, slow cooling rate procedure specified in Section 17 and Table 9. The “D” designator is intended to identify those E7XT-X, -XC, or -XM flux cored electrodes that meet the recommendations for mechanical properties in FEMA 353 when the welds are made in a manner prescribed in FEMA 353. The “Q” designator is intended to identify those E7XT-X, -XC, or -XM flux cored electrodes that meet the additional anticipated requirements of the U.S. Navy.

8. Retest

If the results of any test fail to meet the requirement, that test shall be repeated twice. The results of both retests shall meet the requirement. Material, specimens or samples for retest may be taken from the original test assembly or sample or from one or two new test assem-

Table 3
Tests Required for Classification^a

AWS Classification(s)	Chemical Analysis	Radiographic Test	Tension Test	Impact Test	Bend Test	Fillet Weld Test ^b
EXXT-1C, -1M	R	R	R	R	NR	R
EXXT-4	R	R	R	NR	NR	R
EXXT-5C, -5M	R	R	R	R	NR	R
EXXT-6	R	R	R	R	NR	R
EXXT-7	R	R	R	NR	NR	R
EXXT-8	R	R	R	R	NR	R
EXXT-9C, -9M	R	R	R	R	NR	R
EXXT-11	R	R	R	NR	NR	R
EXXT-12C, -12M	R	R	R	R	NR	R
EXXT-G	R	R	R	NR	NR	R
EXXT-2C ^d , -2M ^d	NR	NR	R ^c	NR	R	R
EX0T-3 ^d	NR	NR	R ^c	NR	R	NR
EX0T-10 ^d	NR	NR	R ^c	NR	R	NR
EX1T-13 ^d	NR	NR	R ^c	NR	R	R
EX1T-14 ^d	NR	NR	R ^c	NR	R	R
EXXT-GS ^d	NR	NR	R ^c	NR	R	R

Notes:

a. The letter “R” indicates the test is required. “NR” indicates the test is not required.

b. For the fillet weld test, electrodes classified for downhand welding (EX0T-XX electrodes) shall be tested in the horizontal position. Electrodes classified for all-position welding (EX1T-XX electrodes) shall be tested in both the vertical and overhead positions (see 9.4.3).

c. Transverse tension test. All others require all weld metal tension test.

d. Intended for single pass welding.

blies or samples. For chemical analysis, retest need be only for those specific elements that failed to meet the test requirement. If the results of one or both retests fail to meet the requirement, the material under test shall be considered as not meeting the requirements of this specification for that classification.

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

9. Test Assemblies

9.1 One or more of the following four test assemblies are required, depending on the classification of the electrode and the manner in which the tests are conducted:

(1) The weld pad in Figure 2 for chemical analysis of the weld metal

(2) For multiple-pass electrodes, the test assembly in Figure 3 for mechanical properties and soundness of the weld metal

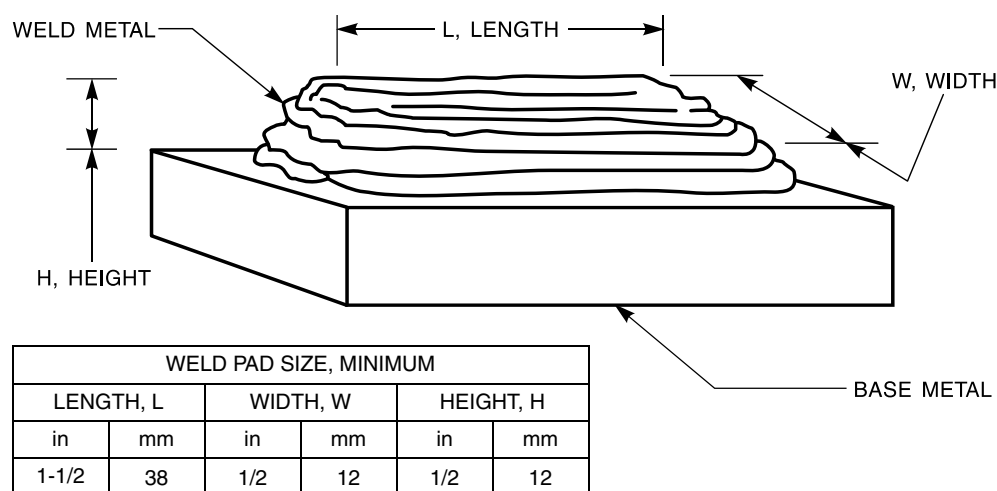
(3) For single pass electrodes, the test assembly in Figure 4 for mechanical properties

(4) The fillet weld test assembly in Figure 5, for usability of the electrode

The sample for chemical analysis may be taken from the reduced section of the fractured tension specimen or from a corresponding location (or any location above it) in the weld metal in the groove weld in Figure 3, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be the referee method.

9.2 Preparation of each test assembly shall be as specified in 9.3 through 9.4.3. The base metal for each assembly shall be as required in Table 4 and shall meet the requirements of any one of the appropriate ASTM specifications shown there, or an equivalent specification. Testing of the welded test assemblies shall be as specified in Sections 10 through 15.

9.3 Weld Pad. A weld pad shall be prepared as specified in Figure 2, except when either alternatives in 9.1 (taking the sample from the broken tension test specimen or from a corresponding location—or any location above it—in

**Notes:**

1. Base metal of any convenient size, of the type specified in Table 4, 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 undiluted weld metal, using the specified shielding gas (if any), using the polarity as specified in Table 2 and following the heat input requirements specified in Table 5.
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 with the amperage employed. The weave shall be limited to 6 times the electrode diameter.
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. The test assembly may be quenched in water (temperature unimportant) between passes to control interpass temperature.
7. The minimum completed pad size shall be that shown above. The sample to be tested in Section 10 shall be taken from weld metal that is at least 3/8 in [10 mm] above the original base metal surface.

Figure 2—Pad for Chemical Analysis of Deposited Weld Metal

the weld metal in the groove weld in Figure 3) is selected. Base metal of any convenient size of the type specified in Table 4 shall be used as the base metal 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 (1/2 in [12 mm] minimum thickness). The welding procedure used for the weld pad shall satisfy the heat input requirements specified in Table 5. The preheat temperature shall not be less than 60°F [15°C] and the interpass temperature shall not exceed 325°F [165°C]. The slag shall be removed after each pass. The pad may be quenched in water between passes. The dimensions of the completed pad shall be as shown in Figure 2. Testing of this assembly shall be as specified in Section 10.

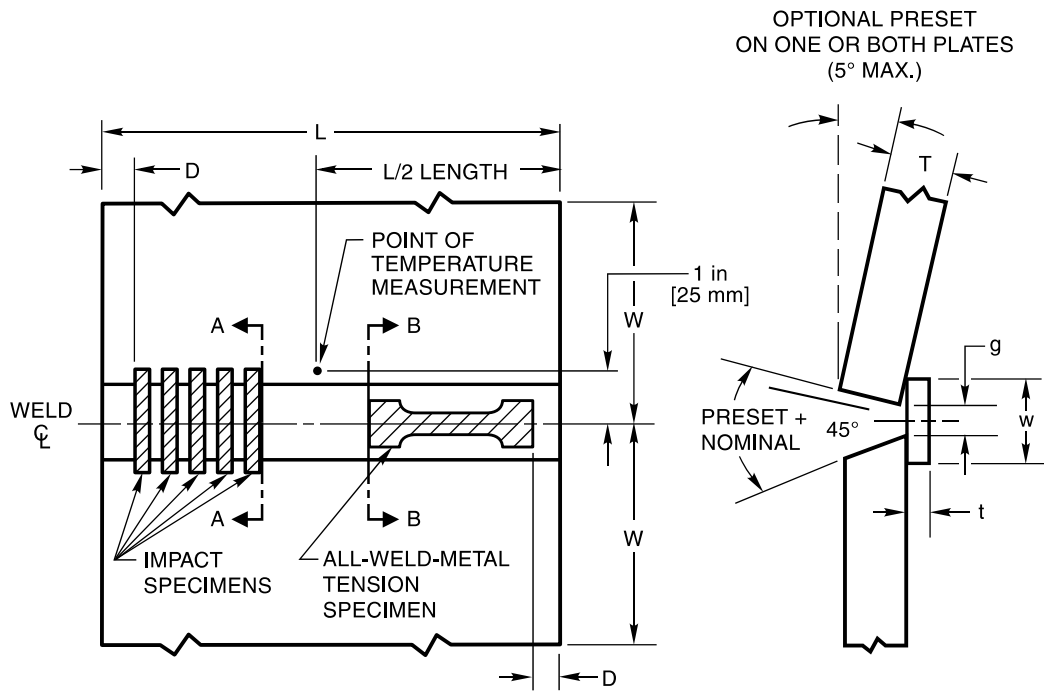
9.4 Weld Test Assemblies

9.4.1 Test Assembly for Multipass Electrodes. For multipass electrodes (EXXT-1X, EXXT-4, EXXT-5X, EXXT-6, EXXT-7, EXXT-8, EXXT-9X, EXXT-11, EXXT-12X, and EXXT-G) one or two groove weld test assemblies shall be prepared and welded as specified in Figure 3, 9.4.1.1, and Table 5, using the base metal of the appropriate type specified in Table 4. The electrode

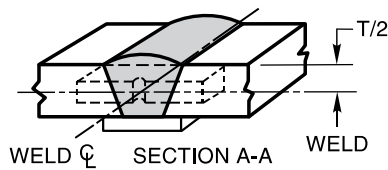
diameter for one test assembly shall be 3/32 in [2.4 mm] or the largest diameter manufactured. The electrode diameter for the other test assembly shall be 0.045 in [1.2 mm] or the smallest size manufactured. If the maximum diameter manufactured is 1/16 in [1.6 mm] or less only the largest diameter need be tested. The electrode polarity shall be as specified in Table 2. Testing of the assemblies shall be in the as-welded condition and as specified in Table 3.

9.4.1.1 Welding shall be in the flat position and the assembly shall be restrained (or preset as shown in Figure 3) during welding to prevent warpage in excess of 5°. An assembly that is warped more than 5° from plane shall be discarded. It shall not be straightened.

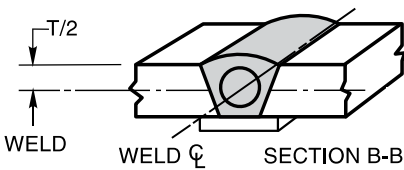
Welding shall begin at 60°F [15°C] minimum. Welding shall continue until the assembly has reached a temperature of 300°F ± 25°F [150°C ± 15°C], measured by temperature indicating crayons or surface thermometers at the location shown in Figure 3. This interpass temperature shall be maintained for the remainder of the weld. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air. The assembly shall be heated to a temperature of 300°F ± 25°F [150°C ± 15°C] before welding is resumed.



(A) TEST PLATE SHOWING LOCATION OF TEST SPECIMENS



(B) ORIENTATION
OF IMPACT
TEST SPECIMEN



(C) LOCATION OF
ALL-WELD-METAL TENSION
TEST SPECIMEN

L Test Plate Length (min.)	W Test Plate Width (min.)	T Test Plate Thickness	D Discard (min.)	I Bevel Angle	g Root Opening	w Backup Width (min.)	t Backup Thickness (min.)
10 in [250 mm]	6 in [150 mm]	3/4 ± 1/32 in [20 ± 1 mm]	1 in [25 mm]	22.5° ± 2°	1/2 – 0 in + 1/16 in [12 – 0 mm + 1 mm]	Approx. 2 × g	1/4 in [6 mm]

Note:
1. Test plate thickness shall be 1/2 in [12 mm] and the maximum root opening shall be 1/4 in –0 in, +1/16 in [6 mm –0 mm, +1 mm] for 0.045 in [1.2 mm] and smaller diameters of the EXXT-11 electrode classifications.

