

SPECIFICATION FOR CARBON STEEL ELECTRODES AND FLUXES FOR SUBMERGED ARC WELDING



SFA-5.17



(Identical with AWS Specification A5.17-89)

1. Scope

This specification prescribes requirements for the classification of carbon steel electrodes (both solid and composite) and fluxes for submerged arc welding.

SECTION A — GENERAL REQUIREMENT

2. Classification

2.1 The welding electrodes and fluxes covered by the specification are classified according to the following:

(a) The mechanical properties of the weld metal obtained with a combination of a particular flux and a particular classification of electrode, as specified in Tables 5 and 6;

(b) The condition of heat treatment in which those properties are obtained, as specified in para. 8.4 (and shown in Fig. 1)

(c) The chemical composition of the electrode (for solid electrodes) as specified in Table 1, or the weld metal produced with a particular flux (for composite electrodes) as specified in Table 2.

2.2 Electrodes classified under one classification shall not be classified under any other classification in this specification, except that solid electrodes meeting the chemical composition requirements of both the EL8 and EL12 classification (Table 1) may be given both classifications. Fluxes may be classified under any number of classifications, for weld metal in either or both the as-welded and postweld heat treated conditions, or using different electrode classifications. The classification system is shown in Fig. 1.

2.3 The electrodes and fluxes classified under this specification are intended for submerged arc welding,

but that is not to prohibit their use with any other process for which they are found suitable.

3. Acceptance

Acceptance of the materials shall be in accordance with the provisions of the latest edition of AWS A5.01, *Filler Metal Procurement Guidelines*¹ (see Appendix A3).

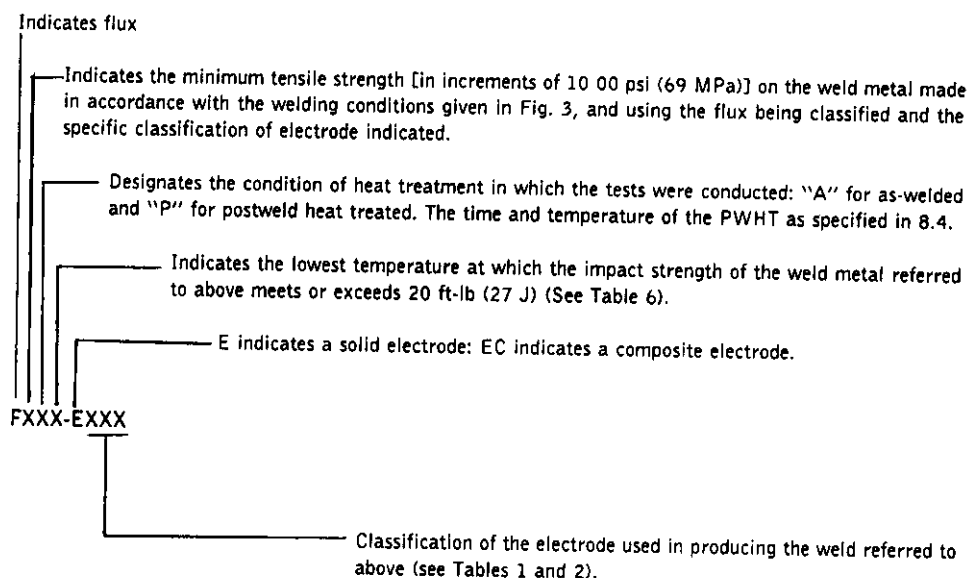
4. Certification

By affixing the AWS Specification and Classification designations to the packaging, the manufacturer certifies that the product meets the requirements of this specification (see Appendix A4).

5. Units of Measure and Rounding-Off Procedure

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

¹ AWS standards may be obtained from the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.



Examples

F7A6-EM12K is a complete designation. It refers to a flux that will produce weld metal which, in the as-welded condition, will have a tensile strength no lower than 70 000 psi (480 MPa) and Charpy V-notch impact strength of at least 20 ft-lb (27 J) at -60°F (-51°C) when produced with an EM12K electrode under the conditions called for in this specification.

F7A4-EC1 is a complete designation for a flux when the trade name of the electrode used in classification is indicated as well. It refers to a flux that will produce weld metal with that electrode, which in the as-welded condition, will have a tensile strength no lower than 70 000 psi (480 MPa) and Charpy V-notch energy of at least 20 ft-lb (27 J) at -40°F (-40°C) under the conditions called for in this specification.

FIG. 1 CLASSIFICATION SYSTEM

5.2 For the purpose of determining conformance with this specification, an observed or calculated value shall be rounded to the nearest 1000 psi for tensile and yield strength, and to the nearest unit in the last right-hand place of figures used in expressing the limiting value for other quantities in accordance with the rounding-off method given in ASTM E 29, *Recommended Practice for Indicating which Places of Figures are to be Considered Significant in Specified Limiting Values*.²

² ASTM standards can be obtained from the American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103.

SECTION B — TESTS, PROCEDURES, AND REQUIREMENTS

6. Summary of Tests

6.1 Electrodes

6.1.1 Solid Electrodes. Chemical analysis of the electrode, or the rod stock from which it is made, is the only test required for classification of a solid electrode under this specification.

6.1.2 Composite Electrodes. Chemical analysis of weld metal produced with the composite electrode and a particular flux is the only test required for classification of a composite electrode under this specification.

TABLE 1
CHEMICAL COMPOSITION REQUIREMENTS FOR SOLID ELECTRODES

Electrode Classification	UNS Number ⁽³⁾	wt. percent ^{(1) (2)}					
		C	Mn	Si	S	P	Cu ⁽⁴⁾
EL8	K01008	0.10	0.25/0.60	0.07	0.030	0.030	0.35
EL8K	K01009	0.10	0.25/0.60	0.10/0.25	0.030	0.030	0.35
EL12	K01012	0.04/0.14	0.25/0.60	0.10	0.030	0.030	0.35
Medium Manganese Electrodes							
EM12	K01112	0.06/0.15	0.80/1.25	0.10	0.030	0.030	0.35
EM12K	K01113	0.05/0.15	0.80/1.25	0.10/0.35	0.030	0.030	0.35
EM13K	K01313	0.06/0.16	0.90/1.40	0.35/0.75	0.030	0.030	0.35
EM14K	K01314	0.06/0.19	0.90/1.40	0.35/0.75	0.025	0.025	0.35
			(Ti 0.03/0.17)				
EM15K	K01515	0.10/0.20	0.80/1.25	0.10/0.35	0.030	0.030	0.35
High Manganese Electrodes							
EH11K	K11140	0.07/0.15	1.40/1.85	0.80/1.15	0.030	0.030	0.35
EH12K	K01213	0.06/0.15	1.50/2.00	0.25/0.65	0.025	0.025	0.35
EH14	K11585	0.10/0.20	1.70/2.20	0.10	0.030	0.030	0.35

NOTES:

- (1) The filler metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated, in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed 0.50 percent.
- (2) Single values are maximum.
- (3) SAE/ASTM Unified Numbering System for Metals and Alloys.
- (4) The copper limit includes any copper coating that may be applied to the electrode.

