

SPECIFICATION FOR LOW ALLOY ELECTRODES FOR FLUX CORED ARC WELDING



SFA-5.29



(Identical with AWS Specification A5.29-80)

Scope

This specification prescribes classification requirements for low alloy steel flux cored electrodes¹ for welding carbon and low alloy steels.

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

1. Classification and Acceptance

1.1 Classification.² Electrodes are classified on the basis of the following:

- (1) Whether CO₂ is used as a separate shielding gas
- (2) Type of current
- (3) Position of welding
- (4) Chemical composition of the weld metal
- (5) Mechanical properties of the weld metal (see Tables 2, 3, 4, and 9).

Any electrode classified under one classification shall not be classified under any other classification of this specification.³

1.2 Acceptance. At the option and expense of the purchaser, any or all of the test requirements of this specification may be used as a basis for acceptance of

the products covered by this specification. AWS A5.01, Filler Metal Procurement Guidelines, shall be referred to for lot definitions and frequency of testing.

1.3 Chemical Composition Requirements. The chemical composition of the weld metal shall conform to the requirements of Table 1. The details of the test are specified in section 3.3.

1.4 Mechanical, Soundness, and Usability Tests and Requirements. Table 2 summarizes the required mechanical, soundness, and usability tests.

1.4.1 Soundness Test. The radiographs of test assemblies shall reveal no cracks or zones of incomplete fusion, nor any porosity or slag inclusions in excess of that allowed by the acceptance standards in Fig. 1. The details of the test are specified in section 3.5.

1.4.2 All-Weld-Metal Tension Test. The tension test specimens shall yield results conforming to the mechanical property requirements prescribed in Table 3. The details of the test are specified in section 3.6.

1.4.3 Impact Test. The Charpy V-notch impact test is required in accordance with Table 2. The test specimens shall yield results conforming to the impact requirements prescribed in Table 4. The details of the test are specified in section 3.7.

1.4.4 Fillet Weld Tests. Electrodes designed to be used in all positions (EX1T) will be required to make a vertical-up fillet and an overhead fillet in addition to other testing (see Table 2). The convexity shall be no greater than 1/8 in. (3.2 mm) with a fillet size no greater than 3/8 in. (9.5 mm). The details of the test are stipulated in 3.8.

¹For the accepted definition of a flux cored electrode, see AWS A3.0, Welding Terms and Definitions.

²For an explanation of the system of classification of electrodes in this specification, see paragraph A2 in the Appendix.

³This restriction does not apply to the designations for primary welding position (see section A2.3).

TABLE 1
CHEMICAL REQUIREMENTS FOR DEPOSITED WELD METAL^a

AWS Classification	Chemical Composition, Percent										
	C	Mn	P	S	Si	Ni	Cr	Mo	V	Al ^b	Cu
Carbon-Molybdenum Steel Electrodes											
E70T-A1 E80T1-A1 E81T1-A1	0.12	1.25	0.03	0.03	0.80	—	—	0.40/0.65	—	—	—
Chromium-Molybdenum Steel Electrodes											
E81T1-B1	0.12	1.25	0.03	0.03	0.80	—	0.40/0.65	0.40/0.65	—	—	—
E80T5-B2L	0.05	1.25	0.03	0.03	0.80	—	1.00/1.50	0.40/0.65	—	—	—
E80T1-B2 E81T1-B2 E80T5-B2	0.12	1.25	0.03	0.03	0.80	—	1.00/1.50	0.40/0.65	—	—	—
E80T1-B2H	0.10/0.15	1.25	0.03	0.03	0.80	—	1.00/1.50	0.40/0.65	—	—	—
E90T1-B3L	0.05	1.25	0.03	0.03	0.80	—	2.00/2.50	0.90/1.20	—	—	—
E90T1-B3 E91T1-B3 E90T5-B3	0.12	1.25	0.03	0.03	0.80	—	2.00/2.50	0.90/1.20	—	—	—
E100T1-B3 E90T1-B3H	0.10/0.15	1.25	0.03	0.03	0.80	—	2.00/2.50	0.90/1.20	—	—	—
Nickel-Steel Electrodes											
E71T8-Ni1 E80T1-Ni1 E81T1-Ni1 E80T5-Ni1	0.12	1.50	0.03	0.03	0.80	0.80/1.10	0.15	0.35	0.05	1.8	—
E71T8-Ni2 E80T1-Ni2 E81T1-Ni2 E80T5-Ni2	0.12	1.50	0.03	0.03	0.80	1.75/2.75	—	—	—	1.8	—
E90T1-Ni2 E91T1-Ni2	0.12	1.50	0.03	0.03	0.80	2.75/3.75	—	—	—	—	—
E80T5-Ni3 E90T5-Ni3	0.12	1.50	0.03	0.03	0.80	—	—	—	—	—	—
Manganese-Molybdenum Steel Electrodes											
E91T1-D1	0.12	1.25/2.00	0.03	0.03	0.80	—	—	0.25/0.55	—	—	—
E90T5-D2 E100T5-D2	0.15	1.65/2.25	0.03	0.03	0.80	—	—	0.25/0.55	—	—	—
E90T1-D3	0.12	1.00/1.75	0.03	0.03	0.80	—	—	0.40/0.65	—	—	—

1.5 Retests. If any test fails, two additional tests of that particular test, as taken from the original test assembly or from new test assemblies, shall be performed and the results of both shall meet the requirements prescribed for that test.

2. Manufacture

2.1 Method of Manufacture. The electrodes may be made by any method that will yield a product conforming to the requirements of this specification.

2.2 Standard Sizes and Lengths. Electrodes shall be available in continuous lengths wound into coils with or without support, into drums, or onto spools. Standard sizes of the electrodes in all forms are shown in Table 5.

2.3 Finish, Temper, Cast, and Helix

2.3.1 Finish. Electrodes shall have a smooth finish except for seams and shall be free from slivers, depressions, scratches, scale, or other foreign matter that

TABLE 1 (CONT'D)
CHEMICAL REQUIREMENTS FOR DEPOSITED WELD METAL^a

AWS Classification	Chemical Composition, Percent										
	C	Mn	P	S	Si	Ni	Cr	Mo	V	Al ^b	Cu
Chemical Composition, Percent											
E80T5-K1	0.15	0.80/1.40	0.03	0.03	0.80	0.80/1.10	0.15	0.20/0.65	0.05	—	—
E70T4-K2	0.15	0.50/1.75	0.03	0.03	0.80	1.00/2.00	0.15	0.35	0.05	1.8	—
E71T8-K2											
E80T1-K2											
E90T1-K2											
E91T1-K2											
E80T5-K2											
E90T5-K2	0.15	0.75/2.25	0.03	0.03	0.80	1.25/2.60	0.15	0.25/0.65	0.05	—	—
E100T1-K3											
E110T1-K3											
E100T5-K3											
E110T5-K3	0.15	1.20/2.25	0.03	0.03	0.80	1.75/2.60	0.20/0.60	0.30/0.65	0.05	—	—
E110T5-K4											
E111T1-K4											
E120T5-K4											
E120T1-K5	0.10/0.25	0.60/1.60	0.03	0.03	0.80	0.75/2.00	0.20/0.70	0.15/0.55	0.05	—	—
E61T8-K6	0.15	0.50/1.50	0.03	0.03	0.80	0.40/1.10	0.15	0.15	0.05	1.8	—
E71T8-K6											
E101T1-K7	0.15	1.00/1.75	0.03	0.03	0.80	2.00/2.75	—	—	—	—	—
EXXTX-G	—	1.00 min*	0.03	0.03	0.80 min*	0.50 min*	0.30 min*	0.20 min*	0.10 min*	1.8	—
E80T1-W	0.12	0.50/1.30	0.03	0.03	0.35/0.80	0.40/0.80	0.45/0.70	—	—	—	0.30/0.75

NOTES:

a. Single values are maximums unless otherwise noted.

b. For self-shielded electrodes only.

* In order to meet the alloy requirements of the G group, the weld deposit need have the minimum, as specified in the table, of only one of the elements listed.

TABLE 2
REQUIRED TESTS (SOUNDNESS, MECHANICAL AND USABILITY)^a

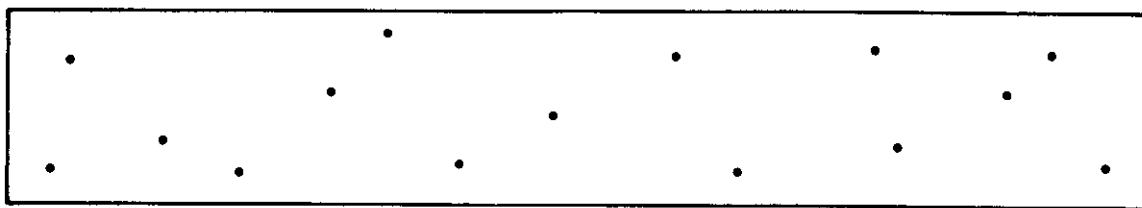
AWS Classification ^b	Radiographic Soundness Test	All-Weld-Metal Tension Test (Flat Position)	Vertical and Overhead Fillet Weld Test	Charpy V-Notch Impact Test
EX0TX-X	req	req	—	c
EX1TX-X	req	req	req	c
EXXTX-G	—	—	—	—

NOTES:

a. The letters "req" indicate that the test is required. Where no indication is shown, the test is not required.

b. The 0 and 1 before the "T"; refer to the usability of the electrode: EX0T = horizontal and flat position; EX1T = all position. The "X"'s indicate the tensile strength, slag system, and chemical composition designations of Table 1 and Table 3 (see also A2).