Figure 3—Test Assembly for Mechanical Properties
and Soundness of Weld Metal

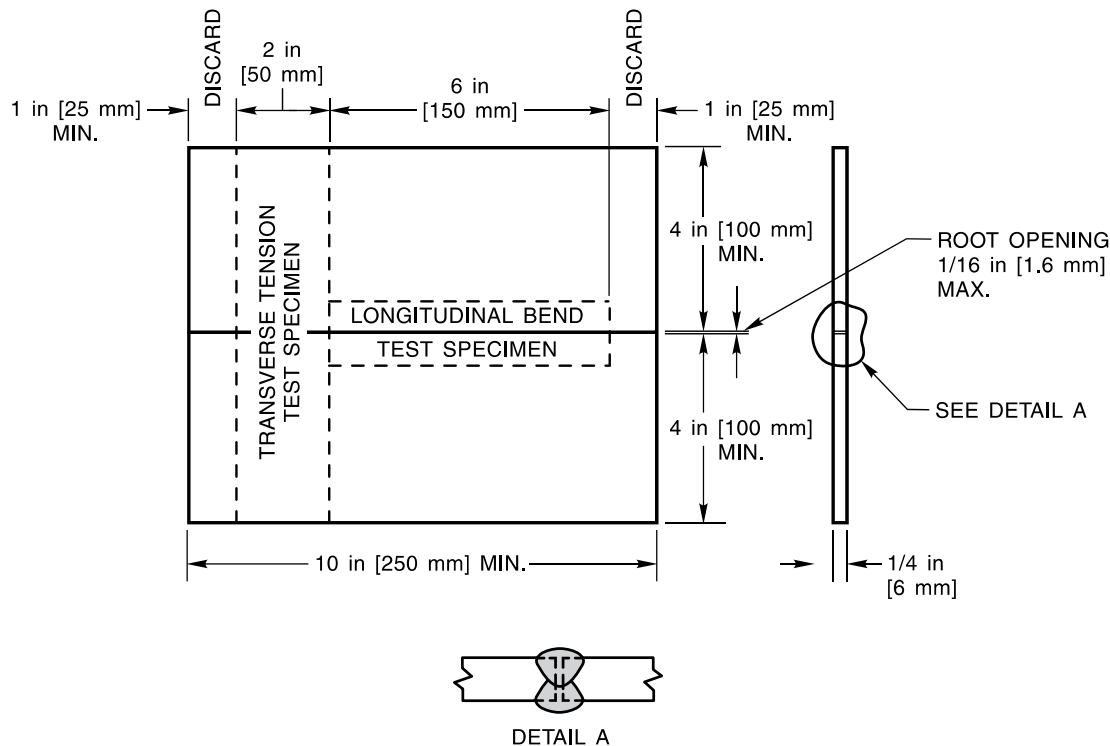


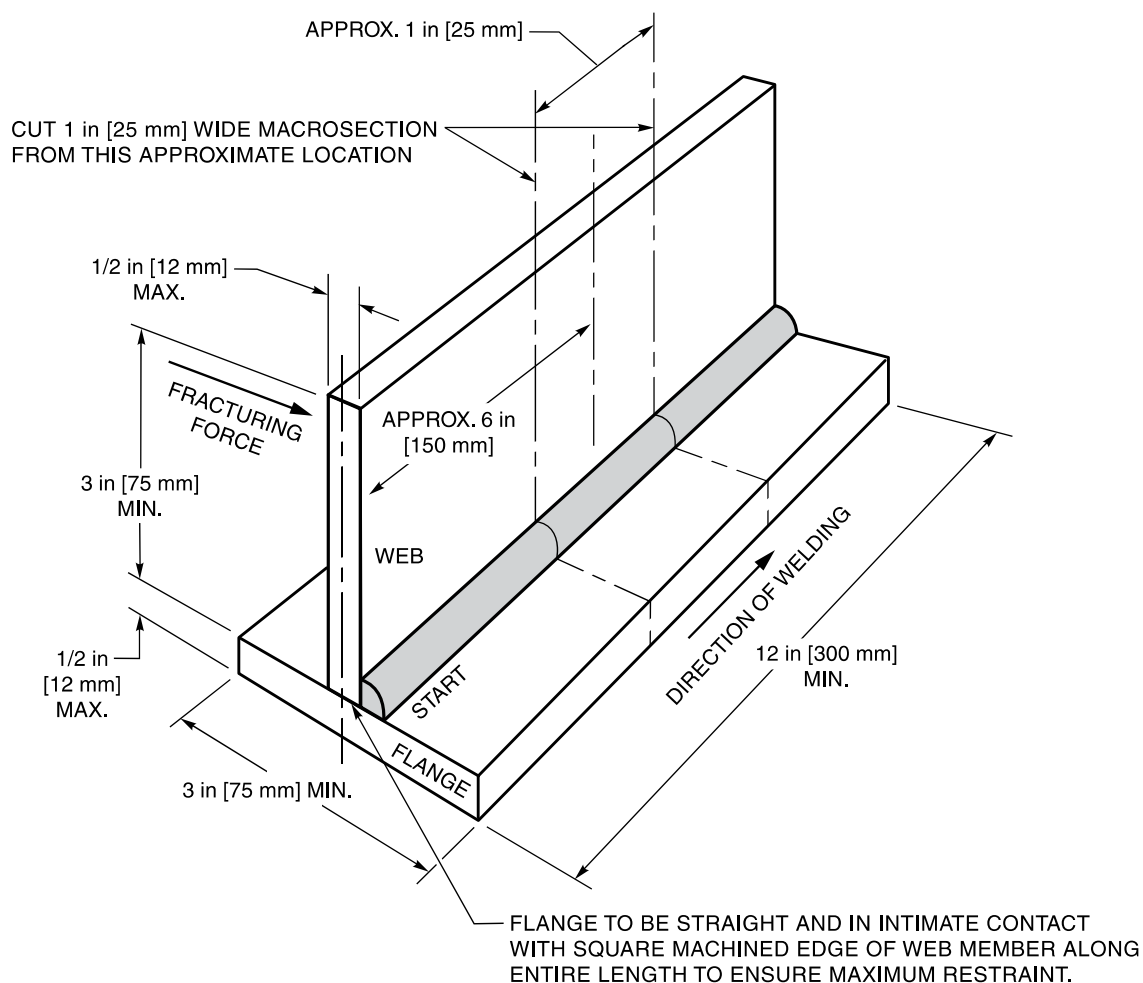
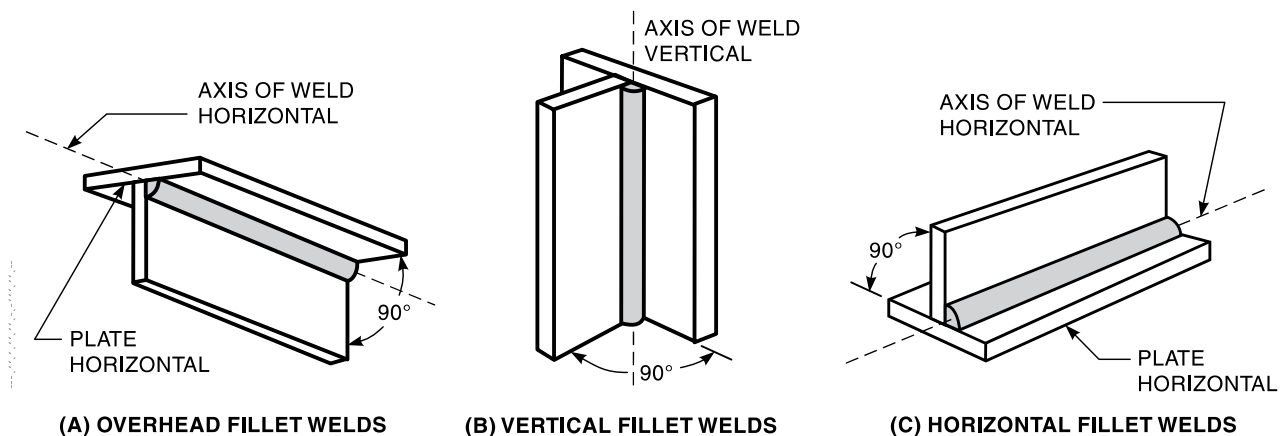
Figure 4—Test Assembly for Transverse Tension and Longitudinal Guided Bend Tests for Welds Made with Single-Pass Electrodes

9.4.2 Test Assembly for Single Pass Electrodes. For single pass electrodes a butt joint test assembly using base metal as specified in Table 4 shall be prepared and welded as specified in Figure 4 and 9.4.2.1. After tack welding the plates at each end, the test assembly shall be welded in the flat position with one bead on each side.

9.4.2.1 Welding shall begin with the assembly at 60°F [15°C] minimum. When the weld bead has been completed on the face side, the assembly shall be turned over and the bead deposited on the root side, as shown in Figure 4. This sequence shall not be interrupted. The electrode size shall be either 3/32 in [2.4 mm] diameter or the size the manufacturer produces that is closest to the 3/32 in [2.4 mm] diameter. The welding polarity shall be as shown in Table 2 for the classification being tested. After welding has been completed and the assembly has cooled, the assembly shall be prepared and tested as specified in Sections 12 and 13, in the as-welded condition (except for the aging of the bend test specimen specified in 13.2).

9.4.3 Fillet Weld Test Assembly. Test assemblies shall be prepared and welded as specified in Table 3 and shown in Figure 5, using any of the base metals listed in Table 4. When specified for an EX0T-XX classification, the test assembly shall be welded in the horizontal position. When specified for an EX1T-XX classification, two test assemblies are required, one welded in the vertical position and one welded in the overhead position. The progression for vertical welding shall be either upward or downward depending on the classification (see Table 2).

Before assembly, the standing member (web) shall have one edge prepared throughout its length and the base member (flange) side shall be straight, smooth and clean. The test plates shall be assembled as shown in Figure 5. When assembled, the faying surfaces shall be in intimate contact along the entire length of the joint. The test assembly shall be secured with tack welds deposited at each end of the weld joint.



Notes:

1. If the web and flange thicknesses are less than or equal to 1/4 in [6 mm], the web and flange widths shall be 2 in [50 mm] minimum.
2. The test plate thickness shall be 3/16 in [5 mm] for the EXXT-3 electrode classifications.

Figure 5—Fillet Weld Test Assembly

Table 4
Base Metal for Test Assemblies

AWS Classification(s)	ASTM Specification	UNS Number ^a
EXXT-1C, -1M EXXT-4 EXXT-5C, -5M EXXT-6 EXXT-7 EXXT-8 EXXT-9C, -9M EXXT-11 EXXT-12C, -12M EXXT-G	A36/A36M A285/A285M Grade C, A515/A515M Grade 70, A516/A516M Grade 70, A830/A830M Grade 1015, A830/A830M Grade 1018 or A830/A830M Grade 1020	K02600 K02801 K03101 K02700 G10150 G10180 G10200
EXXT-2C, -2M EXXT-3 EXXT-10 EXXT-13 EXXT-14 EXXT-GS	A515/A515M Grade 70 or A516/A516M Grade 70	K03101 K02700

Notes:

a. According to ASTM DS-56 (or SAE HS-1086).

b. For the fillet weld test, any of the base metals listed in this table may be used for any classification.

Table 5
Heat Input Requirements and Suggested Pass and Layer Sequence
for Multiple Pass Electrode Classifications

Diameter		Required Average Heat Input ^{a, b, c, d}		Suggested Passes per Layer		Suggested Number of Layers
in	mm	kJ/in	kJ/mm	Layer 1	Layer 2 to Top	
≤ 0.030 0.035	≤ 0.8 0.9	20–35	0.8–1.4	1 or 2	2 or 3	6 to 9
— 0.045 —	1.0 — 1.2	25–50	1.0–2.0	1 or 2	2 or 3	6 to 9
0.052 — 1/16	— 1.4 1.6	25–55	1.0–2.2	1 or 2	2 or 3	5 to 8
0.068 — 0.072 5/64 (0.078)	— 1.8 — 2.0	35–65	1.4–2.6	1 or 2	2 or 3	5 to 8
3/32 (0.094)	2.4	40–65	1.6–2.6	1 or 2	2 or 3	4 to 8
7/64 (0.109)	2.8	50–70	2.0–2.8	1 or 2	2 or 3	4 to 7
0.120 1/8 (0.125)	— 3.2	55–75	2.2–3.0	1 or 2	2	4 to 7
5/32 (0.156)	4.0	65–85	2.6–3.3	1	2	4 to 7

Notes:

a. The calculation to be used for heat input is:

$$(1) \text{ Heat Input (kJ/in)} = \frac{\text{volts} \times \text{amps} \times 60}{\text{Travel Speed (in/min)} \times 1000} \text{ or } \frac{\text{volts} \times \text{amps} \times 60 \times \text{arc time (min)}}{\text{Weld Length (in)} \times 1000}$$

or

$$(2) \text{ Heat Input (kJ/mm)} = \frac{\text{volts} \times \text{amps} \times 60}{\text{Travel Speed (mm/min)} \times 1000} \text{ or } \frac{\text{volts} \times \text{amps} \times 60 \times \text{arc time (min)}}{\text{Weld Length (mm)} \times 1000}$$

b. Does not apply to the first layer. The first layer shall have a maximum of two passes.

c. The average heat input is the calculated average for all passes excluding the first layer.

d. A non-pulsed, constant voltage (CV) power source shall be used.