6.2 Fluxes. The tests required for classification of fluxes (each electrode-flux combination) are specified in Table 3. They determine the mechanical properties and soundness of the weld metal obtained with that electrode-flux combination. The base metal for the test assemblies, the welding and testing procedures to be employed and the results required are given in sections 8 thru 12.

6.3 Flux classification is based upon a $\frac{5}{32}$ in. (4.0 mm) electrode size as standard. If this size electrode is not manufactured, the closest size shall be used for classification tests. See Note (3) of Fig. 3.

7. Retest

If any test fails to meet its requirement, that test shall be repeated twice. The results of both tests shall meet the requirement. Samples for retest may be taken from the original test assembly or from one or two new test assemblies. For chemical analysis, retest need be only for those specific elements that failed to meet their requirement.

TABLE 2
CHEMICAL COMPOSITION REQUIREMENTS FOR
COMPOSITE ELECTRODE WELD METAL

Electrode Classification	wt. percent ^{(1) (2) (3)}					
	C	Mn	Si	S	P	Cu
EC1	0.15	1.80	0.90	0.035	0.035	0.35

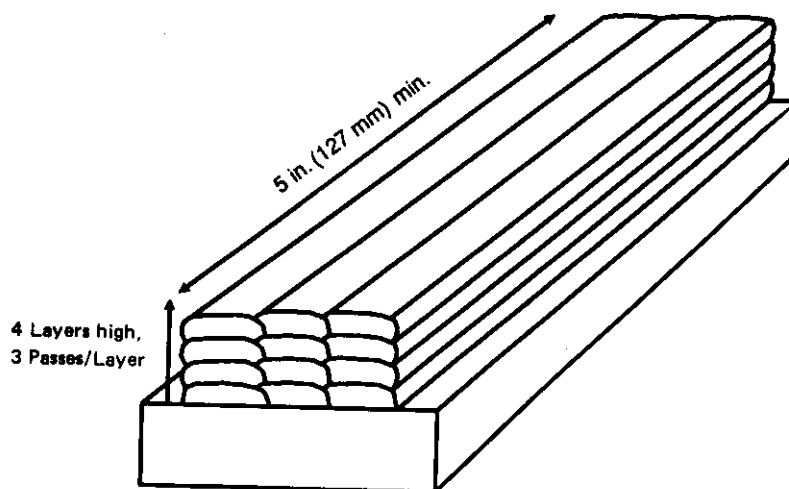
NOTES:

- (1) The weld metal shall be analyzed for the specific elements for which values are shown in this table. If the presence of other elements is indicated, in the course of this work, the amount of those elements shall be determined to ensure that their total (excluding iron) does not exceed 0.50 percent.
- (2) Single values are maximum.
- (3) A low dilution area of the groove weld of Fig. 3 or the fractured tension test specimen of Fig. 5 may be substituted for the weld pad, and shall meet the above requirements. In case of dispute, the weld pad shall be the referee method.

TABLE 3
TESTS REQUIRED FOR CLASSIFICATION

AWS Classification	Chemical Analysis	Radiographic Test	Tension Test	Impact Test
All Solid Electrodes	Required	Not Req'd	Not Req'd	Not Req'd
All Composite Electrodes	Required	Not Req'd	Not Req'd	Not Req'd
All Fluxes	Not Req'd	Required	Required	Required

GENERAL NOTE: When the "Z" impact designator (no impact requirements — Table 6) is used, the Impact Test is not required.



GENERAL NOTES:

- (a) Width and thickness of the base metal plate may be any dimension suitable for the electrode diameter and current in use.
- (b) The first and last 2 in. (51 mm) of the weld length shall be discarded. The top surface shall be removed, and chemical analysis samples shall be taken from the underlying metal of the top layer of the remaining weld metal.

FIG. 2 WELD PAD FOR CHEMICAL ANALYSIS OF WELD METAL FROM COMPOSITE ELECTRODES

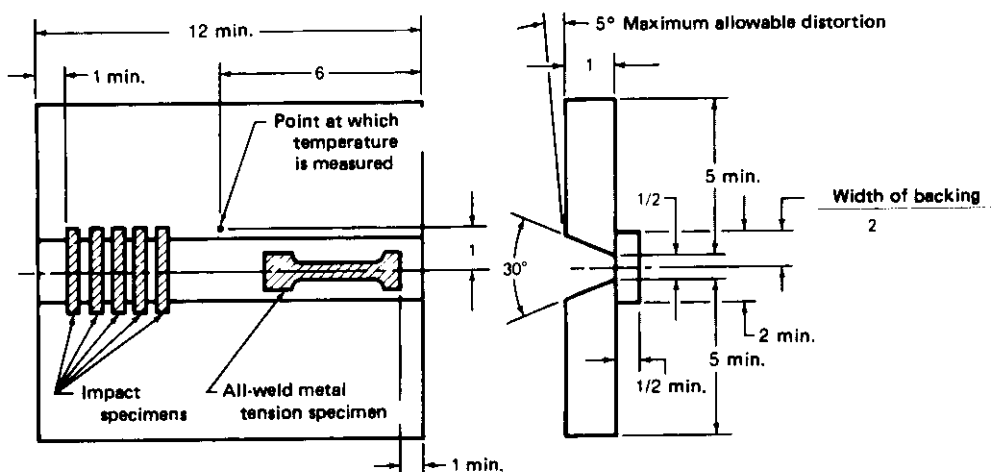
8. Weld Test Assemblies

8.1 No weld test assemblies are required for classification of solid electrodes. One weld test assembly is required for classification of composite electrodes. It is the weld pad in Fig. 2 for chemical analysis of the low dilution weld metal.

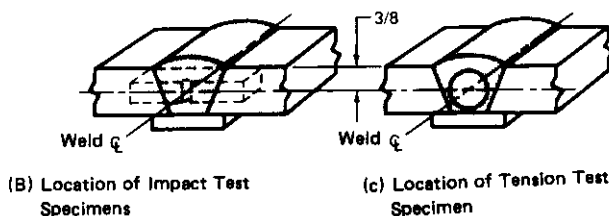
In addition to the above, one weld test assembly is required for each classification of an electrode-flux combination. This is the groove weld in Fig. 3 for mechanical properties and soundness of the weld metal. Note (3) to Table 2 allows the sample for chemical analysis in the case of a composite electrode to be taken from a low dilution area in the groove weld,

Fig. 3, or from the fractured tension test specimen, Fig. 5, thereby avoiding the need to make the weld pad. In case of dispute, the weld pad shall be the referee method. When a Certificate of Test is prepared, it shall indicate whether the groove weld or the pad was used for chemical analysis.