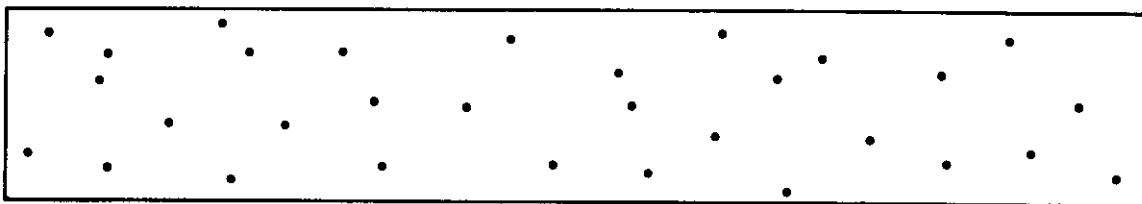
c. The Charpy V-notch impact test is required when the classification in accordance with Table 4 indicates toughness performance.



Medium porosity and/or inclusions

Size 1/32 in. (0.8 mm) to 3/64 in. (1.2 mm) in diameter and/or length.

Maximum number of indications in any 6 in. (150 mm) of weld = 15.



Fine porosity and/or inclusions

Size 1/64 in. (0.4 mm) to 1/32 in. (0.8 mm) in diameter and/or length.

Maximum number of indications in any 6 in. (150 mm) of weld = 30.

FIG. 1 POROSITY AND INCLUSION STANDARDS FOR SOUNDNESS TEST

would adversely affect the welding properties or the operation of the welding equipment.

2.3.2 Temper, Cast, and Helix. Electrodes shall be suitable for uniform uninterrupted feeding on automatic or semiautomatic welding equipment.

2.4 Uniformity in Core of Electrodes. All electrodes shall have the core ingredients distributed throughout their length with sufficient uniformity so that the performance of the electrodes and the properties of the weld metal deposited thereby are not adversely affected.

2.5 Standard Forms — Coils with and without Support, Spools, and Drums

2.5.1 Coils without Support. Dimensions shall be as specified by the purchaser.

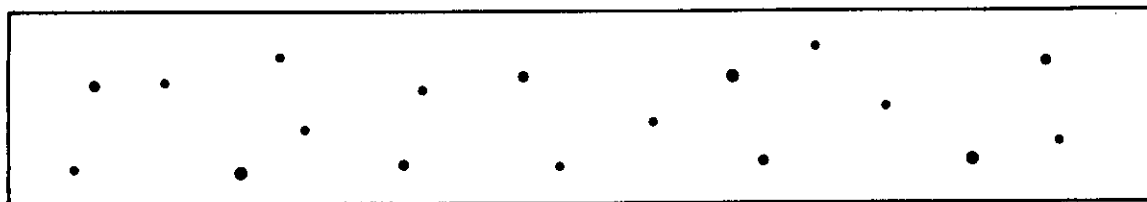
2.5.2 Coils with Support. Standard dimensions and net weights of coils with support shall be as specified in Table 6. Liners shall be of such material and design as to provide adequate protection against damage or distortion of the electrode due to normal handling or use. Liners shall be sufficiently clean and dry to maintain the cleanliness of the electrode.

2.5.3 Spools. Dimensions of standard 4 in. (100 mm) spools shall be as shown in Fig. 2; dimensions of standard 12 and 14 in. (300 and 350 mm) spools shall be as shown in Fig. 3. Spools shall be of such material and design as to provide adequate protection against damage or distortion of themselves and of the electrode due to normal handling or use. Spools shall be sufficiently clean and dry to maintain the cleanliness of the electrode.

2.5.4 Drums. Standard outside diameters of drums shall be 15-1/2, 20, and 23 in. (400, 500, and 600 mm). Drums shall be of such material and design as to provide adequate protection against damage or distortion of the electrode due to normal handling or use. Drums shall be sufficiently clean and dry to maintain the cleanliness of the electrode.

2.6 Winding Requirements

2.6.1 Each coil with or without support, spool, or drum shall contain one continuous length of electrode made from a single lot of material.



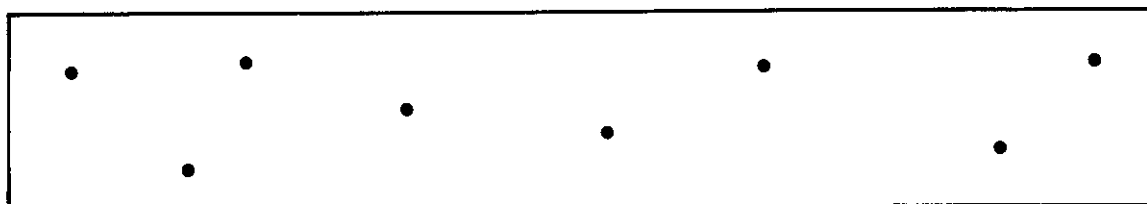
Assorted porosity and/or inclusions

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) diameter and/or length indications = 3.

Maximum number of medium 1/32 in. (0.8 mm) to 3/64 in. (1.2 mm) diameter and/or length indications = 5.

Maximum number of small 1/64 in. (0.4 mm) to 3/64 in. (1.2 mm) diameter and/or length indications = 10.



Large porosity and/or inclusions

Size 3/64 in. (1.2 mm) to 1/16 in. (1.6 mm) in diameter and/or length.

Maximum number of indications in any 6 in. (150 mm) of weld = 8.

Notes:

1. In using these standards, the chart which is most representative of the size of the porosity and/or inclusions 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 smaller than 1/64 in. (0.4 mm) diameter and/or length shall be disregarded.
4. See *Note* in the Scope on page 1.

FIG. 1 POROSITY AND INCLUSION STANDARDS FOR SOUNDNESS TEST (CONT'D)

2.6.2 Butt joints, when present in the electrode, shall be suitably made so as not to interfere with the uniform uninterrupted feeding of the electrode on automatic and semiautomatic equipment.

2.6.3 The electrode shall be wound so as to avoid kinks, waves, or sharp bends that would interfere with the feeding of the electrode, and so that it is free to unwind without restriction. The outside end of the electrode shall be identified, accessible, and secured.

2.7 Standard Packages. Electrodes shall be packaged in accordance with the requirements of Table 7.

2.8 Marking

2.8.1 The outside of each unit package shall be legibly marked with the following information:

2.8.1.1 Specification and classification numbers

2.8.1.2 Standard size and net weight

2.8.1.3 Supplier's name and trade designation

2.8.1.4 Lot, control, or heat number

TABLE 3
MECHANICAL PROPERTY REQUIREMENTS^a

AWS Classification	Tensile Strength Range		Yield Strength, at 0.2% Offset, Min		Percent Elongation in 2 in. (50 mm), Min
	ksi	MPa	ksi	MPa	
E6XTX-X	60 to 80	410 to 550	50	340	22
E7XTX-X	70 to 90	490 to 620	58	400	20
E8XTX-X	80 to 100	550 to 690	68	470	19
E9XTX-X	90 to 110	620 to 760	78	540	17
E10XT-X	100 to 120	690 to 830	88	610	16
E11XT-X	110 to 130	760 to 900	98	680	15
E12XT-X	120 to 140	830 to 970	108	750	14
EXXTX-G	Properties as agreed upon between supplier and purchaser				

NOTE:

- a. Properties of electrodes that use external gas shielding (EXXT1-X and EXXT5-X) vary with gas mixtures. Electrodes classified under this specification should not be used with gases other than those listed in Table 9 without first consulting the manufacturer.

2.8.2 Marking of any or all overpacking with items listed in 2.8.1 shall be optional with the manufacturer.

2.8.3 Within the outer wrapping, electrodes in coils without support shall be identified by tag or otherwise at the inside end, showing the classification and specification number, trade designation, and lot, control, or heat number. The identification shall be attached in such a manner that it cannot be readily removed.

2.8.4 Electrodes wound on liners or into drums shall be identified by the classification and specification number, trade designation, and the lot, control, or heat number placed directly on the liners or drums in such a manner that this identification cannot be readily removed.

2.8.5 Electrodes wound on spools shall be identified by the classification and specification number, trade designation, and the lot, control, or heat number placed on the outside of at least one flange of the spool in such a manner that this identification cannot be readily removed.

2.8.6 Each coil with support, spool, or drum shall have the following precautionary labeling or its equivalent, as a minimum, permanently affixed to the body of the liner, spool, or drum in a prominent position and in legible type. Coils without support shall have a tag bearing the following precautionary labeling or its equivalent, as a minimum, in legible type securely attached to the inside end of the coil.

WARNING: Protect yourself and others. Read and understand this label.