The welding procedure and the size of the electrode to be tested shall be as selected by the manufacturer. The fillet weld shall be a single pass weld deposited in either the semiautomatic or mechanized mode as selected by the manufacturer. The fillet weld size shall not be greater than 3/8 in [10 mm]. The fillet weld shall be deposited only on one side of the joint as shown in Figure 5. Weld cleaning shall be limited to chipping, brushing, and needle scaling. Grinding, filing, or other metal cutting of the fillet weld face is prohibited. The testing of the assembly shall be as specified in Section 15.

10. Chemical Analysis

10.1 When specified in Table 3, the sample for analysis shall be taken from weld metal produced with the flux cored electrode and the shielding gas, if any, with which it is classified. The sample shall be taken from a weld pad, or the reduced section of the fractured tension test

specimen, or from a corresponding location or any location above it in the groove weld in Figure 3. In case of dispute, the weld pad shall be the referee method.

10.2 The top surface of the pad described in 9.3 and shown in Figure 2 shall be removed and discarded, and a sample for analysis shall be obtained from the underlying metal by any appropriate mechanical means. The sample shall be free of slag. The sample shall be taken at least 3/8 in [10 mm] from the nearest surface of the base metal. The sample from the reduced section of the fractured tension test specimen or from a corresponding location in the groove weld in Figure 3 shall be prepared for analysis by any suitable mechanical means.

10.3 The sample 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 6 for the classification of electrode under test.

Table 6
Weld Metal Chemical Composition Requirements for Classification to A5.20/A5.20M

AWS A5.20 Classification	AWS A5.20M Classification	UNS Number ^a	Weight Percent ^{b,c}										
			C	Mn	Si	S	P	Cr ^d	Ni ^d	Mo ^d	V ^d	Al ^{d,e}	Cu ^d
E7XT-1C, -1M	E49XT-1C, -1M	W07601	0.12	1.75	0.90	0.03	0.03	0.20	0.50	0.30	0.08	—	0.35
E7XT-5C, -5M	E49XT-5C, -5M	W07605											
E7XT-9C, -9M	E49XT-9C, -9M	W07609											
E7XT-4	E49XT-4	W07604	0.30	1.75	0.60	0.03	0.03	0.20	0.50	0.30	0.08	1.8	0.35
E7XT-6	E49XT-6	W07606											
E7XT-7	E49XT-7	W07607											
E7XT-8	E49XT-8	W07608											
E7XT-11	E49XT-11	W07611											
E7XT-12C, -12M	E49XT-12C, -12M	W07612	0.12	1.60	0.90	0.03	0.03	0.20	0.50	0.30	0.08	---	0.35
EXXT-G		—	f	1.75	0.90	0.03	0.03	0.20	0.50	0.30	0.08	1.8	0.35
E6XT-13	E43XT-13	W06613											
E7XT-2C, -2M	E49XT-2C, -2M	W07602											
E7XT-3	E49XT-3	W07603											
E7XT-10	E49XT-10	W07610											
E7XT-13	E49XT-13	W07613											
E7XT-14	E49XT-14	W07614											
EXXT-GS		—	Not specified ^g										

Notes:

a. According to ASTM DS-56 (or SAE HS-1086).

b. The weld metal shall be analyzed for the specific elements for which values are shown in this table. The total of all elements listed in this table shall not exceed 5%.

c. Single values are maximums.

d. The analysis of these elements shall be reported only if intentionally added.

e. Applicable to self-shielded electrodes only. Electrodes intended for use with gas shielding normally do not have significant additions of aluminum.

f. The limit for gas shielded electrodes is 0.18% maximum. The limit for self-shielded electrodes is 0.30% maximum.

g. The composition of weld metal is not particularly meaningful since electrodes of these classifications are intended only for single pass welds. Dilution from the base metal in such welds is usually quite high (see A6 in the Annex).

11. Radiographic Test

11.1 The welded test assembly described in 9.4.1 and shown in Figure 3 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:

- (1) no cracks, no incomplete fusion, and no incomplete penetration,
- (2) no slag inclusions longer than 1/4 in [6 mm] or 1/3 of the thickness of the weld, whichever is greater, or no groups of slag inclusions in line that have an aggregate length greater than the thickness of the weld in a length 12 times the thickness of the weld except when the distance between the successive inclusions exceeds 6 times the length of the longest inclusion in the group, and
- (3) no rounded indications in excess of those permitted by the radiographic standards in Figure 8.

In evaluating the radiograph, 1 in [25 mm] of the weld on each end of the test assembly shall be disregarded.

11.3.1 A rounded indication is an indication (on the radiograph) whose length is no more than three times its width. Rounded indications may be circular 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. Test assemblies with indications larger than the large indications permitted in the radiographic standard (Figure 8) do not meet the requirements of this specification.

12. Tension Test

12.1 For multiple pass electrode classifications one all-weld-metal tension test specimen, as specified in the Tension Test section of AWS B4.0 or B4.0M, shall be machined from the welded test assembly described in

9.4.1 and shown in Figure 3. The tension test specimen shall have a nominal diameter of 0.500 in [12.5 mm] (or 0.250 in [6.5 mm] for some electrodes as indicated in Tables 1U and 1M) and a nominal gage length to diameter ratio of 4:1.

12.1.1 After machining, but before testing, the specimen may be aged at a temperature not to exceed 220°F [105°C] for up to 48 hours, then allowed to cool to room temperature. Refer to A8.3 for a discussion of 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 1U or Table 1M, as applicable.

12.2 For single pass electrode classifications, one transverse tension test specimen, as specified in the Tension Test section of AWS B4.0 or B4.0M, shall be machined from the welded test assembly described in 9.4.2 and shown in Figure 4. The transverse rectangular tension specimen shall be a full thickness specimen machined transverse to the weld with a nominal reduced section width of 1.50 in [38 mm].

12.2.1 The specimen shall be tested in the manner described in the Tension Test section of AWS B4.0 or B4.0M.

12.2.2 The results of the tension test shall meet the requirements specified in Table 1U or Table 1M, as applicable.

13. Bend Test

13.1 One longitudinal face bend test specimen, as required in Table 3, shall be machined from the welded test assembly described in 9.4.2 and shown in Figure 4. The dimensions of the specimen shall be as shown in Figure 4. Other dimensions of the bend specimen shall be as specified in the Bend Test section of AWS B4.0 or B4.0M.

13.2 After machining, but before testing, the specimen may be aged at a temperature not to exceed 220°F [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 uniformly through 180° over a 3/4 in [19 mm] radius using any suitable jig as specified in the Bend Test section of B4.0 or B4.0M. Positioning

of the longitudinal face bend specimen shall be such that the weld face of the last side welded is in tension.

13.4 The specimen, after bending, shall conform to the 3/4 in [19 mm] radius, with an appropriate allowance for spring back, and the weld metal shall not show any crack or other open defect exceeding 1/8 in [3.2 mm] in any direction when examined with the unaided eye. Cracks in the base metal shall be disregarded, as long as they do not enter the weld metal. When base metal openings or cracks enter the weld metal, the test shall be considered invalid. Specimens in which this occurs shall be replaced, specimen for specimen, and the test completed. In this case, the doubling of specimens required in Section 8 does not apply.

14. Impact Test

14.1 Five full-size Charpy V-Notch impact specimens, as specified in the Fracture Toughness Test section of AWS B4.0 or B4.0M shall be machined from the welded test assembly shown in Figure 3 for those classifications for which impact testing is required in Table 1U [Table 1M] and Table 3 or when the optional supplemental designator “J”, “D,” or “Q” is utilized.

The Charpy V-Notch specimens shall have the notched surface and the struck surface parallel with each other within 0.002 in [0.05 mm]. The other two surfaces of the specimen shall be square with the notched or struck surfaces 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 50X 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 AWS B4.0 or B4.0M. The test temperature shall be that specified in Table 1U [Table 1M], 7.2.2, or Table 10, as applicable, for the classification or optional supplemental designator 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. For the “D” and “Q” optional supplemental designators the requirements shown in Table 10 shall apply.

15. Fillet Weld Test

15.1 The fillet weld test, when required in Table 3, shall be made in accordance with 9.4.3 and Figure 5. The entire face of the completed fillet shall be examined visually. There shall be no indication of cracks, and the weld shall be reasonably free of undercut, overlap, trapped slag, and surface porosity. After the visual examination, a specimen containing approximately 1 in [25 mm] of the weld (in the lengthwise direction) shall be prepared as shown in Figure 5. One cross-sectional surface of the specimen shall be polished and etched, and then examined as required in 15.2.

15.2 Scribe lines shall be placed on the prepared surface, as shown in Figure 6, and the leg lengths and convexity of the fillet shall be determined to the nearest 1/64 in [0.5 mm] by actual measurement. These dimensions shall meet the requirements specified in Table 7 for convexity, fillet size and permissible difference in the length of the legs.

15.3 The remaining two sections of the test assembly shall be broken longitudinally through the fillet weld by a force exerted as shown in Figure 5. When necessary, to facilitate fracture through the fillet, one or more of the following procedures may be used:

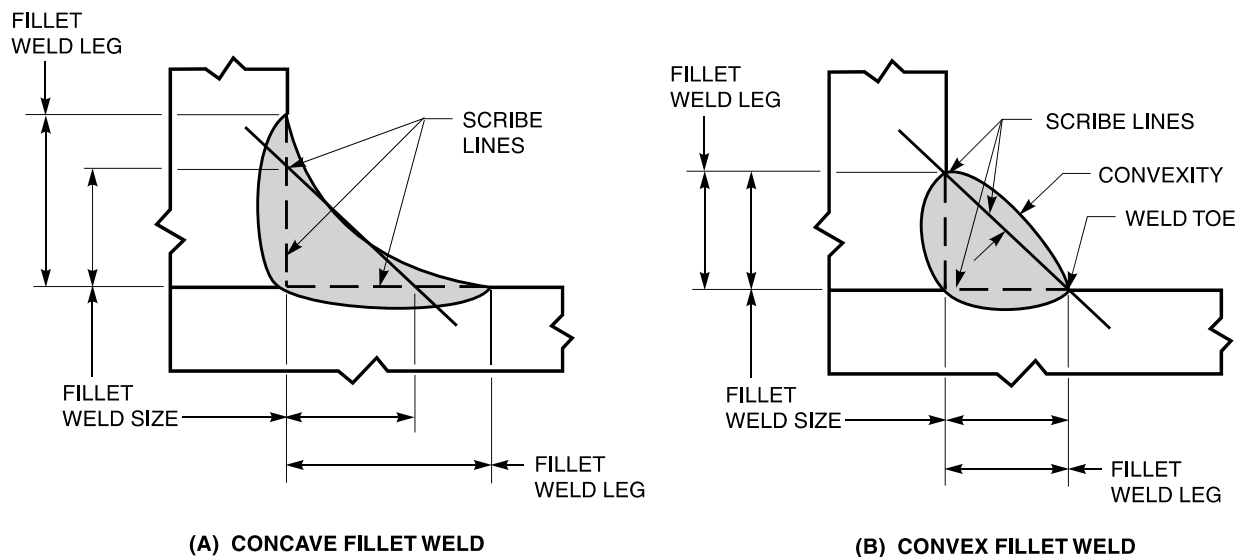
- (1) A reinforcing bead, as shown in Figure 7(A), may be added to each leg of the fillet.
- (2) The position of the web on the flange may be changed, as shown in Figure 7(B).
- (3) The face of the fillet may be notched, as shown in Figure 7(C).

Tests in which the weld metal pulls out of the base metal during bending are invalid. Specimens in which this occurs shall be replaced, specimen for specimen, and the test completed. In this case, the doubling of the specimens required in Section 8, Retest, does not apply.

15.4 The fractured surfaces shall be examined. They shall be free of cracks and shall be reasonably free of porosity and trapped slag. Incomplete fusion at the root of the weld shall not exceed 20 percent of the total length of the weld. Slag beyond the vertex of the isosceles triangle with the hypotenuse as the face, as shown in Figure 6, shall not be considered incomplete fusion.