8.2 The preparation of each weld test assembly shall be as prescribed in paras. 8.3 and 8.4. The base metal for each assembly shall be as required in Table 4, according to the tests to be conducted and shall meet the requirements of the appropriate ASTM specification shown in Table 4, or an equivalent specification. Testing



(A) Joint Configuration and Location of Test Specimens



Note: All dimensions except angles are in inches.

SI EQUIVALENTS

in.	mm
1/16	1.6
1/4	6.4
3/8	9.5
1/2	13
3/4	19
1	25
5	127
6	152
12	305

Welding Conditions for Solid Electrodes^{a,b}

Electrode Size ^c	Amperage ^d (± 25)	Voltage ^e (± 1)	Welding Current	Travel Speed		Base ^f Metal	Preheat Temperature ^g	Interpass Temperature ^g
				ipm (± 1)	mm/s (± 0.4)			
1/16	1.6	350	D.C. either polarity	12	5.1	ASTM A36, A285 Grade C, A515 Grade 70, or A516 Grade 70	65 to 325°F (18 to 163°C)	275 to 325°F (135 to 163°C)
5/64	2.0	400		13	5.5			
3/32	2.4	450		14	5.9			
1/8	3.2	500		15	6.3			
5/32	4.0	550		16	6.8			
3/16	4.8	600		17	7.2			
7/32	5.6	650		18	7.6			
1/4	6.4	Not Specified	Not Specified	Not Specified ^h				

- a. The first layer shall be produced in either 1 or 2 passes. All other layers shall be produced in 2 or 3 passes per layer except the last, which shall be produced in 3 or 4 passes. These welding conditions are intended for machine or automatic welding.
- b. Welding conditions for composite electrodes shall be as agreed between purchaser and supplier.
- c. Classification is based on the properties of weld metal with 5/32 in. (4.0 mm) electrodes or the closest size manufactured, if 5/32 in. (4.0 mm) is not manufactured. The conditions given above for sizes other than 5/32 in. (4.0 mm) are to be used when classification is based on those sizes, or when they are required for lot acceptance testing under A5.01, *Filler Metal Procurement Guidelines* (unless other conditions are specified by the purchaser).
- d. Lower amperages may be used for the first layer.
- e. Contact tube-to-work distance is 1/2 to 3/4 in. (13 to 19 mm) for 1/16 and 5/64 in. (1.6 and 2.0 mm) electrodes; 3/4 to 1 1/4 in. (19 to 32 mm) for 3/32 in. (2.4 mm) electrodes; and 1 to 1 1/2 in. (25 to 38 mm) for 1/8, 5/32, 3/16, and 7/32 in. (3.2, 4.0, 4.8 and 5.6 mm) electrodes. When an electrode manufacturer recommends a contact tube-to-work distance outside the range shown, those recommendations shall be followed within 1/4 in. (6 mm).
- f. In case of dispute, A36 steel and DCEP (electrode positive) shall be used as the referee base metal and current.
- g. The first bead shall be produced with the assembly at any temperature between 65 and 325°F (18 to 136°C). Welding shall continue, bead by bead, until a temperature within the interpass temperature range has been attained. Thereafter, production of subsequent beads may begin only when the assembly is within the interpass temperature range.
- h. When a test assembly is required for 1/4 in. (6.4 mm) electrodes, the welding conditions shall be as agreed between purchaser and supplier.

FIG. 3 GROOVE WELD TEST ASSEMBLY

TABLE 4
BASE METALS FOR TEST ASSEMBLIES⁽¹⁾

Weld pad for chemical analysis	AISI-SAE 1010 or 1020 or ASTM A36, A285 Grade C, A515 Grade 70, or A516 Grade 70
Groove weld of Fig. 3	ASTM A36, A285 Grade C, A515 Grade 70, or A516 Grade 70

NOTE:

(1) In case of dispute, ASTM A36 shall be used as referee.

of the assemblies shall be as prescribed in sections 9 through 12.

8.3 For composite electrodes only, a weld pad shall be prepared as specified in Fig. 1. 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, three passes per layer, four layers high, using the flux for which classification of the electrode is intended. The preheat temperature shall not be less than 60°F (15°C) and the interpass temperature shall not exceed 325°F (163°C). The slag shall be removed after each pass. The pad may be quenched in water between passes. Testing of this assembly shall be as specified in section 9.

8.4 For classification of an electrode-flux combination, a test assembly shall be prepared and welded as specified in Fig. 3 using base metal of the appropriate type specified in Table 4. Testing shall be as specified in sections 9, 10, 11 and 12, with the assembly in either the as-welded or the postweld heat treated condition, according to the classification of the weld metal (See Fig. 1). When the tests are to be conducted in each condition (as-welded and post-weld heat treated), two such assemblies, or one single assembly of sufficient length to provide the specimens required for both conditions shall be prepared. In this case, the single assembly shall be cut transverse to the weld into two pieces; one of the pieces shall be tested in the as-welded condition, and the other piece shall be heat treated. The weld metal for heat treatment shall be heat treated at $1150 \pm 25^\circ\text{F}$ ($621 \pm 14^\circ\text{C}$) for one hour ($-0 + 15$ minutes). The furnace shall be at a temperature not higher than 600°F (316°C) when the test assembly is placed in it. The heating rate, from that point to the $1150 \pm 25^\circ\text{F}$ ($621 \pm 14^\circ\text{C}$) holding temperature, shall not exceed 400°F (222°C) per hour. When the holding time has been completed, the assembly shall be allowed to cool in the furnace to a

temperature below 600°F (316°C) at a rate not exceeding 350°F (194°C) per hour. The assembly may be removed from the furnace at any temperature below 600°F (316°C) and allowed to cool in still air, to room temperature.

9. Chemical Analysis

9.1 For solid electrodes, a sample of the electrode, or the rod stock from which it is made, shall be prepared for chemical analysis. Solid filler metal, when analyzed for elements that are present in a coating (copper flashing, for example), shall be analyzed without removing the coating. When the electrode is analyzed for elements other than those in the coating, the coating must be removed if its presence affects the results of the analysis for other elements. Rod stock may be analyzed prior to coating for those elements not added in the coating.

9.2 Composite electrodes shall be analyzed in the form of weld metal. The sample for analysis shall be taken from weld metal obtained with the electrode and the flux with which it is classified. The sample shall come from a weld pad, a low dilution area of the groove weld, or from the fractured tension test specimen.

The top surface of the pad shown in Fig. 2 shall be removed and discarded, and a sample for analysis shall be obtained from the underlying metal of the top layer by any appropriate mechanical means. The sample shall be free of slag. The reduced section of the fractured tension test specimen, or the specimen from a low dilution area of the groove weld, if either alternative to the weld pad is selected, shall be prepared for analysis by any appropriate mechanical means.

9.3 The sample shall be analyzed by accepted analytical methods. The referee method shall be the procedure in the latest edition of ASTM Standard Method E 350, *Chemical Analysis of Carbon Steel, Low Alloy Steel, Ingot Iron, and Wrought Iron*.