FUMES AND GASES can be dangerous to your health. ARC RAYS can injure eyes and burn skin. ELECTRIC SHOCK can kill.

- Read and understand the manufacturer's instructions and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases from your breathing zone and the general area.
- Wear correct eye, ear, and body protection.
- Do not touch live electrical parts.
- See American National Standard Z49.1, Safety in Welding and Cutting, published by the American Welding Society, 2501 N.W. 7th St., Miami, Florida, 33125; OSHA Safety and Health Standards, 29 CFR 1910, available from Government Printing Office, Washington, D.C. 20402.

DO NOT REMOVE THIS LABEL

2.9 Certification. For all material furnished under this specification, the manufacturer certifies (by meeting the requirements of 2.8) that the material, or representative material, has passed the tests required for classification by this specification. When required by the purchaser, the manufacturer shall furnish a copy of the results of those tests.

TABLE 4
IMPACT REQUIREMENTS

Classification	Condition ^a	Impact Strength
E80T1-A1	PWHT	Not required
E81T1-A1	PWHT	Not required
E70T5-A1	PWHT	20 ft · lb @ -20°F (27 J @ -30°C)
E81T1-B1	PWHT	Not required
E81T1-B2	PWHT	Not required
E80T1-B2	PWHT	Not required
E80T5-B2	PWHT	Not required
E80T1-B2H	PWHT	Not required
E80T5-B2L	PWHT	Not required
E90T1-B3	PWHT	Not required
E91T1-B3	PWHT	Not required
E90T5-B3	PWHT	Not required
E100T1-B3	PWHT	Not required
E90T1-B3L	PWHT	Not required
E90T1-B3H	PWHT	Not required
E71T8-Ni1	AW	20 ft · lb @ -20°F (27 J @ -30°C)
E80T1-Ni1	AW	20 ft · lb @ -20°F (27 J @ -30°C)
E81T1-Ni1	AW	20 ft · lb @ -20°F (27 J @ -30°C)
E80T5-Ni1	PWHT	20 ft · lb @ -60°F (27 J @ -51°C)
E71T8-Ni2	AW	20 ft · lb @ -20°F (27 J @ -30°C)
E80T1-Ni2	AW	20 ft · lb @ -40°F (27 J @ -40°C)
E81T1-Ni2	AW	20 ft · lb @ -40°F (27 J @ -40°C)
E80T5-Ni2 ^b	PWHT	20 ft · lb @ -75°F (27 J @ -60°C)
E90T1-Ni2	AW	20 ft · lb @ -40°F (27 J @ -40°C)
E91T1-Ni2	AW	20 ft · lb @ -40°F (27 J @ -40°C)
E80T5-Ni3 ^b	PWHT	20 ft · lb @ -100°F (27 J @ -73°C)
E90T5-Ni3 ^b	PWHT	20 ft · lb @ -100°F (27 J @ -73°C)
E91T1-D1	AW	20 ft · lb @ -40°F (27 J @ -40°C)
E90T5-D2	PWHT	20 ft · lb @ -60°F (27 J @ -51°C)
E100T5-D2	PWHT	20 ft · lb @ -40°F (27 J @ -40°C)
E90T1-D3	AW	20 ft · lb @ -20°F (27 J @ -30°C)
E80T5-K1	AW	20 ft · lb @ -40°F (27 J @ -40°C)
E70T4-K2	AW	20 ft · lb @ 0°F (27 J @ -18°C)
E71T8-K2	AW	20 ft · lb @ -20°F (27 J @ -30°C)
E80T1-K2	AW	20 ft · lb @ -20°F (27 J @ -30°C)
E90T1-K2	AW	20 ft · lb @ 0°F (27 J @ -18°C)
E91T1-K2	AW	20 ft · lb @ 0°F (27 J @ -18°C)
E80T5-K2	AW	20 ft · lb @ -20°F (27 J @ -30°C)
E90T5-K2	AW	20 ft · lb @ -60°F (27 J @ -51°C)
E100T1-K3	AW	20 ft · lb @ 0°F (27 J @ -18°C)
E110T1-K3	AW	20 ft · lb @ 0°F (27 J @ -18°C)
E100T5-K3	AW	20 ft · lb @ -60°F (27 J @ -51°C)
E110T5-K3	AW	20 ft · lb @ -60°F (27 J @ -51°C)
E110T5-K4	AW	20 ft · lb @ -60°F (27 J @ -51°C)
E111T5-K4	AW	20 ft · lb @ -60°F (27 J @ -51°C)
E120T5-K4	AW	20 ft · lb @ -60°F (27 J @ -51°C)
E120T1-K5	AW	Not required
E61T8-K6	AW	20 ft · lb @ -20°F (27 J @ -30°C)
E71T8-K6	AW	20 ft · lb @ -20°F (27 J @ -30°C)
E101T1-K7	AW	20 ft · lb @ -60°F (27 J @ -51°C)
E80T1-W	AW	20 ft · lb @ -20°F (27 J @ -30°C)
EXXXTX-G	Properties as agreed upon between supplier and purchaser	

NOTES:

a. AW = As welded.

PWHT = Postweld heat treated in accordance with 3.6.

b. PWHT temperatures in excess of 1150°F (620°C) will decrease the impact value.

TABLE 5
STANDARD SIZES AND TOLERANCES OF ELECTRODES^a

AWS Classification	Type of Package ^b	Electrode Size, Diam.		Diameter Tolerance	
		in.	mm	± in.	± mm
All classifications	CS, S, D	$\left\{ \begin{array}{l} 0.045 \\ 0.052 \\ \frac{1}{16} \end{array} \right\}$	$\left\{ \begin{array}{l} 1.2 \\ 1.4 \\ 1.6 \end{array} \right\}$	0.002	0.05
All classifications	C, CS, S, D	$\left\{ \begin{array}{l} \frac{5}{64} \\ \frac{3}{32} \\ \frac{7}{64} \\ 0.120 \\ \frac{1}{8} \\ \frac{5}{32} \end{array} \right\}$	$\left\{ \begin{array}{l} 2.0 \\ 2.4 \\ 2.8 \\ 3.0 \\ 3.2 \\ 4.0 \end{array} \right\}$	0.003	0.08

NOTES:

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

b. Package designations are as follows:

C = Coils without support

CS = Coils with support

S = Spools

D = Drums

TABLE 6
COIL WITH SUPPORT — STANDARD DIMENSIONS AND WEIGHTS^a

Electrode Size	Coil Net Weight ^b		Coil Dimensions			
			Inside Diameter of Liner		Width of Wound Electrode	
	lb	kg	in.	mm	in., max	mm, max
All	14	6.4	$6\frac{3}{4} \pm \frac{1}{8}$	170 ± 3	3	75
	24 and 30	11 and 14	$12 \pm \frac{1}{8}$	305 ± 3	$2\frac{1}{2}$ or $4\frac{5}{8}$	65 or 120
	50 and 60	23 and 27	$12 \pm \frac{1}{8}$	305 ± 3	$4\frac{5}{8}$	120

NOTES:

a. Other sizes and weights may be supplied as agreed upon between the supplier and purchaser.

b. Net weights shall be within 10 percent of the nominal weights.

2.10 Rounding-off Procedure. For purposes of determining conformance with this specification, an observed or calculated value shall be rounded off to the nearest 1000 psi tensile and yield strength, and to the nearest unit in the last right-hand place of figures used in expressing the limiting value for other values in accordance with the rounding-off method of ASTM E29, Recommended Practice for Indicating Which Places of Figures are to be Considered Significant in Specified Limiting Values.⁴

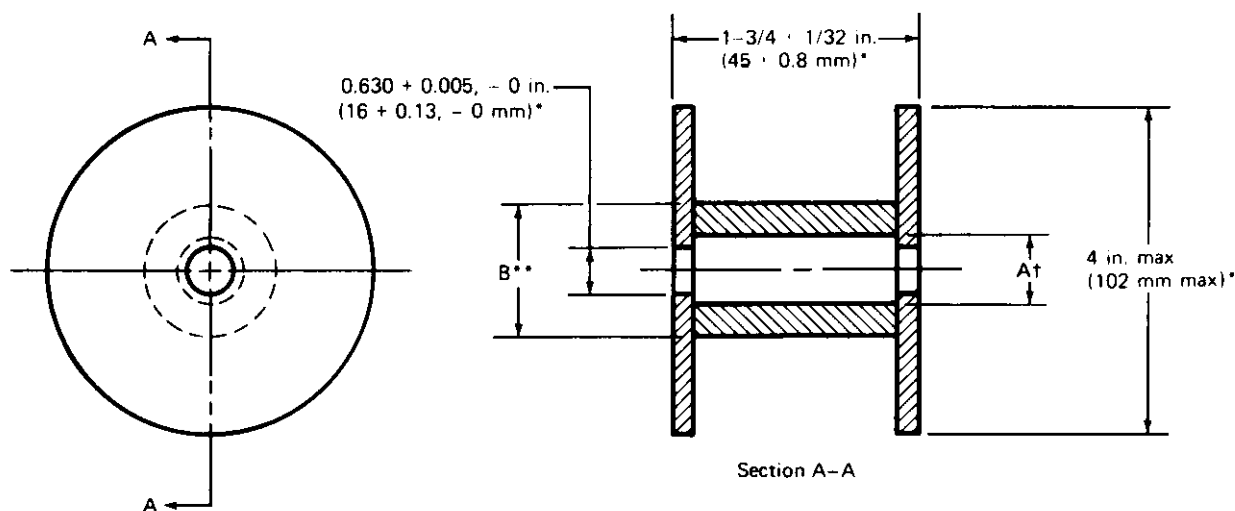
⁴ASTM Standards can be obtained from the American Society for Testing and Materials, 1916 Race St., Philadelphia, PA 19103.