16. Diffusible Hydrogen Test

16.1 Either the 3/32 in [2.4 mm] or the largest diameter and either the 0.045 in [1.2 mm] or the smallest diameter of an electrode to be identified by an optional, supplemental, diffusible hydrogen designator shall be tested according to one of the methods given in AWS A4.3. If



Notes:

1. Fillet weld size is the leg lengths of the largest isosceles right triangle which can be inscribed within the fillet weld cross section.
2. Convexity is the maximum distance from the face of a convex fillet weld perpendicular to a line joining the weld toes.
3. Fillet weld leg is the distance from the joint root to the toe of the fillet weld.

Figure 6—Dimensions of Fillet Welds

Table 7
Dimensional Requirements for Fillet Weld Usability Test Specimens

Measured Fillet Weld Size ^a		Maximum Convexity ^{a, b}		Maximum Difference Between Fillet Weld Legs ^a	
in	mm	in	mm	in	mm
1/8	3.0	5/64	2.0	1/32	1.0
9/64	3.5	5/64	2.0	3/64	1.0
5/32	4.0	5/64	2.0	3/64	1.0
11/64	4.5	5/64	2.0	1/16	1.5
3/16	—	5/64	—	1/16	—
13/64	5.0	5/64	2.0	5/64	2.0
7/32	5.5	5/64	2.0	5/64	2.0
15/64	6.0	5/64	2.0	3/32	2.5
1/4	6.5	5/64	2.0	3/32	2.5
17/64	—	3/32	—	7/64	—
9/32	7.0	3/32	2.5	7/64	3.0
19/64	7.5	3/32	2.5	1/8	3.0
5/16	8.0	3/32	2.5	1/8	3.0
21/64	8.5	3/32	2.5	9/64	3.5
11/32	9.0	3/32	2.5	9/64	4.0
23/64	—	3/32	—	5/32	—
3/8	9.5	3/32	2.5	5/32	4.0

Notes:

- a. All measurements shall be rounded to the nearest 1/64 in [0.5 mm].
- b. Maximum convexity for EXXT-5C, -5M electrodes may be 1/32 in [0.8 mm] larger than the listed requirements.

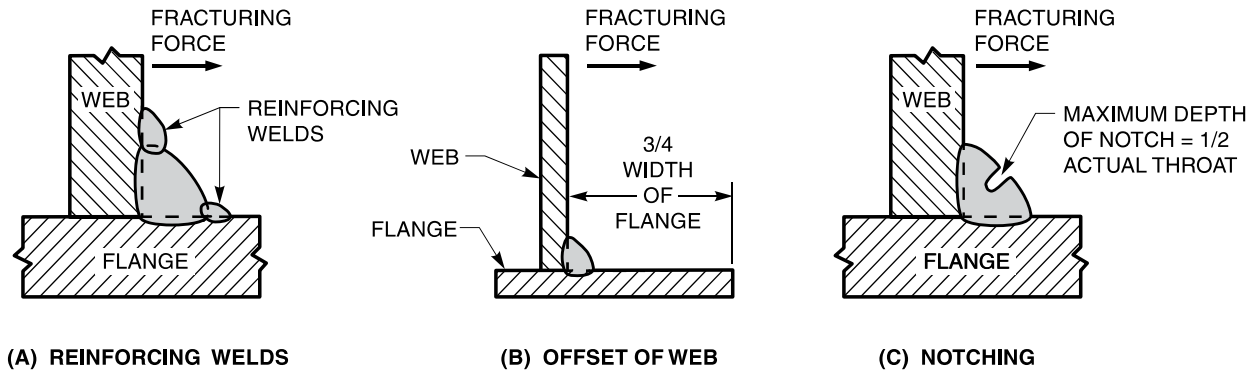


Figure 7—Alternate Methods for Facilitating Fillet Weld Fracture

the maximum diameter manufactured is 1/16 in [1.6 mm] or less, only the largest diameter need be tested. A mechanized welding system shall be used for the diffusible hydrogen test. Based upon the average value of test results which satisfy the requirements of Table 8, the appropriate diffusible hydrogen designator may be added at the end of the classification.

16.2 Testing shall be done with electrode from a previously unopened container. Conditioning of the electrode prior to testing is not permitted. Conditioning can be construed to be any special preparation or procedure, such as baking the electrode, which the user would not usually practice. The shielding gas, if any, used for classification purposes shall also be used for the diffusible hydrogen test. Welds for hydrogen determination shall be made at a wire feed rate (or welding current) which is based upon the manufacturer’s recommended operating range for the electrode size and type being tested. When using wire feed rate, the minimum wire feed rate to be used for the diffusible hydrogen test is given by the equation shown below. When using welding current, the equation shown is modified by substituting “welding current” wherever “WFR” appears. The voltage shall be as recommended by the manufacturer for the wire feed rate (or welding current) used for the test. The contact tip-to-work distance (CTWD) shall be at the minimum recommended by the manufacturer for the wire feed rate (or welding current) used for the test (see 16.3 for “Q” designator requirements). The travel speed used shall be as required to establish a weld bead width that is appropriate for the specimen. See A8.2.7.

$$WFR_{min} = WFR_{mfg. min} + 0.75 (WFR_{mfg. max} - WFR_{mfg. min})$$

Table 8
Diffusible Hydrogen Limits for Weld Metal^a

Optional Supplemental Diffusible Hydrogen Designator ^{b,c,d}	Average Diffusible Hydrogen, Maximum ^{e,f} mL/100g Deposited Metal
H16	16.0
H8	8.0
H4	4.0

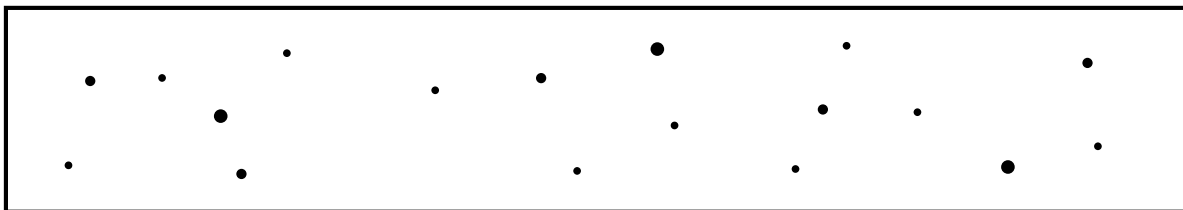
- Notes:
- a. Limits on diffusible hydrogen when tested in accordance with AWS A4.3 as specified in Section 16.
 - b. See Figure 1.
 - c. The lower diffusible hydrogen levels (H8 and H4) may not be available in some classifications (see Annex A8.2.7).
 - d. Electrodes which satisfy the diffusible hydrogen limit for the H4 designator also satisfy the limits for the H8 and H16 designators. Electrodes which satisfy the diffusible hydrogen limit for the H8 category also satisfy the limits for the H16 designator.
 - e. These hydrogen limits are based on welding in air containing a maximum of 10 grains of water per pound [1.43 g/kg] of dry air. Testing at any higher atmospheric moisture level is acceptable provided these limits are satisfied (see 16.4 and 16.5).
 - f. The maximum average diffusible hydrogen requirement for electrodes identified with the “Q” optional, supplemental designator shall be either 5.0 mL/100 g deposited metal or 8.0 mL/100 g deposited metal when testing according to the provisions of this specification (see 16.3).

where:

WFR_{min} is the minimum wire feed rate to be used for the diffusible hydrogen test

$WFR_{mfg. min}$ is the minimum wire feed rate recommended by the manufacturer

$WFR_{mfg. max}$ is the maximum wire feed rate recommended by the manufacturer

**(A) ASSORTED ROUNDED INDICATIONS**

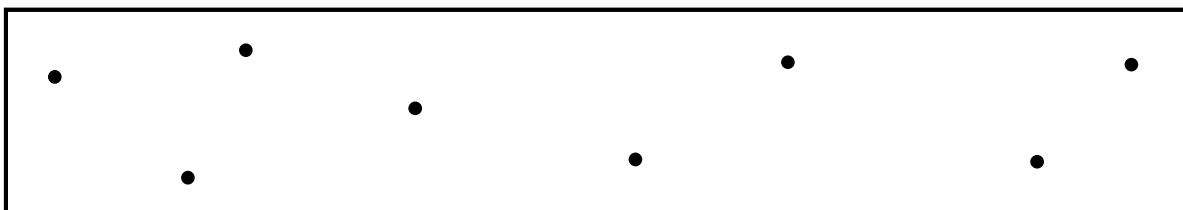
SIZE 1/64 in [0.4 mm] TO 1/16 in [1.6 mm] IN DIAMETER OR IN LENGTH.

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

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

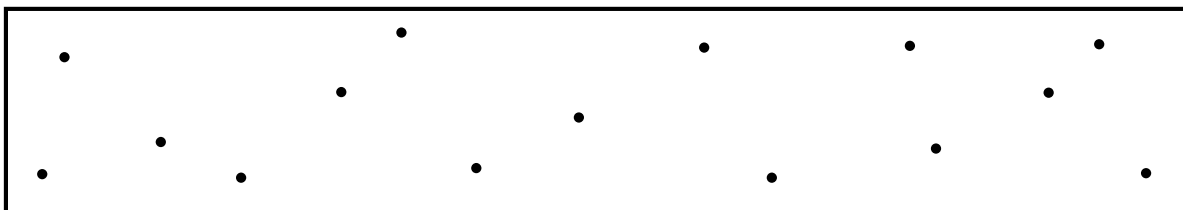
MAXIMUM NUMBER OF MEDIUM 1/32 in [0.8 mm] TO 3/64 in [1.2 mm] IN DIAMETER OR IN LENGTH INDICATIONS = 5.

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

**(B) LARGE ROUNDED INDICATIONS**

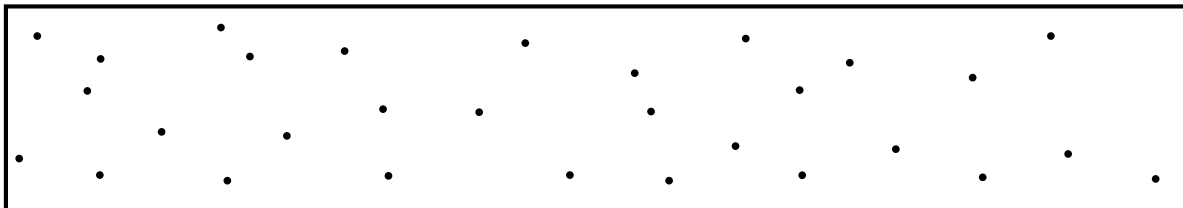
SIZE 3/64 in [1.2 mm] TO 1/16 in [1.6 mm] IN DIAMETER OR IN LENGTH.

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

**(C) MEDIUM ROUNDED INDICATIONS**

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

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

**(D) SMALL ROUNDED INDICATIONS**

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

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

Notes:

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

Figure 8 — Radiographic Standards for Test Assembly in Figure 3

16.3 For the hydrogen testing of electrodes to be identified with the “Q” optional, supplemental designator the CTWD shall be 5/8 in [16 mm] maximum for electrode diameters smaller than 1/16 in [1.6 mm], 3/4 in [20 mm] maximum for 1/16 in [1.6 mm] diameter, and 1 in [25 mm] maximum for electrode diameters larger than 1/16 in [1.6 mm]. Electrodes identified with the “Q” optional supplemental designator shall have a maximum average diffusible hydrogen of either 5.0 mL/100 g deposited metal or 8.0 mL/100 g deposited metal when tested according to the provisions of this specification. No optional, supplemental hydrogen designator is used for “Q” designated electrodes satisfying a maximum average diffusible hydrogen limit of 5.0 mL/100 g deposited metal. “Q” designated electrodes which have average diffusible hydrogen levels over 5.0 mL/100 g deposited metal but which satisfy a maximum average diffusible hydrogen limit of 8.0 mL/100 g deposited metal shall be identified with the “H8” optional, supplemental hydrogen designator (see Figure 1). Electrodes which satisfy a maximum average diffusible hydrogen requirement of 5.0 mL/100 g deposited metal also satisfy the requirement for the “H8” designator.

16.4 For purposes of certifying compliance with diffusible hydrogen requirements, the reference atmospheric condition shall be an absolute humidity of ten (10) grains

of moisture/lb [1.43 g/kg] of dry air at the time of welding (see A8.2.5). The actual atmospheric conditions shall be reported along with the average value for the tests according to AWS A4.3.