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

10. Radiographic Test

10.1 The groove weld described in para. 8.4 and shown in Fig. 3 shall be radiographed to evaluate the soundness of the weld metal. Radiographs of test assemblies equal in length to or longer than the minimum of 12 in. (305 mm) required in Fig. 3 (see para. 8.4), shall include at least 10 in. (254 mm) of the weld, excluding the first and last inch of the test assembly. 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. Both surfaces of the test assembly, in the area of the weld, shall be smooth enough to avoid difficulty in interpreting the radiograph.

10.2 The weld shall be radiographed in accordance with ASTM method E 142 *Controlling Quality of Radiographic Testing*. The quality level of inspection shall be 2-2T.

10.3 The soundness of the weld metal meets the requirements of this specification if the radiograph does not show:

(a) Cracks, incomplete fusion, or incomplete penetration;

(b) Slag inclusions longer than $\frac{1}{4}$ in. (6 mm) or $\frac{1}{3}$ of the thickness of the weld, whichever is greater, or 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 six times the length of the longest inclusion in the group.

(c) Rounded indications in excess of those permitted by the radiographic standards in Fig. 4.

One inch of the weld, measured from each end of the test assembly, shall be disregarded from radiographic evaluation.

11. Tension Test

11.1 One all-weld-metal tension test specimen shall be machined from the groove weld described in para. 8.4 and shown in Fig. 3. The dimensions of the specimen shall be as shown in Fig. 5.

11.2 The specimen shall be tested in the manner described in the tension test section of the latest edition

of ANSI/AWS B4.0, *Standard Methods for Mechanical Testing of Welds*.

11.3 The results of the tension test shall meet the requirements specified in Table 5.

12. Impact Test

12.1 Five Charpy V-notch impact specimens (Fig. 6) shall be machined from the test assembly shown in Fig. 3 for those classifications for which impact testing is required in Table 6.

12.2 The five specimens shall be tested in accordance with the impact test section of ANSI/AWS B4.0. The test temperature shall be that specified in Table 6 for the classification under test.

12.3 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-lb (27 J) energy level. One of the three may be lower, but not lower than 15 ft-lbs (20 J), and the average of the three shall not be less than the required 20 ft-lb (27 J) energy level.

SECTION C — MANUFACTURE, IDENTIFICATION AND PACKAGING

13. Method of Manufacture

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

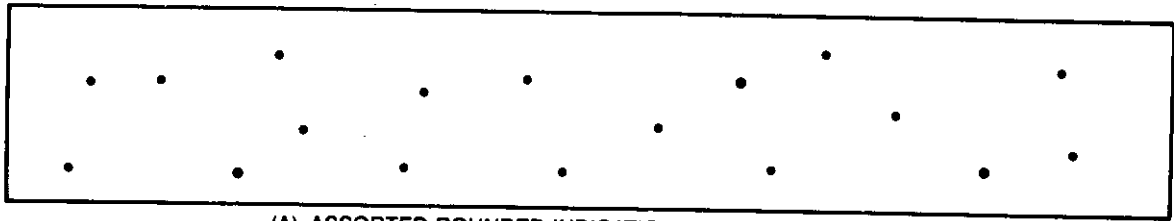
14. Electrode Requirements

14.1 **Standard Sizes.** Standard sizes for electrodes in the different package forms (coils with support, coils without support, and drums) are shown in Table 7.

14.2 Finish and Uniformity

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

14.2.2 Each continuous length of electrode shall be from a single heat or lot of material, and welds, when present, shall have been made so as not to



(A) ASSORTED ROUNDED INDICATIONS

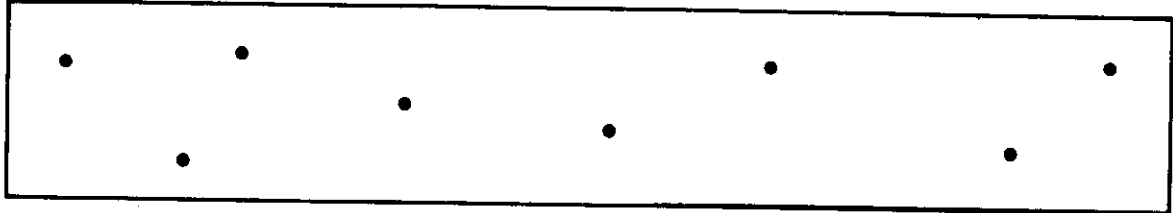
SIZE PERMITTED IS 1/64 in. (0.4 mm) TO 1/16 in. (1.6 mm).

NUMBER PERMITTED IN ANY 6 in. (150 mm) OF WELD IS 18, WITH THE FOLLOWING RESTRICTIONS:

LARGE: 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm)— 3 PERMITTED.

MEDIUM: 1/32 in. (0.8 mm) TO 3/64 in. (1.2 mm)— 5 PERMITTED.

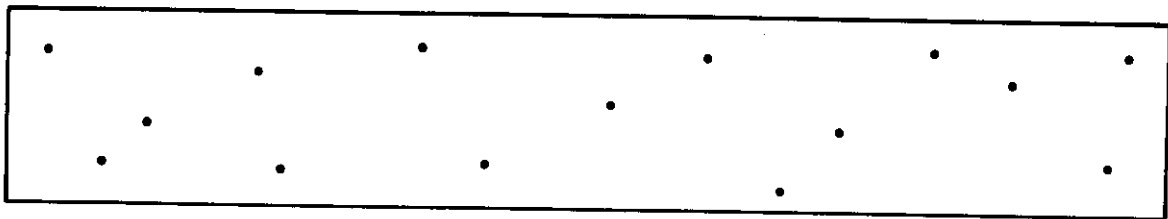
SMALL: 1/64 in. (0.4 mm) TO 1/32 in. (0.8 mm)—10 PERMITTED.



(B) LARGE ROUNDED INDICATIONS

SIZE PERMITTED IS 3/64 in. (1.2 mm) TO 1/16 in. (1.6 mm).

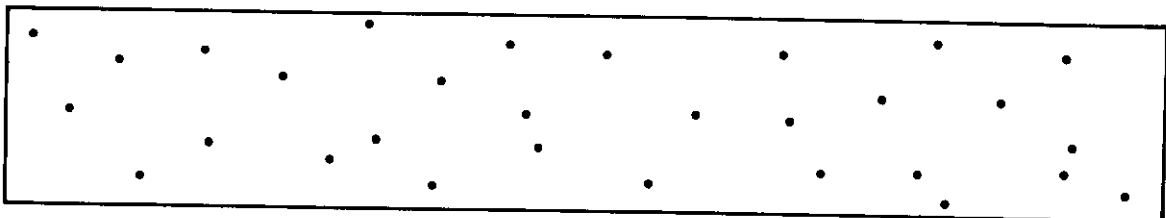
NUMBER PERMITTED IN ANY 6 in. (150 mm) OF WELD IS 8.



(C) MEDIUM ROUNDED INDICATIONS

SIZE PERMITTED IS 1/32 in. (0.8 mm) TO 3/64 in. (1.2 mm).