3. Details of Tests

3.1 Required Tests

3.1.1 The tests specified in 1.3 and 1.4 shall be conducted in accordance with the requirements of section 3.

3.1.2 The chemical analysis, the radiographic soundness test, and the required mechanical tests shall be made using a $\frac{3}{32}$ in. (2.4 mm) diameter electrode. If the $\frac{3}{32}$ in. (2.4 mm) electrode is not manufactured as a standard size by a particular manufacturer, the closest size that is manufactured shall be used. The



* All dimensions are in inches (millimeters). See *Note* in the Scope on page 1.

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

** Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the electrode.

FIG. 2 DIMENSIONS OF 4 in. (100 mm)* SPOOL

fillet weld test shall be made with the size electrode recommended by the manufacturer.

3.2 Material for Test Plates. Unless otherwise specified, the base metal steel used for the tests required herein shall be in accordance with Table 8.

3.3 Chemical Analysis

3.3.1 Chemical analysis samples of the weld metal shall be obtained for those electrodes for which Table 1 lists composition requirements.

3.3.2 Samples for chemical analysis may be obtained from either of the following:

3.3.2.1 The chemical analysis test pad specified in paragraphs 3.3.3 and 3.3.4.

3.3.2.2 Any suitable method, provided it produces results equivalent to those obtained from the weld pad specified in paragraphs 3.3.3 and 3.3.4. In case of dispute, samples for chemical analysis shall be obtained from weld test pads as specified in 3.3.3 and 3.3.4.

3.3.3 The weld pads shall be deposited in the flat position in layers. The minimum size of each pad shall be 1 in. wide x 3 in. long x 1/2 in. thick (25 x 76 x

13 mm). After depositing each layer, the pad may be immersed in water (temperature unimportant).

3.3.4 The sample for analysis shall be free of all foreign matter, and shall be taken at least 3/8 in. (9-1/2 mm) from the surface of the base metal on which the pad was deposited.

3.3.5 Chemical analysis may be made by any suitable method agreed upon by the supplier and purchaser. In case of dispute, the referee method shall be the procedure in the latest edition of the ASTM Standard Methods E350, Chemical Analysis of Carbon Steel, Low-Alloy Steel, Silicon Electrical Steel, Ingot Iron, and Wrought Iron.

3.4 Preparation of Test Assembly for Soundness Tests, All-Weld-Metal Tension Test, and Impact Test

3.4.1 The test assembly detailed in Fig. 5 shall be prepared and welded as prescribed in paragraphs 3.4.2 to 3.4.5 using the electrode size stipulated in paragraph 3.1.2 and the conditions listed in Tables 9 and 10 for the classification of the electrode being tested.

3.4.2 The test assembly shall be welded in the flat position and shall be restrained during welding, or

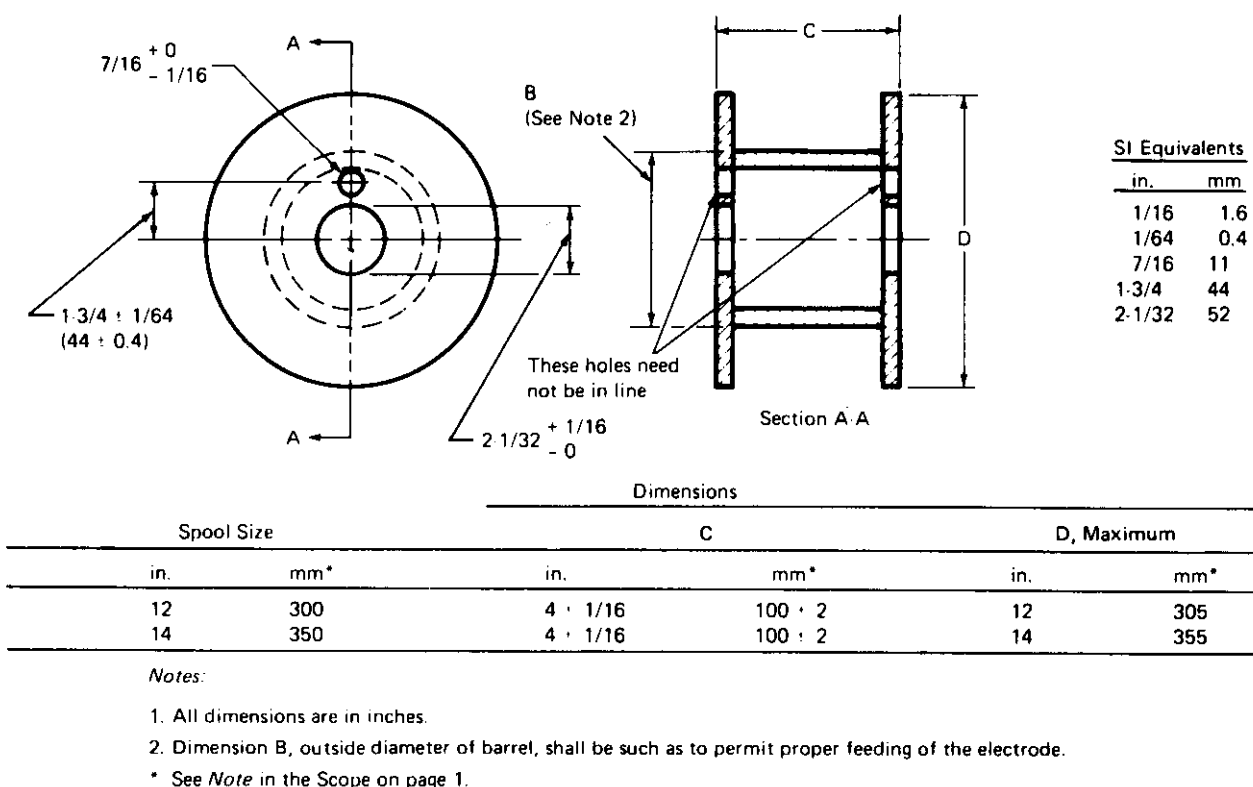


FIG. 3 DIMENSION OF 12 AND 14 in. (300 AND 350 mm)* SPOOLS

preset at approximately 5 degrees to prevent warpage in excess of 5 degrees. A welded test assembly that has warped more than 5 degrees shall be discarded. Welded test assemblies shall not be straightened.

3.4.3 When required in accordance with footnote a of Table 8, the groove faces and the contact face of the backing shall be surfaced by any size of the electrode being tested before welding the assembly as shown in Fig. 5. Each layer of surfacing shall be approximately $\frac{1}{8}$ in. (3.2 mm) thick.

3.4.4 The test assembly shall be tack welded and shall be heated to the preheat temperature prescribed in Table 11 (measured by indicating crayons or surface thermometers at the point specified in Fig. 5) for the electrode classification being tested. This preheat or interpass temperature shall be maintained until the weld joint is completed. The required total passes shall be as shown in Table 10. (Table 10 also includes a suggested pass sequence.)

3.4.5 If it is necessary to interrupt the welding procedure prescribed in 3.4.4, the assembly shall be

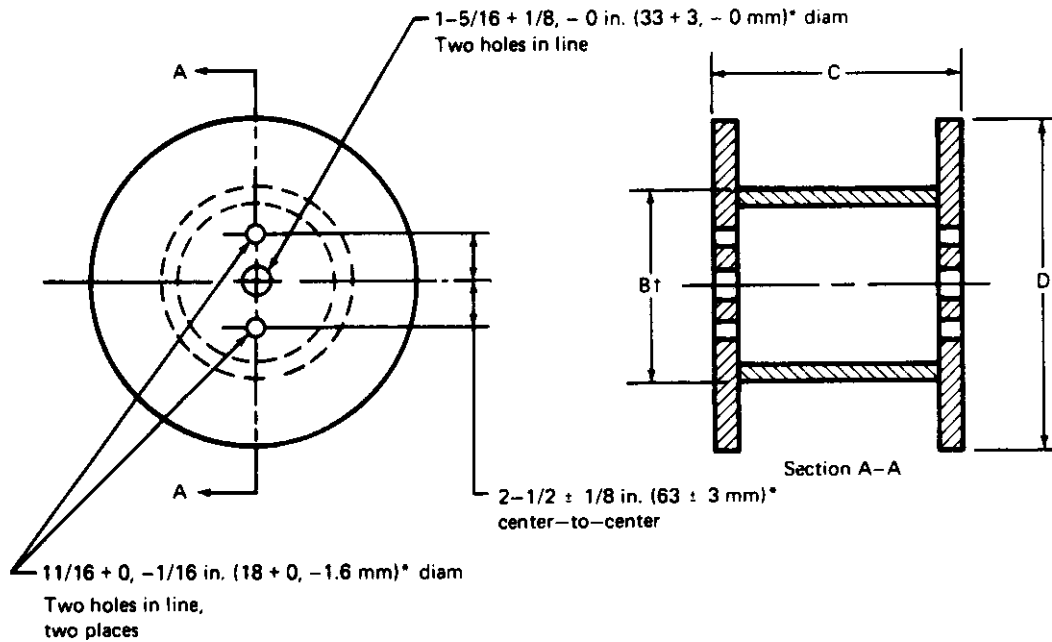
allowed to cool in still air to room temperature. When ready to resume work, the assembly shall be preheated to a temperature within the preheat and interpass temperature range prescribed in Table 11.