16.5 When the absolute humidity equals or exceeds the reference condition at the time of preparation of the test assembly, the test shall be acceptable as demonstrating compliance with the requirements of this specification provided the actual test results satisfy the diffusible hydrogen requirements for the applicable designator. If the actual test results for an electrode meet the requirements for the lower, or lowest hydrogen designator, as specified in Table 8, the electrode also meets the requirements for all higher designators in Table 8 without need to retest.

17. “D” and “Q” Optional Supplemental Designator Tests

17.1 Each diameter of an electrode to be identified with either the “D” or “Q” optional supplemental designator (see Figure 1) shall be tested using both (1) a low heat input, fast cooling rate procedure and (2) a high heat input, slow cooling rate procedure as outlined in 17.2, 17.3, 17.4, 17.5, and Table 9.

Table 9
Procedure Requirements for “D” and “Q” Optional Supplemental Designators

Optional Supplemental Designator	Procedure Heat Input (Fast or Slow Cooling Rate)	Preheat Temperature °F [°C]	Interpass Temperature °F [°C]	Heat Input Requirement for Any Single Pass ^a	Required Average Heat Input for All Passes ^a
D	low (fast cooling rate)	70° ± 25°F [20° ± 15°C]	200° ± 25°F [90° ± 15°C]	For electrode diameters < 3/32 in [2.4 mm]	
				33 kJ/in [1.3 kJ/mm] maximum	30 +2, –5 kJ/in [1.2 +0.1, –0.2 kJ/mm]
	high (slow cooling rate)	300° ± 25°F [150° ± 15°C]	500° ± 50°F [260° ± 25°C]	For electrode diameters ≥ 3/32 in [2.4 mm]	
				44 kJ/in [1.7 kJ/mm] maximum	40 +2, –5 kJ/in [1.6 +0.1, –0.2 kJ/mm]
Q	low (fast cooling rate)	70° ± 25°F [20° ± 15°C]	150°F max. [65°C max.]	33 kJ/in [1.3 kJ/mm] maximum	30 +2, –5 kJ/in [1.2 +0.1, –0.2 kJ/mm]
	high (slow cooling rate)	300° ± 25°F [150° ± 15°C]	300° ± 25°F [150° ± 15°C]	60 kJ/in [2.4 kJ/mm] minimum	70 +5, –2 kJ/in [2.8 +0.2, –0.1 kJ/mm]

Note:

a. Does not apply to first layer. The first layer may have one or two passes.

17.1.1 The test assembly using base metal as specified in Table 4 shall be prepared as shown in Figure 3. The assembly shall be restrained (or preset) during welding to prevent warpage in excess of 5°. An assembly that is warped more than 5° from plane shall be discarded. It shall not be straightened.

17.1.2 The low heat input, fast cooling rate groove weld for both the “D” and “Q” designators shall be welded in the 1G position.

17.1.3 The high heat input, slow cooling rate groove weld for both the “D” and “Q” designators shall be welded in the 1G position for electrodes classified for flat and horizontal welding (position designator “0”).

For electrodes classified for all-position welding (position designator “1”) the high heat input, slow cooling rate groove weld shall be made in the 3G position with upward progression.

17.2 When testing for the “D” designator, the welding of the low heat input, fast cooling rate groove weld shall begin with the test assembly at 70°F ± 25°F [20°C ± 15°C]. Welding shall continue until the assembly has reached the interpass temperature of 200°F ± 25°F [90°C ± 15°C]. This interpass temperature shall be maintained for the remainder of the weld. Should it be necessary to interrupt the welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be heated to a temperature within the interpass temperature range before welding is resumed.

For electrode diameters less than 3/32 in [2.4 mm] the average heat input for all passes, exclusive of the first layer, shall be 30 +2, -5 kJ/in [1.2 +0.1, -0.2 kJ/mm]. No individual pass, exclusive of the first layer, shall exceed 33 kJ/in [1.3 kJ/mm] heat input. See Table 9.

For electrode diameters 3/32 in [2.4 mm] or larger the average heat input for all passes, exclusive of the first layer, shall be 40 +2, -5 kJ/in [1.6 +0.1, -0.2 kJ/mm]. No individual pass, exclusive of the first layer, shall exceed 44 kJ/in [1.7 kJ/mm] heat input. See Table 9.

17.3 When testing for the “D” designator, the welding of the high heat input, slow cooling rate groove weld shall begin with the test assembly preheated to 300°F ± 25°F [150°C ± 15°C] prior to welding. Welding shall continue until the test assembly has reached the interpass temperature of 500°F ± 50°F [260°C ± 25°C]. This interpass temperature shall be maintained for the remainder of the weld. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be heated to a temperature within the interpass temperature range before welding is resumed.

The average heat input for all passes, exclusive of the first layer, shall be 80 +5, -2 kJ/in [3.1 +0.2, -0.1 kJ/

mm]. No individual pass, exclusive of the first layer, shall be made at less than 75 kJ/in [3.0 kJ/mm] heat input. See Table 9.

17.4 When testing for the “Q” designator, the welding of the low heat input, fast cooling rate groove weld shall begin with the test assembly at 70°F ± 25°F [20°C ± 15°C]. Welding shall continue until the test assembly has reached the maximum interpass temperature of 150°F [65°C]. This maximum interpass temperature shall be maintained for the remainder of the weld. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be heated to the maximum interpass temperature before welding is resumed.

The average heat input for all passes, exclusive of the first layer, shall be 30 +2, -5 kJ/in [1.2 +0.1, -0.2 kJ/mm]. No individual pass, exclusive of the first layer, shall exceed 33 kJ/in [1.3 kJ/mm] heat input. See Table 9.

17.5 When testing for the “Q” designator, the welding of the high heat input, slow cooling rate groove weld shall begin with the test assembly preheated to 300°F ± 25°F [150°C ± 15°C] prior to welding. An interpass temperature of 300°F ± 25°F [150°C ± 15°C] shall be maintained for the remainder of the weld. Should it be necessary to interrupt welding, the assembly shall be allowed to cool in still air at room temperature. The assembly shall be heated to a temperature within the interpass temperature range before welding is resumed.

The average heat input for all passes, exclusive of the first layer, shall be 70 +5, -2 kJ/in [2.8 +0.2, -0.1 kJ/mm]. No individual pass, exclusive of the first layer, shall be made at less than 60 kJ/in [2.4 kJ/mm] heat input. See Table 9.

17.6 After welding has been completed and the assembly has cooled, the assembly shall be prepared and tested as shown in Figure 3 and as specified in Sections 11, 12, and 14. The tension and impact tests shall meet the requirements specified in Table 10 for the “D” or “Q” designator, as applicable.

17.7 When certifying an electrode for the “D” or “Q” optional supplemental designator the average heat input used, exclusive of the first layer, for both the low heat input, fast cooling rate and high heat input, slow cooling rate groove welds shall be clearly stated on the test report(s).

18. Method of Manufacture

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

Table 10
Mechanical Property Requirements for “D” and “Q” Optional Supplemental Designators

Optional Supplemental Designator	Tensile Test Requirements	Minimum Charpy V-Notch Requirements
D	58 ksi [400 MPa] min. yield strength 70 ksi [490 MPa] min. tensile strength 22% min. % elongation in 2 in [50 mm]	40 ft·lbf at +70°F [54J at +20°C] (see Notes a, b)
Q	58 to 80 ksi [400–550 MPa] yield strength for high heat input, slow cooling rate test 90 ksi [620 MPa] max. yield strength for low heat input, fast cooling rate test 22% min. % elongation in 2 in [50 mm] (see Note c)	20 ft·lbf at –20°F [27J at –30°C] (see Note d)

Notes:

- Five specimens are to be tested. The lowest and highest values obtained from each of five specimens from a single test plate shall be disregarded. Two of the remaining three values shall equal, or exceed, the specified toughness of 40 ft·lbf [54J] energy level at the testing temperature. One of the three may be lower, but not lower than 30 ft·lbf [41J], and the average of the three shall not be less than the required 40 ft·lbf [54J] energy level.
- The electrode shall also meet a minimum toughness requirement of 20 ft·lbf at 0°F [27J at –18°C] when tested according to the standard A5.20 [A5.20M] classification test requirements.
- Tensile specimens shall not be aged when testing for the “Q” designator.
- Five specimens shall be tested. One of the five specimens may be lower than the specified 20 ft·lbf [27 J] energy level, but not lower than 15 ft·lbf [20 J], and the average of the five shall not be less than the required minimum 20 ft·lbf [27 J] energy level.

19. Standard Sizes

Standard sizes for filler metal in the different package forms such as coils with support, coils without support, drums, and spools are as shown in Table 11.

20. Finish and Uniformity

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

20.2 Each continuous length of electrode shall be from a single lot of material as defined in AWS A5.01, and welds, when present, shall have been made so as not to interfere with the uniform, uninterrupted feeding of the electrode on automatic and semiautomatic equipment.

20.3 Core ingredients shall be distributed with sufficient uniformity throughout the length of the electrodes so as not to adversely affect the performance of the electrode or the properties of the weld metal.

20.4 A suitable protective coating may be applied to any electrode in this specification.

21. Standard Package Forms

21.1 Standard package forms are coils with support, coils without support, spools, and drums. Standard package dimensions and weights for each form are given in Table 12 and Figures 9 and 10. Package forms, sizes, and weights other than these shall be as agreed by purchaser and supplier.

21.2 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 electrode.

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

22. Winding Requirements

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

Table 11
Standard Sizes and Tolerances of Electrodes^a

U.S. Customary Units		International System of Units (SI) ^b	
Diameter (in)	Tolerance (in)	Diameter (mm)	Tolerance (mm)
0.030	±0.002	0.8	+0.02/−0.05
0.035	±0.002	0.9	+0.02/−0.05
0.040	±0.002	1.0	+0.02/−0.05
0.045	±0.002	—	—
—	—	1.2	+0.02/−0.05
0.052	±0.002	—	—
—	—	1.4	+0.02/−0.05
1/16 (0.062)	±0.002	1.6	+0.02/−0.06
0.068	±0.003	—	—
—	—	1.8	+0.02/−0.06
0.072	±0.003	—	—
5/64 (0.078)	±0.003	2.0	+0.02/−0.06
3/32 (0.094)	±0.003	2.4	+0.02/−0.06
7/64 (0.109)	±0.003	2.8	+0.02/−0.06
0.120	±0.003	—	—
1/8 (0.125)	±0.003	3.2	+0.02/−0.07
5/32 (0.156)	±0.003	4.0	+0.02/−0.07

Notes:

a. Electrodes produced in sizes other than those shown may be classified by using similar tolerances as shown.

b. The tolerances shown are as prescribed in ISO 544.

Table 12
Packaging Requirements^a

Type of Package	Package Size ^b				Net Weight of Electrode ^c	
	in		mm		lb	kg
Coils without Support	(d)		(d)		(d)	(d)
Coils with Support (see below)	6-3/4 12	ID ID	170 300	ID ID	14 25, 30, 50, and 60	6 10, 15, 25, and 30
Spools	4 8 12 14 22 24 30	OD OD OD OD OD OD OD	100 200 300 350 560 610 760	OD OD OD OD OD OD OD	1-1/2 and 2-1/2 10, 12, and 15 25, 30, 35, and 44 50 and 60 250 300 600, 750, and 1000	0.5 and 1.0 4.5, 5.5, and 7 10, 15, and 20 20 and 25 100 150 250, 350, and 450
Drums	15-1/2 20 23	OD OD OD	400 500 600	OD OD OD	(d) (d) 300 and 600	(d) (d) 150 and 300
Coils with Support—Standard Dimensions and Weights ^a						
Electrode Size	Coil Net Weight ^c		Inside Diameter of Liner		Width of Wound Electrode	
	lb	kg	in	mm	in (max.)	mm (max.)
All	14 25 and 30 50, 60, and 65	6 10 and 15 20, 25, and 30	6-3/4 ± 1/8 12 ± 1/8 12 ± 1/8	170 ± 3 300 +3, −10 300 +3, −10	3 2-1/2 or 4-5/8 4-5/8	75 65 or 120 120

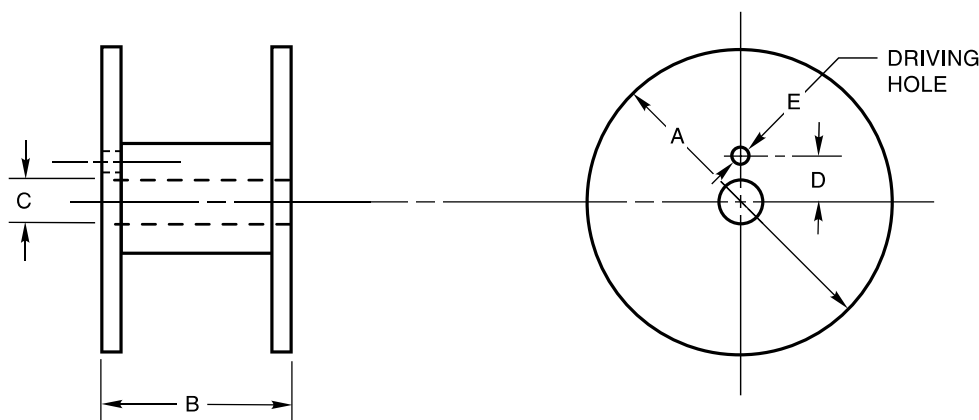
Notes:

a. Sizes and net weights other than those specified may be supplied as agreed between supplier and purchaser.

b. ID = inside diameter, OD = outside diameter.

c. Tolerance on net weight shall be ±10%.

d. As agreed between supplier and purchaser.