NUMBER PERMITTED IN ANY 6 in. (150 mm) OF WELD IS 15.



(D) SMALL ROUNDED INDICATIONS

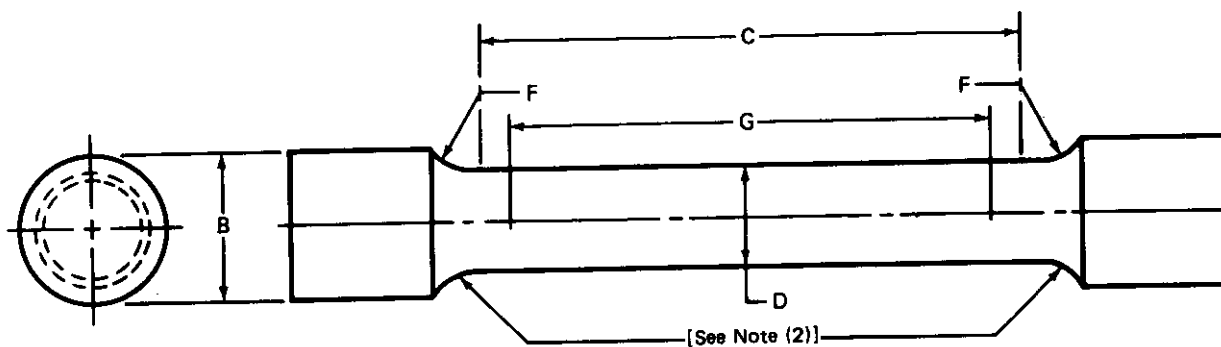
SIZE PERMITTED IS 1/64 (0.4 mm) TO 1/32 in. (0.8 mm).

NUMBER PERMITTED IN ANY 6 in. (150 mm) OF WELD IS 30.

GENERAL NOTES:

- (a) The chart which is most representative of the size of the rounded indications in the radiograph of the test assembly shall be used for determination of conformance with this specification. Rounded indications smaller than 1/64 in. (0.4 mm) shall be disregarded. The largest dimension of the indication (including any tail) is the size of the indication.
- (b) These radiographic requirements are for test welds made in the laboratory specifically for classification purposes. They are more restrictive than those usually encountered in general fabrication. They are equivalent to the Grade 1 Standards in AWS A5.1, Specification for Carbon Steel Covered Electrodes for Shielded Metal Arc Welding.

FIG. 4 RADIOGRAPHIC STANDARDS FOR TEST ASSEMBLY IN FIG. 3



Dimensions of Specimen, in.						
Test Plate Thickness	D	G	C	B	F, MIN	Approximate Area, in. ²
1	0.500 ± 0.010	2.000 ± 0.005	2-1/4	3/4	0.375 (3/8)	1/5

Dimensions of Specimen, mm						
Test Plate Thickness	D	G	C	B	F, MIN	Approximate Area, mm ²
25.4	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 the ends may be as required 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) The finish of the surface within the C dimension shall be no rougher than 63 μ in. (1.6 μ m).

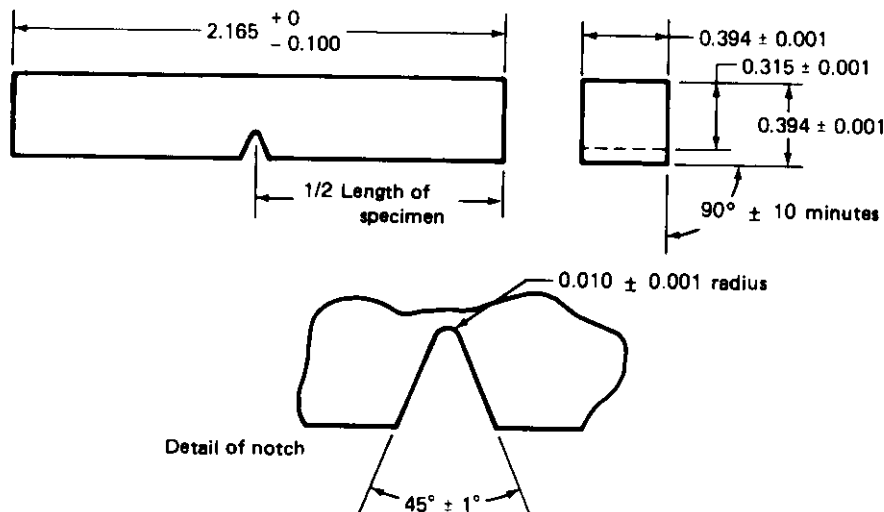
FIG. 5 DIMENSIONS OF TENSION TEST SPECIMEN

TABLE 5
TENSION TEST REQUIREMENTS

Flux Classification ⁽¹⁾	Tensile Strength		Yield Strength min. ⁽²⁾		Elongation % min. ⁽²⁾
	psi	MPa	psi	MPa	
F6XX-EXXX	60 000/80 000	415/550	48 000	330	22
F7XX-EXXX	70 000/95 000	480/650	58 000	400	22

NOTES:

- (1) The letter "X" used in various places in the classifications in this table stands for, respectively, the condition of heat treatment, the toughness of the weld metal, and the classification of the electrode (see Fig. 1).
- (2) Yield strength at 0.2 percent offset and elongation in 2 in. (51 mm) gage length.



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 - 2.5

GENERAL NOTES:

(a) All dimensions except angles are in inches.

(b) The surface finish shall be no rougher than 63 μ in. (1.6 μ m).

FIG. 6 DIMENSIONS OF CHARPY V-NOTCH IMPACT TEST SPECIMEN

TABLE 6
IMPACT TEST REQUIREMENTS⁽¹⁾

Digit	Test Temperature		Average Energy Level, min
	°F	°C	
Z	no impact requirements		20 ft-lbs (27J)
0	0	-18	
2	-20	-29	
4	-40	-40	
5	-50	-46	
6	-60	-51	
8	-80	-62	

NOTE:

- (1) Based on the results of the impact tests of the weld metal, the manufacturer shall insert in the classification (Table 5) the appropriate digit from the table above (Table 6), as indicated in Fig. 1. Weld metal from a specific flux-electrode combination that meets impact requirements at a given temperature also meets the requirements at all higher temperatures in this table (i.e., weld metal meeting the requirements for digit 5 also meets the requirements for digits 4, 2, 0, and Z).

interfere with the uniform, uninterrupted feeding of the electrode on automatic and semiautomatic equipment.

14.2.3 Core ingredients in composite electrodes shall be distributed with sufficient uniformity throughout the length of the electrode so as not to adversely affect

the performance of the electrode or the properties of the weld metal.

14.2.4 A suitable protective coating, such as copper, may be applied to any electrode covered in this specification.

14.3 Standard Package Forms

14.3.1 Standard package forms are coils with support, coils without support, and drums. Standard package dimensions and weights for each form are given in Table 8. Package forms, sizes and weights other than these shall be as agreed between purchaser and supplier.