3.5 Soundness Test

3.5.1 The assembly shall be prepared for radiographic examination in accordance with the following:

3.5.1.1 The backing strip shall be removed prior to performing the radiography.

3.5.1.2 The weld ripples or surface irregularities on both the face and the root of the weld shall be removed by any suitable mechanical process so that the resulting radiographic contrast, due to any remaining irregularities, cannot mask or be confused with that of any objectionable defect. Also, the weld faces shall merge smoothly into the plate surface. The finished surface of the weld may be flush with the plate or have a reasonably uniform reinforcement, not exceeding $\frac{3}{32}$ in. (2.4 mm).



* All dimensions are in inches (millimeters). See *Note* in the Scope on page 1.

† Dimension B, outside diameter of barrel, shall be such as to permit proper feeding of the electrode.

Dimensions					
Spool Size		D		C, Maximum	
in.	mm*	in.	mm*	in.	mm*
22	560	$22 \pm 1/2$	560 ± 13	12	305
24	610	$24 \pm 1/2$	610 ± 13	$13-1/2$	345
30	760	$30 \pm 1/2$	760 ± 13	$13-1/2$	345

FIG. 4 DIMENSIONS OF 22, 24, AND 30 in. (560, 610, AND 760 mm)* SPOOLS

3.5.2 The radiographs shall be obtained in accordance with the 2-2T level of inspection as stipulated in ASTM E142, Standard Method for Controlling Quality of Radiographic Testing.

3.5.3 When evaluating the radiographs, a 1 in. (25 mm) length on each end of the test welds shall be disregarded.

3.6 All-Weld-Metal Tension Test

3.6.1 Test assemblies shall be postweld heat treated when made with electrodes of classifications listed by Table 4 in the PWHT condition. The postweld heat treatment may be either before or after the radiographic examination (but before any impact or tensile test specimens are machined from the test assembly) and

shall be conducted according to the schedule listed in 3.6.2.

3.6.2 The temperature of the assembly shall be raised in a suitable furnace at the rate of 500°F (280°C) per hour maximum until the temperature prescribed in Table 11 for the electrode classification being tested has been attained. This temperature shall be maintained for 1 hour. The assembly shall then be cooled in the furnace at a rate not greater than 350°F (195°C) per hour. The assembly may be removed from the furnace when the temperature has reached 600°F (320°C).

3.6.3 No thermal treatment shall be employed on assemblies that have been welded with electrodes of classifications listed by Table 4 in the as-welded condi-

TABLE 7
PACKAGING REQUIREMENTS^a

Type of Package	Package Size			Net Weight of Electrode ^b	
	in.	mm		lb	kg
Coils without support	As specified by purchaser ^c			As specified by purchaser ^c	
Coils with support	6-3/4	170	ID	14	6.4
	12	300	ID	25, 30, 50, & 60	11, 14, 23, & 27
Spools	4	100	OD	1-1/2 & 2-1/2	0.7 & 1.1
	12	300	OD	25, 30, & 35	11, 14, & 16
	14	360	OD	50 & 60	23 & 27
	22	560	OD	250	110
	24	610	OD	300	140
	30	760	OD	600 & 750	270 & 340
Drums	15-1/2	400	OD	As specified by purchaser ^c	
	20	500	OD	As specified by purchaser ^c	
	23	600	OD	300 & 600	140 & 270

NOTES:

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

TABLE 8
BASE METAL REQUIREMENTS^a

Alloy Class	ASTM Base Metal
A1	A204, Grade A, B, or C
B2, B2L, B2H	A387, Grade 11
B3, B3L, B3H	A387, Grade 22
Ni2	A203, Grade A or B
Ni3	A203, Grade D or E
D1, D2	A302, Grade A or B
W	A588, Grade A, B or C
K3, K4, K7	A514, any grade

NOTE:

- a. ASTM A36 or A285 base metals may be used; however, the joint surfaces shall be clad or buttered (see Fig. 5) using an electrode of the same composition as the classification being tested. For T-4 and T-8 types, buttering is not necessary.

tion, except that the machined tension test specimen shall be aged at 200 to 200°F (90 to 104°C) for 48 $\pm$ 2 hours prior to testing. The specimen shall then be cooled to room temperature.

3.6.4 One all-weld-metal tension test specimen, as shown in Fig. 6, shall be machined from the test assembly (Fig. 5).

3.6.5 The all-weld-metal tension test specimen shall be tested in accordance with the tension test

section of the latest edition of AWS B4.0, Standard Methods for Mechanical Testing of Welds.

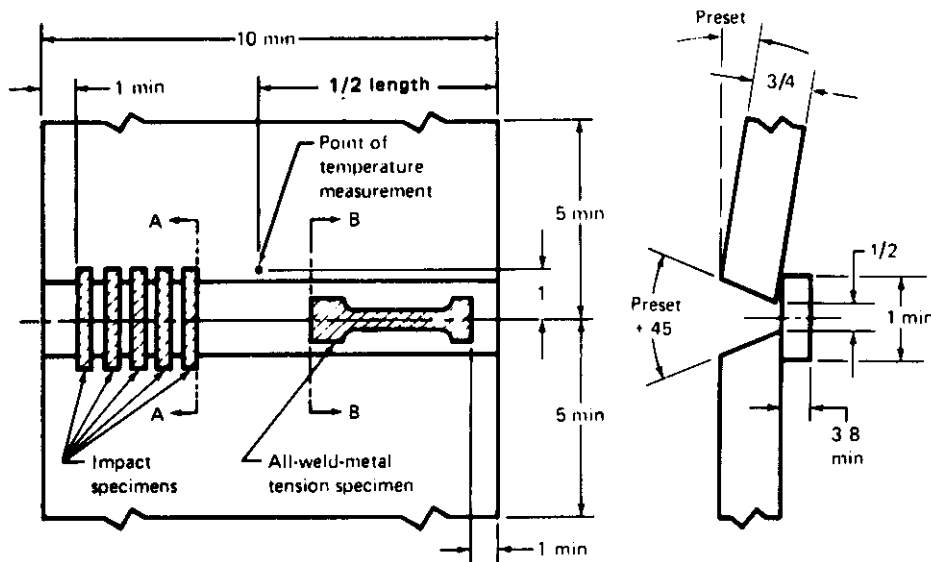
3.7 Impact Test

3.7.1 When required by Tables 2 and 4, five V-notch impact test specimens, as shown in Fig. 7, shall be machined from the same test assembly (Fig. 5) from which the all-weld-metal tension test specimen was machined.

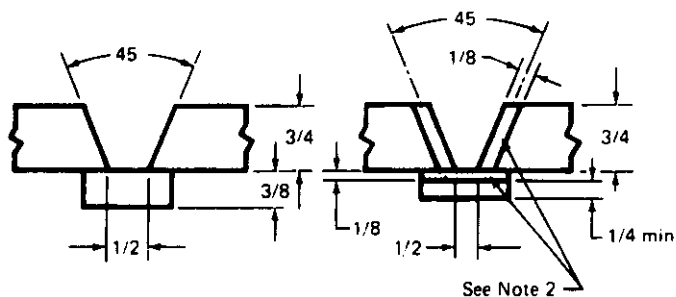
3.7.2 The impact specimens shall be tested in accordance with the impact test section of the latest edition of AWS B4.0, Standard Methods for Mechanical Testing of Welds.

3.7.3 The impact properties of the five specimens shall be obtained at the test temperature specified in Table 4 for the classification being tested.

3.7.4 In computing the average impact value, the specimen with the lowest value and the one with the highest value shall be disregarded. The average value for the three remaining specimens shall be not less than the 20 ft • lb (27 J) energy level specified in Table 4. The impact value of one of these three specimens may be lower than the 20 ft • lb (27 J) specified, but it shall not be less than 15 ft • lb (20 J).