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

Notes:

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

Figure 9—Standard Spools—Dimensions of 4, 8, 12, and 14 in [100, 200, 300, and 350 mm] Spools

22.2 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.

23. Filler Metal Identification

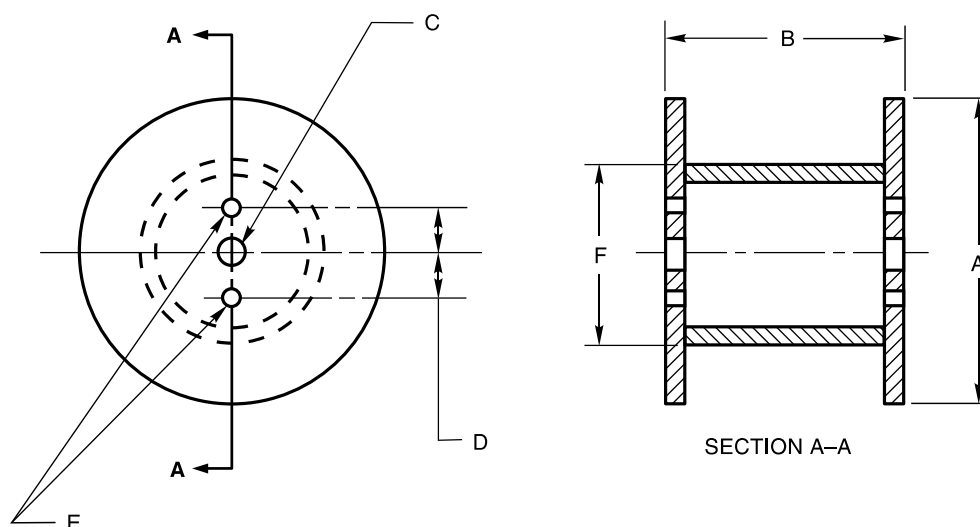
23.1 The product information and the precautionary information required in Section 25, Marking of Packages, for marking each package shall also appear on each coil, spool, and drum.

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

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

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

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



DIMENSIONS							
Spools		22 in [560 mm]		24 in [610 mm]		30 in [760 mm]	
		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	1.31	35.0	1.31	35.0	1.31	35.0
	Tolerance	+0.13, -0	±1.5	+0.13, -0	±1.5	+0.13, -0	±1.5
D	Distance, Center-to-Center	2.5	63.5	2.5	63.5	2.5	63.5
	Tolerance	±0.1	±1.5	±0.1	±1.5	±0.1	±1.5
E	Diameter (Note 3)	0.69	16.7	0.69	16.7	0.69	16.7
	Tolerance	+0, -0.06	±0.7	+0, -0.06	±0.7	+0, -0.06	±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 10—Standard Spools—Dimensions of 22, 24, and 30 in [560, 610, and 760 mm] Spools

24. Packaging

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

25. Marking of Packages

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

- (1) AWS specification (year of issue may be excluded) and classification, along with applicable optional designators

- (2) Supplier's name and trade designation
- (3) Size and net weight
- (4) Lot, control, or heat number

25.2 The appropriate precautionary information⁸ given in ANSI Z49.1, latest edition (as a minimum) or its equivalent, shall be prominently displayed in legible print on all packages of flux cored electrodes, including individual unit packages enclosed 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.

Nonmandatory Annexes

Annex A

Guide to AWS Specification for Carbon Steel Electrodes for Flux Cored Arc Welding

(This Annex is not part of AWS A5.20/A5.20M:2005, *Specification for Carbon Steel Electrodes for Flux Cored Arc Welding*, but is included for informational purposes only.)

A1. Introduction

The purpose of this guide is to correlate the electrode classifications with their intended applications so the specification can be used effectively. This guide provides examples rather than complete listings of the materials and applications for which each filler metal is suitable.

A2. Classification System

A2.1 Classification of Electrodes. The system for identifying the electrode classifications in the A5.20 and A5.20M specifications follows, for the most part, the standard pattern used in other AWS filler metal specifications. An illustration of this system is given in Figure 1.

AWS documents have traditionally used the letter “X” (or series of X’s) as generic designators to represent each of the (non-fixed) designators used in the classification or for optional supplemental designators.

A2.2 Some of the classifications are intended to weld only in the flat and horizontal positions (EX0T-5C, -5M, for example). Others are intended for welding in all positions (EX1T-1C, -1M, for example). As in the case of covered electrodes, the smaller sizes of flux cored electrodes are the ones used for out-of-position work. Flux cored electrodes larger than 5/64 in [2.0 mm] in diameter are usually used for horizontal fillets and flat position welding.

A2.3 Optional Supplemental designators are also used in this specification in order to identify electrode classifications that have met certain supplemental requirements as

agreed to between the supplier and the purchaser. The optional supplemental designators are not part of the electrode classification.

A2.3.1 This specification has included the use of optional designators for diffusible hydrogen (see Table 8 and A8.2) to indicate the maximum average value obtained under a clearly defined test condition in AWS A4.3. Electrodes that are designated as meeting the lower or lowest hydrogen limits as specified in Table 8 are understood to be able to meet any higher hydrogen limits when tested in accordance with Section 16. For example, see footnote “d” of Table 8.

A2.3.2 The A5.20/A5.20M specification has established multiple pass classification requirements using a test assembly as shown in Figure 3 using downhand welding procedures with heat inputs as shown in Table 5. In addition, this specification has included the optional supplemental designators “J,” “D,” and “Q” to indicate conformance to optional, supplemental mechanical property requirements.

A2.3.2.1 In order to include product with improved toughness at lower temperature an optional supplemental designator, “J,” has been added to identify electrodes which, when tested, produce weld metal which exhibits 20 ft-lbf at -40°F [27 J at -40°C]. The user is cautioned that although improved weld metal toughness will be evidenced when welding is performed under conditions specified in this specification, other applications of the electrode, such as long-term postweld heat treatment or vertical up welding with higher heat input, may produce results markedly different from the improved toughness levels given. The users should always perform their own mechanical properties verification testing.

A2.3.2.2 Two optional, supplemental designators have been added to identify electrodes which, when testing using both low heat input, fast cooling rate welding procedures and high heat input, slow cooling rate welding procedures, will conform to the classification radiographic requirements and to the tension test and Charpy V-Notch requirements specified in Table 10 (see Section 17). The first optional, supplemental designator, “D,” is intended to demonstrate conformance to the FEMA guidelines for the welding of steel moment-frame connections for seismic applications as indicated in FEMA 353. The second of these optional, supplemental designators, “Q,” is intended to demonstrate conformance to certain requirements for the welding of Navy ships.

A2.4 “G” Classification

A2.4.1 These specifications include electrodes classified as E6XT-G, E6XT-GS, E7XT-G, and E7XT-GS. The “G” or “GS” indicates that the electrode is of a “general” classification. It is “general” because not all of the particular requirements specified for each of the other classifications are specified for this classification. The intent in establishing this classification is to provide a means by which electrodes that differ in one respect or another (description of usability and/or operating polarity, for example) from all other classifications can still be classified according to this 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 electrodes—each bearing the same “G” classification—may be quite different in some certain respect (usability characteristics and polarity, again, for example).

A2.4.2 The point of difference (although not necessarily the amount of that difference) between an electrode of a “G” classification and an electrode of a similar classification without the “G” (or even with it, for that matter) 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:

(1) “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.

(2) “Not Required” is used in those areas of the specification that refer to the tests that must be conducted in order to classify an electrode. 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 an electrode 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. The purchaser may want to incorporate that information (via AWS A5.01) in the purchase order.

A2.5 Request for Filler Metal Classification

A2.5.1 When an electrode cannot be classified according to some classification other than a “G” classification, the manufacturer may request that a classification be established for that electrode. 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 electrode as long as the electrode is of commercial significance.

A2.5.2 A request to establish a new electrode classification must be a written request and needs to provide sufficient detail to permit the Committee on Filler Metals and Allied Materials or the Subcommittee to determine whether the 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, mechanical property requirements, and usability test requirements.

(2) Any conditions for conducting the tests used to demonstrate that the product meets classification requirements.

(3) Information on Descriptions and Intended Use, which parallels that for existing classifications, for that section of the Annex.

(4) Proposed ASME “F” Number, if appropriate.

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.

A2.5.3 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 will 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.

A2.5.4 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 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.

A2.5.5 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.

A2.6 An international system for designating welding filler metals developed by the International Institute of Welding (IIW) is being adopted in many ISO specifications. Table A1 shows those used in ISO 17632. To understand the proposed designation system as applied to

ISO 17632B, one is referred to Table 2 and the Annex of AWS document IFS:2002: *International Index of Welding Filler Metal Classifications*.

A3. Acceptance

Acceptance of all welding materials classified under this specification is in accordance with AWS A5.01 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 the supplier normally conducts 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

The act of placing the AWS specification and classification designations and optional supplemental designators, if applicable, on the packaging enclosing the

Table A1
Comparison of Classifications^{a,b}

ISO		AWS	
17632-A	17632-B	A5.20	A5.20M
T42 X R X	T49XT1-XXX	E7XT-1X	E49XT-1X
T4T Z R N	T49T2-XX	E7XT-2X	E49XT-2X
T4T Z V N	T49T3-XN	E7XT-3	E49XT-3
T42 Z W N	T49XT4-XNX	E7XT-4	E49XT-4
T42 X B X	T49XT5-XXX	E7XT-5X	E49XT-5X
T42 X Y N	T49XT6-XNX	E7XT-6	E49XT-6
T42 X W N	T49XT7-XNX	E7XT-7	E49XT-7
T42 X Y N	T49XT8-XNX	E7XT-8	E49XT-8
—	—	E7XT-9X	E49XT-9X
T4T Z V N	T49T10-XN	E7XT-10	E49XT-10
T42 X W N	T49XT11-XNX	E7XT-11	E49XT-11
T42 X R X	T49XT12-XXX	E7XT-12X	E49XT-12X
T4T Z V N	T49T13-XN	E7XT-13	E49XT-13
T4T Z V N	T49T14-XN	E7XT-14	E49XT-14

Notes:

a. From Table 2 of IFS:2002

b. AWS publication IFS:2002 in electronic format (CD-ROM) available from Global Engineering Documents, an Information Handling Services (IHS) Group company, 15 Inverness Way East, Englewood, Colorado 80112-5776; telephones: (800) 854-7179, (303) 397-7956; fax: (303) 397-2740; Internet: www-global.ih.com.

products, or the classification on the product itself, constitutes the supplier's (manufacturer's) certification that the product meets all of the requirements of that 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.

A5. Ventilation During Welding

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

- (1) Dimensions of the space in which welding is done (with special regard to the height of the ceiling).
- (2) Number of welders and welding operators working in that space.
- (3) Rate of evolution of fumes, gases, or dust according to the materials and processes used.
- (4) The proximity of the welders or welding operators to the fumes as the fumes issue from the welding zone, and to the gases and dusts in the space in which they are working.
- (5) The ventilation provided to the space in which the welding is done.