14.3.2 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.

14.3.3 Drums 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.

14.4 Winding Requirements

14.4.1 The electrode shall be wound so that kinks, waves, sharp bends, or wedging are not encountered, leaving the electrode free to unwind without restriction. The outside end of the electrode (the end with which

TABLE 7
STANDARD ELECTRODE SIZES AND TOLERANCES⁽¹⁾

Size (Diameter)		Tolerance			
in.	mm	Solid (E)		Composite (EC)	
		± in.	± mm	± in.	± mm
1/16 (0.0625)	1.6	0.002	0.05	0.005	0.13
5/64 (0.078)	2.0	0.002	0.05	0.006	0.15
3/32 (0.094)	2.4	0.002	0.05	0.006	0.15
1/8 (0.125)	3.2	0.003	0.08	0.007	0.18
5/32 (0.156)	4.0	0.004	0.10	0.008	0.20
3/16 (0.188)	4.8	0.004	0.10	0.008	0.20
7/32 (0.219)	5.6	0.004	0.10	0.008	0.20
1/4 (0.250)	6.4	0.004	0.10	0.008	0.20

NOTE:

(1) Other sizes and tolerances may be supplied as agreed between purchaser and supplier.

TABLE 8
STANDARD DIMENSIONS AND WEIGHTS⁽¹⁾

Electrode Size ⁽²⁾		Net ⁽³⁾ Weight of Coil		Inside Diameter of Liner		Width of Coil, Max.		Outside Diameter of Coil, Max.	
in.	mm	lb	kg	in.	mm	in.	mm	in.	mm
Coils With Support									
1/16-1/4	1.6-6.4	[25 11 50 23 60 27 65 30]		12 ± 1/8	305 ± 3	[2 1/2 65 4 5/8 120]		17 1/2 445 17 430	
3/32-1/4	2.4-6.4	[100 45 150 68 200 91]		(4)		5 125		31 1/2 800	
Coils Without Support									
1/16-1/4	1.6-6.4	— — — As agreed between purchaser and supplier — — —							
Drums									
1/16	1.6-6.4	— — — As agreed between purchaser and supplier — — —						20 ⁽⁵⁾	500 ⁽⁵⁾
								23 ⁽⁵⁾	600 ⁽⁵⁾

NOTES:

(1) Other dimensions and weights may be supplied as agreed between purchaser and supplier.

(2) The range is inclusive.

(3) Net weights shall not vary more than ±10 percent.

(4) The diameter of the liner shall be as agreed between purchaser and supplier.

(5) Outside diameter of drums is nominal, not maximum.

welding is to begin) shall be identified so it can be readily located and shall be fastened to avoid unwinding.

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

14.5 Electrode Identification

14.5.1 The product information and the precautionary information required in para. 14.7 for marking each package shall appear also on each coil and drum.

14.5.2 Coils without support shall be identified by a tag containing this information securely attached to the inside end of the coil.

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

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

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

14.7 Marking of Packages

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

- (a) AWS specification and classification number (year of issue may be excluded);
- (b) Supplier's name and trade designation;
- (c) In the case of a composite electrode, the trade designation of the flux (or fluxes) with which its weld metal composition meets the requirements of Table 2;
- (d) Size and net weight;
- (e) Lot, control, or heat number.

14.7.2 The preceding precautionary information (as a minimum) shall be prominently displayed in legible print on all packages of weld electrodes, including individual unit packages enclosed within a larger package.

WARNING:

PROTECT yourself and others.

Read and understand this information.

FUMES AND GASES can be dangerous to your health.

ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can kill.

- Before use, read and understand the manufacturer's instructions, Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone and the general area.
- Wear correct eye, ear and body protection.
- Do not touch live electrical parts.
- See American National Standard Z49.1, *Safety in Welding and Cutting*, published by the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135, and OSHA Safety and Health Standards, 29 CFR 1910, available from the U.S. Government Printing Office, Washington, DC 20402

DO NOT REMOVE THIS LABEL

15. Flux Requirements

15.1 Form and Particle Size. Flux shall be granular in form and shall be capable of flowing freely through the flux feeding tubes, valves, and nozzles of standard submerged arc welding equipment. Particle size is not specified here, but, when it is addressed, it shall be a matter of agreement between the purchaser and the supplier.

15.2 Usability. The flux shall permit the production of uniform, well shaped beads that merge smoothly with each other and the base metal. Undercut, if any, shall not be so deep or so widespread that a subsequent bead will not remove it.

15.3 Packaging

15.3.1 Flux shall be suitably packaged to ensure against damage during shipment.

15.3.2 Flux, in its original unopened container, shall withstand storage under normal conditions for at least six months without damage to its welding characteristics or the properties of the weld. Heating of the flux to assure dryness may be necessary when the very best properties of which the materials are capable are required.

15.4 Marking of Packages

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

- (a) AWS specification and classification number (year of issue may be excluded);

(b) Supplier's name and trade designation (In the case of recrushed slags, the recrusher, not the original producer, shall be considered the supplier). See also Appendix A6.1.5;

(c) The trade designation of each composite electrode with which the flux manufacturer has classified the flux, if applicable;

(d) Net weight;

(e) Lot, control, or heat number;

(f) Particle size if more than one size is produced.

15.4.2 The following precautionary information (as a minimum) shall be prominently displayed in legible print on all packages of welding material, including individual unit packages enclosed within the larger package.

WARNING:

PROTECT yourself and others.

Read and understand this information.

FUMES AND GASES can be dangerous to health.

ARC RAYS can injure eyes and burn skin.

ELECTRIC SHOCK can kill.

- Before use, read and understand the manufacturer's instructions, the Material Safety Data Sheets (MSDSs), and your employer's safety practices.
- Keep your head out of the fumes.
- Use enough ventilation, exhaust at the arc, or both, to keep fumes and gases away from your breathing zone and the general area.
- Wear correct eye, ear and body protection.
- Do not touch live electrical parts.
- See American National Standard Z49.1, *Safety in Welding and Cutting*, published by the American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135; OSHA Safety and Health Standards, 29 CFR 1910, available from the U.S. Government Printing Office, Washington, DC 20402

DO NOT REMOVE THIS LABEL

Appendix

Guide to ANSI/AWS A5.17-89, Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding

(This Appendix is not a part of ANSI/AWS A5.17-89, *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding*, but is included for information purposes only.)

A1. Introduction

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

A2. Classification System

A2.1 Classification of Electrodes. The system for identifying the electrode classifications in this specification follows the standard pattern used in other AWS filler metal specifications. The letter "E" at the beginning of each classification designation stands for electrode. The remainder of the designation indicates the chemical composition of the electrode, or, in the case of composite electrodes, of the low dilution weld metal obtained with a particular flux. See Fig. 1.