A. Test Plate showing location of test specimens



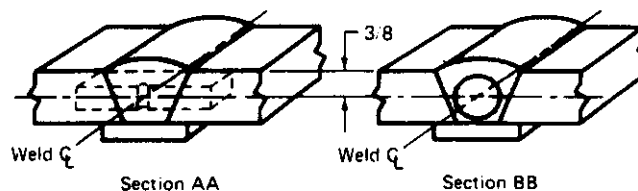
Standard test plate

Buttered test plate
(See footnote "a" of Table 8)

SI Equivalents*

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

B. Groove preparation of test plate



C. Orientation of impact specimen

D. Location of all-weld-metal tension specimen

Notes:

1. Prior to welding, the assembly may be preset as shown so that the welded joint will be sufficiently flat to facilitate test specimen removal. As an alternative, restraint or a combination of restraint and preset may be used.
2. When required, edges of the grooves and the contacting face of the backing shall be buttered as shown. Any size of the electrode being tested may be used for buttering.
3. All dimensions (excluding angles) are in inches. See Note in the Scope on page 1.

FIG. 5 DETAILS OF TEST ASSEMBLY FOR SOUNDNESS TEST, ALL-WELD-METAL TENSION TEST, AND IMPACT TEST

TABLE 9
SHIELDING AND POLARITY

AWS Classification ^a	External Shielding Medium ^b	Current and Polarity
EXXT1-X (multiple pass)	CO ₂	DC, electrode positive
EXXT4-X (multiple pass)	None	DC, electrode positive
EXXT5-X (multiple pass)	CO ₂	DC, electrode positive
EXXT8-X (multiple pass)	None	DC, electrode negative
EXXTX-G (multiple pass)	Not specified	Not specified

NOTES:

- a. The "x" indicates the tensile strength, usability, and chemical composition designations of Tables 1, 3, and 4 (see also A2.2).
b. Some T1 and T5 electrodes may be classified with other than CO₂ shielding gas upon agreement between supplier and purchaser. See footnote a of Table 3 and A5.5.1.

TABLE 10
REQUIREMENTS FOR PASS AND LAYER CONTROL^a

AWS Classification	Electrode Size		Required Total Passes	Suggested Passes Per Layer		Suggested Number of Layers
	in.	mm		Layer #1	Layer #2 to Top	
EXXT1-X EXXT5-X	0.045	1.2	13-19	1 or 2	2 or 3 ^b	6-7
	0.052	1.4	12-18	1 or 2	2 or 3 ^b	6-7
	1/16	1.6	11-16	1 or 2	2 or 3 ^b	6
	5/64	2.0	10-16	1 or 2	2 or 3 ^b	6
	3/32	2.4	9-14	1 or 2	2 or 3 ^b	5-6
	7/64	2.8	9-13	1 or 2	2 or 3	5
	1/8	3.2	7-12	1 or 2	2 or 3	4-5
EXXTG-X	Not specified — to be recorded					
EXXT4-X	c		7-11	1	2	4-6
EXXT8-X	c		12-17	1	2 or 3	6-9

NOTES:

- a. Actual number of passes, electrode diameter, wire feed speed or amperes, arc voltage, travel speed, electrode extension (electrical stickout), and shielding gas shall be recorded and made available to the user on request. See A4.2 in the Appendix.
b. The final layer may be 4 passes.
c. See requirements of section 3.1.2.

3.8 Fillet Weld Tests

3.8.1 In order to classify an electrode to all-position capability, single-pass fillet welds shall be made in both the vertical-up and overhead positions.

3.8.2 The test plates shall be assembled as shown in Fig. 8. Both ends of the plates shall be secured by tack welds. Before assembly, the standing member (web) shall have one edge prepared throughout its length so that when the web is set upon the base plate (flange), which shall be straight and smooth, there will be intimate contact along the entire length of the joint.

3.8.3 A single-pass fillet shall be deposited on one side of the joint for approximately the full length of the test plate. Two test assemblies will be welded: one with a vertical-up fillet weld and one with overhead fillet weld.

3.8.4 The fillet welds shall be deposited using the size of electrode and welding procedures recommended by the manufacturer.

3.8.5 The completed welds and leg lengths of the fillet welds shall first be visually examined. Then a macrosection, approximately 1 in. (25 mm) wide, shall

TABLE 11
PREHEAT, INTERPASS, AND PWHT TEMPERATURES

AWS Classification ^a	Preheat and Interpass Temperature ^b		PWHT Temperature ^b	
	°F	°C	°F	°C
E70T5-A1 E80T1-A1 E81T1-A1 E80T5-Ni1 E80T5-Ni2 ^c E80T5-Ni3 ^c E90T5-Ni3 ^c E90T5-D2 D100T5-D2	300 ± 25	150 ± 15	1150 ± 25	620 ± 15
E81T1-B1 E80T1-B2 E81T1-B2 E80T5-B2 E80T1-B2H E80T5-B2L E90T1-B3 E91T1-B3 E90T5-B3 E100T1-B3 E90T1-B3H E90T1-B3L	350 ± 25	176 ± 15	1275 ± 25	690 ± 15

be removed from a point approximately in the center of the weld. One surface of the macrosection shall be polished, etched, and scribed as shown in Fig. 9. the size, convexity (of convex fillet welds), and leg lengths of the fillet weld shall be determined to the nearest $\frac{1}{64}$ in. (0.4 mm) by actual measurement of the polished and etched macrosection (see Fig. 9).

3.8.6 The remaining two joint sections on each test assembly shall be broken longitudinally through the fillet weld by a force exerted in the direction as shown in Fig. 10. The fractured surfaces shall be examined. If, during bending, the weld pulls out of the test plate, it shall not be considered as failure of the weld metal. The test shall be repeated without penalty.

3.8.7 If necessary to facilitate fracture, one or more of the following procedures may be used:

3.8.7.1 Reinforcing welds, as shown in Fig. 10(a), may be added to each leg of the weld.

3.8.7.2 The position of the web on the flange may be changed as shown in Fig. 10(b).

3.8.7.3 The face of the weld may be notched as shown in Fig. 10(c).

3.8.8 The completed fillet weld test specimens shall be examined visually and the weld shall be free of cracks. The specimens shall be reasonably free of undercut, overlap, trapped slag, and surface porosity.

TABLE 11 (CONT'D)
PREHEAT, INTERPASS, AND PWHT TEMPERATURES

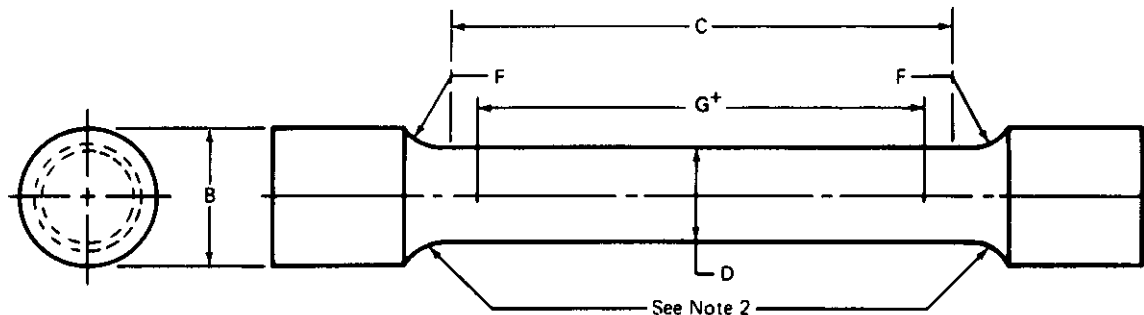
AWS Classification ^a	Preheat and Interpass Temperature ^b		PWHT Temperature ^b	
	°F	°C	°F	°C
E71T8-Ni1				
E80T1-Ni1				
E81T1-Ni1				
E71T8-Ni2				
E80T1-Ni2				
E81T1-Ni2				
E90T1-Ni2				
E91T1-Ni2				
E91T1-D1				
E90T1-D3				
E80T5-K1				
E70T4-K2				
E71T8-K2				
E80T1-K2				
E80T5-K2	300 ± 25	150 ± 15	None	None
E90T1-K2				
E91T1-K2				
E90T5-K2				
E100T1-K3				
E100T5-K3				
E110T1-K3				
E110T5-K3				
E111T1-K4				
E110T5-K4				
E120T5-K4				
E120T1-K5				
E61T8-K6				
E71T8-K6				
E80T1-W				

EXXTX-G

Conditions as agreed upon between supplier and purchaser

NOTES:

- In this table, the digit (i.e., 0 or 1) before the letter "T" indicates the primary welding position for which the electrode is designed (usability). See footnote b to Table 2 and section A2.2.
- These temperatures are specified for testing under this specification and are not to be considered as recommendations for preheat and postweld heat treatment in production welding. The requirements for production welding must be determined by the user.
- Postweld heat treatment temperatures in excess of 1150°F (620°C) will decrease the impact value.