A5.2 American National Standard Z49.1 discusses the ventilation that is required during welding and should be referred to for details. Attention is drawn particularly to the section in that document on Health Protection and Ventilation.

A6. Welding Considerations

A6.1 When examining the properties required of weld metal as a result of the tests made according to this specification, it should be recognized that in production, where the conditions and procedures may differ from those in this specification (electrode size, amperage, voltage, type and amount of shielding gas, position of welding, contact tip to work distance (CTWD), plate thickness, joint geometry, preheat and interpass tempera-

tures, travel speed, surface condition, base metal composition and dilution, for example), the properties of the weld metal may also differ. Moreover, the difference may be large or small.

A6.2 Since it has not been possible to specify one single, detailed, welding procedure for all products classified under any given classification in this specification, details of the welding procedure used in classifying each product should be recorded by the manufacturer and made available to the user, on request. The information should include each of the welding parameters referred to in A6.1 above, as well as the actual number of passes and layers required to complete the weld test assembly.

A6.3 The toughness requirements for the different classifications in this specification can be used as a guide in the selection of electrodes for applications requiring some degree of low temperature notch toughness. For an electrode of any given classification, there can be a considerable difference between the impact test results from one assembly to another, or even from one impact specimen to another, unless particular attention is given to the manner in which the weld is made and prepared (even the location and orientation of the specimen within the weld), the temperature of testing, and the operation of the testing machine.

A6.4 Hardenability. There are inherent differences in the effect of the carbon content of the weld deposit on hardenability, depending on whether the electrode was gas shielded or self-shielded. Gas shielded electrodes generally employ a Mn-Si deoxidation system. The carbon and alloy content affects hardenability in a manner which is typical of many carbon equivalent formulas published for carbon steel. Most self-shielded electrodes utilize an aluminum-based deoxidation system to provide for protection and deoxidation. One of the effects of the aluminum is to modify the effect of carbon on hardenability which will, therefore, be lower than the carbon content would indicate based on typical carbon equivalent formulas.

A7. Description and Intended Use of Flux Cored Electrodes

This specification contains many different classifications of flux cored electrodes. The usability designation (1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, or the letter "G" or the letters "GS") in each classification indicates a general grouping of electrodes that contain similar flux or core components and which have similar usability characteristics, except for the "G" classification where usability characteristics may differ between similarly classified electrodes.

A7.1 EXXT-1C and EXXT-1M Classifications. Both the EXXT-1C and EXXT-1M electrodes have similar type slags and are designed for single and multiple pass welding using DCEP. The larger diameters (usually 5/64 in [2.0 mm] and larger) are typically used for welding in the flat position and for welding fillet welds in the horizontal position. The smaller diameters (usually 1/16 in [1.6 mm] and smaller) are typically used for welding in all positions. These electrodes are characterized by a spray transfer, low spatter loss, flat to slightly convex bead contour, and a moderate volume of slag, which completely covers the weld bead. Electrodes of this classification have a rutile base slag and have the ability to produce high deposition rates.

Electrodes in the EXXT-1C group are classified with CO₂ shielding gas (AWS A5.32/A5.32M, Class SG-C). However, other gas mixtures such as argon-CO₂ (AWS A5.32/A5.32M, Class SG-AC-25 or SG-AC-20) may be used to improve usability, especially for out-of-position applications, when recommended by the manufacturer. Increasing the amount of argon in the argon-CO₂ mixture will increase the manganese and silicon contents, along with certain other alloys such as chromium, in the weld metal. The increase in manganese, silicon, or other alloys will increase the yield and tensile strengths and may affect impact properties.

Electrodes in the EXXT-1M group are classified with 75% to 80% argon/balance CO₂ shielding gas. Increasing the amount of argon in the argon-CO₂ mixture will reduce the manganese and silicon losses, along with losses of certain other elements such as chromium, that occur in the welding arc. The resulting increase of manganese, silicon, or other elements will increase the yield and tensile strengths and may affect impact properties.

A7.2 EXXT-2C and EXXT-2M Classification. Electrodes of these classifications are essentially EXXT-1C and EXXT-1M with higher manganese or silicon, or both, and are designed primarily for single pass welding in the flat position and for welding fillet welds in the horizontal position. The higher levels of deoxidizers in these classifications allow single pass welding of heavily oxidized or rimmed steel.

Weld metal composition requirements are not specified for single-pass electrodes, since checking the composition of the undiluted weld metal will not provide an indication of the composition of a single-pass weld. These electrodes give good mechanical properties in single-pass welds.

The manganese content and the tensile strength of the weld metal of multiple-pass welds made with EXXT-2C and EXXT-2M electrodes will be high. These electrodes can be used for welding base metals which have heavier mill scale, rust, or other foreign matter that cannot be tolerated by some electrodes of the EXXT-1C or EXXT-

1M classifications. The arc transfer, welding characteristics and deposition rates of these electrodes, however, are similar.

A7.3 EXXT-3 Classification. Electrodes of this classification are self-shielded, used on DCEP and have a spray-type transfer. The slag system is designed to make very high welding speeds possible. The electrodes are used for single-pass welds in the flat, horizontal, and vertical (up to 20° incline) positions (downward progression) on sheet metal. Since these electrodes are sensitive to the effects of base metal quenching, they are not generally recommended for the following:

- (1) T- or lap joints in materials thicker than 3/16 in [5 mm]
- (2) Groove, edge, or corner joints in materials thicker than 1/4 in [6 mm]

The electrode manufacturer should be consulted for specific recommendations.

A7.4 EXXT-4 Classification. Electrodes of this classification are self-shielded, operate on DCEP, and have a globular type transfer. The basic slag system is designed to make very high deposition rates possible and to produce a weld that is very low in sulfur for improved resistance to hot cracking. These electrodes produce welds with low penetration enabling them to be used on joints with varying gaps and for single and multiple pass welding.

A7.5 EXXT-5C and EXXT-5M Classifications. Electrodes of the EXXT-5C and EXXT-5M classifications are used primarily for single and multiple pass welds in the flat position and for welding fillet welds in the horizontal position using DCEP or DCEN, depending on the manufacturer's recommendation. These electrodes are characterized by a globular transfer, slightly convex bead contour, and a thin slag that may not completely cover the weld bead. These electrodes have lime-fluoride base slag. Weld deposits produced by these electrodes typically have impact properties and hot and cold crack resistance that are superior to those obtained with rutile base slags. Some of these electrodes, using DCEN, can be used for welding in all positions. However, the operator appeal of these electrodes is not as good as that of those with rutile base slags.

Electrodes of the EXXT-5C classifications are designed to be used with CO₂ shielding gas (AWS A5.32/A5.32M, Class SG-C); however, as with the EXXT-1C classification, argon-CO₂ mixtures may be used to reduce spatter, when recommended by the manufacturer. Increasing the amount of argon in the argon-CO₂ mixture will increase the manganese and silicon contents, along with certain other alloys, which will increase the yield and tensile strengths and may affect impact properties.

Electrodes of the EXXT-5M classification are designed for use with 75% to 80% argon/balance CO₂ shielding. Their use with gas mixtures having reduced amounts of argon with CO₂ shielding gas will result in some deterioration in arc characteristics, an increase in spatter, and a reduction in manganese, silicon, and certain other alloy elements in the weld metal. This reduction in manganese, silicon, or other alloys will decrease the yield and tensile strengths and may affect impact properties.

A7.6 EXXT-6 Classification. Electrodes of this classification are self-shielded, operate on DCEP, and have a spray-type transfer. The slag system is designed to give good low temperature impact properties, good penetration into the root of the weld, and excellent slag removal, even in a deep groove. These electrodes are used for single and multiple pass welding in flat and horizontal positions.

A7.7 EXXT-7 Classification. Electrodes of this classification are self-shielded, operate on DCEN and have a small droplet to spray type transfer. The slag system is designed to allow the larger sizes to be used for high deposition rates in the horizontal and flat positions, and to allow the smaller sizes to be used for all welding positions. The electrodes are used for single and multiple pass welding and produce very low sulfur weld metal which is very resistant to hot cracking.

A7.8 EXXT-8 Classification. Electrodes of this classification are self-shielded, operate on DCEN, and have a small droplet to spray type transfer. These electrodes are suitable for all welding positions, and the weld metal has very good low temperature notch toughness and crack resistance. These electrodes are used for single and multiple pass welds.

A7.9 EXXT-9C and EXXT-9M Classifications. Electrodes of the EXXT-9C group are classified with CO₂ shielding gas (AWS A5.32/A5.32M, Class SG-C). However, gas mixtures of argon-CO₂ are sometimes used to improve usability, especially for out-of-position applications. Increasing the amount of argon in the argon-CO₂ mixture will affect the weld metal analysis and mechanical properties of weld metal deposited by these electrodes, just as it will for weld metal deposited by EXXT-1C and EXXT-1M electrodes (see A7.1).

Electrodes of the EXXT-9M group are classified with a 75–80% argon/balance CO₂ shielding gas (AWS A5.32/A5.32M, Class SG-AC-25 or SG-AC-20). Their use with argon/CO₂ shielding gas mixtures having reduced amounts of argon, or with CO₂ shielding gas, may result in some deterioration of arc characteristics and out-of-position welding characteristics. In addition, a reduction of the manganese and silicon contents in the

weld will result, which will have some effect on properties of weld metal from these electrodes, just as it will on properties of weld metal deposited by EXXT-1C and EXXT-1M electrodes (see A7.1).

Both the EXXT-9C and EXXT-9M electrodes are designed for single and multiple pass welding. The larger diameters (usually 5/64 in [2.0 mm] and larger) are used for welding in the flat position and for welding fillet welds in the horizontal position. The smaller diameters (usually 1/16 in [1.6 mm] and smaller) are often used for welding in all positions.

The arc transfer, welding characteristics, and deposition rates of the EXXT-9C and EXXT-9M electrodes are similar to those of the EXXT-1C or EXXT-1M classifications (see A7.1). EXXT-9C and EXXT-9M electrodes are essentially EXXT-1C and EXXT-1M electrodes that deposit weld metal with improved impact properties. Some electrodes in this classification require that joints be relatively clean and free of oil, excessive oxide, and scale in order that welds of radiographic quality can be obtained.

A7.10 EXXT-10 Classification. Electrodes of this classification are self-shielded, operate on DCEN, and have a small droplet transfer. The electrodes are used for single-pass welds at high travel speeds on material of any thickness in the flat, horizontal, and vertical (up to 20° incline) positions.

A7.11 EXXT-11 Classification. Electrodes of this classification are self-shielded, operate on DCEN, and have a smooth spray-type transfer. They are general purpose electrodes for single- and multiple-pass welding in all positions. Their use is generally not recommended on thicknesses greater than 3/4 in [19 mm]. The electrode manufacturer should be consulted for specific recommendations.

A7.12 EXXT-12C and EXXT-12M Classifications. Electrodes of these classifications are essentially EXXT-1C and EXXT-1M electrodes and are similar in arc transfer, welding characteristics and deposition rates; however, they have been modified to improve impact toughness and to meet the lower manganese requirements of the A-No. 1 Analysis Group in the ASME *Boiler and Pressure Vessel Code*, Section IX. They, therefore, have an accompanying decrease in tensile strength and hardness. Since welding procedures influence all-weld-metal properties, users are urged to check hardness on any application where a maximum hardness level is a requirement.

A7.13 EXXT-13 Classifications. Electrodes of this classification are self-shielded and operate on DCEN and are usually welded with a short-arc transfer. The slag system is designed so that these electrodes can be used in all positions for the root pass on circumferential pipe welds.

The electrodes can be used on all pipe wall thicknesses, but are only recommended for the first pass. They generally are not recommended for multiple-pass welding.

A7.14 EXXT-14 Classification. Electrodes of this classification are self-shielded, operate on DCEN and have a smooth spray-type transfer. They are intended for single-pass welding. The slag system is designed with characteristics so that these electrodes can be used to weld in all positions and also to make welds at high speed. They are used to make welds on sheet metal up to 3/16 in [5 mm] thick, and often are specifically designed for galvanized, aluminized, or other coated steels. Since these welding electrodes are sensitive to the effects of base metal quenching, they are not generally recommended for the following:

- (1) T- or lap joints in materials thicker than 3/16 in [5 mm]
- (2) Groove, edge, or corner joints in materials thicker than 1/4 in [6 mm]

The electrode manufacturer should be consulted for specific recommendations.