The letter "L" indicates that the solid electrode is comparatively low in manganese content. The letter "M" indicates a medium manganese content, while the letter "H" indicates a comparatively high manganese content. The one or two digits following the manganese designator indicate the nominal carbon content of the electrode. The letter "K", which appears in some designations, indicates that the electrode is made from a heat of silicon-killer steel. Solid electrodes are classified only on the basis of their chemical composition, as specified in Table 1 of this specification.

A composite electrode is indicated by the letter "C" after the "E", and a numerical suffix. The composition of a composite electrode is meaningless and the user is therefore referred to weld metal composition (Table 2) with a particular flux, rather than to electrode composition.

A2.2 Classification of Fluxes. Fluxes are classified on the basis of the mechanical properties of the weld metal they produce with some certain classification of electrode, under the specific test conditions called for in Section B of this specification.

As examples of flux classifications, consider the following:

F6A0-EH14

F7P6-EM12K

F7P4-EC1

The prefix "F" designates a flux. This is followed by a single digit representing the minimum tensile strength required of the weld metal in 10 000 psi increments.

When the letter "A" follows the strength designator, it indicates that the weld metal was tested (and is classified) in the as-welded condition. When the letter "P" follows the strength designator, it indicates that the weld metal was tested (and is classified) after postweld heat treatment called for in the specification. The digit that follows the A or P will be a number or the letter "Z". This digit refers to the impact strength of the weld metal. Specifically, it designates the temperature at (and above) which the weld metal meets, or exceeds, the required 20 ft-lb (27 J) Charpy V-notch impact strength (except for the letter Z, which indicates that no impact requirement is specified — see Table

6). These mechanical property designations are followed by the designation of the electrode used in classifying the flux (see Table 1). The suffix (EH14, EM12K, EC1, etc.) included after the hyphen refers to the electrode classification with which the flux will deposit weld metal that meets the specified mechanical properties when tested as called for in the specification.

It should be noted that flux of any specific trade designation may have many classifications. The number is limited only by the number of different electrode classifications and the condition of heat treatment (as welded and postweld heat-treated) with which the flux can meet the classification requirements. The flux marking lists at least one, and may list all, classifications to which the flux conforms.

Solid electrodes having the same classification are interchangeable when used with a specific flux; composite electrodes may not be. However, the specific usability (or operating) characteristics of various fluxes of the same classification may differ in one respect or another.

A3. Acceptance

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

A4. Certification

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

The only testing requirement implicit in this "certification" is that the manufacturer have 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. Rep-

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

A5. Ventilation During Welding

A5.1 The following are five major factors which govern the quantity of fumes to which welders and welding operators can be exposed during welding:

- (a) Dimensions of the space in which welding is done (with special regard to the height of the ceiling);
- (b) Number of welders and welding operators working in that space;
- (c) Rate of evolution of fumes, gases, or dust according to the materials and processes involved;
- (d) The proximity of the welders or welding operators to the fumes as they issue from the welding zone, and to the gases and dusts in the space in which the welders or welding operators are working;
- (e) The ventilation provided to the space in which the welding is done.

A5.2 American National Standard Z94.1, *Safety in Welding and Cutting* (published by the American Welding Society), discusses the ventilation that is required during welding and should be referred to for details. Attention is particularly drawn to the section of that document entitled "Ventilation".

A6. Welding Considerations

A6.1 **Type of Fluxes.** Submerged arc welding fluxes are granular, fusible mineral compounds of various proportions and quantities, manufactured by any of several different methods. In addition, some fluxes may contain intimately mixed metallic ingredients to deoxidize the weld pool. Any flux is likely to produce weld metal of somewhat different composition than that of the electrode used with it due to chemical reactions in the arc and sometimes to the presence of metallic ingredients in the flux. A change in arc voltage during welding will change the quantity of flux interacting with a given quantity of electrode and may, therefore, change the composition of the weld metal. This latter change provides a means of describing fluxes as "neutral", or "alloy".

A6.1.1 Neutral Fluxes. Neutral fluxes are those which will not produce any significant change in the weld metal chemical analysis as a result of a large change in the arc voltage, and thus, the arc length.

The primary use for neutral fluxes is in multiple pass welding, especially when the base metal exceeds 1 in. (25 mm) in thickness.

Note the following considerations concerning neutral fluxes:

(a) Since neutral fluxes contain little or no deoxidizers, they must rely on the electrode to provide deoxidation. Single pass welds with insufficient deoxidation on heavily oxidized base metal may be prone to porosity, centerline cracking, or both.

(b) While neutral fluxes do maintain the chemical composition of the weld metal even when the voltage is changed, it is not always true that the chemical composition of the weld metal is the same as the chemical composition of the electrode used. Some neutral fluxes decompose in the heat of the arc and release oxygen, resulting in a lower carbon value in the weld metal than the carbon content of the electrode itself. Some neutral fluxes contain manganese silicate which can decompose in the heat of the arc to add some manganese and silicon to the weld metal even though no metallic manganese or silicon was added to these particular fluxes. These changes in the chemical composition of the weld metal are fairly consistent even when there are large changes in voltage.

(c) Even when a neutral flux is used to maintain the weld metal chemical composition through a range of welding voltages, weld properties such as strength level and impact properties can change because of changes in other welding parameters such as depth of fusion, heat input, and number of passes.

A6.1.2 Active Fluxes. Active fluxes are those which contain small amounts of manganese, silicon, or both. These deoxidizers are added to the flux to provide improved resistance to porosity and weld cracking caused by contaminants on or in the base metal.

The primary use for active fluxes is to make single pass welds, especially on oxidized base metal.

Note the following considerations concerning active fluxes:

(a) Since active fluxes do contain some deoxidizers, the manganese, silicon, or both in the weld metal will vary with changes in arc voltage. An increase in manganese or silicon increases the strength of the weld metal in multiple pass welds but may lower the impact properties. For this reason, voltage must be more tightly controlled for multiple pass welding with active fluxes than when using neutral fluxes.

(b) Some fluxes are more active than others. This means they offer more resistance to porosity due to base metal surface oxides in single pass welds than a flux which is less active, but may pose more problems in multipass welding.

A6.1.3 Alloy Fluxes. Alloy fluxes are those which can be used with a carbon steel electrode to make alloy weld metal. The alloys for the weld metal are added as ingredients in the flux.

The primary use for alloy fluxes is to weld low alloy steels and for hardfacing. As such, they are outside of the scope of this specification. See the latest edition of ANSI/AWS A5.23, *Specification for Low Alloy Steel Electrodes and Fluxes for Submerged Arc Welding*, for a more complete discussion of alloy fluxes.

A6.1.4 Wall Neutrality Number. The Wall Neutrality Number is a convenient relative measure of flux neutrality. The Wall Neutrality Number addresses fluxes and electrodes for welding carbon steel with regard to the weld metal manganese and silicon content. It does not address alloy fluxes. For an electrode-flux combination to be considered neutral, it should have a Wall Neutrality Number of 40 or less. The lower the wall neutrality number, the more neutral is the flux.