G^+ = Gage length

Dimensions of specimen, in.						
Test plate thickness	D	G	C	B	F, min	Approximate area, in.
3/4	0.500 ± 0.010	2.000 ± 0.005	2 1/4	3/4	0.375 (3/8)	0.05

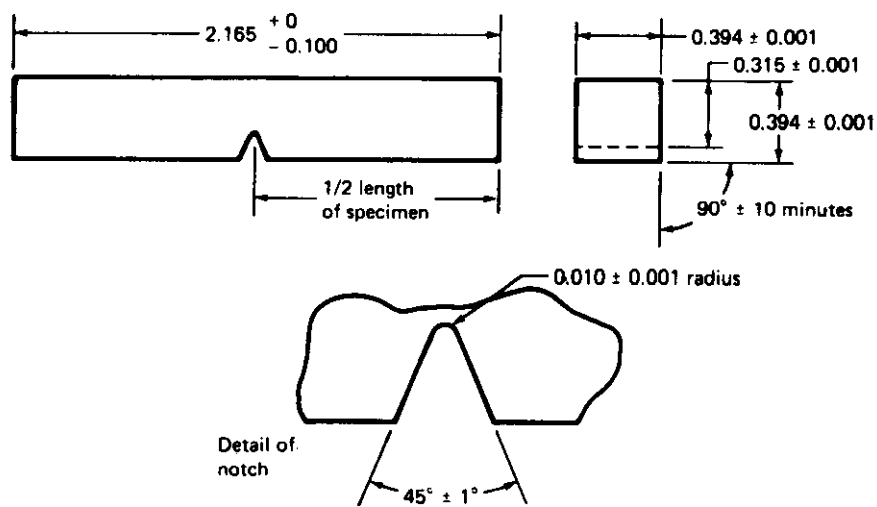
Dimensions of specimen, mm						
Test plate thickness	D	G	C	B	F, min	Approximate area, mm
19.1	12.7 ± 0.25	50.8 ± 0.13	57.1	19.1	9.5	129

Notes:

1. Dimensions G and C shall be as shown, but ends may be of any shape to fit the testing machine holders as long as the load is axial.
2. The diameter of the specimen within the gage length shall be slightly smaller at the center than at the ends. The difference shall not exceed one percent of the diameter.
3. When the extensometer is required to determine elastic properties or yield strength, dimension C may be modified. However, the percent elongation shall be based on dimension G.
4. The surface finish with the C dimension shall be no rougher than 63 μ in. (1.6 μ m).*

*See Note in the Scope on page 1.

FIG. 6 ALL-WELD-METAL TENSION TEST SPECIMEN DIMENSIONS

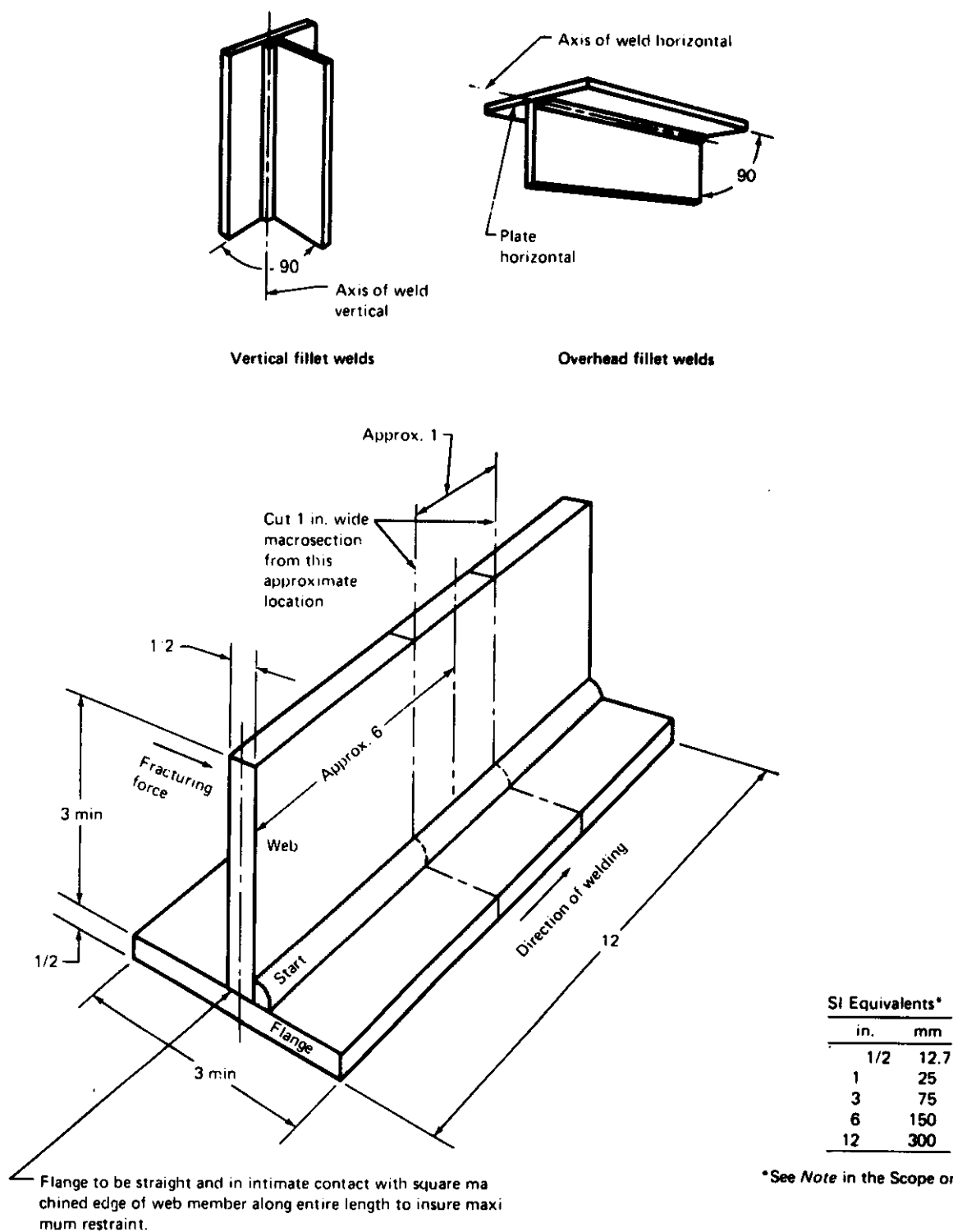


SI Equivalents*	
in.	mm
0.010 ± 0.001	0.25 ± 0.025
0.315 ± 0.001	8 ± 0.025
0.394 ± 0.001	10 ± 0.025
$2.165^{+0}_{-0.100}$	$55^{+0}_{-2.5}$

*See Note in the Scope on page 1.

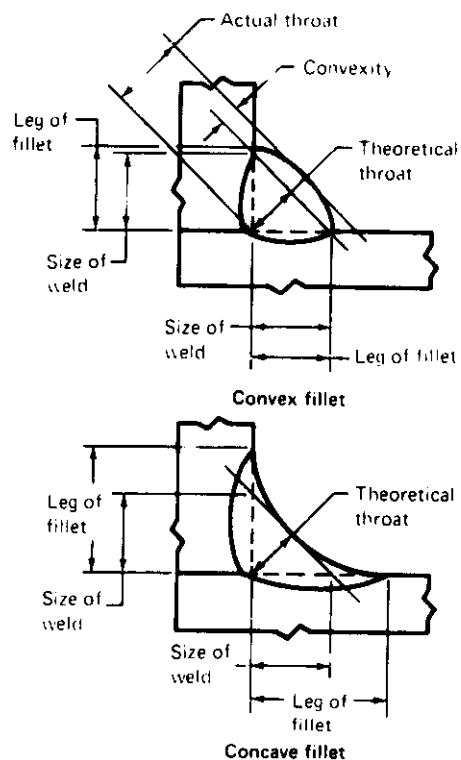
Note: All dimensions except angles are in inches. The surface finish shall be no rougher than 63μ in. (1.6μ m).

FIG. 7 DETAILS OF V-NOTCH IMPACT TEST SPECIMEN



*See Note in the Scope on page 1.

FIG. 8 PREPARATION OF FILLET WELD TEST SPECIMEN



Note: Size of fillet weld = Leg length of largest inscribed isosceles right triangle. Fillet weld size, convexity, and leg lengths shall be determined by actual measurement (to nearest 1/64 in. (0.4 mm))* on a section laid out with scribed lines as shown.

*See Note in the Scope on page 1.

FIG. 9 DIMENSIONS OF FILLET WELDS

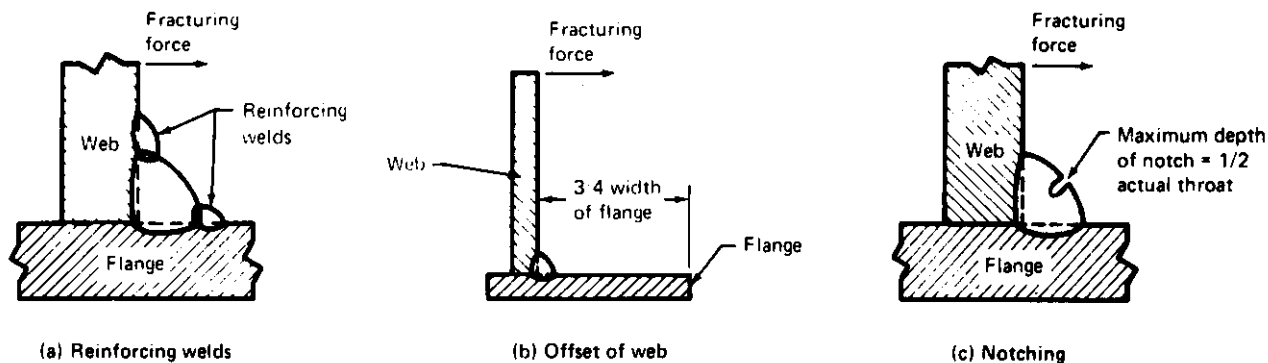


FIG. 10 ALTERNATE METHODS FOR FACILITATING FILLET WELD FRACTURE

Appendix: Guide to AWS Classification of Low Alloy Steel Electrodes for Flux Cored Arc Welding

A1. Introduction

This guide is appended to the specification as a source of information; it is not mandatory and does not form a part of the specification.