A7.15 EXXT-G Classification. This classification is for multiple pass electrodes that have usability characteristics not covered by any presently defined classification. Except for chemical requirements to assure a carbon steel deposit and the tensile strength, which is specified, the requirements for this classification are not specified. They are those that are agreed to by the purchaser and the supplier.

A7.16 EXXT-GS Classification. This classification is for single pass electrodes that have usability characteristics not covered by any presently defined classification. Except for the tensile strength, which is specified, the requirements for this classification are not specified. They are agreed upon by the purchaser and supplier.

A8. Special Tests

A8.1 It is recognized that supplementary tests may need to be conducted to determine the suitability of these welding electrodes for applications involving properties such as hardness, corrosion resistance, mechanical properties at higher or lower service temperatures, wear resistance, and suitability for welding combinations of dissimilar metals. Supplemental requirements as agreed between purchaser and supplier may be added to the purchase order following the guidance of AWS A5.01.

A8.2 Diffusible Hydrogen Test

A8.2.1 Hydrogen-induced cracking of weld metal or the heat-affected zone generally is not a problem with

carbon steels containing 0.3% 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 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. This cracking (or its detection) is usually delayed some hours after cooling. It may appear as transverse weld cracks, longitudinal cracks (especially in the 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 designators for diffusible hydrogen to indicate the maximum average value obtained under a clearly defined test condition in AWS A4.3.

A8.2.4 Most flux cored electrodes deposit weld metal having diffusible hydrogen levels of less than 16 mL/100 g of deposited metal. For that reason, flux cored electrodes are generally considered to be low hydrogen. However, some commercially available products will, under certain conditions, produce weld metal with diffusible hydrogen levels in excess of 16 mL/100 g of deposited metal. Therefore it may be appropriate for certain applications to utilize the optional supplemental designators for diffusible hydrogen when specifying the flux cored electrodes to be used.

A8.2.5 The use of a reference atmospheric condition during welding is necessitated because the arc is subject to atmospheric contamination when using either self-shielded or gas-shielded flux cored electrodes. Moisture from the air, distinct from that in the electrode, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. This effect can be minimized by maintaining as short an arc length as possible consistent with a steady arc. Experience has shown that the effect of arc length is minor at the H16 level, but can be very significant at the H4 level. An electrode meeting the H4 requirements under the reference atmospheric conditions may not do so under conditions of high humidity at the time of welding, especially if a long arc length is maintained.

A8.2.6 The user of this information is cautioned that actual fabrication conditions may result in different diffusible hydrogen values than those indicated by the designator. The welding consumable is not the only source of diffusible hydrogen in the welding process. In actual practice, the following may contribute to the hydrogen content of the finished weldment.

(1) **Surface Contamination.** Rust, primer coating, anti-spatter compounds, dirt and grease can all contribute to diffusible hydrogen levels in practice. Consequently, standard diffusible hydrogen tests for classification of welding consumable require test material to be free of contamination. AWS A4.3 is specific as to the cleaning procedure for test material.

(2) **Atmospheric Humidity.** The welding arc is subject to atmospheric contamination when using either a self-shielded or gas shielded welding consumable. Moisture from the air, distinct from that in the welding consumable, can enter the arc and subsequently the weld pool, contributing to the resulting observed diffusible hydrogen. AWS A4.3 has established a reference atmospheric condition at which the contribution to diffusible hydrogen from atmospheric humidity is considered to be negligible. This influence of atmospheric humidity also can be minimized by maintaining as short an arc length as possible consistent with a steady arc. For flux cored electrodes arc length is controlled primarily by arc voltage. Experience has shown that the effect of arc length is minor at the H16 level, but can be very significant at the H4 level. An electrode meeting the H4 requirements under the reference atmospheric conditions may not do so under conditions of high humidity at the time of welding, especially if a long arc length is maintained.

(3) **Shielding Gas.** The reader is cautioned that the shielding gas itself can contribute significantly to diffusible hydrogen. Normally, welding grade shielding gases are intended to have very low dew points and very low impurity levels. This, however, is not always the case. Instances have occurred where a contaminated gas cylinder resulted in a significant increase of diffusible hydrogen in the weld metal. Further, moisture permeation through some hoses and moisture condensation in unused gas lines can become a source of diffusible hydrogen during welding. In case of doubt, a check of gas dew point is suggested. A dew point of -40°F [-40°C] or lower is considered satisfactory for most applications.

(4) **Absorbed/Adsorbed Moisture.** Flux cored electrodes can absorb/adsorb moisture over time which contributes to diffusible hydrogen levels. This behavior is well documented for shielded metal arc electrode coverings exposed to the atmosphere. Hydration of oxide films and lubricants on solid electrode surfaces under what may be considered “normal” storage conditions has also

been reported to influence diffusible hydrogen. Moisture absorption/adsorption can be particularly significant if material is stored in a humid environment in damaged or open packages, or if unprotected for long periods of time. In the worst case of high humidity, even overnight exposure of unprotected electrodes can lead to a significant increase of diffusible hydrogen. For these reasons, indefinite periods of storage should be avoided. The storage and handling practices necessary to safeguard the condition of a welding consumable will vary from one product to another even within a given classification. Therefore, the consumable manufacturer should always be consulted for recommendations on storage and handling practice. In the event the electrode has been exposed, the manufacturer should be consulted regarding probable damage to its controlled hydrogen characteristics and possible reconditioning of the electrode.

(5) **Effect of Welding Process Variables.** Variations in welding process variables (e.g., amperage, voltage, contact tip to work distance (CTWD), type of shielding gas, current type/polarity, single electrode vs. multiple electrode welding, etc.) are all reported to influence diffusible hydrogen test results in various ways. For example, with respect to CTWD, a longer contact tip to work distance will promote more preheating of the electrode, causing some removal of hydrogen-bearing compounds (e.g., moisture, lubricants, etc.) before they reach the arc. Consequently, the result of longer contact tip to work distance can be to reduce diffusible hydrogen. However, excessive contact tip to work distances with external gas shielded welding processes may cause some loss of shielding if the contact tip is not adequately recessed in the gas cup. If shielding is disturbed, more air may enter the arc and increase the diffusible hydrogen. This may also cause porosity due to nitrogen pickup.

Since welding process variables can have a significant effect on diffusible hydrogen test results, it should be noted that an electrode meeting the H4 requirements, for example, under the classification test conditions should not be expected to do so consistently under all welding conditions. Some variation should be expected and accounted for when making welding consumable selections and establishing operating ranges in practice.

A8.2.7 As indicated in A8.2.6 (5), the welding procedures used with flux cored electrodes will influence the values obtained on a diffusible hydrogen test. To address this, the AWS A5M Subcommittee on Carbon and Low Alloy Steel Electrodes for Flux Cored Arc Welding has incorporated into its specification test procedure requirements for conducting the diffusible hydrogen test when determining conformance to the hydrogen optional supplemental designator requirements shown in Table 8. See Section 16. The following is provided as an example.

EXAMPLE: Manufacturer ABC, an electrode manufacturer, recommends and/or publishes the following procedure range for its EX1T-1C electrode.

Electrode Diameter	Shielding Gas	Wire Feed Rate in/min [cm/min]	Arc Voltage (volts)	CTWD in [mm]	Deposition Rate lbs/hr [kg/hr]
0.045 in [1.2 mm]	CO ₂	175–300 [445–760] 300–425 [760–1080] 425–550 [1080–1400]	22–26 25–29 28–31	1/2–3/4 [12–20] 5/8–7/8 [16–22] 3/4–1 [20–25]	3.3–5.8 [1.5–2.6] 5.8–8.1 [2.6–3.7] 8.1–10.5 [3.7–4.8]
1/16 in [1.6 mm]	CO ₂	150–225 [380–570] 225–300 [570–760] 300–375 [760–950]	23–26 25–28 27–32	3/4–1 [20–25] 7/8–1-1/8 [22–29] 1–1-1/4 [25–32]	5.4–8.0 [2.5–3.6] 8.0–10.8 [3.6–4.9] 10.8–12.2 [4.9–5.5]

Based upon the manufacturer's recommended operating range, the minimum wire feed rate and the CTWD to be used for hydrogen testing are determined as follows:

- For 0.045 in [1.2mm] diameter the minimum wire feed rate (WFR_{min}) to be used for the hydrogen test, as specified in 16.2, is $WFR_{min} = 175 \text{ in/min} + 0.75 (550 \text{ in/min} - 175 \text{ in/min}) = 456 \text{ in/min}$ [$WFR_{min} = 445 \text{ cm/min} + 0.75 (1400 \text{ cm/min} - 445 \text{ cm/min}) = 1160 \text{ cm/min}$].
The CTWD to be used for the hydrogen test is 3/4 in [20 mm], the minimum CTWD recommended by the manufacturer for the test wire feed rate of 456 in/min. [1160 cm/min].
- For 1/16 in [1.6 mm] diameter the minimum wire feed rate (WFR_{min}) to be used for the hydrogen test, as specified in 16.2, is $WFR_{min} = 150 \text{ in/min} + 0.75 (375 \text{ in/min} - 150 \text{ in/min}) = 319 \text{ in/min}$ [$WFR_{min} = 380 \text{ cm/min} + 0.75 (950 \text{ cm/min} - 380 \text{ cm/min}) = 808 \text{ cm/min}$].
The CTWD to be used for the hydrogen test is 1 in [25 mm], the minimum CTWD recommended by the manufacturer for the test wire feed rate of 319 in/min [808 cm/min].

A8.2.8 Not all classifications may be available in the H16, H8, or H4 diffusible hydrogen levels. The manufacturer of a given electrode should be consulted for availability of products meeting these limits.

A8.3 Aging of Tensile Specimens. Weld metal 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 toward its inherent value, while yield, tensile, and impact strengths remain relatively unchanged. The A5.20 and A5.20M specifications permit the aging of the tensile test specimens at elevated temperatures not exceeding 220°F [105°C] for up to 48 hours before cooling them to room temperature and subjecting them to tension testing. The purpose of this treatment is to facilitate removal of hydrogen from the test specimen in order to minimize discrepancies in testing.

Aging treatments are sometimes used for low hydrogen electrode deposits, especially when testing high

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

A9. General Safety Considerations

Note: Safety and health issues and concerns are beyond the scope of this standard and, therefore, are not addressed herein. Some safety and health information is available from other sources, including, but not limited to, the Safety and Health Fact Sheets listed in A9.2, ANSI Z49.1, and applicable federal and state regulations.

A9.1 Safety and Health Fact Sheets. The Safety and Health Fact Sheets listed below are published by the American Welding Society (AWS). They may be downloaded and printed directly from the AWS website at <http://www.aws.org>. The Safety and Health Fact Sheets are revised and additional sheets added periodically.

A9.2 AWS Safety and Health Fact Sheets Index (SHF)

<u>No.</u>	<u>Title</u>
1	Fumes and Gases
2	Radiation
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 Safety and Health Documents
15	Style Guidelines for Safety and Health Documents
16	Pacemakers and Welding

<u>No.</u>	<u>Title</u>
17	Electric and Magnetic Fields (EMF)
18	Lockout/Tagout
19	Laser Welding and Cutting Safety
20	Thermal Spraying Safety
21	Resistance Spot Welding
22	Cadmium Exposure from Welding and Allied Processes
23	California Proposition 65
24	Fluxes for Arc Welding and Allied Processes
25	Metal Fume Fever
27	Thoriated Tungsten Electrodes
29	Grounding of Portable and Vehicle Mounted Welding Generators

A10. Discontinued Classifications

E60T-7 and E60T-8 have been discontinued and replaced with E7XT-7 and E7XT-8 respectively.

Annex B

Guidelines for Preparation of Technical Inquiries for AWS Technical Committees

(This Annex is not a part of AWS A5.20/A5.20M:2005, *Specification for Carbon Steel Electrodes for Flux Cored 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 the proposed revision, if that is what the inquirer seeks.

B3. Interpretation of Provisions of the Standard

Interpretations of provisions of the standard are made by the relevant AWS Technical Committee. The secretary of the committee refers all inquiries to the Chair of the particular subcommittee that has jurisdiction over the portion of the standard addressed by the inquiry. The subcommittee reviews the inquiry and the proposed reply to determine what the response to the inquiry should be. Following the subcommittee's development of the response, the inquiry and the response are presented to the entire committee for review and approval. Upon

approval by the committee, the interpretation 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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American Welding Society (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	<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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