Determination of the Wall Neutrality Number (N) can be done in accordance with the following:

(a) A weld pad of the type required in the specification is welded with the electrode-flux combination being tested. Welding parameters are the same as those specified for the weld test plate for the diameter electrode being used.

(b) A second weld pad is welded using the same parameters, except that the arc voltage is increased by 8 volts.

(c) The top surface of each of the weld pads is ground or machined smooth to clean metal. Samples sufficient for analysis are removed by machining. Weld metal is analyzed only from the top (fourth) layer of the weld pad. The samples are analyzed separately for silicon and manganese.

(d) The Wall Neutrality Number depends on the change in silicon, regardless of whether it increases or decreases, and on the change in manganese, regardless of whether it increase or decreases. The Wall Neutrality Number is the absolute value (ignoring positive or negative signs) and is calculated as follows:

$$N = 100 (|\Delta\%Si| + |\Delta\%Mn|)$$

where:

$\Delta\%Si$ = the difference in silicon levels of the two pads and

$\Delta\%Mn$ = the corresponding difference in manganese levels.

A6.1.5 Recrushed Slags. The slag formed during submerged arc welding may not have the same chemical composition as unused (virgin) flux. Its composition is affected by the composition of the original flux, by the base metal and electrode composition, and by the welding parameters.

Although it is possible to recrush and reuse submerged arc welding slag as a welding flux, the recrushed slag, regardless of any addition of virgin flux to it, is a new, chemically different flux. It can be classified under this specification, but must not be considered to be the same as the virgin flux. Such flux must be provided with its own marking (see para. 15.4) using the crusher's name and trade designation.

A6.2 Choice of Electrodes. In choosing an electrode classification for submerged arc welding or carbon steel, the most important considerations are the manganese and silicon contents in the electrode, the effect of the flux on recovery of manganese and silicon in the weld metal, whether the weld is to be single pass or multipass, and the mechanical properties expected of the weld metal.

A certain minimum weld metal manganese content is necessary to avoid centerline cracking. This minimum depends upon restraint of the joint and upon the weld metal composition. In the event that centerline cracking is encountered, especially with a low manganese electrode (see Table 1) and neutral flux, a change to a higher manganese electrode, a change to a more active flux, or both, may eliminate the problem.

Certain fluxes, generally considered to be neutral, tend to remove carbon and manganese to a limited extent and to replace these elements with silicon. With such fluxes, a silicon-killed electrode is often not necessary though it may be used. Other fluxes add no silicon and may therefore require the use of a silicon-killed electrode for proper wetting and freedom from porosity. The flux manufacturer should be consulted for electrode recommendations suitable for a given flux.

In welding single pass fillet welds, especially on scaled base metal, it is important that the flux, electrode, or both, provide sufficient deoxidation to avoid unacceptable porosity. Silicon is a more powerful deoxidizer than manganese. In such applications, use of a silicon-killed electrode or of an active flux, or both, may be essential. Again manufacturer's recommendations should be consulted.

The EM14K electrodes are alloyed with small amounts of titanium, although they are considered as carbon steel electrodes. The titanium functions to im-

prove strength and notch toughness under certain conditions of high heat input welding or stress relief. The manufacturer's recommendations should be consulted.

Electrodes of the EH12K classification are high Mn electrodes with the Mn and Si balanced to produce good impact properties on applications that require high deposition rates or multiple arc procedures, or both, in both the as welded and post weld heat treated conditions. The EH12K classification is a modification of the S3 classification found in the DIN 8557 (Deutsches Institut für Normung) Specification.

Composite electrodes are generally designed for a specific flux. The flux identification is required (para. 14.7) to be marked on the electrode package. Before using a composite electrode with a flux not indicated on the electrode package markings, the electrode producer should be contacted for recommendations. A composite electrode might be chosen for higher melting rate and lower depth of fusion at a given current level than would be obtained under the same conditions with a solid electrode.

A6.3 Mechanical Properties of Submerged Arc Welds. Tables 5 and 6 of this specification list the mechanical properties required of weld metal from electrode-flux classifications (the electrodes are classified in Tables 1 and 2). The mechanical properties are determined from specimens prepared according to the procedure called for in the specification. That procedure minimizes dilution from the base metal and thereby more accurately reflects the properties of the weld metal from each electrode-flux combination. In use, the electrodes and fluxes are handled separately, and either of them may be changed without changing the other. For this reason, a classification system with standardized test methods is necessary to relate the electrodes and fluxes to the properties of their weld metal. Chemical reactions between the molten portion of the electrode and the flux, and dilution by the base metal all affect the composition of the weld metal.

Submerged arc welds are not always made with the multipass procedure required in the specification. They frequently are made in a single pass, at least within certain limits on the thickness of the base metal. When a high level of notch toughness is required, multipass welds may be necessary.

The specific mechanical properties of a weld are a function of its chemical composition, cooling rate, and postweld heat treatment. High amperage, single-pass welds have greater depth of fusion and hence, greater dilution by the base metal than lower current, multipass welds. Moreover, large, single-pass welds solidify and cool more slowly than the smaller individual beads of

a multipass weld. Furthermore, the succeeding passes of a multipass weld subject the weld metal of previous passes to a variety of temperature and cooling cycles that alter the metallurgical structure of different portions of those beads. For this reason, the properties of a single-pass weld may be somewhat different from those of a multipass weld made with the same electrode and flux.

The weld metal properties in this specification are determined either in the as-welded condition or after a postweld heat treatment (one hour at 1150°F [621°C]), or both. Most of the weld metals are suitable for service in either condition, but the specification cannot cover all of the conditions that such weld metals may encounter in fabrication and service. For this reason, the classifications in this specification require that the weld metals be produced and tested under certain specific conditions encountered in practice. Procedures employed in practice may require voltage, amperage, type of current, and travel speeds that are considerably different from those required in this specification. In addition, differences encountered in electrode size, electrode extension, joint configuration, preheat, interpass temperatures, and postweld heat treatment can have a significant effect on the properties of the joint. Extended postweld heat

treatment (conventionally 20 to 30 hours for extremely thick sections) may have a major influence on the strength and toughness of the weld metal. Both can be substantially reduced. The user needs to be aware of this and of the fact that the mechanical properties of carbon steel weld metal produced with other procedures may differ from the properties required by Tables 5 and 6 of this specification.

A6.4 Diffusible Hydrogen. Submerged arc welding is normally a low hydrogen welding process when care is taken to maintain the flux in a dry condition. In submerged arc welding with carbon steel electrodes and fluxes classified in the specification, weld metal or heat-affected zone cracking associated with diffusible hydrogen is generally not a problem. Exceptions may arise when joining high carbon steels or when using carbon steel electrodes to weld on low alloy high strength steels (e.g., for a joint of carbon steel to low alloy steel).

If an assessment of the diffusible hydrogen content is to be made. The method of ANSI/AWS A4.3-86, *Standard Procedures for Determination of the Diffusible Hydrogen Content of Martensitic, Bainitic, and Ferritic Steel Weld Metal Produced by Arc Welding*, is appropriate.