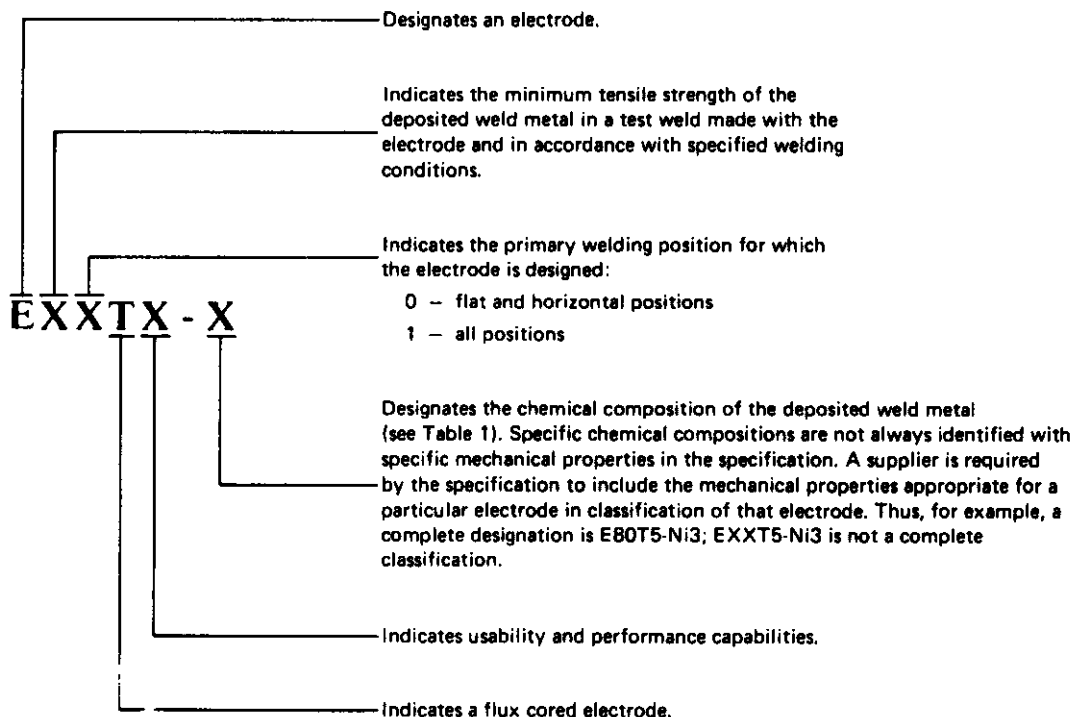
A2. Method of Classification

A2.1 The classification system used in this specification follows as closely as possible the standard pattern used in other AWS filler metal specifications. The inherent nature of the products being classified has,

however, necessitated specific changes that more suitably classify the product.

A2.2 An illustration of the method of classification of electrodes is shown below.

A2.3 Some products may be designed for the flat and horizontal positions regardless of size. Others may be designed for out-of-position welding in the smaller sizes and flat and horizontal positions in the larger sizes. The mandatory section of this specification allows



Note: The letter "X" as used in this figure and in electrode classification designations in this specification substitutes for specific designations indicated by this figure.

dual classification for the primary weld positions on the latter types.

A3. Ventilation During Welding

A3.1 Three major factors in arc and gas welding that govern the concentration of airborne substances to which welders or welding operators may be exposed are:

A3.1.1 Dimensions of space in which welding is to be done (with special regard to height of ceiling)

A3.1.2 Number of welders or welding operators in that space

A3.1.3 Possible evolution of hazardous fumes, gases, or dusts according to the metals involved

A3.2 American National Standard Z49.1, Safety in Welding and Cutting, discusses the ventilation that is required during welding and should be referred to for details. Attention is particularly drawn to Section 8, Health Protection and Ventilation.

A4. Welding Procedure

A4.1 When examining the weld metal properties required in test welds in accordance with this specification, it should be recognized that the properties may vary widely, depending on electrode size, amperage and voltage used, type and amount of shielding gas, electrical extension, plate thickness, joint geometry, preheat and interpass temperature, surface condition, base metal composition, and admixture of the base metal with the deposited metal, etc.

A4.2 Since it is not possible to list an exact welding procedure for any given classification for all products so classified the mandatory section of this specification requires that welding procedure information be recorded so that it can be made available to the user on request. This type of information will include the electrode diameter, feed speed or amperes, arc voltage, travel speed, and electrode extension (electrical stickout), as well as the actual number of passes and layers to complete the weld test assembly.

A5. Description and Intended Use

A5.1 The toughness requirements for classifications in this specification can be used as a guide in the selection of electrodes for applications where low temperature notch toughness is specifically required. For a given electrode, there can be a considerable difference between impact test results from one assembly to

another, or even from one impact specimen to another, unless particular attention is given to the welding procedure, details of specimen preparation (even its location within the weld), temperature of testing, and the operation of the testing machine.

A5.2 Electrodes covered by this specification are capable of producing weld deposits that meet most radiographic quality requirements.

A5.3 The steels commonly welded with low alloy steel electrodes are usually used for specific purposes. The welding of these steels requires an understanding of their properties and heat treatment beyond that which could be covered in an appendix to a filler metal specification. Users not familiar with the characteristics of low alloy steels are referred to Chapter 63 of the Welding Handbook, 6th edition, and other publications of low alloy steels.

A5.4 It should be noted that the flux cored electrodes classified in this specification are intended primarily for welding in the flat and horizontal positions, if designated EX0TX-X. These electrodes may be used in other positions if the proper welding current and electrode diameter are used. Electrode diameters below $\frac{3}{32}$ in. (2.4 mm), and currents on the low side of the range recommended by the manufacturer, may be used for out-of-position welding. The EX1TX-X electrodes are designed for all-position usability.

A5.5 This specification classifies four general types of flux cored electrodes: T1, T4, T5, and T8. Each suffix (T1, T4, T5, or T8) indicates a general grouping of electrodes that contain similar flux or core components that produce distinctive welding characteristics and similar slag systems.

A5.5.1 T1 Electrode Classification. Electrodes of the T1 group are classified with CO₂ shielding gas by this specification. However, gas mixtures of argon-CO₂ may be used where recommended by the manufacturer to improve usability, especially for out-of-position applications. These electrodes are designed for single- and multiple-pass welding. The larger diameters (usually $\frac{5}{64}$ in. [2.0 mm] and larger) are used for welding in the flat position and for horizontal fillets. The smaller diameters (usually $\frac{1}{16}$ in. [1.6 mm] and smaller) are used for welding in all positions. The T1 electrodes are characterized by a spray transfer, low spatter loss, flat to slightly convex bead configuration, and a moderate volume of slag, which completely covers the weld bead. Most electrodes in this group have a rutile base slag.

A5.5.2 T4 Electrode Classification. Electrodes of the T4 classification are self-shielded, operate on DC with positive polarity, and have a globular type transfer. The slag system is designed to give characteristics that make possible very high deposition rates and to desulfurize the weld metal to a very low level, which helps make the weld deposit very resistant to cracking. These electrodes are designed for low penetration beyond the root of the weld, enabling them to be used on weld joints with poor fit-up and for single- and multiple-pass welding in the flat and horizontal positions.

A5.5.3 T5 Electrode Classification. Electrodes of the T5 group are designed to be used with CO₂ shielding gas (argon-CO₂ mixtures may be used where recommended by the manufacturer as in the T1 types) for single- and multiple-pass welding in the flat position, and for horizontal fillets. Certain T5 electrodes are designed to weld on straight polarity with argon-CO₂ mixtures for out-of-position welding. These electrodes are characterized by a globular transfer, slightly convex bead configuration, and a thin slag, which may not

completely cover the weld bead. Electrodes in this group have a lime-fluoride base slag. Weld deposits produced by electrodes of this group have improved impact properties and crack-resistance in comparison to the rutile types.

A5.5.4 T8 Electrode Classification. Electrodes of the T8 classification are self-shielded and operate on DC with negative polarity. The slag system is designed to give characteristics that make it possible to use these electrodes for all-position welding. The slag system is also designed to produce very good low temperature impact properties in the weld metal and to desulfurize the weld metal to a very low level, which helps resist weld cracking. They are used for single- and multiple-pass welding.

A5.5.5 TX-G Electrode Classification. The EXXTX-G classification is for new multiple-pass electrodes that are not covered under any of the presently defined classifications. The multiple-pass properties can be anything covered by these specifications. The slag system, arc characteristics, weld appearance, and polarity are not defined.

